316 DEMONSTRATION
BIG BEND STATION - UNIT 4

VOLUME I

August 1980

TECO
TAMPA ELECTRIC COMPANY

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316(A) & (B) DEMONSTRATION
BIG BEND STATION - UNIT 4
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Prepared By

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SECTION 1

SUMMARY

This document represents a demonstration pursuant to Sections 316(a) and 316(b) of the Clean Water Act of 1977 for Big Bend Station Unit 4. This Demonstration addresses the requirements of the state of Florida site certification process for assessment of the operational effects of Big Bend Unit 4 on the aquatic environment.

This Demonstration presents (1) the engineering design of the Big Bend Station intake and discharge system and, (2) through an analysis of hydrodynamic and biological data, an assessment of the impact of these systems on the biota of Tampa Bay. Since the Unit 4 discharge will be combined with that of the existing three units at Big Bend and since the Unit 4 intake will be located in the same canal as the intakes for Units 1 through 3, this Demonstration considers the combined effects of Units 1 through 4.

As suggested in the U.S. Environmental Protection Agency (EPA) draft Guidance Manual for 316 Demonstrations (EPA 1977) the impact analysis considers Station-induced mortality due to thermal, entrainment, and impingement effects on Representative Important Species (RIS). Also considered is the response of the benthic invertebrate community to thermal additions from Big Bend Station.

The results of the assessment indicate that the RIS affected by power station operation represent a small fraction of each population. These losses should be less than the observed year-to-year variation in total standing crop for those species. The effect of the thermal discharge on the benthic community will be small.

The general nature of the ecosystem in Tampa Bay has been assessed from studies conducted at the site. The trophic structure is diverse at all levels with many interactions among species. There appears to be redundancy in functional groups. These characteristics suggest the ecosystem should withstand the predicted effects of Big Bend Station with a minimal change in structure and function. Thus, the chance of irreversible damage to the ecosystem should be minimal.

This Demonstration has shown, therefore, that the proposed once-through cooling system for Big Bend Units 1-4 will not adversely affect and, therefore, will assure protection of the "balanced indigenous population of fish, shellfish, and wildlife" in Tampa Bay.

An alternative intake system, using fine-mesh screens as a filtering medium on the "conventional" traveling water screens, has been evaluated. This technology has been found effective in reducing the loss of organisms entrained or impinged by the circulating water system of Big Bend Station. However, since the Station's effect on aquatic populations is not adverse, the utilization of a fine-mesh screen intake system is not warranted.

SECTION 2

INTRODUCTION

The Clean Water Act (CWA) of 1977 requires the United States Environmental Protection Agency (EPA) to promulgate standards of performance for new sources (NSPS) and effluent limitations for existing sources that discharge pollutants directly to the waters of the United States. NSPS and effluent limitations guidelines for steam electric power plants were promulgated by EPA in 1974 and required the use of closed-cycle cooling to limit the thermal component of the discharge. In 1976, the thermal NSPS and effluent limitations were invalidated by the United States Court of Appeals for the Fourth Circuit in Appalachian Power Co. v. Train, 545 F.2d 1351 (4th Cir. 1976), and remanded to EPA for further consideration. To date, EPA has not repromulgated the standards and effluent limitations. Although the Agency has indicated that the revised regulations are expected to be finalized in March 1981, it apparently does not intend to publish final thermal standards and effluent limitations at that time. [See, Environmental Protection Agency, Agenda of Regulations, 45 Federal Register 44,106, 44,171 (Column 1) (June 30, 1980).]

Big Bend Unit 4 has been determined by EPA to be a "new source." Since there presently are no nationally applicable NSPS for thermal discharges from steam electric power plants, EPA will establish those standards for this Unit on a case-by-case basis taking into account the factors enumerated in Section 306 of the CWA. Section 316(a) of the Act then provides the permit Applicant with the opportunity to demonstrate that alternate effluent limitations are appropriate due to the fact that the limitations proposed by EPA "will require effluent limitations more stringent than necessary to assure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife in and on the body of water into which the discharge is to be made. . . ." Section 316(b) of the CWA specifies that in adopting limitations or standards applicable to point sources pursuant to Section 301 or 306 of the Act, EPA must require that the location, design, construction, and capacity of any cooling water intake structures reflect the best technology available for minimizing adverse environmental impact.

This 316 Demonstration considers the effects of both the station intake structure and thermal discharge and addresses the requirements for both Sections 316(a) and 316(b). It was prepared in accordance with the draft technical guidance manuals for 316(a) and 316(b) Demonstrations issued by EPA on May 1, 1977. The Demonstration is intended (1) to meet the requirements of the Florida Electrical Power Plant Siting Act and Chapter 17-3, Florida Administrative Code, relating to state water quality standards, and (2) to provide information for the Environmental Impact Statement for Big Bend Unit 4 under preparation by EPA pursuant to the National Environmental Policy Act of 1969.

Since the Unit 4 discharge will be combined with the discharge from the three existing units and since the Unit 4 intake will be located in the same canal as Units 1-3, this report addresses the combined effects of all four units. Pertinent scientific literature, reports, and environmental and engineering studies associated with the Big Bend Station have been used to support the conclusions of this report.

This Demonstration describes the physical and chemical characteristics of Tampa Bay (Section 3) and the aquatic communities of the Bay including the area surrounding Big Bend Station (Section 4). The communities discussed include phytoplankton, aquatic macrophytes, benthic invertebrates, macroinvertebrates, and fish. Rare and endangered species found in the area are also discussed. The rationale for selection of Representative Important Species (RIS) and their life history characteristics are presented in Section 5. A description of the intake and discharge systems is presented for Big Bend Units 1 through 3 (Section 6.1) and Unit 4 (Section 6.2).

This Demonstration provides an assessment of Big Bend Station's impact on the RIS (Section 7), considering the effects of entrainment into the circulating water system, impingement in the intake structure, and effects related to the thermal discharge of the Station. The assessment identifies potential impact that could occur, and based on available data and expected Station characteristics, quantifies the effects of the Station on the RIS (Sections 7.1 and 7.2). An assessment is also provided of the response of benthic invertebrate communities and populations to thermal additions from Big Bend Station (Section 7.3).

An evaluation of fine-mesh screening for the intake has been made as a part of the evaluation presented under Section 316(b). These screens remove planktonic organisms from the circulating water and allow them to be returned to the water body. The results to date of the evaluation of fine-mesh screening (Appendices 3 and 4), their application, and the impact implications of using fine-mesh screen at Big Bend Station are discussed (Section 7.4).

Several assumptions used in the analysis of impact are conservative which results in an overstatement of the magnitude of the Station-induced effect. This approach permits quantitative impact assessments where biological information is limited but where scientific understanding permits a reasonable assumption. A summary of the environmental impacts is presented in Section 8.

SECTION 3

PHYSICAL AND CHEMICAL CHARACTERISTICS OF TAMPA BAY

3.1 HYDROLOGICAL CHARACTERISTICS

3.1.1 General Physical Description

The Tampa Bay system is centrally located on the west coast of Florida (Figure 3.1-1). The main components of this estuary are Tampa Bay, Old Tampa Bay, Hillsborough Bay, McKay Bay, Boca Ciega Bay, and Terra Ceia Bay, which together comprise a surface area of about 900 square km and a total shoreline length of about 334 km (U. S. Army Corps of Engineers 1975). The Tampa Bay system extends about 56 km (north to south) and has a maximum width of about 34 km (east to west). The mean water depth is 3.4 m (mean low water), and 90 percent of the estuary is less than 6.7 m deep (mean low water).

Hillsborough Bay in the northeast section of the Tampa Bay system is approximately 13 km long and 6 km wide. The surface area of Hillsborough Bay is about 90 square km and the water depth averages 3 m (mean low water).

3.1.2 Tides

The tides in Tampa Bay are predominantly diurnal with a strong semi-diurnal component. High tides generally occur at the mouth of the Bay 3 hours earlier than at the head of the Bay. Low tides generally occur 4 hours earlier at the mouth than at the head (U. S. Army Corps of Engineers 1975). The tide range increases from the mouth to the head of the Bay. Thus, while the tide range in Tampa Bay averages about 0.67 m, the tide range in Hillsborough Bay averages about 0.76 m (Goodwin 1977). Strong, sustained winds blowing over the Bay can produce water level fluctuations equal to or greater than those due to tidal effects (U. S. Army Corps of Engineers 1975).

3.1.3 Tidal Currents and Flows

Currents in Tampa Bay are predominantly of tidal origin, except for occasional wind-induced surface currents. In general, tidal flows and velocities decrease from the mouth to the head of the Bay. Tidal flow at the mouth of Tampa Bay averages approximately 25,500 cu m/sec and, at the mouth of Hillsborough Bay, approximately 2,550 cu m/sec. Current velocity exhibits a similar relationship, with maximum ebb velocities near the mouth of Tampa Bay reaching 1.8 m/sec and velocities at the mouth of Hillsborough Bay seldom exceeding 0.14 m/sec (Goodwin 1977). An exception to this pattern occurs at the mouth of Old Tampa Bay

where a constriction in the Bay width yields velocities nearly as great as those at the mouth of Tampa Bay.

Figures 3.1-2 through 3.1-5 show current velocities in Tampa Bay at various times throughout a typical tidal cycle. These velocity plots were generated using results from the finite element hydrodynamic model CAFE-1, which was developed at the Massachusetts Institute of Technology (Wang & Connor 1975). This model and its application to Tampa Bay is described in detail in Appendix 5.

3.1.4 Tidal Circulation

Water in the Tampa Bay system moves predominantly counterclockwise (Figure 3.1-6). This apparently occurs because the incidence angle between Tampa Bay and the Gulf of Mexico normally directs flood flow entering the estuary along the deeper eastern shore. In addition, Old Tampa Bay in the northwest sector tends to direct ebb flow emanating from this area along the western shore, thus completing the counterclockwise rotation (U. S. Army Corps of Engineers 1975). Figure 3.1-6, generated using results from the CAFE-1 model, illustrates tidal average velocities resulting from averaging tidal flux at each point throughout an entire tidal cycle.

The net circulation pattern in Hillsborough Bay predicted by CAFE-1 (as seen in Figure 3.1-6) is a weak counterclockwise gyre. Other studies have indicated different circulation patterns for Hillsborough Bay. For example, a hydrodynamic modeling effort by the U.S. Geological Survey showed a counterclockwise circulation in the majority of the Bay but a clockwise circulation in the southernmost portion (Goodwin 1977). Nevertheless, these studies agree that this mechanism results in very little net exchange of water within the main portion of Tampa Bay.

3.1.5 Freshwater Inflow

The drainage area of the Tampa Bay system is estimated to be 5,786 square km. The freshwater addition to this system originates mainly from the Hillsborough, Alafia, Palm, Little Manatee, and Manatee Rivers. The mean annual discharge rate from these rivers and lesser sources is about 44.0 cu m/sec. Freshwater inflows and watershed areas for the major sources of freshwater to Tampa Bay are presented in Table 3.1-1.

TABLE 3.1-1

FRESHWATER INFLOW TO TAMPA BAY(*)

Location	Stream	Watershed Area (sq km)	Inflow (cu m/sec)
Old Tampa Bay	Sweetwater Creek	76.4	0.7
	Rocky Creek	98.9	1.3
	Double Branch Bay	49.7	1.1
	Brooker Creek	176.8	0.8
	Additional Area	303.2	-
Hillsborough Bay	Hillsborough River	1,673.5	19.0
	Palm River	117.0	1.8
	Alafia River	1,082.7	10.9
	Additional Area	239.7	-
Lower Tampa Bay	Little Manatee River	531.2	5.3
	Manatee River	945.7	3.1
	Additional Area	322.1	-
Boca Ciega Bay		169.1	-
Total		5,786.0	44.0

SOURCE:

* Ross, B.E. 1973. The hydrology and flushing of the bays, estuaries, and nearshore areas of the eastern Gulf of Mexico. In: J.I. Jones et al. A summary of the knowledge of the eastern Gulf of Mexico. Martin Marietta Aerospace, Orlando, Florida.

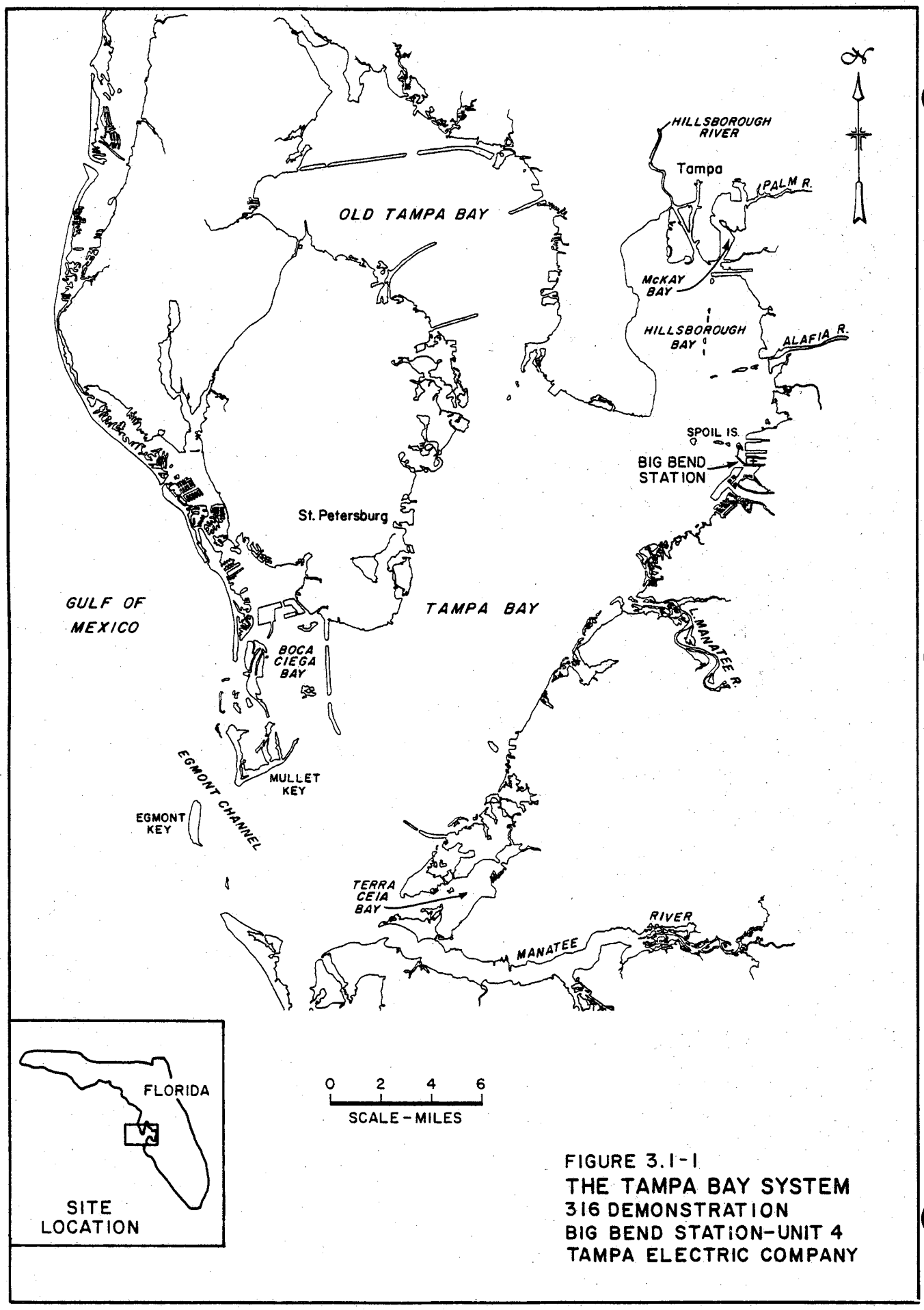


FIGURE 3.1-1
THE TAMPA BAY SYSTEM
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

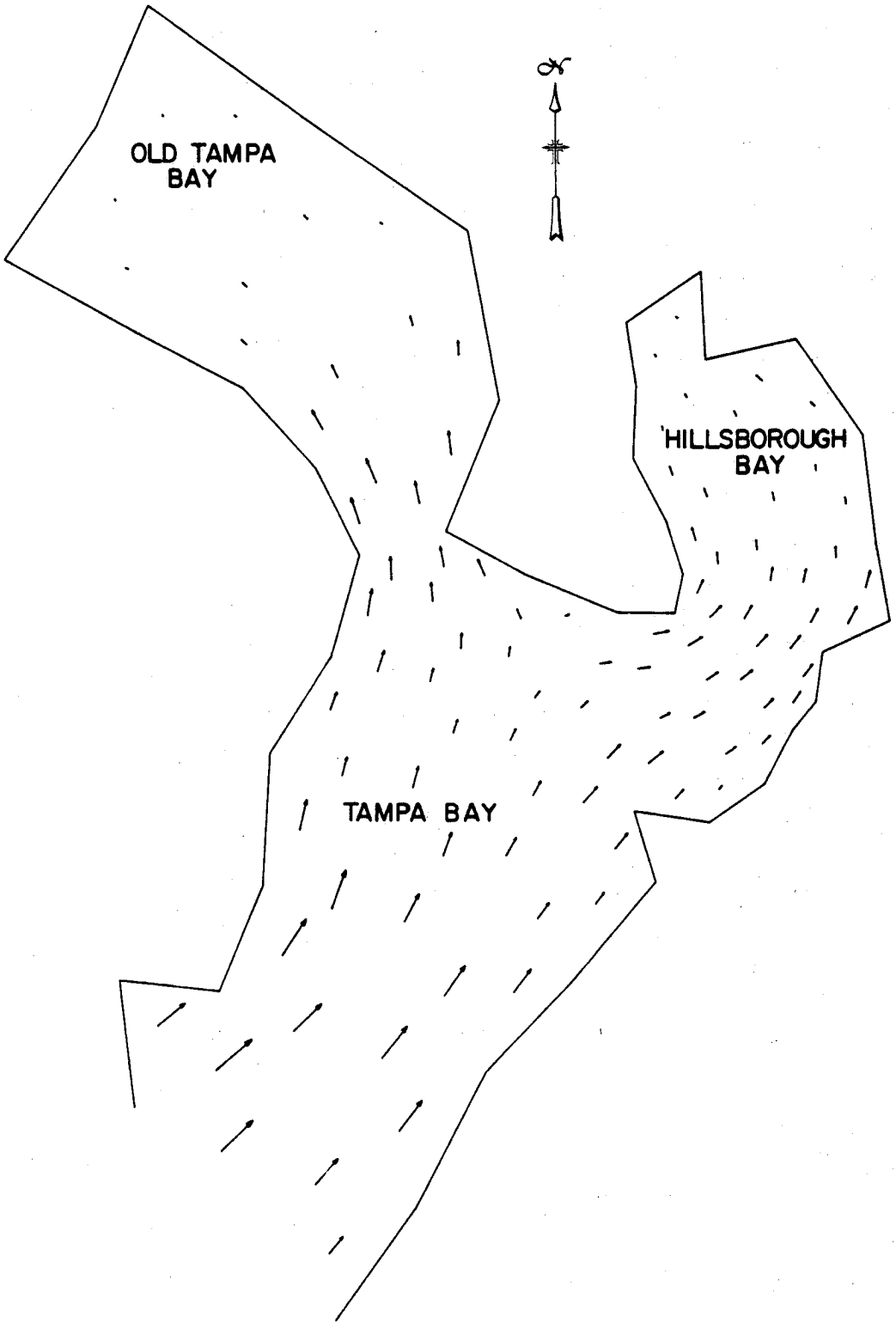


FIGURE 3.1-2
CURRENT VELOCITIES-TAMPA BAY
BEGINNING OF FLOOD
316 DEMONSTRATION
BIG BEND STATION – UNIT 4
TAMPA ELECTRIC COMPANY

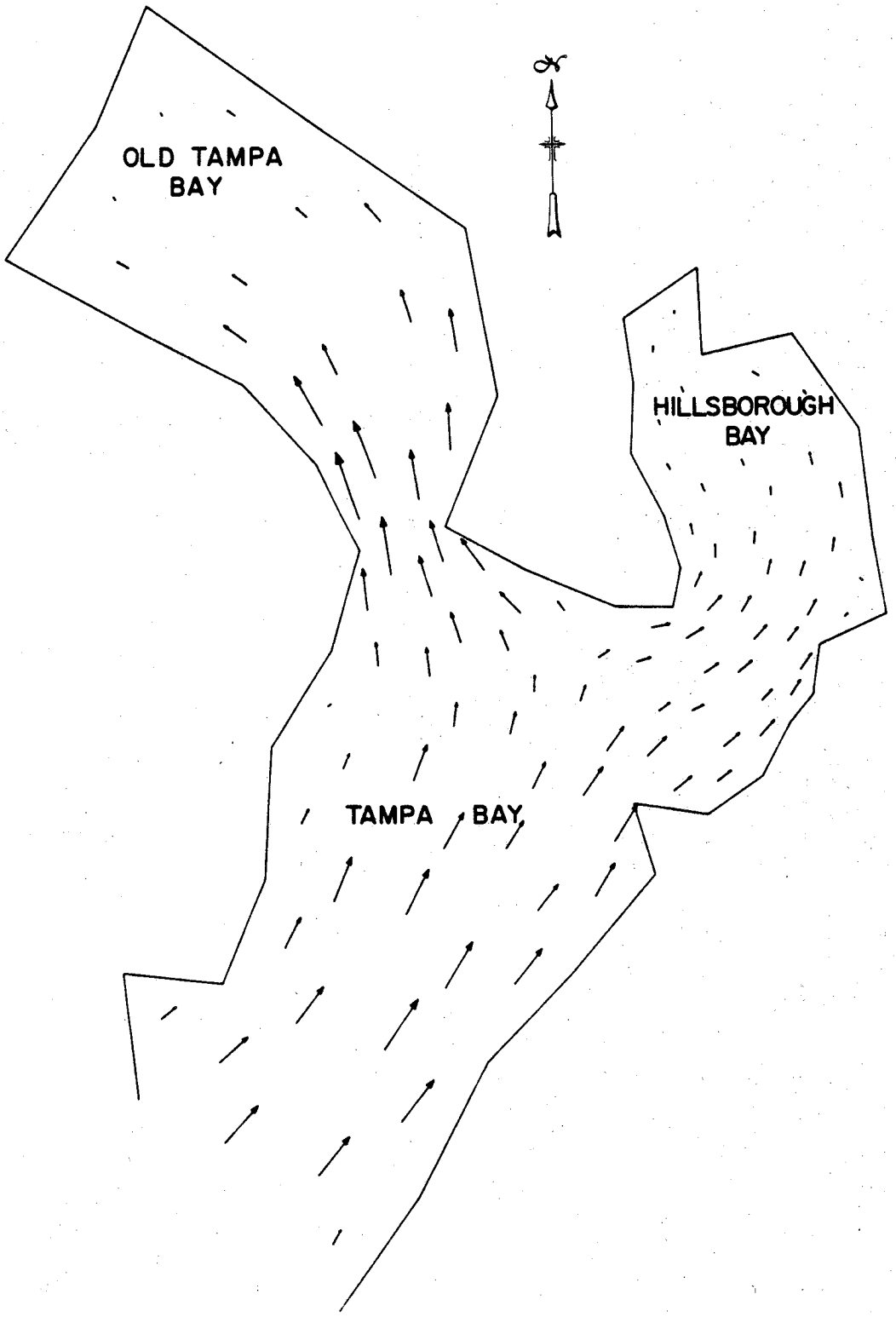


FIGURE 3.1-3

CURRENT VELOCITIES-TAMPA BAY

MID-FLOOD

316 DEMONSTRATION

BIG BEND STATION -UNIT 4

TAMPA ELECTRIC COMPANY

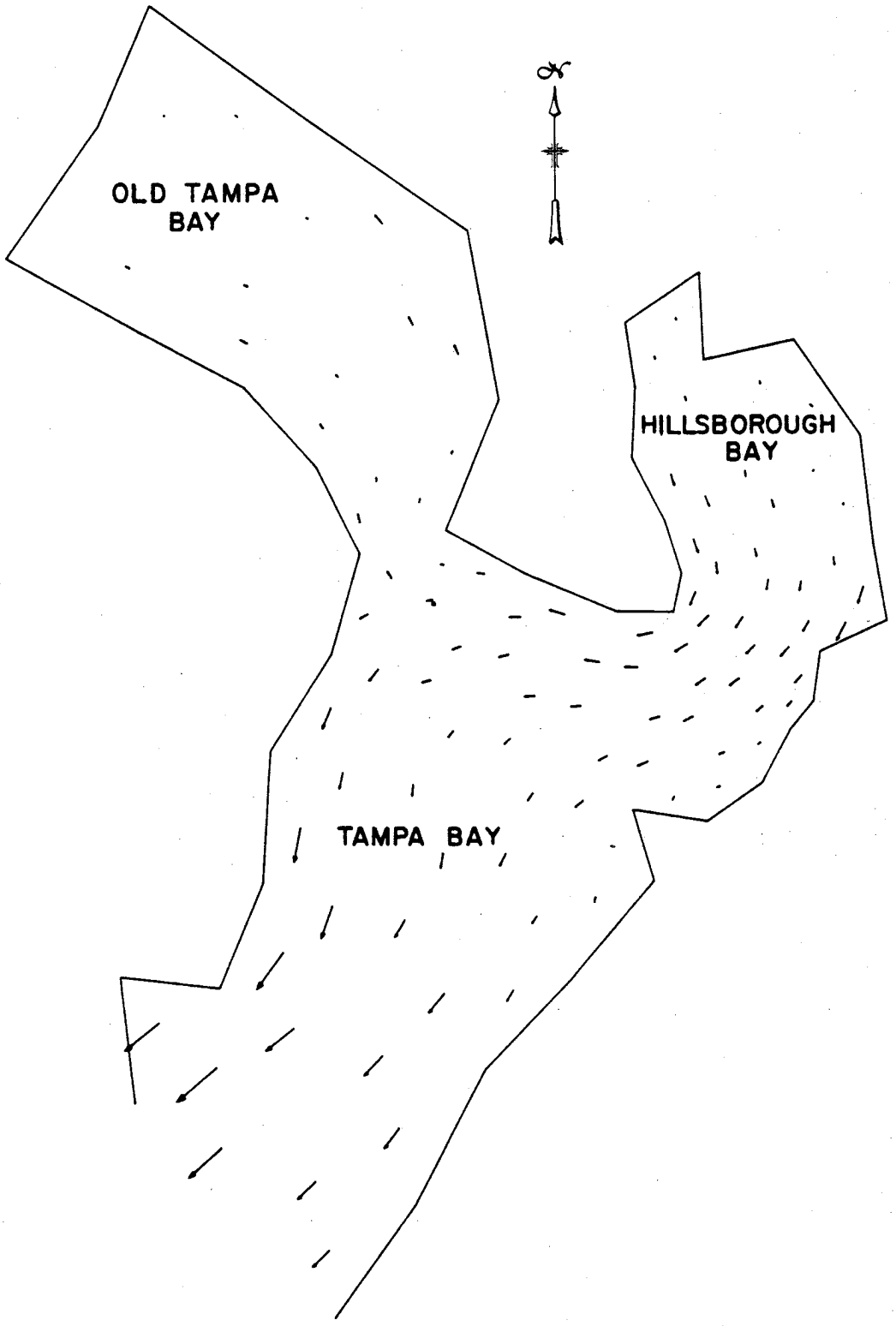


FIGURE 3.1-4

CURRENT VELOCITIES - TAMPA BAY

BEGINNING OF EBB

316 DEMONSTRATION

BIG BEND STATION - UNIT 4

TAMPA ELECTRIC COMPANY

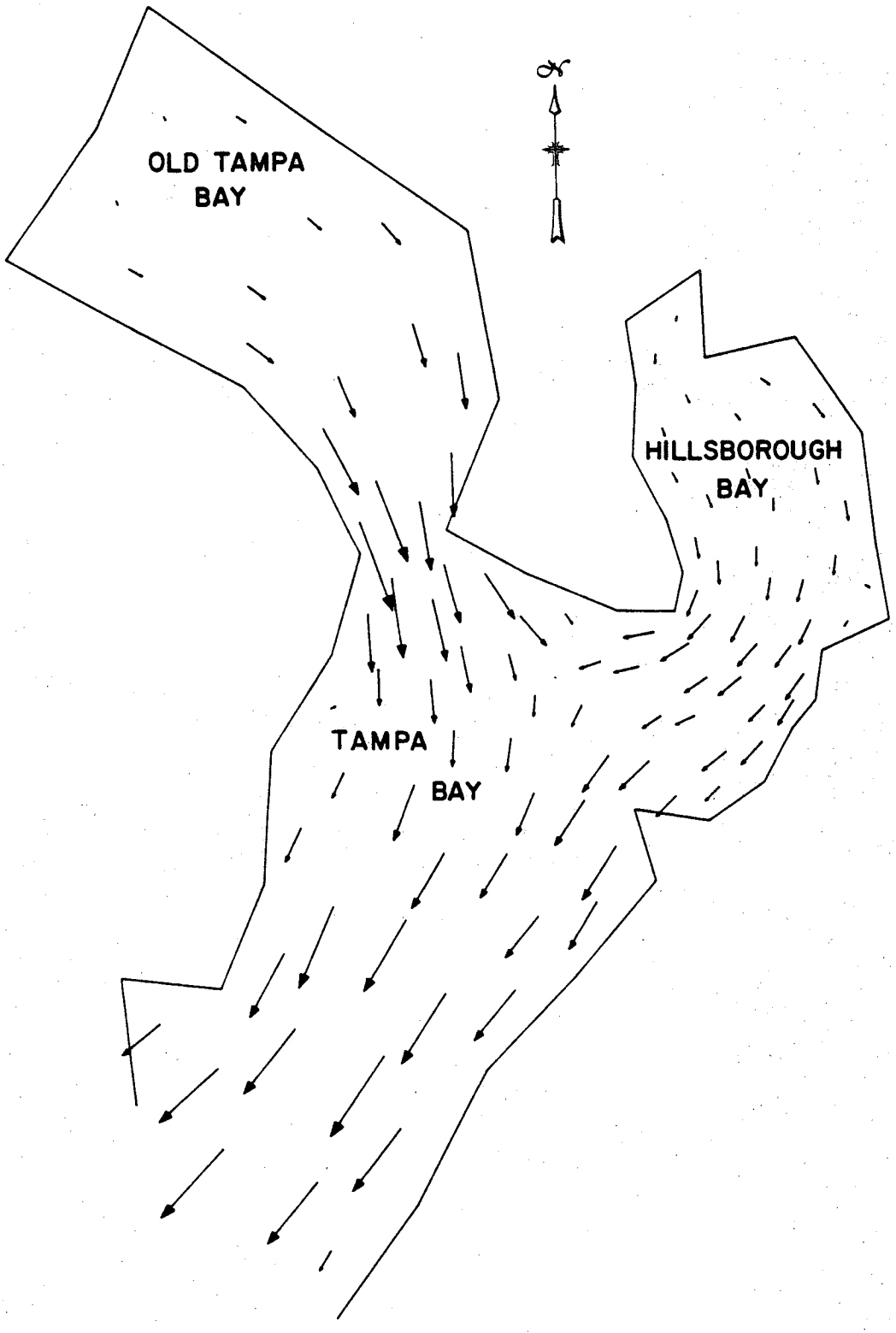


FIGURE 3.1-5
CURRENT VELOCITIES-TAMPA BAY
MID-EBB
316 DEMONSTRATION
BIG BEND STATION – UNIT 4
TAMPA ELECTRIC COMPANY

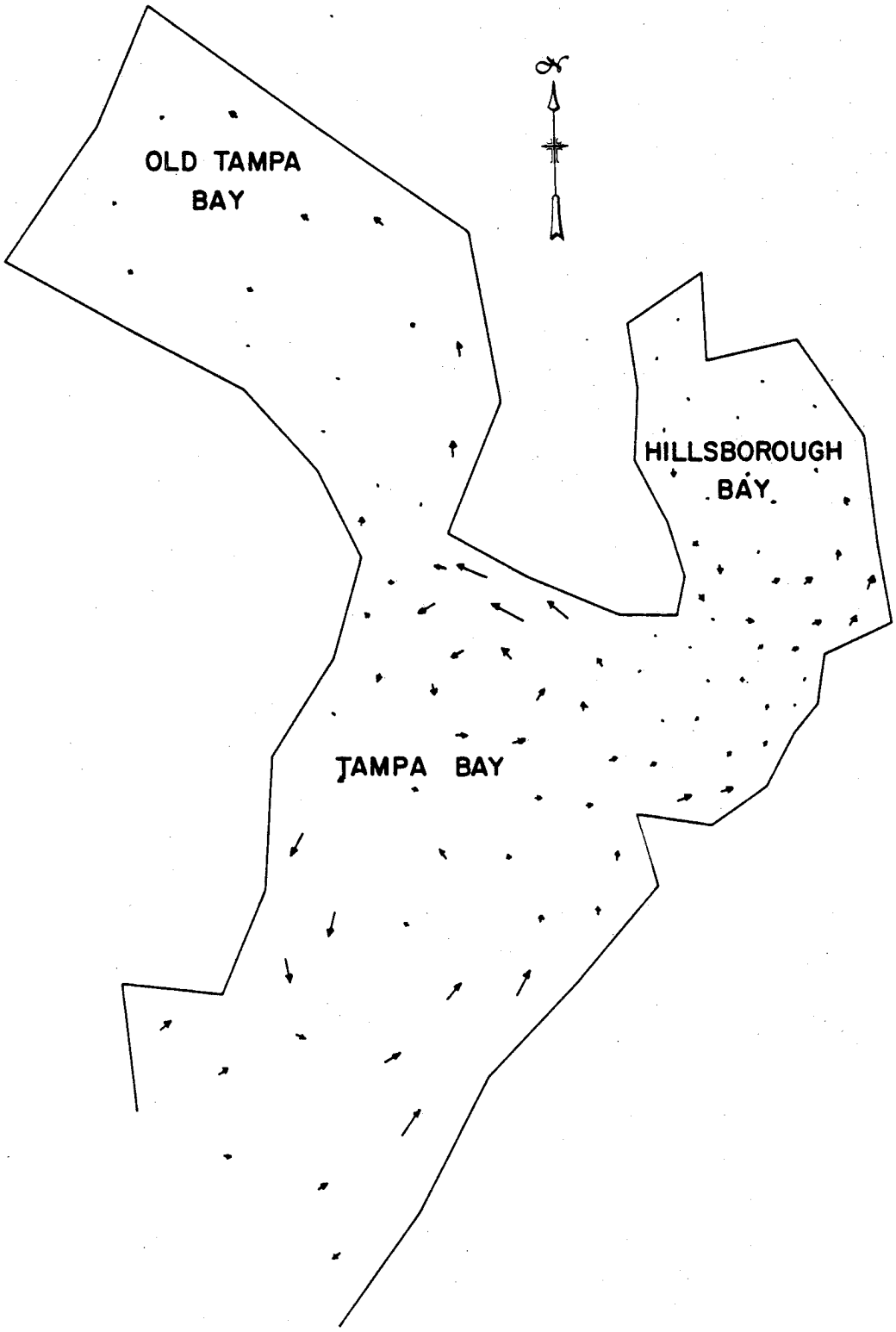


FIGURE 3.1-6

NET TIDAL AVERAGE VELOCITIES

TAMPA BAY

316 DEMONSTRATION

BIG BEND STATION - UNIT 4

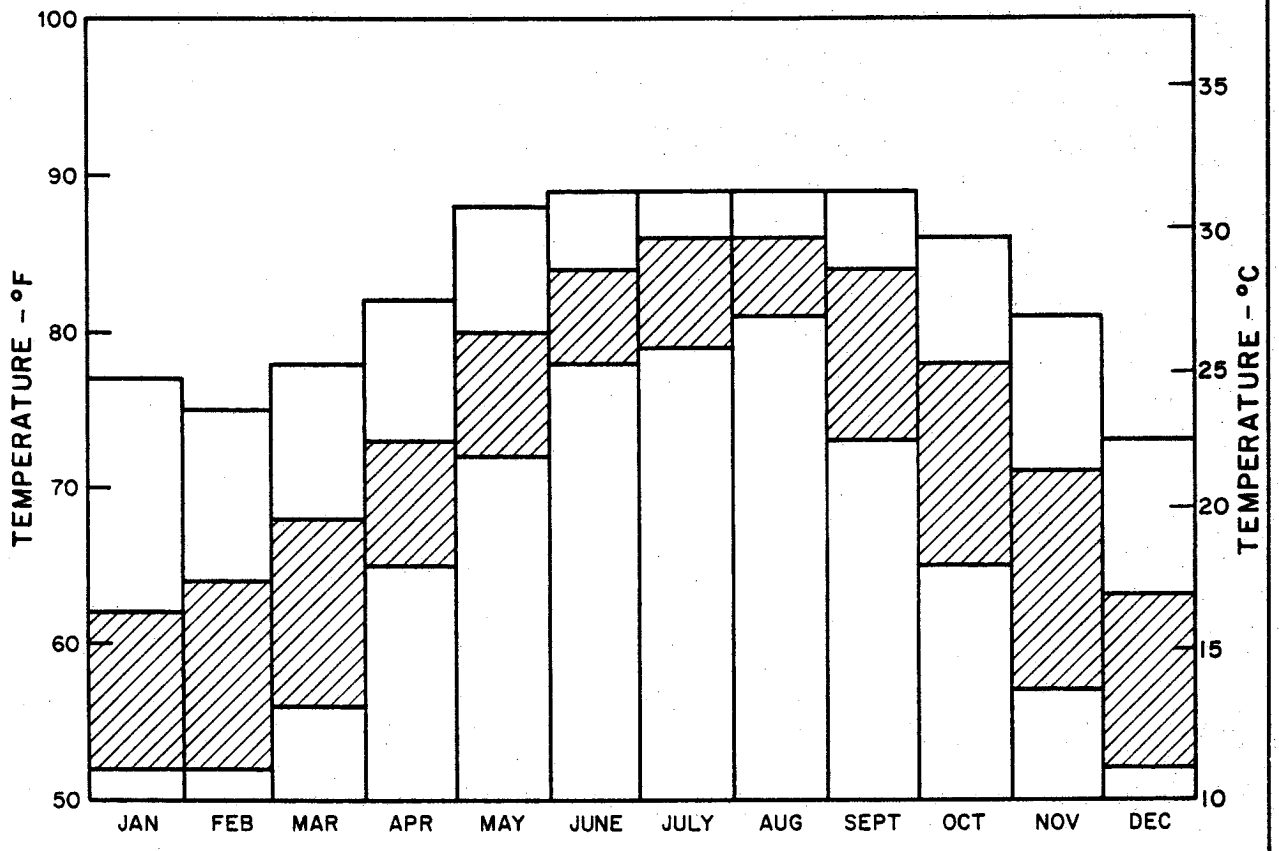
TAMPA ELECTRIC COMPANY

3.2 TEMPERATURE CONDITIONS

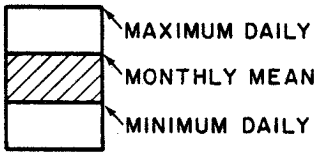
Considerable variations of water temperature occur throughout the Tampa Bay system. Summer, fall, winter, and spring temperatures for this estuary average 30, 23, 16, and 27°C, respectively (U. S. Army Corps of Engineers 1975). Annual means and ranges of water temperature in the Bay are listed below:

Area	Annual Mean Temperature (°C)	Annual Range (°C)
Old Tampa Bay	22.6	10.8 to 32.6
Hillsborough Bay	23.2	11.2 to 35.1
Upper Tampa Bay	22.6	11.8 to 32.0
Lower Tampa Bay	21.5	8.8 to 32.0
Boca Ciega Bay	22.5	11.2 to 31.6
Terra Ceia Bay	21.8	12.5 to 29.6

Recent studies, which included water temperature measurements in Hillsborough Bay (TECO 1977f), indicate that there is a significant amount of solar heating in the Bay. Natural water temperatures in Hillsborough Bay were monitored to determine daily minimum, maximum, and mean temperatures. The data demonstrate a close correlation with data collected at St. Petersburg. Figure 3.2-1 shows the daily water temperature at St. Petersburg, based on 20 years of data.



LEGEND



SOURCE: Water Temperature Data at St. Petersburg, Florida, 1947-1966 U.S. Dept of Commerce, Environmental Science Services, Administration, Coast and Geodetic Survey

FIGURE 3.2-1
TAMPA BAY
WATER TEMPERATURE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

3.3 WATER QUALITY CHARACTERISTICS

3.3.1 Water Classification

Tampa Bay water adjacent to the Big Bend Station has been classified by the State of Florida Department of Environmental Regulation (FDER) as Class III, suitable for recreation and propagation - management of fish and wildlife. Nearby ship access channels and dock areas are also designated Class III.

Approximately 80 percent of Old Tampa Bay is classified as Class II water, suitable for shellfish harvesting; the remainder is Class III. About 55 percent of Upper and Lower Tampa Bay is classified as Class III with the remainder designated Class II. McKay Bay is Class III. Most of Hillsborough Bay and Boca Ciega Bays are Class III. Egmont Key and Mullet Key areas are Class II (U.S. Army Corps of Engineers 1974).

The Class III water standards applicable to Hillsborough Bay are presented in Table 3.3-1.

3.3.2 Salinity

Horizontal salinity gradients exist within the Tampa Bay system. At the mouth of the estuary, salinity values seldom drop below 33 to 34 parts per thousand (ppt) due to the influence of the Gulf of Mexico. In Hillsborough Bay, salinity values normally range between 20 and 28 ppt resulting from freshwater inflow sources and the effluent of the Tampa Sewage Treatment Plant. The salinity gradient changes slightly in character throughout the year due to the variability in seasonal runoff patterns (U.S. Army Corps of Engineers 1974).

Salinity values, acquired during an intensive monitoring program between January 1976 and March 1977 in Hillsborough Bay (TECO 1977e), ranged from 6.8 ppt at the mouth of the Hillsborough River to 34.9 ppt in the Egmont Channel just north of Egmont Key. The southern part of Hillsborough Bay averaged between 22.0 and 26.0 ppt. Salinity values were lowest during months of greatest rainfall and highest during the drier months. Salinity was typically well-mixed, and increased slightly from surface to bottom.

Salinities were also measured in Hillsborough Bay during the 1979-1980 aquatic ecology studies. Mean monthly salinity at meroplankton sampling stations ranged from 16 to 25 ppt, with minimum and maximum observed salinities of 8 and 28 ppt, respectively. As with the previous studies, salinity values were lowest in the early fall, coincident with increased rainfall, and were highest in drier months in winter and early spring (Table 3.3-2).

3.3.3 Dissolved Oxygen

Corps of Engineers data show that, throughout the Tampa Bay estuary, the water column is saturated or supersaturated with oxygen at most times. The yearly mean dissolved oxygen (DO) concentration in the estuary is about 6 mg/l. Mean values of DO in the estuary are 6.4 mg/l in Hillsborough Bay, 6.3 mg/l in Old Tampa Bay, 5.8 mg/l in Upper Tampa Bay, and 5.7 mg/l in Lower Tampa Bay (U.S. Army Corps of Engineers 1974).

Average monthly DO values for Hillsborough Bay collected by the Hillsborough County Environmental Protection Commission are shown on Figure 3.3-1 for the period 1976 to 1980. The results indicate a seasonal pattern of with a mean value of approximately 6.5 to 7 mg/l and an annual range from approximately 5 to 10 mg/l. The lower values were observed during the warmer months of the year and the higher occurred during the cooler months.

Data from the 12-month 1979 Aquatic Ecology Study in Hillsborough Bay indicate that DO averaged about 8.2 mg/l with a range of observed values of between 0.7 and 15.8 mg/l. Higher values reflect supersaturation and were typically observed in surface samples. Lower values were observed adjacent to the bottom during the warmer months when saturation levels were low and stratification may have occurred resulting in a depleted oxygen layer. Oxygen stratification was also observed in samples collected in 1978 at stations in Hillsborough Bay in the vicinity of the dredging operations for the Tampa Harbor Deepening Project (Knutilla 1980).

3.3.4 Sedimentation and Turbidity

Sand and shelly sand are the predominant sediment types throughout the estuary. Localized deposits of silt and clay are found in the poorly drained natural and man-made depressions throughout the bay system. These deposits are principally the result of disposal of dredge material and poorly treated sewage. Sediments in upper reaches of the estuary have a smaller mean grain size than those nearer the Gulf due to a progressively greater proportion of shell fragments in sediments near the Gulf.

Silt and clay fractions increase inland from the mouth of the estuary. Frequent passage of deep-draft ships keeps these particles in suspension in the area of ship channels. Greater deposits of silt and clay are generally found in the less turbulent waters adjacent to a ship channel than at the channel bottom. Sediments outside the channel areas of Upper Tampa and Hillsborough Bays contain 20 to 50 percent fine-grained material. The Hillsborough, Palm, and Alafia Rivers, as well as wastewater flows from municipal sewage treatment plants and several industries, carry sediment to Hillsborough Bay. Relatively low current velocity and poor flushing characteristics in this Bay

allow fine-grained material to settle to the bottom and remain in the system (U.S. Army Corps of Engineers 1974).

In a study performed in 1975, turbidity decreased and light penetration increased in a general north-to-south pattern in Hillsborough Bay, demonstrating the impact of wastes discharged into the northern portion of the Bay. Water clarity near the Big Bend Station is similar to that of Tampa Bay (TECO 1977e).

Turbidity measurements made in 1975 in Tampa Bay ranged from 7.0 Jackson Turbidity Units (JTU) near Big Bend Station to 2.3 JTU near Mullett Key (TECO 1977e). Mean values of turbidity in the estuary are 13.7 JTU in Hillsborough Bay, 7.4 JTU in Old Tampa Bay, 7.9 JTU in Upper Tampa Bay, and 10.6 JTU in Lower Tampa Bay (U.S. Army Corps of Engineers 1974).

More recent studies in Tampa Bay, conducted in 1977 and 1978, suggest an increase in bay turbidity due to the Tampa Harbor Deepening Project (Knutilla 1980). Turbidity during 1978 reached a high of 10.4 NTU (nephelometric turbidity units) near the mouth of the Little Manatee River to a low of 3.2 NTU at the mouth of Old Tampa Bay. The channel dredging in Hillsborough Bay, initiated in 1978, may have caused increased turbidity in Hillsborough Bay that year. This effect should continue for several years until the harbor deepening project is completed and may remain for a longer period as fine-grained sediment is resuspended by wind-driven waves (Wilkins 1978).

TABLE 3.3-1

WATER QUALITY OF HILLSBOROUGH BAY

Parameter[1]	1972 Annual Average Ambient Concentration[1,3,4]	1978 Annual Average Ambient Concentration[2,3,5]	Florida Class III Water Standards[6]	Average Composition of Sea Water[7]
Alkalinity, total	100.9			
Biochemical Oxygen Demand	2.0	3.1		
Calcium	342			413
Chloride	15,030			19,353
Chromium (total)	<0.01		<0.5	
Color (Pt Co units)	9.2	13.3		
Conductivity (micromho/cm)	36,692	39,535		
Copper	<0.01		<0.5	<0.002
Effective light penetration (inches)	54.1	32.5		
Fluoride	2.8	2.4	10	1
Hardness	4,449			
Iron, total	0.03		<0.3	<0.001
Lead, dissolved	<0.01		<0.05	
Magnesium	951			1,294
N, total Kjeldahl	0.47	0.13		0.02
N, total nitrate	0.08	0.02		
N, total nitrite	0.01	0.03		
Oxygen, dissolved	6.36	7.2	<4.0	
pH (standard units)	7.99		6-8.5	8.1
Phosphorous, dissolved orthophosphate	2.03	1.22		0.073
Potassium, dissolved	265.8			387
Salinity (parts per thousand)	27.8	24.9		
Sodium, dissolved	8,197			10,760
Solids, suspended	21.2	42.6		
Sulfate (as SO4-)	2,055			2,712
Sulfide	0.10			
Turbidity (Jackson Units)	5.6	5.9	50	
Water temperature (°C)	24.2	22.4		
Zinc	<0.01		<0.01	<0.05

SOURCES:

1. Hillsborough County Environmental Protection Commission. 1972. 1972 Water Quality, Hillsborough County, Florida. Tampa, Florida.

2. Hillsborough County Environmental Protection Commission. 1978. 1978 Water Quality, Hillsborough County, Florida. Tampa, Florida.

TABLE 3.3-1 (Cont)

NOTES:

3. mg/l unless otherwise stated.
4. Average value from seven sampling stations in Hillsborough Bay.
5. Average value from four sampling stations in Hillsborough Bay adjacent to Big Bend Station.
6. Applicable to most of Hillsborough Bay.
7. Martin, D.F. 1970. Marine chemistry. Dekker, Inc., New York, N.Y.

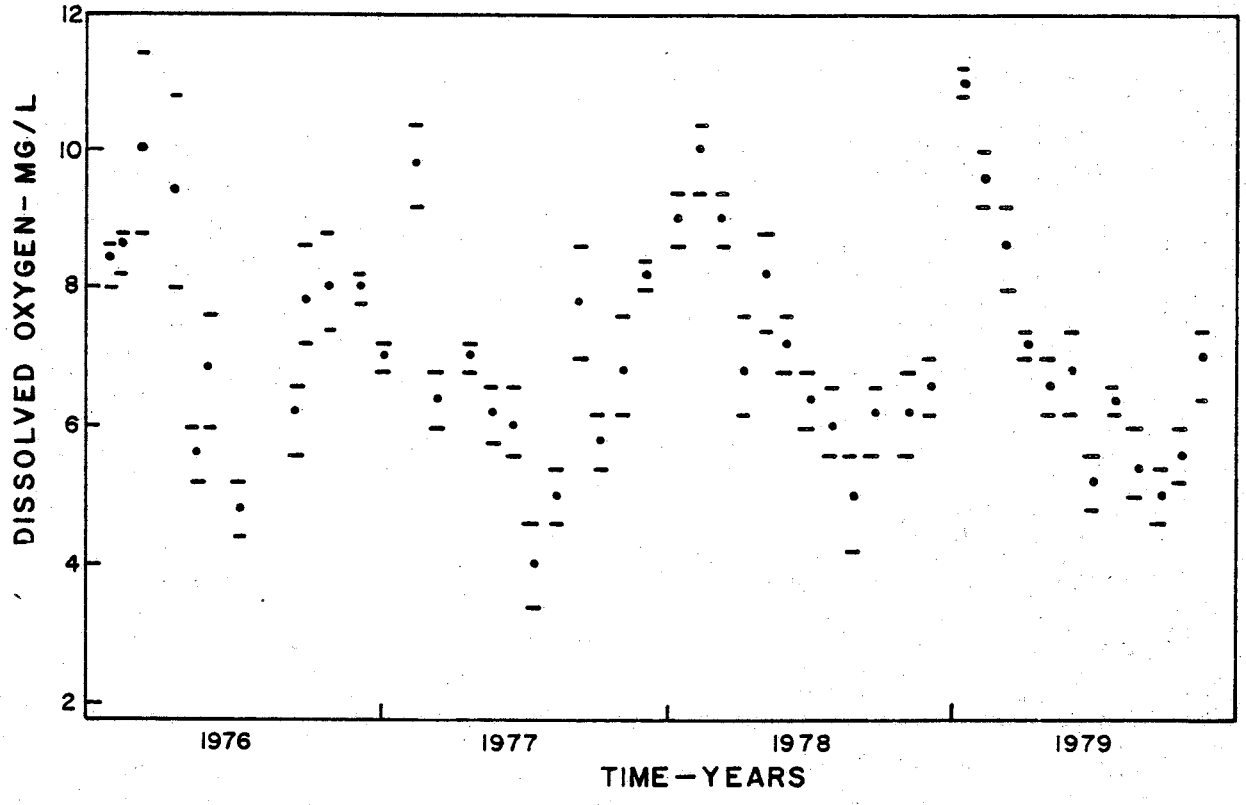
TABLE 3.3-2

MEAN AND RANGE OF TEMPERATURE, SALINITY, AND DISSOLVED OXYGEN AT SELECTED MEROPLANKTON SAMPLING STATIONS, FEBRUARY 1979 TO FEBRUARY 1980(*)

Month	Temperature (°C) Mean	Temperature (°C) Range	Salinity (o/oo) Mean	Salinity (o/oo) Range	Dissolved Oxygen (mg/l) Mean	Dissolved Oxygen (mg/l) Range
1979						
February	16.8	16-17.5	24	23-26	8.8	7.8-9.7
March	18.6	17.5-20.0	23	19-25	9.5	7.2-15.8
April	23.8	23.0-25.0	25	23-27	8.0	4.2-10.8
May	26.4	25.7-28.0	23	19-26	7.8	2.8-12.3
June	28.9	27.0-31.0	23	21-27	7.6	0.7-14.0
July	30.4	27.0-32.0	23	19-28	6.9	0.9-11.8
August	29.3	27.5-31.0	23	17-26	7.1	0.7-14.6
September	28.0	27.0-29.5	18	8-25	6.5	1.6-9.9
October	26.3	25.5-27.5	16	9-22	7.7	1.4-12.8
November	21.4	20.0-23.0	22	18-25	8.8	5.6-11.0
December	16.9	16.0-18.5	24	21-26	9.0	5.7-11.4
1980						
January	17.5	16.0-19.0	24	22-26	9.0	5.3-12.8
February	14.6	14.0-15.0	23	19-28	9.4	6.8-11.6

SOURCE:

* Data from Stations A,C,D,E 1979 Aquatic Ecology Study (Refer to Appendix 1, Figure 2.1).



NOTES:

3 OBSERVATIONS HAD MISSING VALUES OR WERE OUT OF RANGE

PROVISIONAL DATA COLLECTED AND ANALYZED BY HILLSBOROUGH COUNTY ENVIRONMENTAL PROTECTION COMMISSION (KNUTILLA 1980)

FIGURE 3.3-1
MEAN AND STD. ERROR OF THE MEAN VALUE FOR DO CONC. HILLSBOROUGH BAY, 1976-1979
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

SECTION 4

BIOLOGICAL CHARACTERISTICS OF THE SITE

4.1 SUMMARY OF SITE INVESTIGATIONS

Tampa Electric Company (TECO) contracted with Conservation Consultants, Inc. (CCI) in March 1970 to conduct a survey of preoperational and operational conditions around Big Bend Station. The studies began 7 months prior to the startup of Unit 1 and continued through construction and startup of Unit 2. Although TECO voluntarily conducted the survey the first year, by the end of that year the Department of Environmental Regulation (DER) granted a construction permit for Unit 2 requiring that the studies continue. These studies documented the following:

1. Baseline chemical and physical water quality conditions;

2. Numbers and kinds of phytoplankton in source and receiving waters;

3. Abundance and species composition of benthic organisms in near- and far-field waters;

4. Numbers and kinds of foraminiferans in near- and far-field waters;

5. Abundance and species composition of shellfish, fish, and other organisms in receiving and control water bodies;

6. Numbers and kinds of nekton and shellfish impinged on the intake structure;

7. Counts of total and coliform bacteria in the vicinity of the Station;

8. Organisms amenable to mariculture, utilizing thermal effluent from the discharge flume as a water source.

The studies ended in March 1975. Reports on the data and results were issued quarterly, and a 5-year summary report was issued in July 1975 (TECO 1975a).

In the spring of 1975, TECO determined that the use of once through cooling was appropriate for Unit 3, based on the criteria set forth in Section 316 of the Federal Water Pollution Control Act (FWPCA) Amendments of 1972. Consequently, studies were designed, based on EPA's "Basic Guide to the Design of 316 Demonstrations" (EPA 1974), to evaluate the impact of the cooling water system on local aquatic organisms (CCI 1975a and 1975b). A

refined study design was approved by the Environmental Protection Agency (EPA), the Florida Department of Environmental Regulation (FDER), the U.S. Fish and Wildlife Service, and the National Marine Fisheries Service (NMFS) in December 1975. Sampling began in January 1976 and continued through March 1977. Unit 3 came on line during the study, in May 1976.

The scope of the 316 Demonstration Study for Big Bend Station Units 1-3 (TECO 1977f, 1977g, and 1977h) differed from that of the previous investigation in that additional emphasis was placed on meroplankton in order to determine:

1. The abundance and species composition of meroplankton in the vicinity of the site,

2. The number of selected meroplankton species entrained by the station.

Quarterly reports of these programs were prepared, and the final report was published as Appendix Volumes I, II and III of the 316 Demonstration for Units 1 through 3 (TECO 1977f, 1977g, and 1977h).

In 1979, as part of the licensing effort for Big Bend Station Unit 4, additional studies were initiated. The 1979 Aquatic Ecology Program was designed to provide specific ecological data for a list of important species, found in the area, which were potentially susceptible to impact from the operation of Big Bend's cooling system. Sampling was conducted from February 1979 through February 1980 by Mote Marine Laboratory (MML) of Sarasota, Florida. This study included:

1. Collection of meroplankton, adult invertebrates and fishes, and oyster spat (refer to Appendix 1)

2. Systematic observation of manatees (refer to Appendix 2).

The sampling methodology focused on the collection of Representative Important Species (RIS) in selected life stages and provided estimates of their abundance. Results of this study are reported in Appendices 1 and 2 of this document.

Several specialized studies related to the ecology of the area or the effect of the station on aquatic organisms were conducted in conjunction with the 1979 Aquatic Ecology Program. These studies included the 1979 Benthic Community Study, the Studies to Develop an Intake Design For Reducing Entrainment Losses, the Dilution Pump Viability Study, and the 1980 Prototype Study. The 1979 Benthic Community Study was designed to document changes in the

local benthic community in response to cessation of dilution pumping (MML 1980b).

Appendix 3 is a report on the Studies to Develop an Intake Design for Reducing Entrainment Losses. The purpose of this report was to summarize studies conducted in 1979 to evaluate alternative cooling water intake designs for minimizing entrainment at Big Bend Station.

The Dilution Pump Viability Study was conducted to evaluate the mortality of meroplankton entrained in the dilution pump and discharge canal at Big Bend Station (S&W 1980a).

Advanced phases of Fine Mesh Screen Prototype Study will continue through September 1980.

The study results to date are described in a report included as Appendix 4 of this document. The purpose of this study is to evaluate the survival of selected planktonic organisms impinged on a fine-mesh traveling water screen.

In summary, the goal of these studies is to thoroughly describe the impact of plant operation on the environment near Big Bend Station. Numerous studies independent of the TECO study effort have been conducted in the Tampa Bay area over the years. Where applicable, the findings of these studies have been discussed in the appropriate sections of this document.

4.2 PHYTOPLANKTON

Many studies on phytoplankton and primary productivity have been conducted in Tampa Bay, largely due to occasional blooms (rapid growth and reproduction) of the red tide dinoflagellate Gymnodinium breve. Gross annual phytoplankton productivity amounts to 314 to 427 gm carbon/sq m, as high (or higher) than any other similar area in the world (CCI 1971; Steidinger 1973; Sykes 1970). Phytoplankton productivity peaks in the late spring, late summer, and early fall. Hillsborough Bay always has the highest productivity in the Bay System (Table 4.2-1) (Kelly & Johnson 1967). Primary production contributes 61,000 lbs (31,450 kg) of organic carbon per day to Hillsborough Bay (FWPCA 1969).

Turner and Hopkins (1974) conducted a study of phytoplankton in Tampa Bay from the fall of 1969 to early summer 1971. Their study noted 42 diatom and 23 dinoflagellate species. The most abundant diatom was Skeletonema costatum, and the most abundant dinoflagellates were Gonyaulax balechii and Ceratium hircus.

The first reported fish kill accompanied by "discolored water" off Florida's west coast occurred in 1844. Since then, about 30 red tides have been reported (Steidinger & Joyce 1973), but it was not until the 1946-1947 red tide that the cause was determined (Davis 1948). Major Florida red tides are caused by blooms of the unarmored, photosynthetic dinoflagellate, Gymnodinium breve. It produces a toxin which can kill fish and other marine animals; filter-feeding shellfish accumulate the toxin and cause respiratory paralysis and death when eaten by humans.

G. breve can survive and multiply only within a narrow range of chemical and physical parameters. Apparently, specific levels of temperature, light, stability of surrounding media, organic nutritional substances, and metals must coincide for blooms to develop.

G. breve is a coastal species and, under normal conditions, is restricted by low salinities from entering estuaries where shellfish are harvested. If an offshore bloom is supported by sufficient environmental conditions, it may be concentrated by wind and currents and transported inshore. During droughts, when bays and estuaries are more saline, a bloom that has been driven inshore has a greater chance of survival (Morton & Burklew 1969; Steidinger 1973; Steidinger & Ingle 1972). However, red tide outbreaks are also associated with lower salinity waters when rainfall and runoff are high (Torpey & Ingle 1948).

Wall and Dale (1968) confirmed that many marine dinoflagellates have benthic resting cysts which Von Stosch (1973) indicated may be benthic zygotes. The Florida Department of Natural Resources

is attempting to document the existence of these stages for G. breve (Steidinger 1975) and map their distribution. Pyle and Wallace (1974) are examining the possibility of a relationship between underground springs and initial G. breve blooms. The goals of these, and other, studies are to determine why G. breve blooms occur, to predict their path and duration, and to lessen the impact on affected aquatic communities.

Unless otherwise noted, the following information is derived from Chapter 3, Volume I, of the Appendix to Big Bend Station 316 Demonstration for Units 1-3, September 1977 (TECO 1977f). Data were gathered from seven stations (shown on Figure 4.2-1) for 14 months beginning in January 1976. Samples were taken approximately once every 2 weeks.

Between January 1976 and March 1977, 83 species of diatoms, 42 of dinoflagellates, and 8 species from other groups were identified for a total of 133 species. Table 4.2-2 lists the 20 most abundant taxa of phytoplankton found in the Big Bend area. Ten species accounted for over 90 percent of the total phytoplankton. The most abundant was the diatom Skeletonema costatum, followed by Oscillatoria sp. and Hemiaulus sinensis. Skeletonema costatum was present throughout the study, reaching maximum abundance in the late winter and early spring. The maximum abundance of Oscillatoria sp., a blue-green alga, was recorded in August and September 1976. Hemiaulus sinensis, a diatom, was the third most abundant species collected. Its maximum abundance was recorded during the winter. The most common dinoflagellate, Ceratium hircus, reached its maximum abundance during the summer.

In general, diatoms were the most common phytoplankton collected, and greatest densities were recorded during fall and winter. Figures 4.2-2 and 4.2-3 illustrate the seasonal variation in abundance of diatoms at different sampling locations. Table 4.2-3 lists the most common diatoms in order of abundance with a short description of seasonality and annual percent composition for each species.

Dinoflagellates were collected at all times during the study and demonstrated a succession of blooms during the summer. Two major blooms occurred: the first was noted March 30, 1976, and the dominant species was Gonyaulax polygramma; the second was noted July 8, 1976, and was attributed to Ceratium hircus.

Occasionally, blooms of algae occur when appropriate environmental conditions coincide. Red tides are examples of this phenomenon and are caused by blooms of the dinoflagellates Gonyaulax or Gymnodinium. No red tide outbreaks were observed during the 1976-1977 studies, but a few instances were noted during earlier surveys at Big Bend. In January 1971, isolated blooms of the dinoflagellate Gymnodinium splendens occurred and continued through February of that year, at times turning the

water rust-red (CCI 1971). In late July and early August 1971, G. breve appeared in the water samples, coinciding with a red tide caused by that organism in Tampa Bay. The bloom in Tampa Bay caused massive fish kills but prevailing winds kept the heaviest concentrations of the organism and the resultant dead fish away from Big Bend Station (TECO 1972). On October 18, 1971, the intake canal water was colored dark brown. Microscopic examination of a dipped sample confirmed the presence of a heavy bloom of the estuarine dinoflagellate, Gonyaulax balechii (TECO 1972). There was no evidence of damage to other flora or fauna caused by this sporadic bloom. Two days later, G. balechii was present in only very limited numbers in the intake and discharge canals as well as at nearshore stations in Tampa Bay.

Eight species of phytoplankton other than diatoms or dinoflagellates were collected. The blue-green alga Oscillatoria sp. was the most abundant of these with the highest concentration occurring between August 3 and October 4, 1976.

Blue-green algae are known to prefer high ambient temperatures (>30°C) (Patrick 1966). The study reflected the following: Oscillatoria sp. was the dominant phytoplankton during the warmest part of the year and was generally most abundant at stations directly influenced by the Big Bend thermal plume. However, Oscillatoria sp. was also noted in extremely high numbers at stations outside the influence of the plume. The dilution pump intake station (0-8) had the greatest number (cells/l) of all stations on three consecutive sample dates, August 3, August 23, and September 14, 1976. On October 4, 1976, Oscillatoria sp. was the dominant phytoplankton species and had the highest relative abundance at the "open bay" control station.

Oscillatoria sp. has also been noted in past Big Bend studies. It occurred briefly in 1972, and in August 1975 was as abundant as during the 1976-1977 study (TECO 1977f).

Total biomass of all phytoplankton was determined by season during the study and values increased through spring to a maximum in the summer. Lowest values corresponded to the presence of diatoms and highest to dinoflagellates. Station I-3, located at the point of discharge (POD), had the lowest average biomass for the study period, 3.6 mg/l. The highest average was calculated for an open bay station (E-5), 5.6 mg/l; this was attributed to disproportionately high values recorded during summer months.

Community structure was analyzed in terms of three ecological parameters: species richness, diversity, and equitability. Consistent spatial patterns in these parameters were not evident. Temporally, the coincident extreme dominance (by abundance) of certain species influenced the seasonal variation in the parameters. The seasonal variation in abundance of Skeletonema costatum strongly influenced the seasonal trend of the parameters

for diatoms. To a lesser extent, seasonal variation in Ceratium hircus influenced the seasonal trends in these parameters for the dinoflagellates. In general, richness and diversity tended to be highest during the late summer and fall for both diatoms and dinoflagellates.

TABLE 4.2-1

CARBON VALUES IN THE TAMPA BAY SYSTEM - 1966(*)

Subarea	Annual Average (lb/acre/day)
Hillsborough Bay	15.6
Old Tampa Bay	10.4
Tampa Bay (intermediate)	10.1
Egmont Key	5.5

SOURCE:

* Kelly, J.A. and L. Johnson, Jr. 1967. Chemical environmental project (primary production). In: Report of the Bureau of Commercial Fisheries Biological Laboratory, St. Petersburg Beach, Florida, FY 1966. U.S. Fish & Wildl. Serv., pp 11-72.

TABLE 4.2-2

DOMINANT PHYTOPLANKTON SPECIES
IN ORDER OF ABUNDANCE(*)

1. Skeletonema costatum (Greville) Cleve (diatom)
2. Oscillatoria sp. (blue-green algae)
3. Hemiaulus sinensis Greville (diatom)
4. Rhizosolenia delicatula Cleve (diatom)
5. Ceratium hircus Schroder (dinoflagellate)
6. Asterionella japonica Cleve & Moller ex Gran (diatom)
7. Gonyaulax polygramma Stein (dinoflagellate)
8. Rhizosolenia setigera Brightwell (diatom)
9. Chaetoceros spp. (diatom)
10. Nitzschia delicatissima Cleve (diatom)
11. Nitzschia pungens v. atlanticum Cleve (diatom)
12. Certaulina pelagica (Cleve) Hendey (diatom)
13. Leptocylindrus danicus Cleve (diatom)
14. Peridinum pellucidum (Bergh) Schutt (dinoflagellate)
15. Nitzschia closterium (Ehrenberg) Wm. Smith (diatom)
16. Thalassionema nitzschioides Hurstedt (diatom)
17. Licmorpha sp. Agardh (diatom)
18. Prorocentrum minimum Schiller (dinoflagellate)
19. Gonyaulax digitalis (Pouchet) Kofoid (dinoflagellate)
20. Dinophysis caudata F. acutiformis Saville-Kent (dinoflagellate)

SOURCE:

* TECO (Tampa Electric Company). 1977e. Big Bend Station 316 Demonstration. September 1977. TECO, Tampa, Florida.

TABLE 4.2-3

SEASONAL OCCURRENCE OF THE MOST ABUNDANT DIATOM SPECIES AND THEIR RELATIVE CONTRIBUTION TO TOTAL NUMBER(*)

Diatom	Seasonal Occurrence	Total Diatoms (Percent)	Comments
Skeletonema costatum	Fall and Winter Peak	39.5	Common throughout the year; highest concentration 1/21/77
Hemiaulus sinensis	Winter	24.4	Highest concentration 2/18/77
Rhizosolenia delicatula	Late Summer Through Winter	18.6	Sporadic throughout year; bloomed 8/23/76 and 12/16/76
Asterionella japonica	Fall and Winter	6.8	Highest concentration 1/21/77
Rhizosolenia setigera	Late Summer and Early Fall	2.6	Sporadic throughout the year; bloomed 8/23/76
Chaetoceros	Late Summer and Early Fall	1.7	Present through most of the year
Nitzschia delicatissima	Late Summer and Fall	1.3	Highest concentration 9/14/76
Nitzschia pungens v. atlanticum	Late Summer and Fall	0.8	Highest concentration 10/4/76

SOURCE:

* TECO (Tampa Electric Company). 1977f. Final report of ecological surveys of the Big Bend area, Vol. 1. Appendix to 316 Demonstration, Vol. I. An analysis and summary on the effect of the cooling water system on aquatic fauna, Vol. I. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

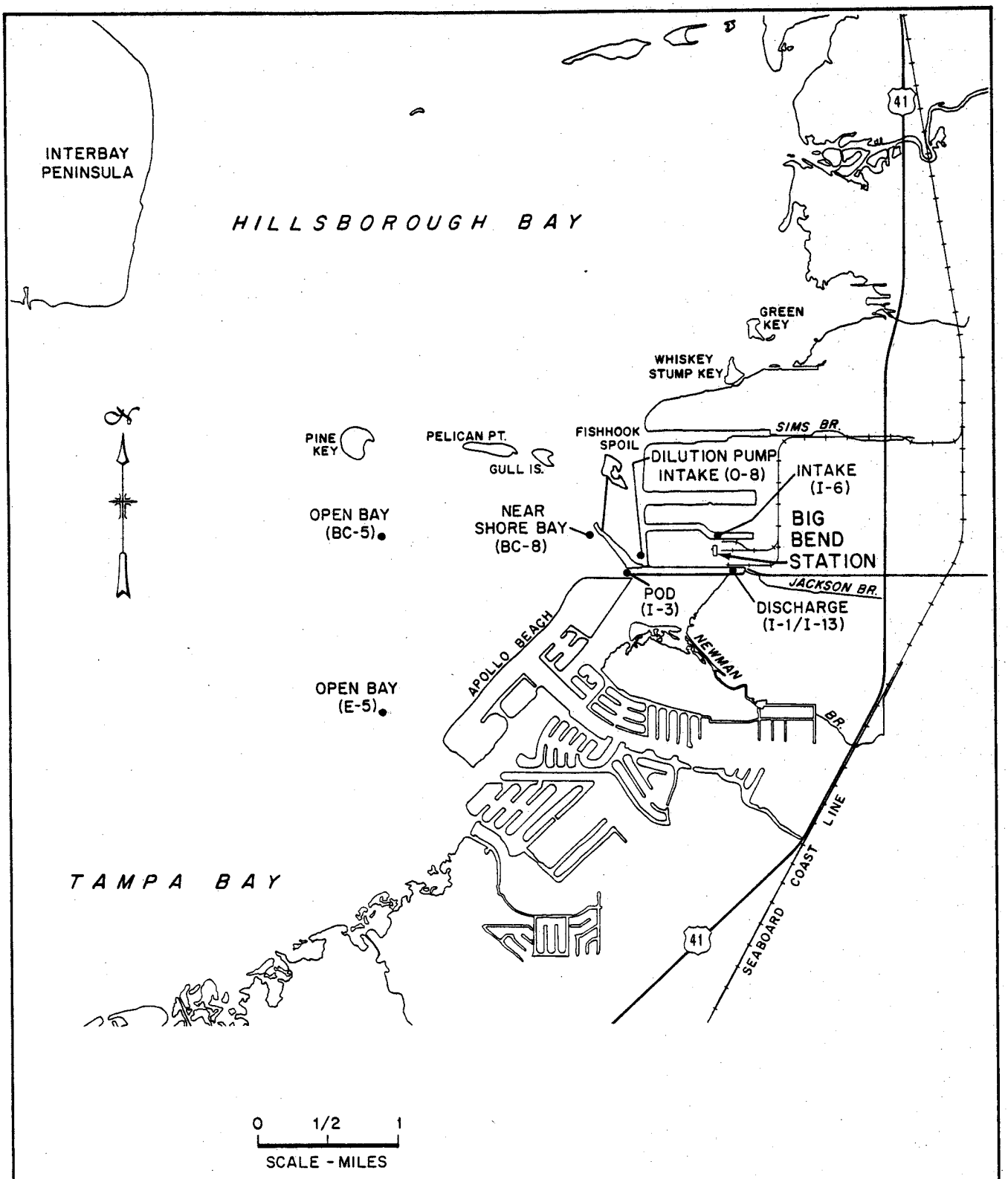


FIGURE 4.2-1
PHYTOPLANKTON STATIONS
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

SOURCE: TECO, 1977f. Adapted from Appendix to 316 Demonstration, Big Bend Station Units 1-3, Volume I, Pages 3-13

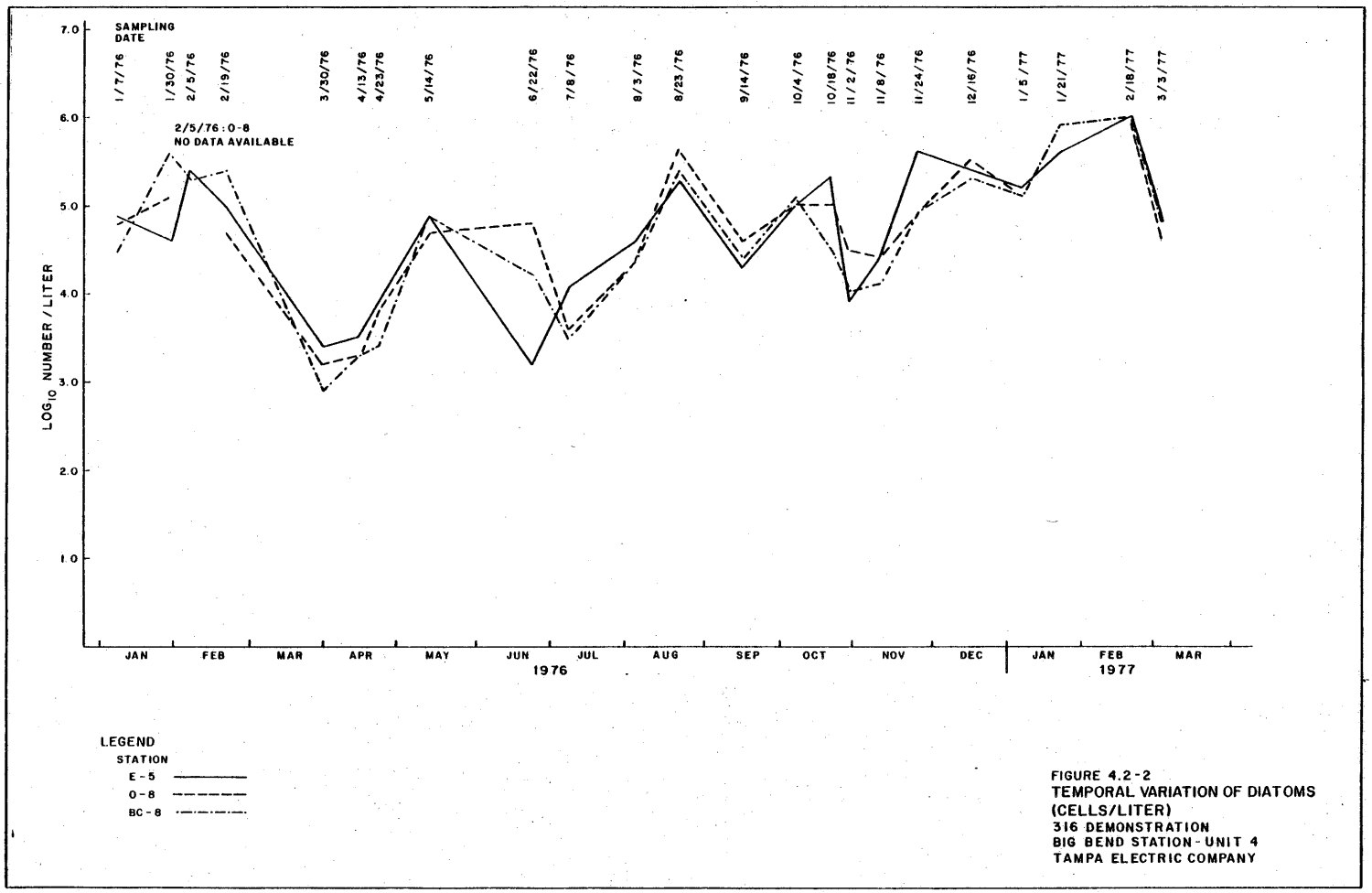
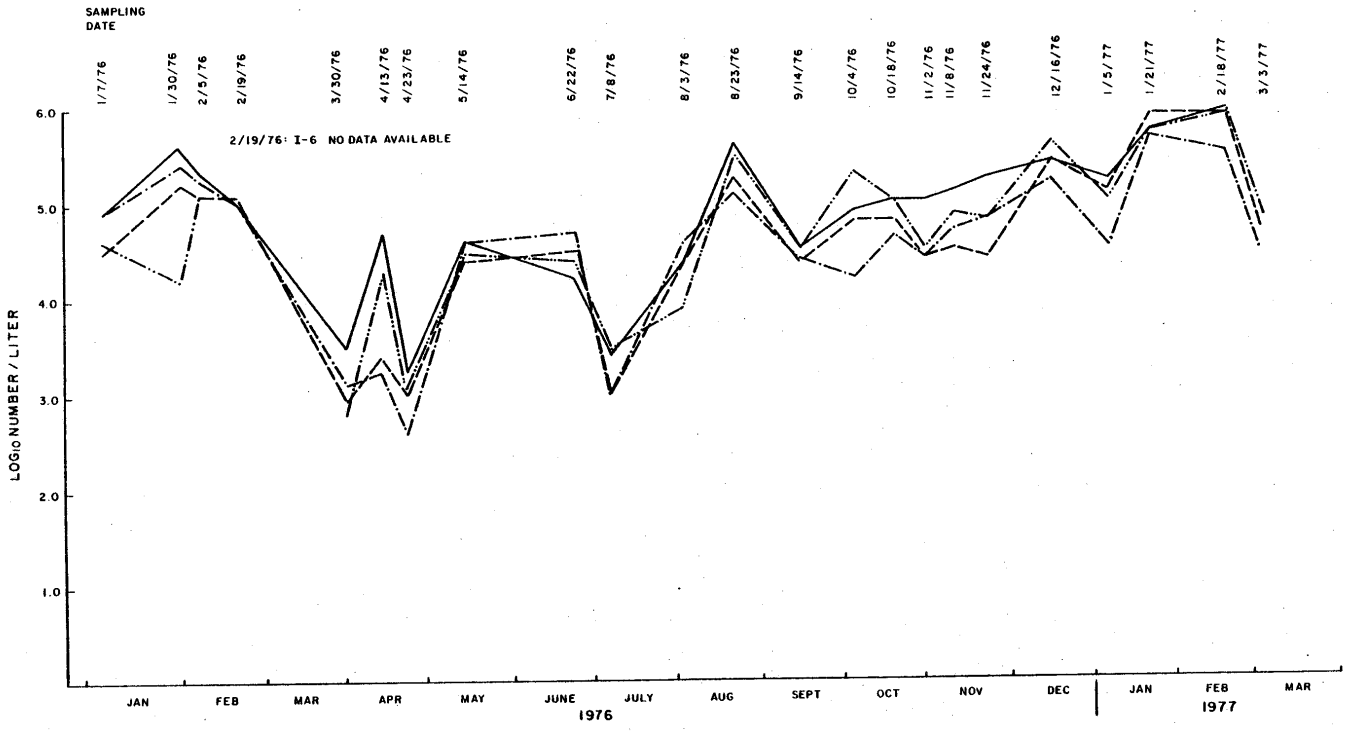


FIGURE 4.2-2
TEMPORAL VARIATION OF DIATOMS
(CELLS/LITER)
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

STATION

- BC-5
- I-3
- I-1/I-13
- I-6

FIGURE 4.2-3
TEMPORAL VARIATION OF DIATOMS (CELLS/LITER)
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

4.3 AQUATIC MACROPHYTES

According to the literature, submerged vegetation in the Tampa Bay estuary system is composed of four important species of seagrass (Phillips 1960a) and 216 species of algae exclusive of the Cyanophyta (Phillips 1960b; Dawes 1967; McNulty et al 1972; Humm 1973a). Approximately 10 percent of the estuary is vegetated by seagrasses and conspicuous benthic algae (Taylor 1971). The seagrass beds serve as nursery and feeding grounds for young fish and shrimp, and provide habitat for large numbers of small marine animals, fishes, worms, small crustaceans, and bacteria. Nutrients released by decay of seagrass leaves help support a large plankton population. Leaves and roots prevent erosion and build substrate by slowing currents and trapping sediments. The seagrasses also provide substrate for epiphytic growth (Phillips 1960a).

Phillips (1960b) reported 86 taxa of algae from three sampling locations in Tampa Bay (including Old Tampa Bay). Large masses of unattached red algae were found at most stations and attached green algae were often abundant. In the bays, Hypnea musciformis, Gracilaria verrucosa, and Spyridia filamentosa were plentiful. Enteromorpha intestinalis formed massive growths in winter and spring.

Phillips also suggested salinity had an effect on algal growth since the number of algal taxa decreased as salinity decreased.

The number of species present is lowest during the hot summer months.

Due to eutrophic conditions, some algal species such as Gracilaria occur in troublesome quantities in Hillsborough Bay. Decaying Gracilaria produces extremely obnoxious odors of rotting vegetation or of hydrogen sulfide (FWPCA 1969). Other algae that grow abundantly under eutrophic conditions include several species of Enteromorpha, Hypnea musciformis, and several blue-greens (FWPCA 1969; Humm 1973b).

Phillips (1960a and 1962) also conducted studies of seagrasses in the Tampa Bay area. He identified four important species: manatee grass, shoal grass, turtle grass, and widgeon grass. He concluded that optimal salinity was less than 25 ppt for widgeon grass, 25-38.5 ppt for turtle grass, and greater than 20-25 ppt for manatee grass (Phillips 1960a). No optimal salinity was determined for shoal grass, although it appears to tolerate a wide range. Optimal temperatures for all four species are between 20 and 30°C.

Reproduction is primarily vegetative and continuous throughout the year, except during the coldest months, for all species except widgeon grass (Phillips 1960a). In widgeon grass, both

sexual and vegetative reproduction account for new growth. At two sampling stations in Tampa Bay, copious flowering and fruiting occurred from May (water temperature 23.5-27.5°C) through June 1958, tapering off in July (water temperature 29.4-32.5°C), and disappearing in August. Fruits may have remained dormant into the winter and germinated when water temperature began to rise in the late winter and spring (Phillips 1960a). No relationship between salinity and flowering was apparent. Setchell (1924) concluded that a temperature range of 15 to 20°C was necessary for germination and seedling development, and a range of 20 to 25°C was necessary for vegetative growth and reproduction.

In describing the distribution of species in Tampa Bay, Phillips (1962) generally found shoal grass dominant in the southerly portions of the Bay, while widgeon grass dominated the northerly portion. In the Big Bend area, shoal grass was common and widgeon grass abundant. Offshore, within the 1.83-m curve, manatee grass was plentiful and widgeon grass sparse. Phillips also noted that all attached seagrasses found in Tampa Bay grew on muddy sand bottom and that growth was limited to bottom areas shoreward of the 1.83-m curve, apparently due to the high turbidity of Tampa Bay. Turtle grass was encountered in the Big Bend area only rarely, probably because of sub-optimal salinity.

Surveys of marine macrophytes conducted for TECO occurred during three time periods: 1970 to 1973, 1975, and 1977 to 1978. The first two studies were conducted prior to modifications to the discharge channel performed in mid 1976. During this time, partially-cooled water was discharged directly into the embayment south of Big Bend (Figure 4.3-1). Presently, as during the 1977 to 1978 studies, the partially-cooled water is discharged into Hillsborough Bay as illustrated in Figure 4.3-2.

Surveys from 1970 to 1973 sampled stations in the embayment and in Tampa Bay. Results showed the Big Bend area was characterized by a paucity of marine grasses and limited algal diversity (TECO 1972), a condition also noted prior to operation of Big Bend Unit 1 in October 1970 (CCI 1971). The perennial Ruppia maritima (widgeon grass) was the most commonly reported seagrass, while Gracilaria spp. and Ulva lactuca (sea lettuce) were the common algal macrophytes. A report on water quality in Hillsborough Bay (FWPCA 1969) listed only three principal genera of algae in the area: Gracilaria spp., Ulva lactuca, and Chaetomorpha linum. Results of the Big Bend surveys are consistent with the FWPCA report: both indicate limited algal diversity is characteristic of the Big Bend area. Table 4.3-1 lists all algae encountered during the studies.

During the summer of 1975, a synoptic survey of marine angiosperms within the Big Bend embayment was undertaken. As in previous studies, limited floral diversity was found, possibly

due to lack of suitable substrate, previous dredge and fill activities, and the polluted nature of Hillsborough Bay (Lewis 1976; Phillips 1962; Godcharles 1971; Taylor & Saloman 1968a). Limited patches of Halodule wrightii (shoal grass) were noted in all areas surveyed. However, dense patches of Ulva and Hypnea were present in all areas surveyed except the shoreline south and west of the former discharge location (Area I). Table 4.3-3 lists the species found in the three study areas shown on Figure 4.3-1.

Observations on aquatic macrophytes made after discharge channel modifications are based on a study designed to assess natural revegetation of areas disturbed by the construction and operation of Big Bend (Mangrove Systems, Inc. 1977 and 1978). Sampling transects were established as shown on Figure 4.3-3. Only those macrophytes found in the vicinity of transects are described here.

The submerged transects (A-1, A-2, A-3, and B-1) and control transect contained a total of four species of seagrasses: Syringodium filiforme (manatee grass), Halodule wrightii (shoal grass), Thalassia testudinum (turtle grass), and Ruppia maritima (widgeon grass). Only the widgeon grass was found at the embayment transects (A-1, A-2, A-3) where it exhibited wider variation in coverage and density than at the control transect (Mangrove Systems 1978). Figure 4.3-2 shows generalized locations of seagrass beds in the transect areas.

The control transect exhibited two disjunct areas of coverage (Mangrove Systems 1978). The inshore area was dominated by widgeon grass in March, June, and September 1978 and by shoal grass in December 1978. A small area of turtle grass was also found in December. The offshore area at the control contained only manatee grass with density and coverage remaining fairly constant throughout the sampling period. Table 4.3-3 lists all species encountered during March, June, September, and December 1978 samplings.

In addition to the submerged transects, intertidal transects (C, D, and E) were also studied. The 27 species found in the intertidal and associated upland areas are included in Table 4.3-3 (Mangrove Systems 1978). During the 1977 March and June sampling, Paspalum vaginatum (seaside paspalum) predominated in Transect E-3 and appeared to be gradually colonizing the intertidal zone (Mangrove Systems 1977). Avicennia germinans (black mangrove) and Laguncularia racemosa (white mangrove) were the only plants present at Transect E-2. Primary species present at Transect E-1 were seaside paspalum, Spartina patens (saltmeadow cordgrass), and Casuarina equisetifolia (Australian pine). Similar species were present at Transects C-1, C-2, and C-3. Colonization of the intertidal zone appeared slow with a few mangroves visible near Transect E-3.

In summary, algal diversity appears limited in the Big Bend vicinity according to observations made before and after startup of Big Bend Unit 1 in October 1970 (CCI 1971). The abundant algal species noted by TECO consultants were Gracilaria spp., Ulva lactuca, and Hypnea spp. An independent study (FWPCA 1969) also found Gracilaria spp. and Ulva lactuca in the vicinity of Big Bend, in addition to Chaetomorpha linum. These observations, which are specific to Big Bend, show some agreement with Phillips' study of macrophytes in Hillsborough Bay (Phillips 1960a) in which Hypnea, Gracilaria, and Enteromorpha spp. were most abundant.

Seagrasses were scarce during the studies at Big Bend, including a period prior to startup of Big Bend Unit 1 (CCI 1971). Widgeon grass was most common and shoal grass was noted sporadically in isolated patches in the embayment before the discharge channel was closed in 1976. After the channel was closed, preventing thermal discharge into the embayment, widgeon grass alone was found at sampling transects in the embayment.

The observed patterns of widgeon and shoal grasses may be the result of competition for dominance between the two species as elucidated by Phillips (1960a). He found widgeon grass dominated during the cooler portions of the year and was replaced by shoal grass as temperatures warmed. Furthermore, he found shoal grass dominant in southern portions of Hillsborough Bay while widgeon grass dominated in northern portions; both species were present near Big Bend (Phillips 1962). Thus, incidence of the grasses may be determined by temperature and location in the Bay.

TABLE 4.3-1

SPECIES LIST OF MARINE ALGAE OF THE BIG BEND AREA, 1970-1973 SURVEY(*)

Cyanophyta (Blue-green algae)
- Hormothamnion sp.
- Oscillatoria sp.
- Spirulina sp.

Chlorophyta (Green algae)
- Caulerpa prolifera
- Chaetomorpha sp.
- Cladophora gracilis (?)
- Enteromorpha intestinalis
- Rhizoclonium sp.
- Ulva lactuca

Rhodophyta (Red algae)
- Acanthophora specifera
- Agardhiella tenera
- Centroceras clavulatum
- Ceramium fastigiatum
- Ceramium sp.
- Champia parvula
- Chondria sp.
- Chondria sedifolia
- Gracilaria sp.
- Gracilaria blodgettii
- Gracilaria compressa
- Gracilaria debilis (?)
- Gracilaria verrucosa
- Gelidium sp. (?)
- Hypnea cervicornis
- Hypnea cornuta
- Hypnea musciformis
- Hypnea spinella

Rhodophyta
- Lomentaria bailyana
- Polysiphonia denudata
- Spyridia filamentosa

Phaeophyta (Brown algae)
- Ectocarpus sp.

SOURCE:

* TECO (Tampa Electric Company). 1973. Ecological surveys of the Big Bend area. Supplement to quarterly progress report on Big Bend thermal and ecological surveys. April 15, 1973. TECO, Mar. Res. Lab.

TABLE 4.3-2

MAJOR ALGAL AND ANGIOSPERM FLORA OF THE BIG BEND EMBAYMENT, 1975 SURVEY(*)

Species	Area I	Area II	Area III
Algae			
Chaetomorpha sp.	L		
Cladophora sp.	L	L,SBL	SBL
Cladophoropsis sp.	L	L	L,SBL
Enteromorpha sp.	L,SBL	SBL	SBL
Hypnea sp.		SBL	SBL
Laurencia sp.		SBL	SBL
Ulva lactuca	L	L	SBL,L
Angiosperms			
Avicennia germinans	SPL,L	SPL,L	SPL,L
Coccoloba sp.	SPL	SPL	SPL
Halodule wrightii	SBL	SBL	SBL
Laguncularia racemosa	SPL	SPL,L	SPL,L
Rhizophora mangle	L	SPL,L	SPL,L
Spartina alterniflora	L		

KEY:

SBL = Sublittoral

L = Littoral

SPL = Supralittoral

SOURCE:

* TECO (Tampa Electric Company). 1975b. Ecological surveys of the Big Bend area. 24th Quarterly Report on Big Bend thermal and ecological surveys. TECO, Mar. Res. Lab.

TABLE 4.3-3

SPECIES LIST OF FLORA COLLECTED IN THE 1978 SURVEY(*)

Species	Common Name
Andropogon virginicus	Broom sedge
Avicennia germinans	Black mangrove
Baccharis halimifolia	Groundsel tree
Canavalia maritima	June bean
Casuarina equisetifolia	Australian pine
Cenchrus pauciflorus	Sandspur
Cenchrus tribuloides	Sandspur
Chloris glauca	Finger grass
Eupatorium capillifolium	Dog fennel
Halodule wrightii	Shoal grass
Heterotheca subaxillaris	Golden aster
Ipomoea pes-caprae	Railroad vine
Iva frutescens	Marsh elder
Laguncularia racemosa	White mangrove
Lepidium virginicum	Pepper grass
Medicago lupulina	Black medick
Oenothera humifusa	Seaside evening primrose
Paspalum vaginatum	Seaside paspalum
Philoxerus vermicularis	Saltweed
Rhizophora mangle	Red mangrove
Ruppia maritima	Widgeon grass
Sesuvium portulacastrum	Sea purslane
Solidago sempervirens	Goldenrod
Spartina patens	Saltmeadow cordgrass
Sporobolus poiretii	Smutgrass
Stenotaphrum secundatum	St. Augustine grass
Suaeda linearis	Seablite
Syringodium filiforme	Manatee grass
Thalassia testudinum	Turtle grass
Uniola paniculata	Sea oats
Vigna luteola	Cow pea

SOURCE:

* Mangrove Systems, Inc. 1978. Assessment of natural revegetation on disturbed dredged material islands, breakwaters, and bay bottoms in the vicinity of the Big Bend Station, Report No. 3. Prepared for Tampa Electric Company, July 1978.

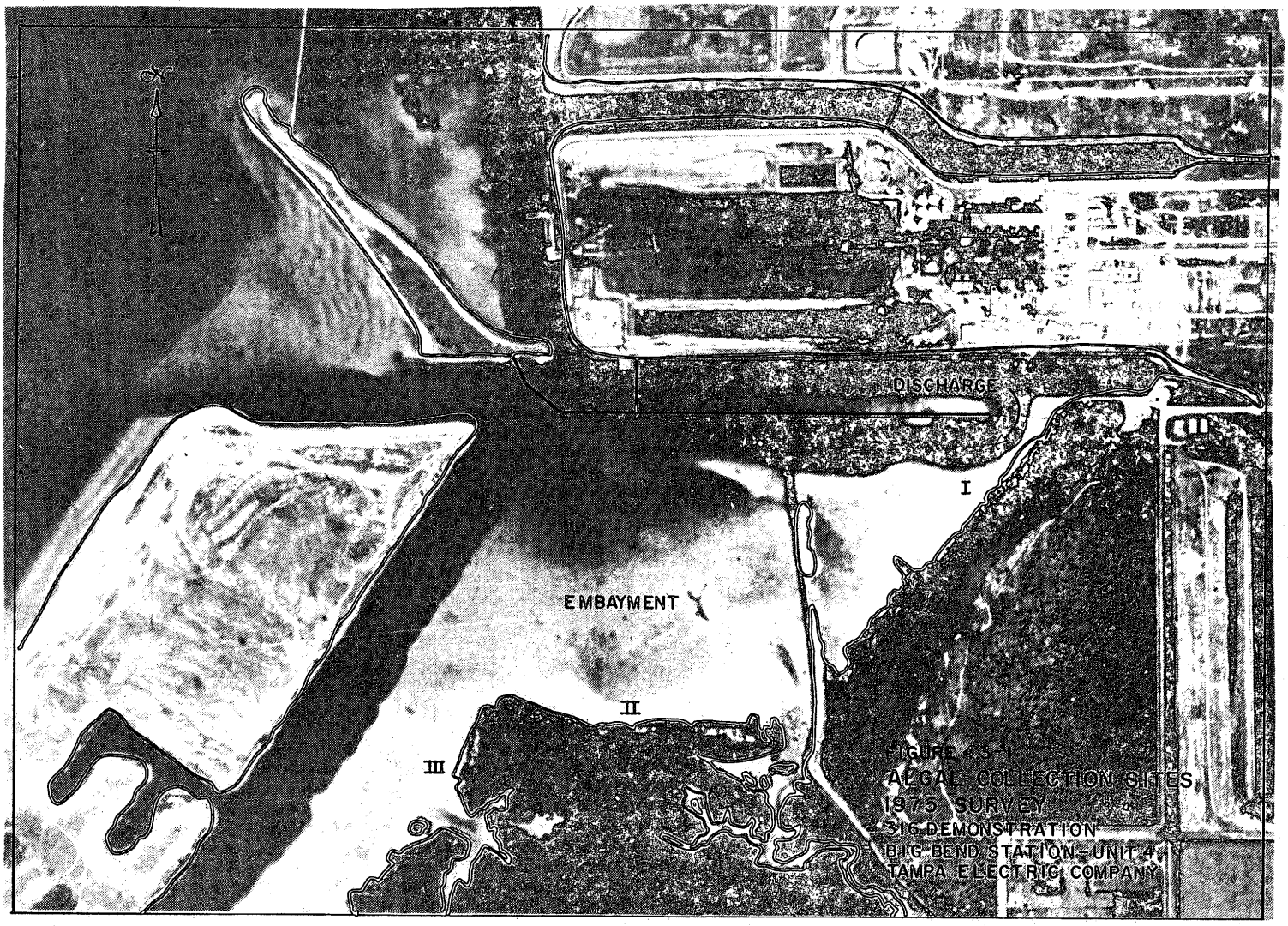
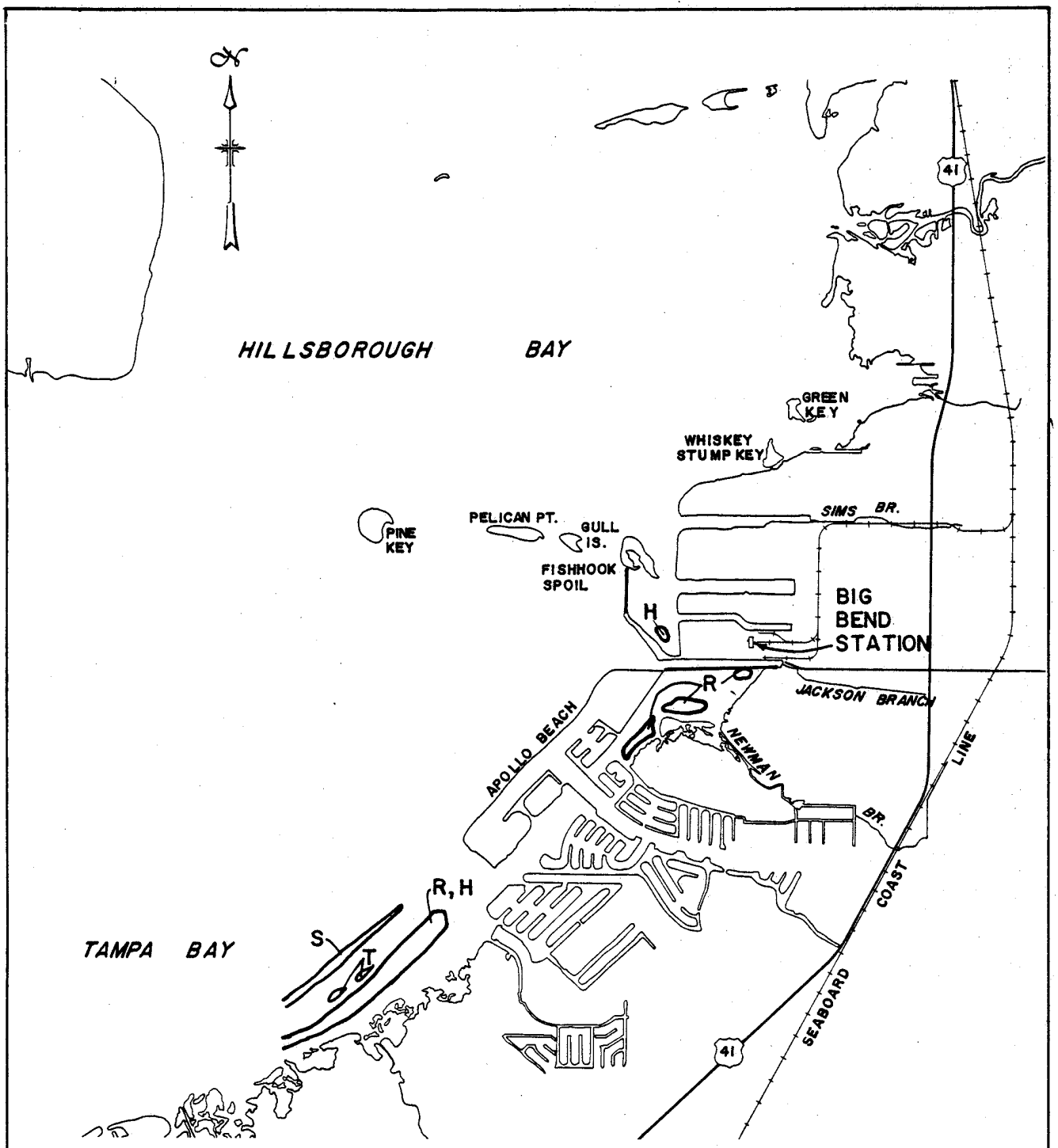


FIGURE 4.3-1
ALGAL COLLECTION SITES
1975 SURVEY
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



SOURCE: Mangrove Systems. 1978. Assessment of Natural Revegetation on Disturbed Dredged Material Islands, Breakwaters, and Bay Bottoms in the Vicinity of the Big Bend Station, Report No. 3. prepared for Tampa Electric Company, July 1978.

FIGURE 4.3-2
LOCATION OF SEAGRASS MEADOWS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

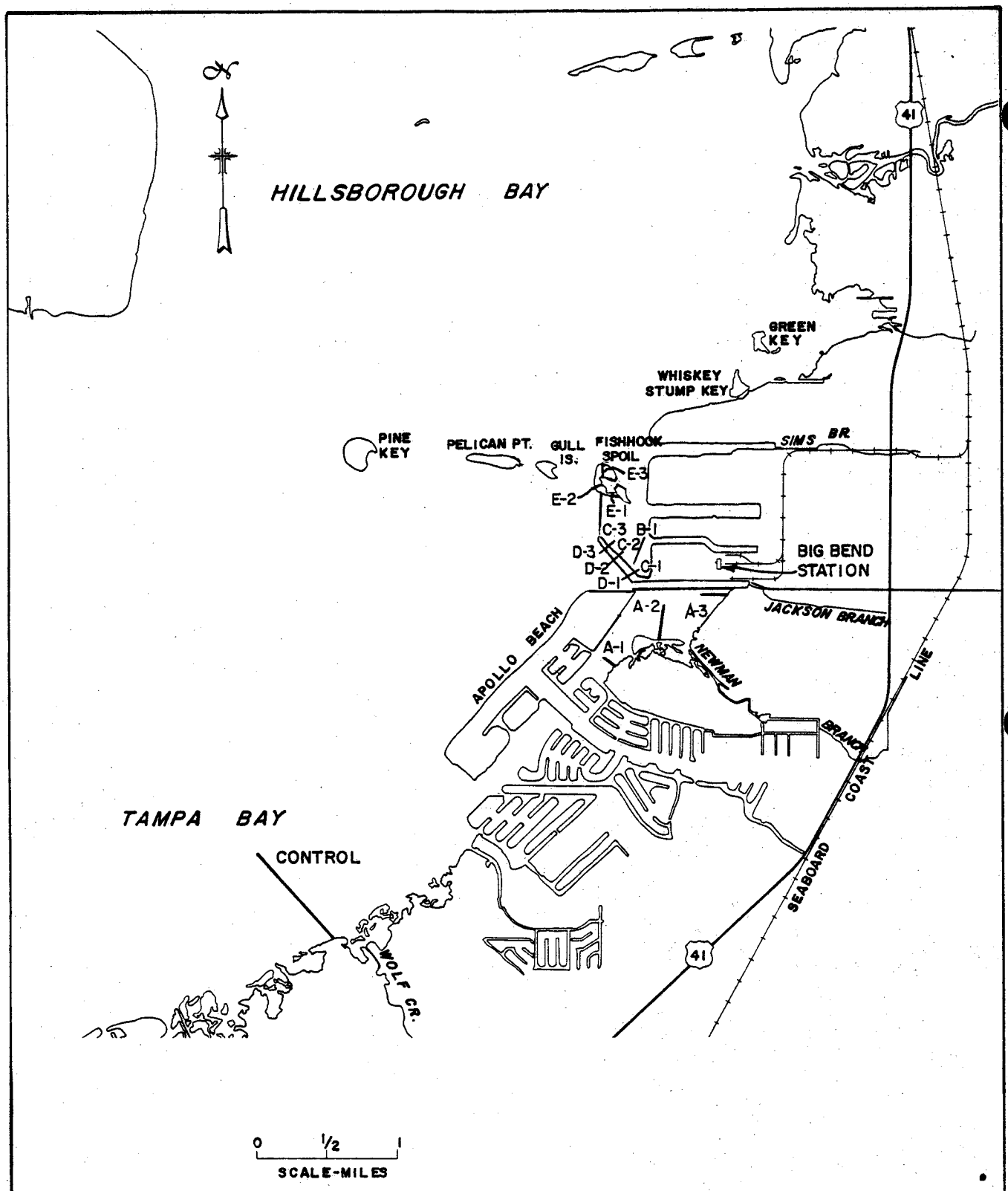


FIGURE 4.3-3
VEGETATIVE SAMPLING TRANSECTS
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

4.4 INVERTEBRATES

4.4.1 Macroinvertebrates Collected by Seine and Trawl

Between 1971 and 1975, invertebrate data were collected by trawls and seines at selected stations (Figure 4.4-1) in the Big Bend area. Tables 4.4-1 through 4.4-5 list the 25 most abundant species of all organisms found during the last 2 years of the study for selected stations. The lists included fishes as well as invertebrates. Results of the sampling are discussed in more detail in the series of quarterly reports entitled "Ecological Surveys of the Big Bend Area" (TECO 1977d).

Further trawl and seine studies were conducted from January 1976 through March 1977. Stations and frequency of sampling were modified from those of the 1971-1975 studies. Figure 4.4-2 shows stations sampled; seine stations were sampled monthly and trawls four times a year. Results of these studies are also reported in "Ecological Surveys of the Big Bend area" (TECO 1977d) and in the Appendix to the 316 Demonstration for Units 1-3 (TECO 1977h).

The most abundant macroinvertebrate collected by seine during the later study was the crown conch Melongena corona, primarily taken on the mud flats of embayment Station SB-10. Young of this species were captured in May and June 1976. Peak abundance of all organisms occurred in September 1976 through February 1977. The blue crab, Callinectes sapidus, was also abundant in seine hauls, generally being among the three numerically dominant invertebrate species in any given haul. Almost half of those collected were caught at Station SB-10 in the embayment north of Apollo Beach.

Macroinvertebrates were most abundant at Station SB-10 and least abundant at Station SB-14. Seasonal peak abundances, noted at most stations, generally occurred in the spring and fall; lowest abundance occurred during the winter.

Only four trawls were conducted between January 1976 and March 1977 (none were taken during the first quarter of 1976). Table 4.4-6 lists total numbers of macroinvertebrates caught by station. The large numbers taken at Station TB-13 reflect a disproportionate number of Molgula sp. captured in February 1977. Table 4.4-7 lists macroinvertebrate catches excluding Molgula sp. During the February 1977 trawl, sampling was conducted both day and night. Table 4.4-8 lists numbers of macroinvertebrates caught by station in day and night samples for February 1977 only. Greater numbers of organisms were caught at night. Otherwise, the low number of organisms collected during the program (approximately 400) does not provide sufficient data to elucidate spatial or temporal patterns.

The 1979 Aquatic Ecology Study also included trawl and seine studies. The sampling stations are shown on Figure 4.4-3. Seining occurred every 4 weeks at high tide between March 14, 1979, and January 15, 1980. Trawl samples were collected at night every 4 weeks. The number of Representative Important Species (RIS) collected are summarized by date in Tables 4.4-9 and 4.4-10, and the non-RIS collected are listed in Table 4.4-11.

Only 6 pink shrimp (Penaeus duorarum Burkenroad) were captured by seine. This low number was probably due to gear selectivity, the type of habitat sampled, and the shrimp's habit of burrowing during the daylight hours.

A total of 936 pink shrimp were collected by trawl. They appeared in each month's sample and were most abundant in the late summer through early winter. Collected at most stations throughout the year, they were consistently abundant at the inshore stations.

A total of 20 blue crabs (Callinectes sapidus) were collected by seine, and 86 by trawl. Most of the blue crabs were collected by trawl in April, and were taken in the intake and discharge canals.

Only 1 stone crab (Menippe mercenaria) was collected during the study, and was taken by trawl. The stone crab's prime habitat is not accessible to the sampling gear used. Therefore, this species was not expected to appear in the otter trawl or shoreline seine samples.

Forty-five non-RIS invertebrates, representing 9 species, appeared in the seine samples. The crown conch (Melongena corona) was the most abundant and constituted 51 percent of the total catch.

A total of 983 non-RIS invertebrates, representing 25 species, were collected by trawl. The common grass shrimp, Trachypenaeus constrictus, constituted 63 percent of these organisms. Collected year-round, T. constrictus were most abundant in December 1979 and January 1980 when 451 individuals were collected.

Detailed results of this study are reported in Appendix 1 of this document.

4.4.2 Macroinvertebrates Collected by Benthic Sampling Gear

Ecological investigations of benthos in the Big Bend area have been conducted since 1970, including two particularly comprehensive surveys from February 1976 to February 1977 and from May to December 1979. Information collected from the former investigation is treated in detail in Chapter 5, Volume II, of

the Appendix to Big Bend Station 316 Demonstration for Units 1-3, September 1977 (TECO 1977g). Information collected from the latter investigation is reported in the 1979 Benthos Study Report by Mote Marine Lab (MML 1980b). The description provided in this section is from these two documents, unless otherwise noted. Location of the 1976-1977 sampling stations and frequency of sampling are shown on Figure 4.4-4. For the 1979 study, many of the same sampling stations were again sampled with similar frequency (Figure 4.4-5). Six ponar grab samples were taken per station on every sampling trip. The ponar gear sampled a bottom area of 0.022 sq m per grab in the 1976-1977 study and 0.0225 sq m per grab in the 1979 study.

4.4.2.1 Results of the 1976-1977 Study

A total of 352 species were identified from the 400,740 organisms collected. Nine species accounted for about 70 percent of the fauna (by abundance) collected during the study period; the abundance and distribution of these species is discussed below. Figures 4.4-6 to 4.4-8 illustrate the density of the most abundant of these species at each sampling station.

Mysella planulata, a small bivalve, was the most abundant species collected at the sampling stations. Its distribution appears to be influenced by sediment type: M. planulata was more abundant at medium sand stations. Generally, communities dominated by Mysella planulata were the most frequently encountered type of association. Stations within the influence of Big Bend Station's thermal plume showed a higher proportion of M. planulata than stations outside the plume's influence. Sampling revealed frequent fluctuations in abundance throughout the duration of the study; correspondingly, no seasonal trends in abundance were evident.

Three amphipods were among the most abundant benthos. Ampelisca abdita (previously identified in the Unit 1-3 316 Demonstration (TECO 1977e) as A. vadorum) was the second most abundant species collected. Its distribution does not appear to be related to sediment. Its occurrence was sporadic; no temporal or spatial patterns were evident from the data. A. holmesi (previously identified in the Unit 1-3 316 Demonstration (TECO 1977e) and the Site Certification Application (TECO 1979) as A. verrilli) was the seventh most abundant species, primarily because it was collected in high numbers at the intake station, I-18. The species was sparsely present at other stations. No temporal pattern was evident from the data. Another amphipod, Rudilemboides naglei, was the ninth most abundant species. It was most abundant at Station SP-1, a control, and was collected at Stations SP-2 and I-18 which are adjacent to Station SP-1. The species was notably sparse at other stations. Spring and late fall abundance peaks were noted at Station SP-1.

The third most abundant benthic organism was Parasterope pollex, an ostracod. It was most abundant in spring and fall and greater numbers were found at stations under the influence of the thermal plume. Another ostracod, Haplocytherida setipunctata, was the fifth most abundant benthic species. It was most abundant at stations having medium-grain sand containing a low fraction of silt and clay. Otherwise, no spatial or temporal variations were evident.

A bivalve species, Mulinia lateralis (previously identified in the Unit 1-3 316 Demonstration (TECO 1977e) and the Site Certification Application (TECO 1979) as Mulinia-Mactra complex) was the fourth most abundant benthic organism. The sediment at stations where these organisms were most abundant was usually medium-grain sand. In addition, these stations were either affected by Big Bend's discharge or were subject to relatively greater solar heating. In general, the species showed a small increase in abundance during the spring of 1976.

Several polychaete species were collected in the study; the most abundant being Pseudopolydora sp. It was the sixth most abundant benthic organism collected. The species was most abundant at three stations, along the BC transect (Figure 4.4-6), and appears to prefer fine sand sediments. In general, an abundance peak occurred in late 1976.

A cumacean species, Cyclaspis varians, was the eighth most abundant benthic organism collected. It was the dominant species (by number) at the discharge sampling station from May to July 1976. It was also found at most open bay stations, but was characterized by sporadic peaks of abundance. The studies suggest C. varians is an opportunistic species, briefly colonizing a habitat when conditions allow.

In general, most stations were dominated by a few species, with Mysella planulata most frequently the dominant species. Its occurrence was temporally erratic, however. Abundances of Cyclaspis varians, Ampelisca abdita, and A. holmesi were sporadically high at most stations. Ostracods tended to demonstrate two abundance peaks, in May and November. Bivalves did not demonstrate a consistent pattern of abundance in time but appeared to prefer medium-grain sand sediment. For all dominants, extreme fluctuations in abundance were common at Big Bend.

Benthic species which have been suggested as indicators of pollution (thermal and other) were collected at Big Bend. Nereis succinea, a polychaete, was abundant and persistent at the discharge stations (I-1 and I-16) and a station near the Point of Discharge (POD) (BC-8). Highest abundance was found during summer months. In August 1976, N. succinea accounted for 78 percent of the faunal abundance at the outfall station (I-1).

However, it accounted for only 8 percent of the BC-8 collection at the same time, its maximum value for the entire study period at BC-8. Most other stations averaged less than 1 percent relative abundance of N. succinea.

Capitella capitata, another polychaete species and suggested pollution indicator, was found at several inshore stations (I-1, I-16, I-2, I-17, I-15, and F-3). Its highest relative abundance was encountered at the outfall station, I-1, in April 1976 when C. capitata represented 41 percent of the benthos collected at the station. Its highest average relative abundance (for the study period) was 20 percent at the finger-fill canal station, F-3. This station is outside the influence of the thermal plume, but is considered polluted by development activity in Apollo Beach (TECO 1977h). Relative abundance of C. capitata averaged less than 1 percent at most of the remaining sampling locations.

A number of parameters were calculated to characterize the benthic assemblages in the Big Bend area. These include density and biomass, diversity, richness, equitability and similarity, and are discussed at length in the Units 1-3 316 Demonstration (TECO 1977e). Faunal density calculated for several of the stations is shown on Figure 4.4-9. Density values were notably low at discharge canal stations, but other stations considered to be controls (E transect) had similar values. Only stations under the influence of Big Bend's discharge appeared to demonstrate temporal patterns: densities at discharge stations peaked in May and thermal transect stations showed more variability in density early and late in 1976. Biomass values did not exhibit temporal patterns but spatial patterns were found. Stations along the C transect exhibited relatively higher biomass than corresponding E transect stations. Average biomass values at I stations were slightly less than those of all other stations.

Most communities were dominated by a few species, so equitability (a measure of the distribution of individuals among species) was low. Species richness (the number of species) was low at stations in the discharge canal, the northern embayment of Apollo Beach, and Station SP-2. Species diversity (a measure of community heterogeneity), which is a function of both richness and equitability, generally increased with distance from shore in the bay transects. Diversity values at discharge canal stations were higher than those from BC stations, but were similar to E station values. In general, diversity was higher during two periods of the study, May-July and November-December; lower values occurred in August and September. Similarity of faunal composition at different stations fluctuated during the study due to shifts in dominance (i.e., the most abundant species at a station was replaced by another as the study progressed). Results of the similarity analysis showed the benthos distributed according to sediment type. However, some dissimilarity that

could not be attributed to differences in sediment occurred between communities at stations along the BC and E transects.

4.4.2.2 Results of 1979 Study

A total of 198 species were identified from the 72,619 organisms collected.

The more abundant species include five polychaetes: Mediomastus californiensis, Pseudopolydora sp., Paraprionospio pinnata, Streblospio benedicti, and Nereis succinea; and one bivalve, Mulinia lateralis. Early in the study period, two species of amphipods, Ampelisca holmesi and Ampelisca abdita, were abundant in the north embayment and off Apollo Beach.

Mediomastus californiensis comprised a much greater portion of the benthos in this 1979 study than in the 1976-1977 study. This species was more abundant at Stations 4 and 7 through 11 and less abundant in the discharge canal stations.

Pseudopolydora sp. A. was collected in great abundance only at offshore stations and was not collected in November or December of 1979. The spatial pattern is consistent with that of the 1976-1977 study; however, the species has been collected in November and December in the past.

Paraprionospio pinnata occasionally represented a large proportion of the benthos at stations on both the thermal and control transects, but seldom represented more than 5 percent of the total collected at Stations 1, 2, 3, or 14. This is consistent with the pattern of relative abundance observed for this species in the 1976-1977 study where relatively lower abundance was observed at the inshore sampling stations.

Streblospio benedicti was seldom captured in June or August sampling. However, at other times, it often accounted for a large portion of the benthos in the discharge canal. During the September and November samplings, this species occasionally accounted for a good portion of the benthos at a variety of offshore stations. This species had a much lower relative abundance in the 1976-1977 study. In fact, its relative abundance was great only at Station I-15. This high abundance was attributed to dredging and spilling of silt in the area.

Nereis succinea consistently showed a high relative abundance at the discharge station (1) and the first station outside the discharge canal (3). On one occasion, this species had a high relative abundance at the dilution pump station but, at other times, and at all other locations, this species seldom accounted for more than 5 percent of the catch. This species showed a very similar pattern of relative abundance in the 1976-1977 study.

The bivalve, Mulinia lateralis, comprised only a small portion of the benthos at all stations until December, when it made up a large part of the benthos at nearly all stations. This species was relatively abundant throughout all periods of the previous study.

Some of the biotic indices used to measure community or species assemblage characteristics such as faunal density, species richness, diversity, and equitability are presented in the 1979 Thermal Effects Benthos Study (Tables 17 to 20 and Figures 10 to 37 of MML 1980b). In general, faunal density and species richness dropped for the three sampling periods prior to the dilution pump shutdown, remained low during August and September samplings, and rose during the November and December sampling periods. Faunal similarity was greatest among the December samples due to the widespread abundance of Mulinia lateralis.

4.4.2.3 Additional Historical Information

Benthic surveys show that Tampa Bay supports an abundant and diverse community of benthic invertebrates (Simon 1974; Godcharles 1971; Santos 1972; Santos & Simon 1974; Taylor 1971; Taylor & Saloman 1966, 1968b, and 1970; Paine 1961 and 1963; Dauer 1972). In Hillsborough Bay, however, soft, highly organic sediments have replaced native sands, and high Biochemical Oxygen Demand (BOD) makes the Bay uninhabitable for most benthic organisms (U.S. Army Corps of Engineers 1974). As a result of dredging activities, sewage, and runoff, Hillsborough and Tampa Bays are typified by altered benthic habitats.

Taylor et al (1970) conducted an extensive survey of the benthic mollusks of Hillsborough Bay in 1963. Sampling with a bucket dredge and a rigid frame net, they collected 64 species, of which only 36 were represented by living specimens. Samples at all stations where live individuals were taken always included one or more of the following species: the dwarf surf clam, Mulinia lateralis; the paper mussel, Amygdalum papyria; the common eastern nassa, Nassarius vibex; and the stout tagelus, Tagelus plebius. Other numerous mollusks were the crown conch, Melongena corona, and the luna dove-shell, Mitrella lunata.

On the basis of the distribution and occurrence of certain mollusks found in this survey, the researchers classified the Hillsborough Bay bottom environment into three zones: healthy, marginal, and unhealthy. These classifications were correlated with the degree of man-made alteration that had occurred. Using this system, 42 percent of the Bay bottom was considered unhealthy, 36 percent marginal, and 22 percent healthy. Those areas termed unhealthy were marked by accumulations of sediment unsuitable for colonization by benthic infauna. These sediments were either highly organic anaerobic fine-grained silts, coarse-grained spoil from channel dredging, or gypsum spoil from the

processing of phosphate. There were no living mollusks found in this zone. The marginal areas represented transitional zones between the unhealthy and healthy areas. Marginal zones contained a limited number and diversity of mollusks. The healthy area supported numerous and diverse assemblages of species. The sediments were primarily fine-grained sand. Most of the healthy stations were at the mouth of Hillsborough Bay in the offshore areas.

A massive outbreak of red tide in 1971 eradicated the polychaete fauna of a sandy, intertidal area of old Tampa Bay. This provided an excellent opportunity to study the recovery of a benthic community. Analysis of the 22 most common infaunal invertebrates showed a decrease of 97 percent in the total number of individuals and a 77 percent decrease in the number of species between April 1970 and August 1971 (Bloom et al 1972; Simon & Dauer 1972). The rates of species immigration and extinction were studied over the next 2 years, and the resulting recolonization curve showed that repopulation conformed to the species equilibrium model of MacArthur and Wilson (1963 and 1967). Immigration of polychaete species to the area was rapid for the first few months, rose slowly after that, then leveled off 11 months later when there were 28 species in the area. A total of 54 polychaete species were collected during the study (Dauer & Simon 1976b). Although the average species number and density of individuals were not significantly different at specific tide levels, the species composition was highly variable over time (Dauer & Simon 1975). The species that were dominant during the first year, Eteone heteropoda, Gyptis vittata, Nereis succinea, and Paraprionospio pinnata, were opportunistic and expanded their distributions. Second year dominants, Capitita ambiseta, Minuspio cirrifera, and Travisia sp. were collected later, took longer to increase their densities, and did not show habitat expansion (Dauer & Simon 1976a). Adult dispersal was important when the populations were becoming established, and larval settlement maintained the population (Kelly & Johnson 1967).

Much of the scientific literature concerning Tampa Bay benthos has concentrated on the environmental effects of a variety of dredging activities. These include channel deepening, maintenance dredging, shell dredging, and dredging for landfill.

In a study done for the U.S. Army Corps of Engineers (1974), the benthos of the Tampa Ship Channel were surveyed from outside Tampa Bay to Hillsborough Bay in 1963 (Taylor 1973). More than 300 species representing 17 major taxa were collected. Faunal analysis by taxonomic group showed that annelid worms (polychaetes, oligochaetes, and a few marine leeches) made up most of the benthos collected, and dominated the bottom assemblage at each transect. Arthropods (isopods, amphipods, and cumaceans) were the next most common group, followed by mollusks,

other minor phyla (predominantly nematodes), chordates (mostly lancelets), and echinoderms (almost entirely ophiuroids). Annelids, arthropods, and mollusks were more numerous at two transects north of Big Bend in Hillsborough Bay than elsewhere in Tampa Bay. One transect, south of the spoil islands, produced the greatest number of organisms in the study area.

Sediment type alone had little bearing on abundance or variety of benthic organisms in the Ship Channel. The most noticeable difference between soft and firm bottom sediments was that those having a weight percentage of more than 20 percent silt and clay almost always contained very large numbers of specific mollusks and polychaetes. Corbula, Tellina, Mulinia, and Macoma were the most common mollusks, and polychaetes from the Family Spionidae were dominant. Although a few species were dominant at soft bottom stations, the diversity indices still indicated fair to good environmental conditions.

The presence of the Ship Channel may have greater influence on infaunal abundance and variety than sediment type alone. Taylor (1973) divided the bay bottom into five sediment types: deep ship channel, soft spoil, firm spoil, soft undredged bottoms, and firm undredged bottoms. Firm bottoms (combination of sand and shell) supported the greatest number of species and individuals, while channel areas supported the least. The sampling method and number of stations in each bottom type may have influenced these results.

In the 2-year period between the 1976-1977 study and the 1979 benthos study at Big Bend, species composition changed considerably. In 1976-1977, mollusks and peracarids were the more abundant benthic groups. In the 1979 study, polychaetes were more abundant than mollusks or peracarids. This rapid change in species composition can be attributed to potential cyclic abundance patterns (Santos 1979) and dredging activities (MML 1980b).

Once the ship channels are deepened, maintenance dredging must be carried out periodically to remove sedimentation resulting from sewage treatment effluents and natural sources that gradually fill in the channels. Instead of open water disposal of this spoil, which was prohibited in 1973, spoil from the Tampa Harbor Deepening Project is deposited in diked areas within Hillsborough Bay (U.S. Army Corps of Engineers 1976). These spoil areas will total 50 million sq ft in Hillsborough Bay alone (Lewis 1976), and they are planned to hold 30 years of maintenance spoil. Whether anticipated improvement in water quality will offset the loss of benthic habitat is impossible to determine at this time (Lewis 1976).

Nearly 18 million tons of oyster shells have been removed from Tampa Bay for commercial purposes since 1946 (Taylor 1972).

Shells and sediment are removed by hydraulic cutterhead dredge and sorted over screens; the sediment and water are returned to the Bay. Simon, Doyle, and Connors (1976) conducted a study of the modification of biological communities in dredged areas. They found the area disturbed by shell dredging resumed its initial species assemblage, number of species, density patterns, and the same or slightly lower biomass within 1 year of dredging activity when compared to undisturbed bay bottom. However, the effects of small, tightly controlled, target specific shell dredging operations cannot be directly compared to the massive changes resulting from large channel deepening projects (Lewis 1976).

Hillsborough Bay has been greatly modified by dredging intended for landfill. One hundred years ago, there were 2,378 hectares (ha) of marine wetlands in Hillsborough Bay. In 1976, however, only 400 ha of wetlands remained, representing a loss of 83 percent (Lewis 1976). Twelve years ago, filled areas in Tampa Bay estuary totaled 4,266 ha (McNulty et al 1972). Nearly all of this was created through dredging submerged or intertidal bay bottom and pumping the spoil into emergent landsites. The magnitude of this loss can be seen by comparison with studies in Boca Ciega Bay. Taylor and Saloman (1968a) estimate that filling in of 1,400 ha of bay bottom resulted in a minimum loss of 25,841 metric tons/year of infauna.

TABLE 4.4-1

RELATIVE ABUNDANCE OF THE TWENTY-FIVE MOST ABUNDANT ORGANISMS COLLECTED AT TRAWL STATION TB-2 (DISCHARGE CANAL) 1973-1975(*)

Species (Phylum)	Percent of Total
Melongena corona (Mollusca)	25.19
Crepidula plana (Mollusca)	18.15
Molgula sp. (Chordata)	14.93
Amphipoda (Arthropoda)	9.88
Hexapanopeus augustifrons (Arthropoda)	2.68
Callinectes sapidus (Arthropoda)	2.60
Pagurus longicarpus (Arthropoda)	2.45
Pagurus pollicaris (Arthropoda)	1.91
Neopanope texana (Arthropoda)	1.84
Penaeus duorarum (Arthropoda)	1.76
Lolliguncula brevis (Mollusca)	1.53
Chaetodipterus faber (Chordata)	1.23
Eurypanopeus depressus (Arthropoda)	1.23
Cynoscion arenarius (Chordata)	1.00
Pogonias cromis (Chordata)	1.00
Mitrella lunata (Mollusca)	0.84
Diapterus plumieri (Chordata)	0.84
Micropogon undulatus (Chordata)	0.84
Unidentified xanthid crabs (Arthropoda)	0.69
Palaemon floridanus (Arthropoda)	0.54
Styela plicata (Chordata)	0.54
Anchoa mitchilli (Chordata)	0.54
Archosargus probatocephalus (Chordata)	0.46
Mugil sp. (Chordata)	0.46
Limulus polyphemus (Arthropoda)	0.38
TOTAL	93.51

SOURCE:

* TECO (Tampa Electric Company). 1975a. Ecological surveys of the Big Bend area - Five year data evaluation. A summary and analysis of past ecological studies in the vicinity of Big Bend Steam Electric Station, Tampa Bay, Florida. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.4-2

RELATIVE ABUNDANCE OF THE TWENTY-FIVE MOST ABUNDANT ORGANISMS COLLECTED AT TRAWL STATION TB-3 1973-1975(*)

Species (Phylum)	Percent of Total
Brittle stars, unidentified (Echinodermata)	87.03
Anemone, unidentified (Coelenterata)	5.50
Luidia clathrata (Echinodermata)	1.69
Bairdiella chrysura (Chordata)	0.70
Orthopristis chrysopteris (Chordata)	0.60
Chaetodipterus faber (Chordata)	0.57
Chloroscombrus chrysura (Chordata)	0.48
Anchoa mitchilli (Chordata)	0.36
Menticirrhus americanus (Chordata)	0.34
Penaeus duorarum (Arthropoda)	0.23
Portunus gibbesii (Arthropoda)	0.21
Polyonyx gibbesii (Arthropoda)	0.19
Prionotus scitulus (Chordata)	0.17
Molgula sp. (Chordata)	0.14
Leiostomus xanthurus (Chordata)	0.11
Lolliguncula brevis (Mollusca)	0.11
Arius felis (Chordata)	0.10
Symphurus plaquisa (Chordata)	0.10
Lagodon rhomboides (Chordata)	0.10
Chaetopterus variopedatus (Annelida)	0.08
Cynoscion arenarius (Chordata)	0.08
Glottidia pyramidata (Brachiopoda)	0.06
Anchoa hepsetus (Chordata)	0.05
Crepidula plana (Mollusca)	0.05
Libinia dubia (Arthropoda)	0.05
TOTAL	99.10

SOURCE:

* TECO (Tampa Electric Company). 1975a. Ecological surveys of the Big Bend area - Five year data evaluation. A summary and analysis of past ecological studies in the vicinity of Big Bend Steam Electric Station, Tampa Bay, Florida. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.4-3

RELATIVE ABUNDANCE OF THE TWENTY-FIVE MOST ABUNDANT ORGANISMS COLLECTED AT TRAWL STATION TB-4 (INTAKE CANAL) 1973-1975(*)

Species (Phylum)	Percent of Total
Neopanope texana (Arthropoda)	15.84
Mulinia lateralis (Mollusca)	14.81
Cynoscion arenarius (Chordata)	13.54
Anchoa mitchilli (Chordata)	11.88
Penaeus duorarum (Arthropoda)	7.79
Lolliguncula brevis (Mollusca)	5.11
Hexapanopeus angustifrons (Arthropoda)	3.70
Squilla empusa (Arthropoda)	2.68
Bairdiella chrysura (Chordata)	2.68
Callinectes sapidus (Arthropoda)	2.17
Portunus gibbesii (Arthropoda)	2.17
Menticirrhus americanus (Chordata)	1.53
Platynereis dumerilii (Annelida)	1.40
Micropogon undulatus (Chordata)	1.28
Trinectes maculatus (Chordata)	1.28
Palaemonetes vulgaris (Arthropoda)	1.15
Alpheus heterochaelis (Arthropoda)	1.02
Luidia clathrata (Echinodermata)	1.02
Styela plicata (Chordata)	0.89
Anadara transversa (Mollusca)	0.77
Macoma tenta (Mollusca)	0.64
Corbula sp. (Mollusca)	0.51
Glottidia pyramidata (Brachiopoda)	0.51
Prunum apicunum (Mollusca)	0.38
Pagurus longicarpus (Arthropoda)	0.38
TOTAL	95.13

SOURCE:

* TECO (Tampa Electric Company). 1975a. Ecological surveys of the Big Bend area - Five year data evaluation. A summary and analysis of past ecological studies in the vicinity of Big Bend Steam Electric Station, Tampa Bay, Florida. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.4-4

RELATIVE ABUNDANCE OF THE TWENTY-FIVE MOST ABUNDANT ORGANISMS COLLECTED AT SEINE STATION SB-1 1973-1975(*)

Species (Phylum)	Percent of Total
Anchoa mitchilli (Chordata)	37.39
Eucinostomus argenteus (Chordata)	13.07
Eucinostomus gula (Chordata)	10.07
Melongena corona (Mollusca)	5.90
Trachinotus falcatus (Chordata)	5.35
Oligoplites saurus (Chordata)	5.08
Membras martinica (Chordata)	4.08
Fundulus similis (Chordata)	3.18
Sciaenops ocellata (Chordata)	1.72
Hyporhamphus unifasciatus (Chordata)	1.54
Callinectes sapidus (Arthropoda)	1.45
Pagurus longicarpus (Arthropoda)	1.45
Menidia beryllina (Chordata)	1.09
Elops saurus (Chordata)	0.73
Mugil trichodon (Chordata)	0.64
Strongylura timucu (Chordata)	0.54
Strongylura notata (Chordata)	0.54
Archosargus probatocephalus (Chordata)	0.54
Polinices duplicatus (Mollusca)	0.45
Crepidula plana (Mollusca)	0.45
Lagodon rhomboides (Chordata)	0.45
Unidentified gerrid (Chordata)	0.45
Penaeus duorarum (Arthropoda)	0.27
Microgobius gulosus (Chordata)	0.27
Unidentified nereid (Annelida)	0.18
TOTAL	96.88

SOURCE:

* TECO (Tampa Electric Company). 1975a. Ecological surveys of the Big Bend area - Five year data evaluation. A summary and analysis of past ecological studies in the vicinity of Big Bend Steam Electric Station, Tampa Bay, Florida. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.4-5

RELATIVE ABUNDANCE OF THE TWENTY-FIVE MOST ABUNDANT ORGANISMS COLLECTED AT SEINE STATION SB-3 1973-1975(*)

Species (Phylum)	Percent of Total
Menidia beryllina (Chordata)	21.13
Harengula jaguana (Chordata)	19.18
Eucinostomus argenteus (Chordata)	18.29
Unidentified gerrid (Chordata)	13.69
Eucinostomus gula (Chordata)	5.77
Anchoa mitchilli (Chordata)	4.10
Melongena corona (Mollusca)	2.72
Portunus gibbesii (Arthropoda)	2.02
Neopanope texana (Arthropoda)	1.20
Lagodon rhomboides (Chordata)	1.13
Strongylura timucu (Chordata)	1.06
Brevoortia sp. (Chordata)	0.88
Callinectes sapidus (Arthropoda)	0.78
Fundulus similis (Chordata)	0.78
Pagurus longicarpus (Arthropoda)	0.71
Penaeus duorarum (Arthropoda)	0.67
Palaemonetes pugio (Arthropoda)	0.50
Menticirrhus focaliger (Chordata)	0.50
Trachinotus falcatus (Chordata)	0.50
Menticirrhus americanus (Chordata)	0.46
Oligoplites saurus (Chordata)	0.46
Mugil cephalus (Chordata)	0.42
Oliva sayana (Mollusca)	0.35
Amygdalum papyrium (Mollusca)	0.25
Hyporhamphus unifasciatus (Chordata)	0.21
TOTAL	97.76

SOURCE:

* TECO (Tampa Electric Company). 1975a. Ecological surveys of the Big Bend area – Five year data evaluation. A summary and analysis of past ecological studies in the vicinity of Big Bend Steam Electric Station, Tampa Bay, Florida. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.4-6

MACROINVERTEBRATES CAPTURED BY TRAWL (DAY SAMPLES ONLY)
BETWEEN JUNE 1976 AND FEBRUARY 1977

Transect	Total Number of Macroinvertebrates	Percent of Total Catch
TB-1	15	3.9
TB-12	25	6.5
TB-5	53	13.8
TB-7	34	8.9
TB-6	19	5.0
TB-13	198	51.7
TB-4	39	10.2
Total	383	100.0

TABLE 4.4-7

MACROINVERTEBRATES CAPTURED BETWEEN JUNE 1976 AND FEBRUARY 1977 EXCLUDING *MOLGULA* SP.(*)

Transect	Total Number of Macroinvertebrates	Percent of Total Catch
TB-1	15	7.0
TB-12	22	10.3
TB-5	53	24.9
TB-7	34	16.0
TB-6	19	8.9
TB-13	31	14.6
TB-4	39	18.3
Total	213	100.0

SOURCE:

* TECO (Tampa Electric Company). 1977h. Final report of ecological surveys of the Big Bend area, Vol 3. Appendix to 316 Demonstration, Vol III. An analysis and summary of studies on the effect of the cooling water system on aquatic fauna, Vol. III. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.4-8

TOTAL NUMBER OF MACROINVERTEBRATES CAPTURED
IN FEBRUARY 1977 TRAWLS - DAY VS NIGHT SAMPLING(1)

Transect	Total Number of Macroinvertebrates(2) Day	Night
TB-1	2	3
TB-12	10	85
TB-5	4	9
TB-7	0	5
TB-6	3	34 (33)
TB-13	188 (21)	80 (28)
TB-4	23	31

SOURCE:

1. TECO (Tampa Electric Company). 1977h. Final report of ecological surveys of the Big Bend area, Vol 3. Appendix to 316 Demonstration, Vol III. An analysis and summary of studies on the effect of the cooling water system on aquatic fauna, Vol. III. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

NOTE:

2. Numbers in parentheses indicate the number of macroinvertebrates that were captured excluding *Molgula* sp.

TABLE 4.4-9

LIST OF RIS INVERTEBRATES COLLECTED BY SEINE
FROM MARCH 14, 1970, TO JANUARY 15, 1980

	Species		
Date	Penaeus duorarum	Callinectes sapidus	Menippe mercenaria
3/14/79	-	5	-
4/10/79	1	4	-
5/10/79	-	1	-
6/5/79	-	1	-
7/3/79	-	4	-
7/31/79	3	1	-
8/28/79	-	2	-
9/25/79	-	-	-
10/23/79	1	1	-
11/20/79	1	-	-
12/18/79	-	-	-
1/15/80	-	1	-
Total	6	20	0

TABLE 4.4-10

LIST OF RIS INVERTEBRATES COLLECTED BY TRAWL
FROM MARCH 14, 1970, TO JANUARY 15, 1980

Date	Species		
	Penaeus duorarum	Callinectes sapidus	Menippe mercenaria
3/14/79	34	8	-
4/10/79	75	42	-
5/10/79	20	6	-
6/5/79	13	6	-
7/3/79	37	2	-
7/31/79	55	-	-
8/28/79	109	-	-
9/25/79	72	-	-
10/23/79	220	2	-
11/20/79	142	3	-
12/18/79	122	10	1
1/15/80	58	7	-
Total	957	86	1

TABLE 4.4-11

LIST OF ALL NON-RIS INVERTEBRATES COLLECTED BY SEINE AND TRAWL BETWEEN MARCH 14, 1979, AND FEBRUARY 12, 1980

Species/Common Name	Seine	Trawl
Polinices duplicatus Moon snail		X
Busycon contrarium Lightning whelk		X
Melongena corona Crown conch	X	X
Fasciolaria illium hunteria Banded tulip		X
Oliva sayana Lettered olive		X
Lollinguncula brevis Brief squid	X	X
Limulus polyphemus Horseshoe crab	X	X
Squilla empusa Mantis shrimp		X
Trachypenaeus constrictus Penaeid shrimp		X
Palaemonetes pugio Grass shrimp	X	X
Pagurus longicarpus Hermit crab	X	X
Pagurus pollicaris Hermit crab	X	X
Pagurus sp. Hermit crab	X	X
Hepatus pudibundus		X
Persephona aquilonaris Purse crab		X

TABLE 4.4-11 (Cont)

Species/Common Name	Seine	Trawl
Portunus gibbesii Portunid crab	X	X
Neopanope texana Xanthid crab		X
Eurypanopeus depressus Xanthid crab	X	X
Unidentified Xanthid crab		X
Pinnixa chaetopterana Commensal crab		X
Libinia dubia Spider crab		X
Luidia clathrata Sea star		X
Molgula sp. Tunicate		X

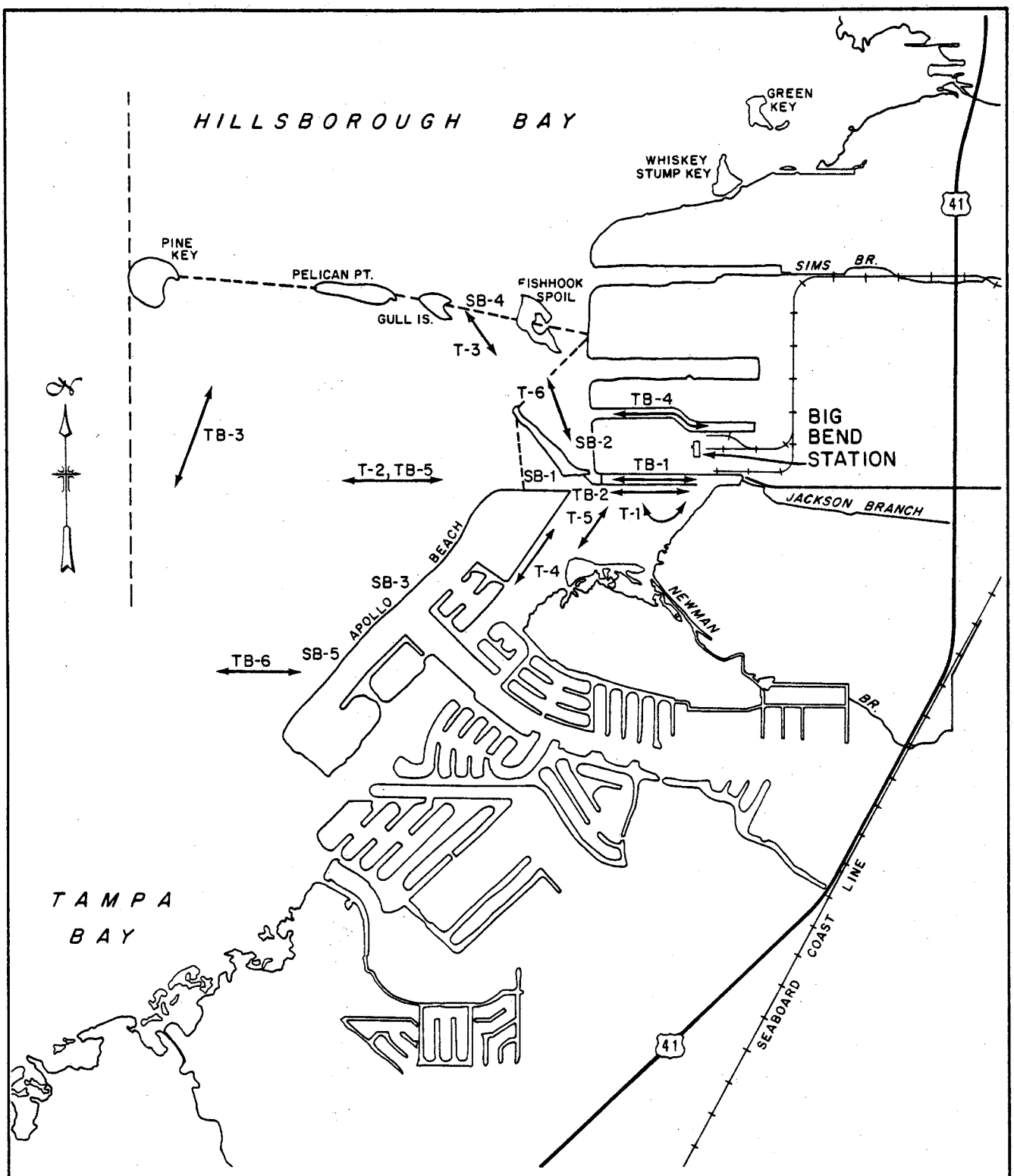
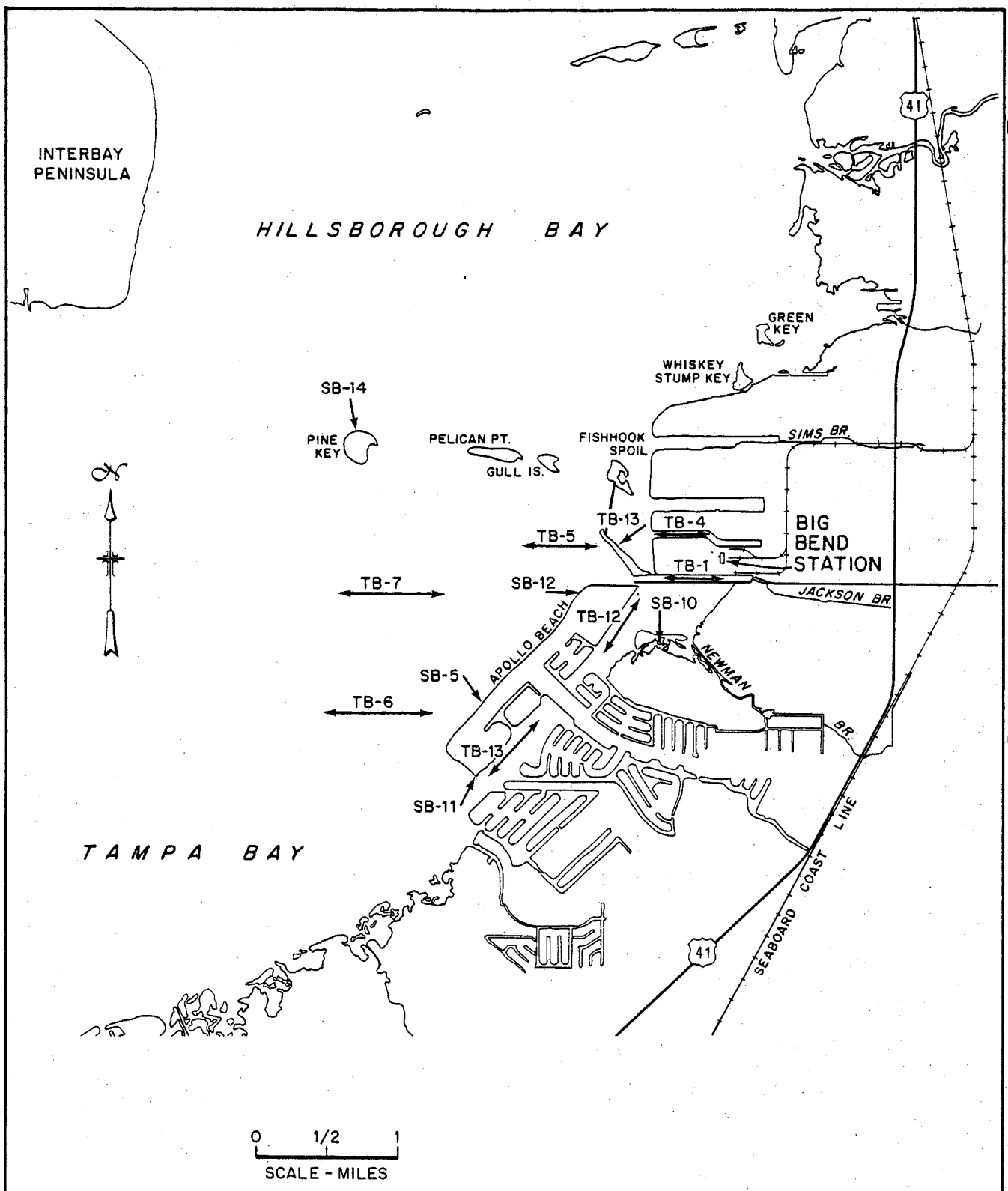


FIGURE 4.4-1
TRAWL AND SEINE STATIONS 1970-1975
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

SOURCE: TECO, 1975a. Modified from Ecological Surveys of the Big Bend Area Five Year Data Summary, Page 312.



LEGEND

TB - TRAWL STATION

SB - SEINE STATION

FIGURE 4.4-2

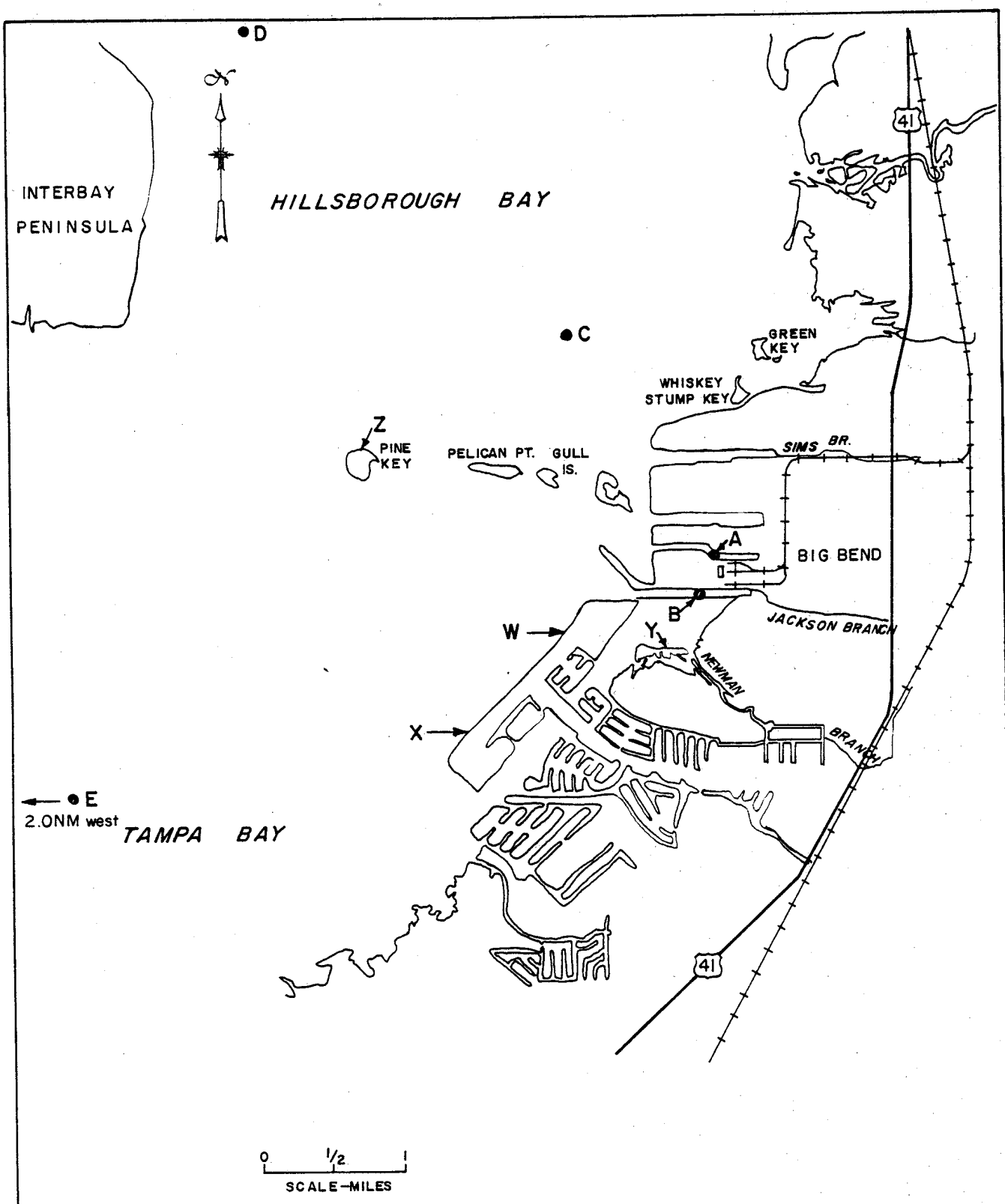
TRAWL AND SEINE STATIONS 1976-1977

316 DEMONSTRATION

BIG BEND STATION - UNIT 4

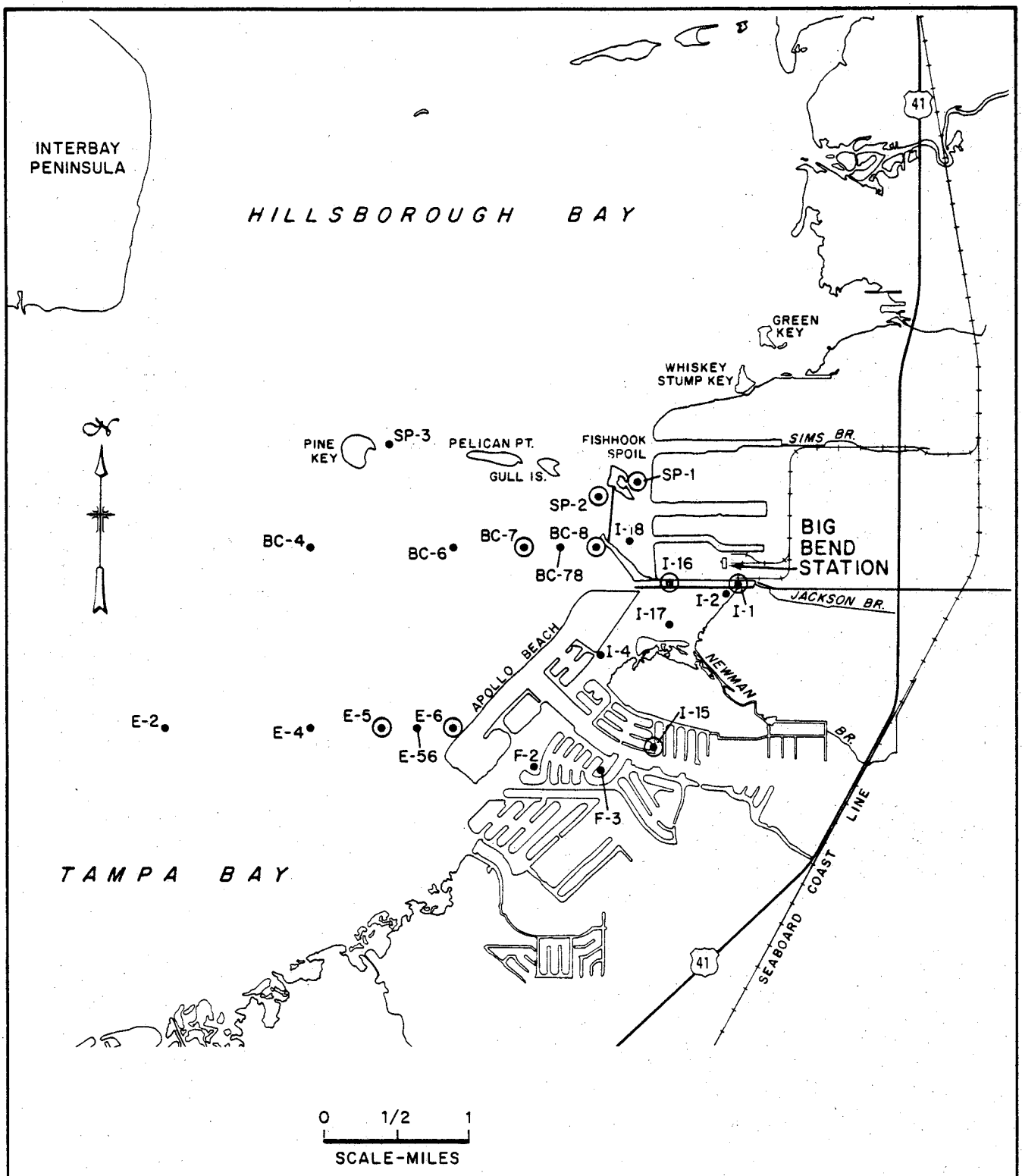
TAMPA ELECTRIC COMPANY

SOURCE: TECO 1977h, Appendix to 316 Demonstration for Units 1-3, Volume III, Page 8-8.



SOURCE: In Appendix 1.
Stone & Webster Engineering Corporation.1980b. 1979 Aquatic Ecology Program, Big Bend Power Station, Tampa, Florida. Draft Final Report. Selvakumaran Mahadevan (ed), Mote Marine Laboratory, Sarasota, Florida. April 21, 1980.

FIGURE 4.4-3
LOCATION OF TRAWL AND SEINE STATIONS 1979-1980
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- • STATIONS SAMPLED ONCE A QUARTER
- ⊙ STATIONS SAMPLED ONCE EVERY SIX WEEKS

FIGURE 4.4-4
BENTHOS SAMPLING STATIONS 1976-1977
316 DEMONSTRATION
BIG BEND STATION–UNIT 4
TAMPA ELECTRIC COMPANY

SOURCE: TECO, 1977h. Adapted from Appendix to 316 Demonstration, Units 1-3, Volume III, pages 4-10.

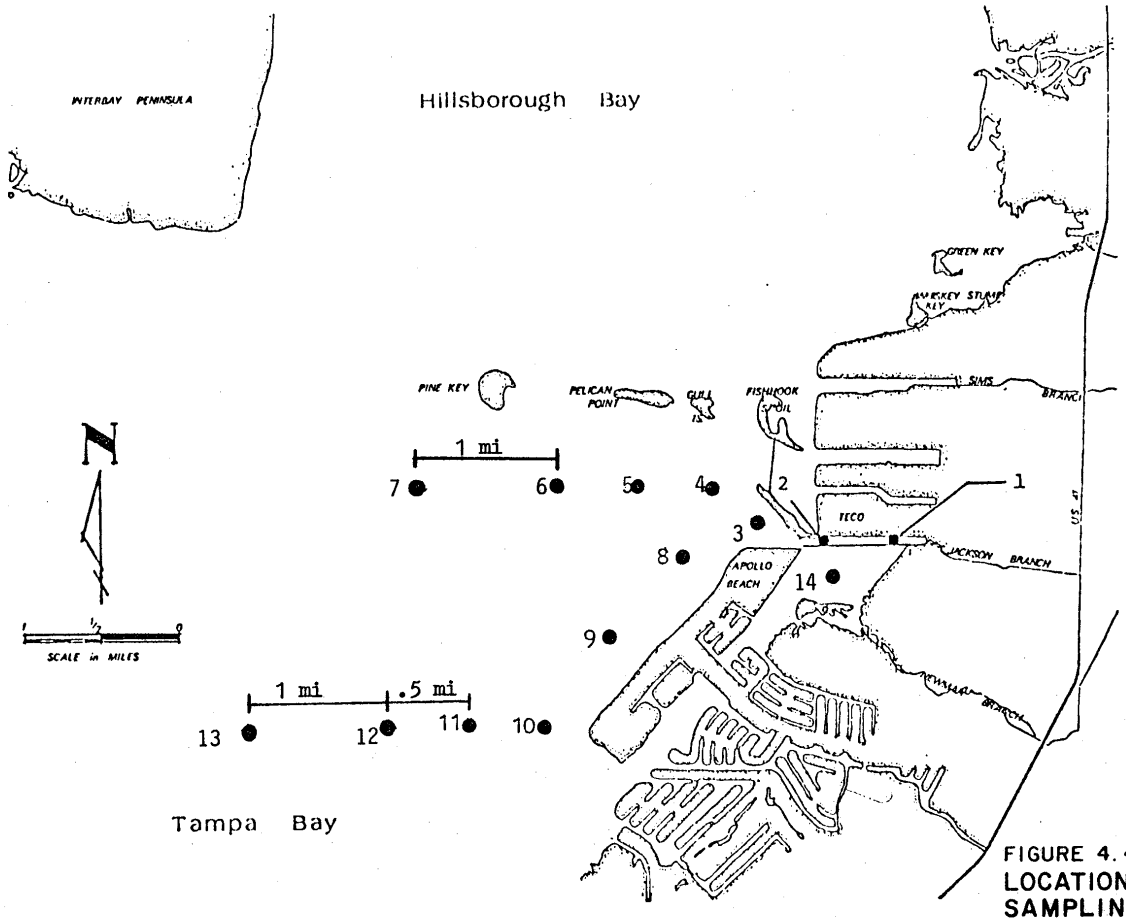
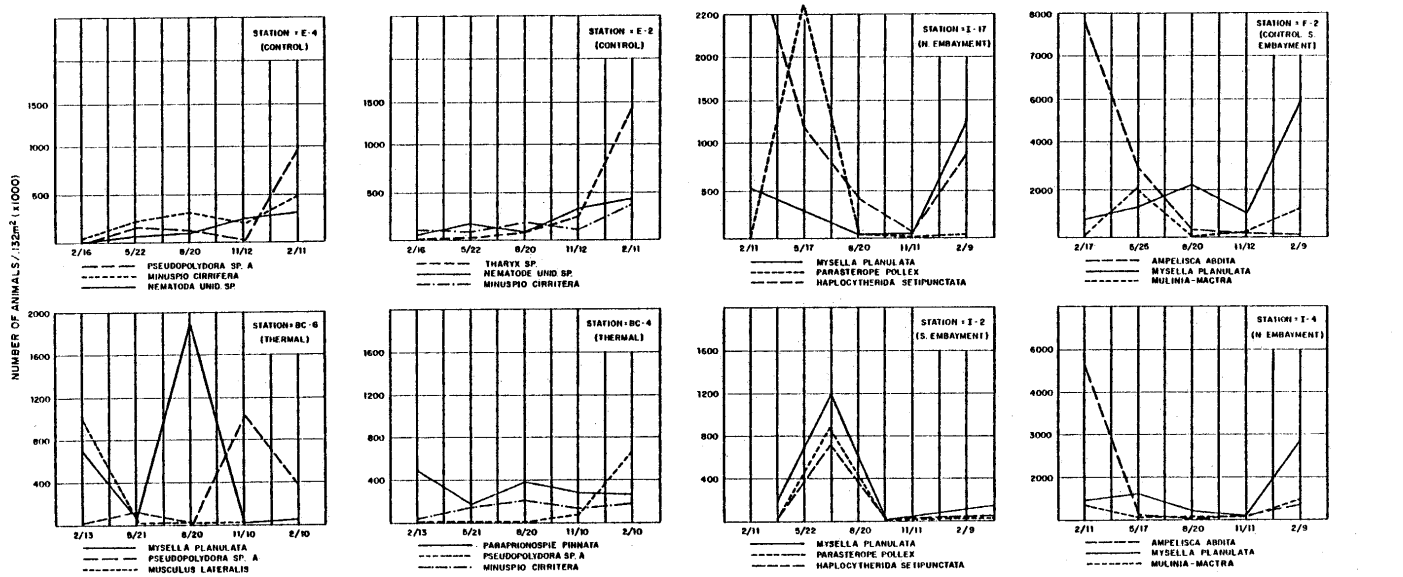
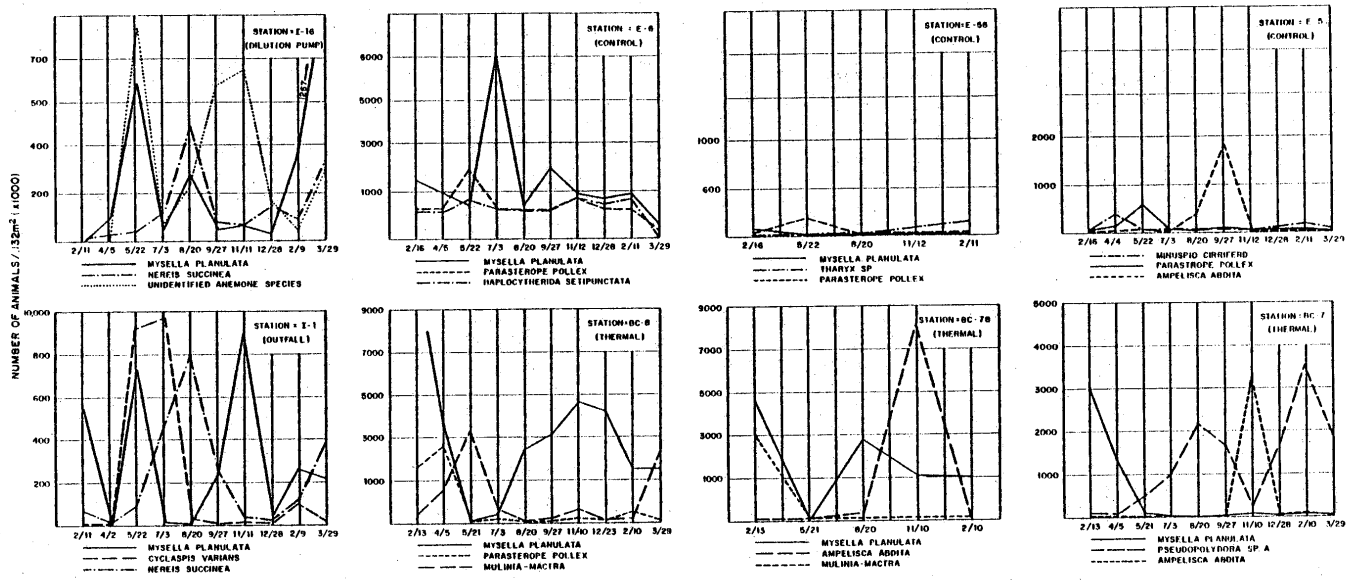


FIGURE 4.4-5
LOCATION OF BENTHIC SAMPLING STATIONS-1979
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



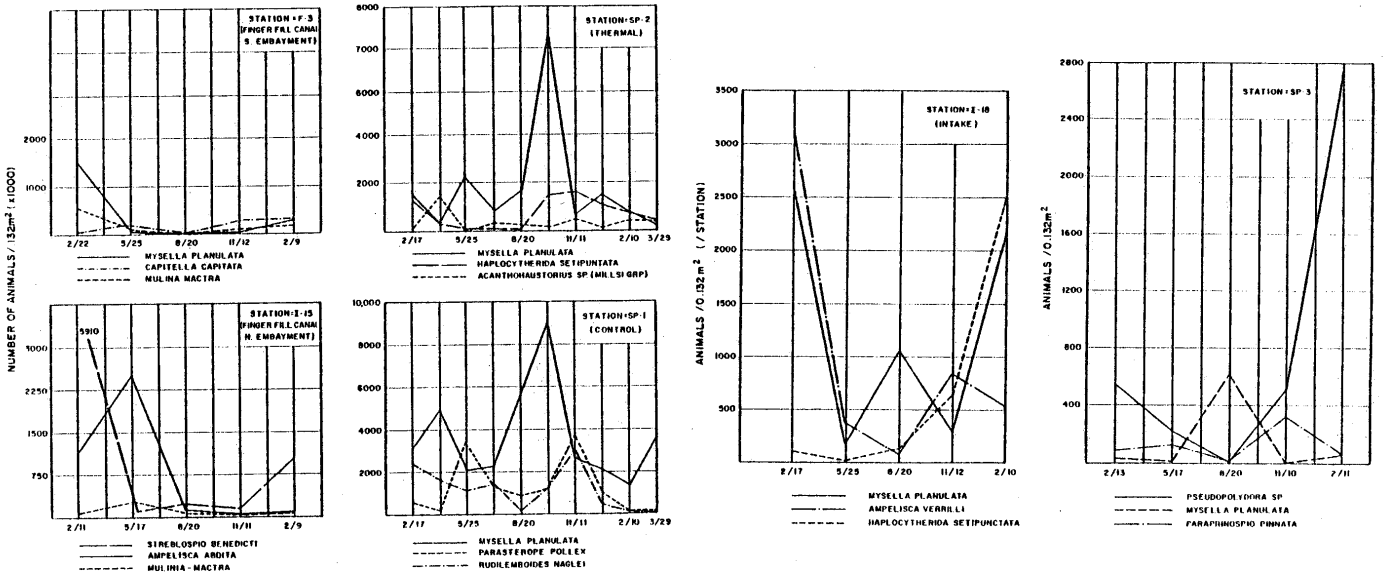
SOURCE: TECO 1977b pp. 4-71, 4-72, 4-77, 4-79

FIGURE 4.4-6
DENSITY OF BENTHIC ORGANISMS COLLECTED AT SELECTED STATIONS, 1976 - 1977
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



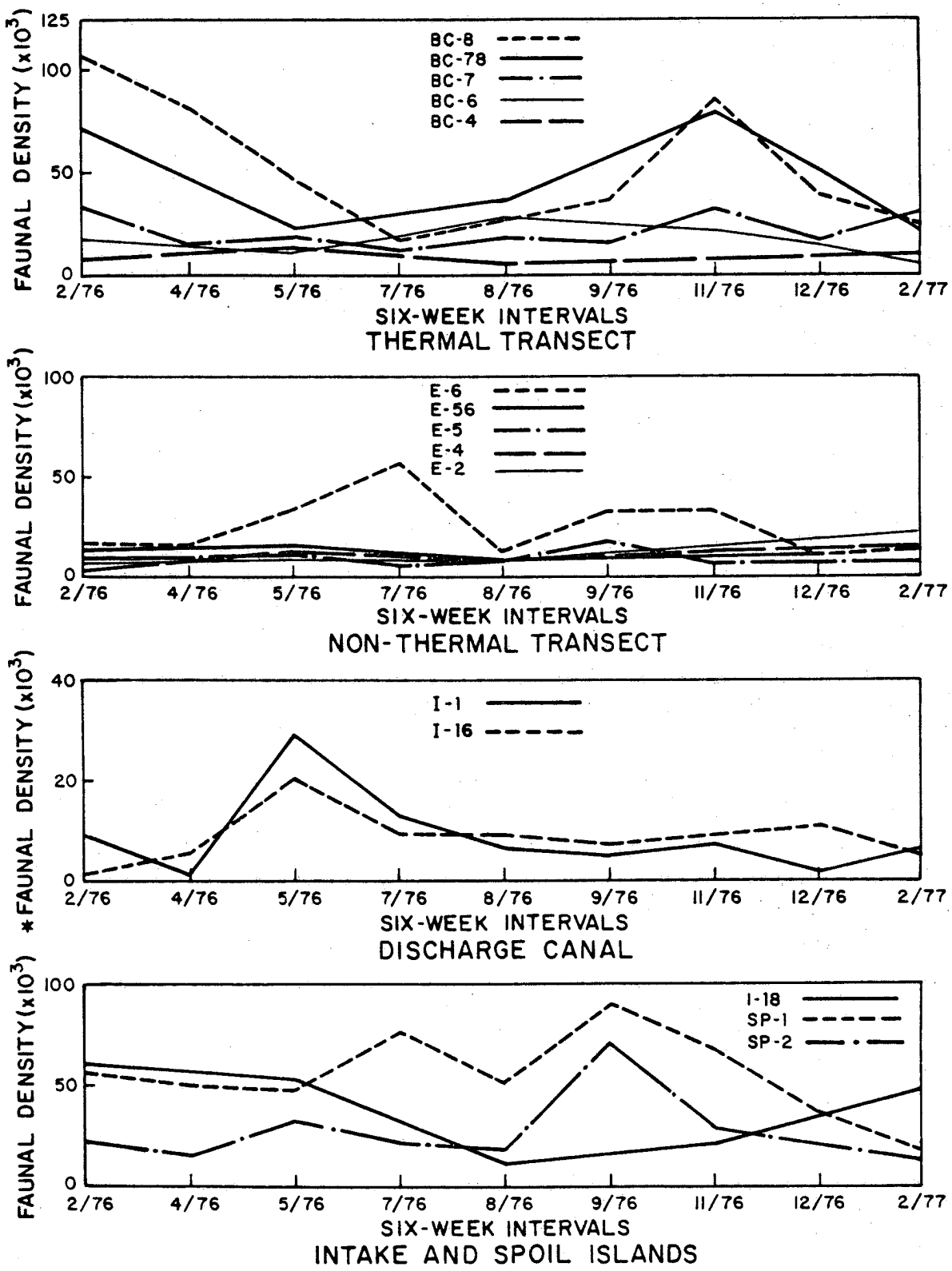
SOURCE: TECO, 1977f pp. 4-66, 4-68, 4-69, 4-70
Mahadevan and Cutter 1978 pp. 54-63

FIGURE 4.4-7
DENSITY OF BENTHIC ORGANISMS COLLECTED AT SELECTED STATIONS, 1976 - 1977
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



SOURCE TECO, 1977I pp.4-80,4-82,4-84,4-321
Mahadevan and Culter 1978 pp. 84-86

FIGURE 4.4-8
DENSITY OF BENTHIC ORGANISMS COLLECTED AT SELECTED STATIONS, 1976 - 1977
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



NOTE

* SCALE DIFFERENT FOR PURPOSE OF CLARITY

FIGURE 4.4-9

TEMPORAL PATTERNS IN FAUNAL DENSITY AT SELECTED STATIONS

316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

SOURCE: TECO, 1977f.

4.5 MEROPLANKTON

4.5.1 General Observations

4.5.1.1 Invertebrate Plankton

Kelly and Dragovich (1967) studied the occurrence of macrozooplankton in the Tampa Bay area between September 1961 and August 1962. Although results of this study are not entirely comparable with those obtained at Big Bend, it is probably the most comprehensive study of zooplankton in the area. Surface plankton tows were taken monthly with a 1.024 mm mesh plankton net. The greatest numbers of macrozooplankton were taken in Tampa Bay, central Tampa Bay, lower Hillsborough Bay, central Old Tampa Bay, and 6.5 km offshore in the Gulf of Mexico.

Of all zooplankton taken, 53.5 percent were holoplanktonic, 46.2 percent were meroplanktonic, and 0.3 percent were hypoplanktonic. Lucifer faxoni comprised 45.6 percent of the zooplankton. This species was the most abundant organism in fall, winter, and summer, and was dominant in Tampa Bay. Porcellanid larvae, comprising 27.4 percent of the zooplankton, were the dominant zooplankter in the spring and were most numerous in upper Tampa Bay and lower Hillsborough Bay.

Larval brachyurans were third in abundance, comprising 10.5 percent of the zooplankton. These zoea and megalops were most abundant in upper Tampa Bay and lower Hillsborough Bay. Copepods were the fourth most abundant zooplankter, though due to the large net mesh only larger specimens were retained. The greatest numbers of copepods occurred in spring; in winter they were the third most abundant of all taxa.

Invertebrate plankton have been studied in detail at Big Bend primarily in two studies. The first, conducted from 1976 to early 1977, focused on meroplankton of the decapod crustaceans. The second study was the 1979 Aquatic Ecology Study which focused primarily on Representative Important Species (RIS) in the plankton.

From January 1976 through March 1977, samples of meroplankton were taken at approximately 2-week intervals by towing a 363 um mesh net at 11 stations (see Figure 4.5-1 for sampling station locations); additional oblique (January-March 1975) and vertical (April 1976-February 1977) tows were taken using a 30 cm or 50 cm mouth diameter No. 20 mesh (75 um) net. Specimens from the 363 um net were identified and subjected to comprehensive study if they were either fish or decapod crustacean. In addition, indication of the relative abundance of non-decapod invertebrate plankton was obtained by enumerating those organisms collected from the 363 um and 75 um nets. Results of the decapod

crustacean investigation are reported in detail in the Appendix to 316 Demonstration, Volume III (TECO 1977h).

The density of all meroplankton species from the 363 um mesh net showed peaks of abundance in April and October (Figure 4.5-2). Larval decapod crustaceans accounted for 94 percent of the larval forms taken. In the coldest months when decapod larvae were rare, molluscan larvae dominated the catch. A total of 105 taxonomic groups belonging to 7 phyla were identified from the samples (Table 4.5-1).

Most samples from the No. 20 mesh nets were not examined; however, results were reported for one sampling date, January 6, 1976. The abundance of such forms as barnacle nauplii, gastropod veligers, and bivalve veligers in the No. 20 mesh net was 2 to 4 orders of magnitude greater than their abundance noted in the 363 um net. Additionally, gastropod veligers and barnacle nauplii accounted for 3.0 and 1.7 percent, respectively, of the meroplankton collected in the larger mesh net. Based on this evidence, abundance of non-decapod larvae is underestimated by the 363 um mesh net. Numerically, these forms would probably be the most dominant meroplankton.

On a species basis, a brachyuran crab, Pinnixa sayana, was the most abundant larval decapod in the 363 um mesh net samples. Major spawning peaks were apparent in April and October, with a smaller peak in July.

Larvae of the anomuran crab Polyonyx gibbesi were next in abundance. Large swarms of first and predominantly second stage zoea were noted throughout the area during the warm months. More larvae were found during the daytime than nighttime in samples in which they were abundant (with the exception of September 22 when both zoeal stages were more abundant at night). Abundance was quite variable between stations. Sandifer (1973) found P. gibbesi larvae predominantly in bottom tows, but the 1976-1977 study found many swarms of these zoea near the surface. Also, 10 percent of Sandifer's larvae were megalopae, nearly all from bottom samples, while 2 percent of the larvae from this study were megalopae.

Third in larval abundance was the macruran shrimp Upogebia affinis. There is some indication in the August 18 samples that breeding may have recommenced outside the study area somewhat more rapidly than within the area after the mid-summer depression, as evidenced by the second and third stage zoea in these samples. Sandifer (1973) reported most specimens as occurring above 23°C with peak abundance at 25-27°C. This correlates well with findings of the meroplankton study though Sandifer found his largest numbers from June to October; highest numbers in this study were found in spring and early summer samples.

Neopanope texana and Hexapanopeus angustifrons were the most abundant xanthid species overall, and the fourth and fifth most abundant decapod species. Both species exhibit late summer/fall breeding which seems to be bimodal. Rouse (1969) found Neopanope texana to be ovigerous in the winter, while Lyons et al (1971) found the species bred from February to October.

Both species had unusually high relative abundance of late stage larvae in some mid-summer samples. Late stage zoea were more abundant than Stage I zoea in the July 20 samples, indicating a recent, rather abrupt end to the production of larvae in the area. In August 18 samples, Stage I zoea were still rather rare, while numbers of later zoea increased well over the previous samples' level. These later stage zoea were probably produced outside the study area and were carried into the area by currents, as the low numbers of Stage I zoea indicated that hatching within the area was still at a low level.

Not one of the most abundant xanthids, the stone crab Menippe mercenaria, an important commercial species, was regularly collected. Larvae were found from April through October but never in great abundance. Of the larvae taken, 78 percent were first stage zoea. Abundance of the species is illustrated on Figures 4.5-3 and 4.5-4. Densities at inshore stations were slightly greater than at offshore stations, with strong peaks in abundance in spring and fall. The strongest pattern evident in the graphs, however, is the difference in density between day and night sampling. Stone crab larvae were less abundant at night, suggesting that the organisms are more evenly distributed in the water column during the day.

The blue crab, Callinectes sapidus, is commercially important in Tampa Bay. Larvae of this portunid crab were rarely collected, though a few zoea were found between April and September.

The commercially important pink shrimp, Penaeus duorarum, was found in the meroplankton only in late postlarval stages. Numbers collected were quite low, only 24 during the entire study, 11 of which were taken in sampling at Station BC-8 during July and August. All but one larva were collected at night. The low numbers were attributed to the offshore spawning behavior of this species.

Generally, seasonal fluctuation in numbers of decapod crustacean larvae is the strongest pattern evident in the collected data. As illustrated on Figure 4.5-5, density of most species peaked in spring and fall. Spatial patterns, as reflected by the stone crab, were weak or absent. This suggests that the sampled area is well mixed by tidal action, or that no unique spawning habitat exists within the study area.

The 1979 Aquatic Ecology Study concentrated on describing RIS abundance in the plankton. The invertebrate RIS included blue crab (Callinectes sapidus), stone crab (Menippe mercenaria), pink shrimp (Penaeus duorarum), and the American oyster (Crassostrea virginica).

Of the invertebrate RIS, only the stone crab and pink shrimp were taken in the 1979 meroplankton study. No larval stages of the blue crab were observed in any samples. Zoea of this species were not anticipated to occur in the meroplankton in the study area, since the species spawns offshore and, by the time early life stages could be transported to study areas, they would have matured and settled out of the plankton. The American oyster larvae were not sampled in the 1979 Aquatic Ecology Study because their small size precluded capture in the plankton nets. The sampling plan for the 1979 study is contained in Appendix 1.

Stone crab larvae were collected on most sampling dates after March 13, 1979. Peak densities occurred on May 25, 1979, and densities remained relatively high through early July, except on June 19 when densities at all stations were low. Densities were generally higher at the intake and discharge stations than at open water stations. This pattern was maintained for both Stage 1 and Stage 2 zoea. Additional details on the spatial and temporal abundance of the stone crab larvae are presented in Section 4.5.2.

Post-larval pink shrimp were first collected in samples in late June and reached a peak abundance on September 25, 1979. Shrimp were most abundant at stations in the plant intake (Station A) and the plant discharge (Station B). As with the adult shrimp, the post-larval forms were always taken in higher densities at night than during the day.

The results of the 1979 Aquatic Ecology Study, including a discussion of the meroplankton studies, are discussed in detail in Appendix 1.

4.5.1.2 Ichthyoplankton

Two major studies have been conducted of the fish eggs and larvae in the vicinity of Big Bend. Description of the distribution and abundance of the early life stages of fish was an objective of the sampling program conducted at Big Bend Station from 1976 to early 1977. The second study was conducted to evaluate the abundance and distribution of selected species (RIS) in the vicinity of Big Bend. The 1976–1977 study results are reported in Big Bend Station 316 Demonstration, September 1977 (TECO 1977e) and are summarized here to provide a brief account of the ichthyoplankton community found near the Station. The results of the 1979 meroplankton study are presented in Appendix 1 and detailed analyses of the spatial and temporal

distribution patterns of the more abundant fish eggs and larvae taken in the 1979 study are presented in Section 4.5.2.

Throughout this document the term prolarvae refers to fish larvae having yolk sacs, postlarvae refers to those larvae that have absorbed the yolk sac, and larvae refers to both stages collectively.

In brief, the 1976–1977 study was conducted as follows: single samples were collected at 11 stations, day and night, once every 2 weeks, for 15 months. Station locations are shown on Figure 4.5–6. The gear was a 1-meter mouth diameter conical plankton net which employed 363 um mesh net.

The eggs of 12 families of fishes were collected during the study, but two families accounted for more than 99 percent of the specimens. Engraulid and sciaenid eggs represented 73.1 and 26.2 percent, respectively, of all eggs collected. Table 4.5–3 provides the taxonomic composition of the collected eggs by family. Anchoa mitchilli (Valenciennes) eggs were the most frequently encountered engraulid, although A. hepsetus (Linnaeus) was also found and A. cubana (Poey) was tentatively identified. Sciaenid eggs are difficult to identify, but three genera, Bairdiella, Cynoscion, and Menticirrhus were identified among sciaenid eggs.

Larvae of 22 families representing 41 species were collected during the study; relative composition by family is provided in Table 4.5–3. As was true for fish eggs, the most abundant larval family was Engraulidae, constituting 87.4 percent of all larvae collected. Two, or possibly three, species of Engraulidae were represented in the collections, although Anchoa mitchilli larvae were most numerous by a wide margin. Larval sciaenids were second in abundance, followed closely by Gobiidae and Pomadasyidae. Seven sciaenid species of five genera were identified in the larval collections. Of the 22 larval families, six families accounted for 98.3 percent of all larvae collected.

Figures 4.5–7 to 4.5–30 illustrate the densities of Anchoa mitchilli, Harengula jaguana, and sciaenid family plankton collected at each station during the study. Strongest patterns in the data are temporal, demonstrating the seasonal fluctuations expected in early life stage abundances of these species. The temporal patterns are discussed more extensively below for these and other species. Weaker patterns are evident in the distribution of ichthyoplankton among the study's stations. Bay anchovy eggs were more abundant at offshore stations than inshore, although density of the species' larvae did not reflect this pattern. For scaled sardine, the reverse was true; no differential distribution of eggs was evident, but larvae were more abundant offshore than inshore. Sciaenid eggs were more abundant at inshore stations than offshore; no spatial pattern

was found for larvae. These data suggest some ideas concerning the ecology of the species. Due to the differential distribution of their eggs, bay anchovies appear to spawn in the open bay, but larvae of the species exhibit no spatial preference. Eggs of the scaled sardine were uniformly distributed (though the adult is typically an ocean spawner), but larvae appeared to prefer open bay conditions to near-shore habitat. The predominant abundance of sciaenid eggs in near-shore areas gives some indication of the species which may be spawning in the area: only a few sciaenids, such as silver perch and spotted seatrout, are believed to be estuarine spawners.

Seasonal incidence of ichthyoplankton was broad and variable, reflecting the subtropical climate of this area. Figure 4.5-31 illustrates the seasonal occurrence of fish eggs and larvae, as noted from the Big Bend sampling study. In general, the spawning season extended from mid-spring to the end of summer, although several species demonstrated longer and more sporadic spawning behavior. For example, Anchoa mitchilli ichthyoplankton were collected in all months except December and January, and Blenniidae and Gobiidae larvae were collected nearly continuously. A more detailed description of the incidence of ichthyoplankton of selected fish taxa is provided below.

Engraulid eggs and larvae were more abundant in Big Bend ichthyoplankton samples than those of any other family, accounting for 73.1 percent of all eggs and 84.4 percent of all larvae taken during the 15 months of sampling. Eggs and larvae of both the striped anchovy, Anchoa hepsetus, and the bay anchovy, A. mitchilli, were common in spring and summer samples. A. mitchilli eggs and larvae were the most commonly collected engraulid, and frequently, were more numerous than the eggs and larvae of any other species.

A. mitchilli eggs were first taken in early March 1976 and were collected regularly through late October 1976. Peak densities occurred from April through July, reaching 50,000 per 100 cu m. The lower numbers taken after July may represent a second spawning by the same individuals or may reflect initial spawning by a smaller number of late maturing females. Larvae were collected from late March through early November. Peak densities of approximately 10,000 per 100 cu m occurred from April through October. Unexpectedly low numbers of larvae in samples from June 22 and August 3, 1976, probably reflect sampling variability, since the number of eggs taken on these dates remained high.

Sciaenid eggs and larvae, as a family, were the second most abundant of all families collected during 1976. Only anchovies comprised a larger portion of the total number of eggs and larvae collected. Sciaenid eggs and larvae accounted for 26.2 and 3.9 percent, respectively, of all eggs and larvae taken and were present in relatively large numbers between early March and early

November 1976. Egg densities reached a peak of approximately 50,000/100 cu m in early April, and larval concentration peaked at 500/100 cu m in April, May, and July. Eggs were always more numerous than larvae, indicating that a large amount of spawning occurred within the study area. Neither eggs nor larvae were collected from late November 1976 through January 1977. Low numbers of eggs and larvae were taken during February, and numbers increased steadily through the final sampling date in March 1977.

Eggs and early prolarvae of sciaenids were generally indistinguishable to genus and species. However, of those ichthyoplankton that could be identified, sciaenids were represented by a larger number of species (seven) than any other family. The seven species collected were: Bairdiella chrysura (Lacepede), silver perch; Cynoscion arenarius (Ginsburg), seatrout; C. nebulosus (Cuvier), spotted seatrout; Leiostomus xanthurus (Lacepede), spot; Menticirrhus americanus (Linnaeus), southern kingfish; M. saxatilis (Bloch and Schneider), northern kingfish; and Pogonias cromis (Linnaeus), black drum.

At least two species of clupeids were collected, including menhaden larvae identified as Brevoortia sp. and eggs and larvae of the scaled sardine, Harengula jaguana Poey. Eggs and larvae of the scaled sardine were present within the study area from late April through August 1976. This species has slight commercial value as a baitfish, but stocks in the Big Bend area are not fully exploited for this purpose. Maximum mean numbers per 100 cu m for eggs and larvae were approximately 200 and 100, respectively. Peak egg density occurred in May, preceding peak larval density which occurred in July. Eggs were always more numerous than larvae, except on July 20, 1976, but densities of both were always unexpectedly low, indicating that the waters in the vicinity of the plant may not be a major nursery area for the species. The later spring and summer spawning season observed in Tampa Bay coincides with the spawning season noted for the species in other parts of its range (Gunter 1945; Martinez & Houde 1975).

Carangid eggs were taken on all sampling dates between April and early September. Three species of carangid eggs were tentatively identified. Only one of these was positively identified to species, Oligoplites saurus (Bloch and Schneider), leatherjacket. Three species of carangid larvae were also present in samples collected between April and October, including O. saurus, Chloroscombrus chrysura (Linnaeus), and an unidentified member of the family. Eggs were most numerous in May (approximately 900/100 cu m), with what appears to be a second, smaller peak during July. Inexplicably low numbers of both eggs and larvae occurred on June 22 and August 3, 1976. It is unknown whether these low numbers indicate a cessation of spawning on these dates or whether they reflect sampling variability.

4.5.2 Spatial and Temporal Distribution of RIS Meroplankton

One of the principal objectives in the 1979 meroplankton field study was to obtain information on the spatial and temporal abundance of the RIS. This information provides a basis for evaluating the potential for plant-induced effect on any organisms, and the analysis allows confirmation of the major factors affecting meroplankton distribution in the Big Bend area. This section discusses the distribution of RIS in the meroplankton during the 1979 study. The impact of the Station on the plankton stages of the RIS is discussed in Section 7. A detailed description of the study design is contained in Appendix 1. Pertinent aspects are summarized below.

Sampling took place at 2-week intervals for 1 year beginning February 1979. Table 4.5-4 presents the dates of each sampling trip. During each of the 26 sampling trips, each of the five sampling stations was sampled during the day and the night. Figure 4.5-31 shows the sampling stations, three of which were located in Tampa Bay (C,D,E), one at the intake (A), and one at the discharge of Big Bend (B). Each time a station was sampled, two tows were made consisting of tandem plankton nets with 505-u mesh.

The density of RIS for each sample (number/cu m) was determined by extrapolating the number of individuals in subsamples with the volume of water sampled. Refer to Appendix 1 for additional details. The sampling schedule was complete, resulting in a balanced design for data analyses.

The data contain a number of sampling trips when the abundance of organisms was low; many of the 40 samples per trip contained no organisms of a particular species life stage. The data were characterized by sampling trip as the number of non-zero observations (Figures 4.5-32 to 4.5-40). This was reasonable since the stations had similar numbers of non-zero observations. Due to the underlying assumption of normality for parametric statistics, trips which contained fewer than 50 percent (20 samples) non-zero observations were not considered in the analyses of variance procedures. Therefore, the analyses of variance are concerned with the spatial and temporal distribution during the periods of abundance for each RIS life stage.

Descriptive statistics were developed for this study to summarize the results more fully than the analysis of variance. Because of the large number of zero observations, a frequency distribution of the non-zero observations was developed for all species combined (Figure 4.5-41) and for each species by life stage (Figures 4.5-42 to 4.5-65). Figures are not presented for species life stages with fewer than 10 non-zero observations. The figures, in conjunction with Figures 4.5-32 to 4.5-40, provide an indication of when the organisms were most numerous.

From these analyses, a subset of the data was developed for the analyses of variance. Table 4.5-5 presents the sampling trips included in the analyses of variance by species and life stage.

The distribution of the observations for trips included in the analyses of variances was further investigated by testing for skewness and kurtosis. The density, the natural logarithm plus one of the density, and the square root of the density were examined. In most cases, the natural logarithm was the preferred transformation (Table 4.5-6) and this transformation was used for all analyses of variance.

An analysis of variance was performed for each of the species and life stages presented in Table 4.5-5. The design of the analysis of variance for each species life stage was the same since all organisms were collected in the same sampling program. The fixed effects independent variables were trip, station, and period, plus their two- and three-way interactions. The tow was considered a nested variable within these three independent variables. If the tow effect was found to be significant ($p \leq 0.05$), it was used as the denominator of the F-ratio for the other variables. If the tow effect was nonsignificant ($p > 0.05$), the sums of squares was added to the residual sums of squares to give a combined residual for the F-ratio.

In general, the results of the analyses of variance can be characterized as having high R^2 values, indicating that the statistical model explained much of the observed variation. The trip was always a significant effect as well as its interaction, unless trip interacted with a nonsignificant independent variable. The station effect was significant in all cases, except silver perch larvae for which only one trip was analyzed. The period effect varied in significance with species and life stage, as did the nested tow variable. The specific results for each species and life stage are discussed below.

4.5.2.1 Bay Anchovy

The bay anchovy was the most frequently caught species as well as the most numerous. All independent variables and interactions were significant except the tow variable for larvae (Table 4.5-7). The main effects were more significant than the interactions.

The analysis of bay anchovy eggs revealed trip as the most significant variable, which is associated with the seasonal increases and decreases. Figure 4.5-66 shows the seasonal pattern as well as the trip by station interaction which indicates the transitory nature of the spatial pattern through the season. The station means are presented in Table 4.5-8 which indicates that the only two stations (A and D) were not

different. The day samples had higher concentrations than the night samples (Table 4.5-9).

The analysis of bay anchovy prolarvae revealed patterns similar to the egg analysis. Figure 4.5-67 depicts the seasonal pattern and the interaction of this trend with stations. The stations were associated in groups of two, except Station E which had significantly lower densities than the other stations (Table 4.5-8). The densities of day samples had higher concentrations of larvae than night samples (Table 4.5-9).

The results of the analysis of bay anchovy post-larvae were similar to that of eggs and larvae, except that the period effect was more significant. The day concentrations were almost five times the night concentrations (Table 4.5-9). The station differences were as pronounced with the post-larvae as the eggs with only Stations B and C not being different. The seasonal pattern of abundance and its interaction with stations are shown on Figure 4.5-68.

4.5.2.2 Silver Perch

The analysis for silver perch was limited to the eggs and prolarvae, since the post-larvae were collected too infrequently for the analysis of variance (Figure 4.5-36). The results of the analysis of variance for silver perch eggs indicate that trip and period, as well as their interaction, are the most significant variables (Table 4.5-10). The station means were different, other than Stations A and C which were grouped together (Table 4.5-8). The day concentrations were higher than the night concentrations (Table 4.5-9). Figure 4.5-69 presents the seasonal trend and the interaction of stations.

The silver perch prolarvae were only represented during one trip with greater than 50 percent non-zero observations (Figure 4.5-36). The analysis of variance model was therefore reduced by eliminating the trip main effect and interactions which included trip. The reduced model did not detect significance for stations, period, or their interaction (Table 4.5-10). The effects were not significant; however, the difference in means was as great as some of the significant differences in other analyses; i.e., a 5 times greater concentration at Station A than at Station D (Table 4.5-8). The limited number of trips in which the prolarvae were available in consistent abundance limits the power of the analysis to detect differences in stations.

4.5.2.3 Scaled Sardine

The analysis of variance for the scaled sardine eggs was similar to that for silver perch prolarvae in that only one trip had greater than 50 percent non-zero observations. Therefore, the

statistical model was reduced as previously described. Unlike the silver perch prolarvae, the analysis of scaled sardine egg revealed significant differences in all variables (Table 4.5-11). The day samples had higher concentrations than the night samples (Table 4.5-9). The stations were grouped with Stations B, C, and D in the group of smallest densities. Stations A and E were different from all other stations (Table 4.5-8).

The analysis of prolarvae for scaled sardine included four trips; therefore, the full statistical model was used. The station effect was the most significant (Table 4.5-11), with only Stations C and D being grouped (Table 4.5-8). The period effect was nonsignificant (Table 4.5-9). The trip effect was significant (Table 4.5-11). Trips 7 and 10 were grouped together (means 1.38 and 1.44/cu m) with trips 8 and 9 (means 0.84 and 0.21/cu m) being different than all others.

The analysis of scaled sardine post-larvae gave similar results to that of the scaled sardine prolarvae (Table 4.5-11). The period effect was nonsignificant (Tables 4.5-9 and 4.5-11). The stations were associated into three groups. Station B had the highest density and was different than all other stations. Stations A and E were grouped as were Stations C and D (Table 4.5-8). The trip effects showed the same qualitative pattern as the prolarvae; however, the means for each trip were different than all other trips. The means were 0.50, 0.20, 0.02, and 1.19 for trips 7 through 10, respectively.

4.5.2.4 Unidentified Sciaenids

The unidentified sciaenids were analyzed as a group since the identification of the eggs of this family to lower taxa was very difficult (Appendix 1). Therefore, an analysis of variance was performed on the sciaenid eggs. All independent variables were significant with period effects being most significant, followed by station and trip (Table 4.5-12). The period effect was opposite the previously described patterns, with higher densities occurring in the night than the day (Table 4.5-9). The stations were all different from each other (Table 4.5-8). The seasonal pattern is shown on Figure 4.5-70, which also shows the interaction of the stations with trip.

4.5.2.5 Stone Crab

The zoeal stages of stone crab were analyzed by analysis of variance. Due to the densities and number of non-zero observations (Figure 4.5-32), only stages 1 through 3 were included in the analysis. The analyses of variance results are presented in Table 4.5-13 and were developed from the logarithmic transformation as were all other analyses discussed in this section. The analysis of skewness and kurtosis suggested that, for crab zoea, the square root transformation was also an

acceptable transformation. Therefore, the analyses presented in Table 4.5-13 were also run with a square root transformation and the conclusions of significance were the same as the logarithmic transformation. Consequently, only the logarithmic transformation is presented.

The analyses revealed that all independent variables were significant for Stage 1, all but tow were significant for Stage 2, and all but period and tow were significant for Stage 3 (Table 4.5-13). The station effect was the most significant variable and an analysis of station means indicated a similar ranking of the stations for zoeal stages abundance (Table 4.5-8). The period effect was the least significant of the main effects and an analysis of the means indicates that the mean difference was small (Table 4.5-9).

The seasonal patterns for the zoeal Stages 1 and 2 are shown on Figures 4.5-71 and 4.5-72. These figures also present the station interaction of the seasonal effects. Zoeal Stage 3 was only represented by 50 percent or greater non-zero observations in trips 8 through 11 and their trip means were 0.05, 0.03, 0.18, and 0.14, respectively.

TABLE 4.5-1

SPECIES LIST, DENSITY, AND RELATIVE ABUNDANCE FOR ALL INVERTEBRATE MEROPLANKTON COLLECTED IN THE BIG BEND AREA FROM JANUARY 6, 1976, TO MARCH 11, 1977[1]

Species	Mean No./cu m	Total (percent)
Pinnixa sayana	148.41	34.70
Polyonyx gibbesi	120.95	28.28
Upogebia affinis	46.05	10.77
Neopanope texana	18.94	4.43
Gastropoda[2]	12.69	2.97
Hexapanopeus angustifrons	10.78	2.52
Pinnixa chaetopterana	8.78	2.05
Balanus sp.[2]	7.26	1.70
Ambidexter symmetricus	5.21	1.22
Xanthidae (damaged)	5.06	1.18
Alpheidae sp. A	4.65	1.09
Periclimenes spp.	4.23	<1.0
Eurypanopeus depressus	3.66	
Grapsizoea spp.[3]	3.15	
Uca spp.	2.83	
Menippe mercenaria	2.31	
Pinnotheres maculatus	2.26	
Persephona punctata	1.94	
Brachiopoda[2]	1.69	
Spionidae[2]	1.49	
Ogyrides limicola	1.32	
Echinodermata	1.09	
Pelecypoda	0.93	
Latreutes parvulus	0.925	
Panopeus herbstii	0.838	
Petrolisthes spp.	0.830	
Porcellanidae (damaged)	0.732	
Caridea (damaged)	0.678	
Hippolyte spp.	0.615	
Pagurus longicarpus	0.575	
Nereidae[2]	0.474	
Sesarma cinereum	0.460	
Decapoda (damaged)	0.450	
Paguridae sp. A	0.381	<0.1
Alpheidae sp. C	0.368	
Sesarma reticulatum	0.362	
Alpheidae (damaged)	0.348	
Processa spp.	0.338	
Polychaeta[2]	0.305	
Rithropanopeus harrisii	0.262	
Palaemonetes intermedius	0.253	
Pinnotheridae (damaged)	0.247	

TABLE 4.5-1 (Cont)

Species	Mean No./cu m	Total (percent)
Palaemonidae (damaged)	0.228	
Libinia dubia	0.200	
Squilla sp.	0.195	
Palaemonetes spp.	0.151	
Urochordata	0.140	
Brachyura (unidentified)	0.123	
Hippolytidae (damaged)	0.122	
Neopanope packardii	0.103	
Leptochela sp.	0.101	
Alpheidae sp. B	0.098	
Megalops (unidentified)	0.094	
Periclimenes americanus (postlarvae)	0.075	
Palaemonetes pugio/vulgaris	0.059	
Palaemonidae sp. C	0.058	
Portunidae sp. A	0.053	
Alpheidae sp. D	0.048	
Palaemon floridanus	0.047	
Callianassa sp. A	0.046	
Tozeuma carolinense	0.046	
Polynoidae(2)	0.043	
Pinnixa sp. A	0.043	
Pagurus annulipes	0.039	<0.01
Pinnotheres sp. A	0.038	
Brachyura sp. A	0.031	
Processidae (damaged)	0.029	
Callinectes sp. A	0.029	
Hipolytidae sp. D	0.029	
Callianassa sp. D	0.025	
Paguridae (damaged)	0.023	
Penaeus duorarum	0.022	
Euceramus praelongus	0.020	
Aegathoa	0.020	
Phoronida(2)	0.019	
Zoea (unidentified)	0.015	
Callianassa sp. C	0.014	
Paguridae sp. C	0.012	
Flabelligeridae(2)	0.012	
Pinnotheres sp. B	0.012	
Postlarvae (unidentified)	0.010	
Syllidae(2)	0.010	
Brachyura sp. B	0.008	
Callianassa sp. B	0.007	
Leptochela serritorbita	0.007	
Leucosiidae (damaged)	0.007	
Hippolytidae sp. B	0.006	

TABLE 4.5-1 (Cont)

Species	Mean No./cu m	Total (percent)
Branchiostoma caribaeum(2)	0.006	
Majidae (damaged)	0.006	
Palaemonidae sp. B	0.005	
Periclimenes longicaudatus (postlarvae)	0.005	
Grapsizoea sp. A(3)	0.005	
Limulus polyphemus(2)	0.005	
Portunidae (damaged)	0.004	<0.001
Thor floridanus	0.003	
Grapsidae (damaged)	0.003	
Pinnixa sp. B	0.003	
Hippolytidae sp. A	0.002	
Hippolyte zostericola (postlarvae)	0.002	
Orbiniidae(2)	0.002	
Alpheidae sp. E	0.002	
Pagurus pollicaris	0.002	
Alpheus sp. (postlarvae)	0.002	
Alpheus heterochaelis (postlarvae)	0.001	
Porcellana sayana	0.001	
Leander sp.	0.001	
Naushonia sp.	0.001	
Penaeidae (damaged)	0.001	
Callianassidae (damaged)	0.001	
Cirratulidae(2)	0.001	
Callinectes sapidus (postlarvae)	0.001	
TOTAL	427.706	

SOURCE:

1. TECO (Tampa Electric Company). 1977h. Final report of ecological surveys of the Big Bend area, Vol. 3. Appendix to 316 Demonstration, Vol. III. An analysis and summary of studies on the effect of the cooling water system on aquatic fauna, Vol. III. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

NOTES:

2. Qualitatively sampled

3. Unidentified organisms believed to include Uca spp. or Sesarma sp.

TABLE 4.5-2

ZOOPLANKTON TAXA COLLECTED IN 1970-1975(*)

Phylum Protozoa
- Dictyocha fibula
- Coccolithophora sp.
- Unident. Cryptomonaidida
- Ebria sp.
- Euglena mutabilis
- Trachelocera sp.
- Unident. Euglenida
- Amoeba sp.
- Unident. Foraminiferida
- Unident. Radiolaria
- Unident. Heliozoia
- Lacrymaria oloa
- Carchesium sp.
- Vorticella spp.
- Stentor sp.
- Condonella sp.
- Coxtella sp.
- Eutintinnus sp.
- Farella sp.
- Helicostomella sp.
- Salpingella sp.
- Stentosemella sp.
- Tintinniopsis spp.
- Unident. Hypotrichida

Cnidaria (Ceolenterata)
- Unident. Hydrozoa fragments
- Unident. Anthomedusae
- Obelia sp.
- Unident. Leptomedusa
- Unident. Actinulida larvae
- Unident. Actinaria
- Ephyra larvae
- Pleurobrachia sp.
- Mnemiopsis sp.
- Beroe sp.

Platyhelminthes
- Muller's larvae
- Unident. Turbellaria

Rhynchocoela (Nemertinea)
- Philidium larvae

TABLE 4.5-2 (Cont)

Phylum Rotifera
- Synchaeta sp.
- Trichocera sp.
- Unident. Rotifera

Phylum Gastrotricha
- Heterolipidoderma sp.
- Unident. Gastrotricha

Phylum Nematoda
- Unident. Nematoda

Phylum Annelida
- Unident. Polychaeta larvae
- Unident. Polychaeta trochophores
- Unident. Neridae larvae
- Unident. Nephthidae
- Unident. Spionidae
- Chaetopterus sp.
- Unident. Capitellidae
- Unident. Hirudinea

Phylum Mollusca
- Unident. Gastropoda veligers
- Unident. Bivalvia veligers

Phylum Arthropoda
- Halacardiae
- Unident. Ostracoda
- Evadne spp.
- Podon sp.
- Pneilia avirostus
- Unident. Calanoida
- Unident. Pontellidae nauplii
- Unident. Harpacticoida
- Unident. Cyclopoida
- Saphirella spp.
- Unident. Copepoda nauplii
- Unident. Cirripedia nauplii
- Unident. Cypris
- Unident. Cypris larvae
- Unident. Mysida
- Unident. Cumacea
- Unident. Isopoda
- Unident. Caprellidea
- Unident. Amphipoda
- Unident. Penaeidea larvae
- Unident. Caridea larvae
- Lucifer shrimp
- Procellenidae zoea

TABLE 4.5-2 (Cont)

Pinnixa sp.
Unident. Euphausiacea
Unident. Decapoda
Crab zoea

Phylum Phoronida
Actinotroch larvae

Phylum Bryozoa
Bryzoan fragments
Ectoproct fragments
Cyphonautes larvae

Phylum Brachiopoda
Brachiopoda larvae

Phylum Echinodermata
Echinodermata larvae
Auricularia larvae
Unident. Holothuroidea

Phylum Hemichordata
Tornaria larvae

Phylum Chordata
Ascidiacea larvae
Oikopleura sp.
Branchiostoma floridae

Phylum Chaetognatha
Chaetognatha
Chaetognatha eggs
Chaetognatha larvae

SOURCE:

* TECO (Tampa Electric Company). 1975a. Ecological surveys of the Big Bend area - five year data evaluation. A summary and analysis of past ecological studies in the vicinity of Big Bend Steam Electric Station, Tampa Bay, Florida. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

TABLE 4.5-3

PERCENT OF TOTAL EGGS AND LARVAE TAKEN DURING ICHTHYOPLANKTON SAMPLING AT BIG BEND, BY FAMILY(*)

Eggs		Larvae	
Family	Percent of Total	Family	Percent of Total
Engraulidae	73.1	Engraulidae	87.4
Sciaenidae	26.2	Sciaenidae	3.9
Carangidae	0.4	Gobiidae	2.7
Clupeidae	0.2	Pomadasyidae	2.1
		Carangidae	1.1
Soleidae		Sparidae	1.1
Triglidae		Clupeidae	0.5
Pomadasyidae		Blenniidae	0.4
Ephippidae	0.1%	Soleidae	0.2
Belonidae	(total)	Triglidae	0.2
Atherinidae		Atherinidae	0.1
Gobiidae			
		Gobiesocidae	
		Syngnathidae	
		Cynoglossidae	
		Ephippidae	
		Ophicthidae	
		Tetraodontidae	0.3%
		Mugilidae	(total)
		Belonidae	
		Bothidae	
		Cyprinodontidae	
		Gerreidae	

SOURCE:

* TECO (Tampa Electric Company). 1977e. Big Bend Station 316 Demonstration. September 1977. TECO, Tampa, Florida.

TABLE 4.5-4

1979 MEROPLANKTON STUDY SAMPLING TRIPS

Trip	Date	Trip	Date
1	2/27/79	14	8/28/79
2	3/13/79	15	9/14/79
3	3/27/79	16	9/25/79
4	4/10/79	17	10/9/79
5	4/26/79	18	10/23/79
6	5/10/79	19	11/6/79
7	5/24/79	20	11/20/79
8	6/5/79	21	12/4/79
9	6/19/79	22	12/18/79
10	7/3/79	23	1/2/80
11	7/17/79	24	1/17/80
12	7/31/79	25	1/29/80
13	8/14/79	26	2/12/80

TABLE 4.5-5

SAMPLING TRIPS BY SPECIES AND LIFE STAGE
INCLUDED IN THE ANALYSES OF VARIANCE

Species	Life Stage		
	Egg	Prolarvae	Post-Larvae
Fish(1)			
Bay anchovy	1-18	2-16	2-19
Silver perch	1-7	3	None
Scaled sardine	8	7-10	7-10
Unidentified sciaenids	2-15	None	None
	Zoea 1	Zoea 2	Zoea 3
Invertebrates			
Stone crab(2)	4-16	7-13	8-11

NOTES:

1. Black drum, Cynoscion sp., spotted seatrout, and tidewater silverside were not included in analysis of variance.

2. Zoeal Stages 4 and 5 were not included in analysis of variance.

TABLE 4.5-6

TESTS FOR SKEWNESS AND KURTOSIS

Organism	Density		Logarithm		Square Root	
	Skewness	Kurtosis	Skewness	Kurtosis	Skewness	Kurtosis
Bay anchovy						
egg	5.16	47.36	0.32	-1.31	1.64	3.13
prolarvae	11.95	189.07	2.13	5.52	3.50	21.22
post-larvae	5.75	49.97	1.18	0.82	2.52	8.30
Silver perch						
egg	6.95	52.29	2.33	5.20	3.99	19.06
prolarvae	2.03	4.18	1.97	3.90	0.66	-0.50
Scaled sardine						
egg	3.41	11.59	2.44	4.94	2.52	5.75
prolarvae	3.19	12.67	1.17	0.31	1.34	1.49
post-larvae	5.10	31.53	2.31	5.44	2.35	6.76
Unidentified sciaenids						
egg	6.82	73.52	0.57	-1.14	2.01	5.47
Stone crab						
zoea 1	9.14	104.02	2.67	7.65	4.04	21.99
zoea 2	3.75	16.51	2.60	7.04	1.72	3.25
zoea 3	6.72	60.77	3.74	20.82	1.84	5.76

TABLE 4.5-7

RESULTS OF ANALYSIS OF VARIANCE FOR BAY ANCHOVY

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	Significance
Egg				
Trip (T)	17	1,239.34	412.01	***
Station (S)	4	132.90	187.78	***
Period (P)	1	63.45	358.63	***
T x S	68	806.66	67.04	***
T x P	17	452.66	150.49	***
S x P	4	154.04	217.65	***
T x S x P	68	487.90	40.55	***
Tow (TSP)	180	31.85	2.18	***
Error	360	29.16		
Total	719	3,398.00		
Prolarvae				
Trip (T)	14	72.99	53.34	***
Station (S)	4	6.91	17.69	***
Period (P)	1	6.30	64.52	***
T x S	56	79.10	14.45	***
T x P	14	22.64	16.54	***
S x P	4	8.66	22.17	***
T x S x P	56	37.60	6.87	***
Tow (TSP)	150	14.09	0.93	NS
Error	300	30.38		
Total	599	278.71		
Post-Larvae				
Trip (T)	17	513.20	358.60	***
Station (S)	4	56.33	167.29	***
Period (P)	1	64.18	762.32	***
T x S	68	201.85	35.26	***
T x P	7	43.93	30.69	***
S x P	4	11.80	35.03	***
T x S x P	68	71.91	12.56	***
Tow (TSP)	180	20.41	1.35	***
Error	360	30.31		
Total	719	1,013.91		

TABLE 4.5-7 (Cont)

NOTES:

NS - not significant at $p > 0.05$

*** - $p \leq 0.001$

TABLE 4.5-8

MEAN DENSITY BY STATION (No/cu m) (*)

Organism	Station A	B	C	D	E
Bay anchovy					
egg	12.9	9.5	17.4	12.2	4.2
prolarvae	0.64	0.81	0.92	0.69	0.40
post-larvae	2.35	4.66	3.43	2.46	1.48
Silver perch					
egg	1.02	0.57	0.98	0.40	1.45
prolarvae	0.030	0.011	0.019	0.006	0.011
Scaled sardine					
egg	0.46	0.11	0	0.07	2.48
prolarvae	3.41	1.50	0.04	0.06	1.02
post-larvae	0.66	1.00	0.06	0.04	0.57
Unidentified sciaenids					
egg	10.1	20.6	3.0	1.9	6.7
Stone crab					
zoea 1	1.18	2.3	0.07	0.05	0.16
zoea 2	0.20	0.41	0.04	0.03	0.22
zoea 3	0.09	0.14	0.03	0.03	0.22

NOTE:

* Stations which are not different ($p \leq 0.05$) are connected by lines.

TABLE 4.5-9

MEAN DENSITY BY PERIOD (No/cu m) (*)

Organism	Period	
	Day	Night
Bay Anchovy		
egg	14.2	7.4
prolarvae	0.86	0.52
post-larvae	4.00	1.76
Silver Perch		
egg	1.20	0.56
prolarvae	0.018	0.012
Scaled Sardine		
egg	0.72	0.20
prolarvae	0.92	0.88
post-larvae	0.50	0.34
Unidentified Sciaenids		
egg	1.9	17.8
Stone Crab		
zoea 1	0.67	0.47
zoea 2	0.19	0.15
zoea 3	0.10	0.10

NOTE:

* Periods which are not different ($p \leq 0.05$) are connected by lines.

TABLE 4.5-10

RESULTS OF ANALYSIS OF VARIANCE FOR SILVER PERCH

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	Significance
Egg				
Trip (T)	6	63.29	320.14	***
Station (S)	4	10.89	82.69	***
Period (P)	1	8.45	256.54	***
T x S	24	62.54	79.08	***
T x P	6	129.19	653.42	***
S x P	4	20.28	153.42	***
T x S x P	24	48.38	61.18	***
Tow (TSP)	70	2.30	2.32	***
Error	140	1.98		
Total	279	347.35		
Prolarvae				
Station (S)	4	0.0026	1.62	NS
Period (P)	1	0.0003	0.88	NS
S x P	4	0.0036	2.27	NS
Tow (SP)	10	0.0031	0.71	NS
Error	20	0.0089		
Total	39	0.0187		

NOTES:

NS - not significant at $p > 0.05$

*** - $p \leq 0.001$

TABLE 4.5-11

RESULTS OF ANALYSIS OF VARIANCE FOR SCALED SARDINE

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	Significance
Egg				
Station (S)	4	8.51	14.76	***
Period (P)	1	1.29	8.98	*
S x P	4	11.76	20.41	***
Tow (SP)	10	1.44	4.77	**
Error	20	0.60		
Total	39	23.61		
Prolarvae				
Trip (T)	3	12.56	35.20	***
Station (S)	4	47.40	99.63	***
Period (P)	1	0.02	0.19	NS
T x S	12	14.08	9.87	***
T x P	3	0.83	2.33	NS
S x P	4	1.18	2.50	*
T x S x P	12	6.37	4.47	***
Tow (TSP)	40	4.92	1.05	NS
Error	80	9.34		
Total	159	96.74		
Post-Larvae				
Trip (T)	3	13.02	38.89	***
Station (S)	4	10.78	24.15	***
Period (P)	1	0.52	4.74	NS
T x S	12	10.54	7.87	***
T x P	3	0.85	2.56	*
S x P	4	1.36	3.06	*
T x S x P	12	3.31	2.47	***
Tow (TSP)	40	3.86	0.81	NS
Error	80	9.53		
Total	159	53.82		

NOTES:

NS - not significant at $p > 0.05$

* - $p \leq 0.05$
** - $p \leq 0.01$
*** - $p \leq 0.001$

TABLE 4.5-12

RESULTS OF ANALYSIS OF VARIANCE FOR UNIDENTIFIED SCIAENIDS

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	Significance
Egg				
Trip (T)	13	689.60	377.78	***
Station (S)	4	286.39	509.90	***
Period (P)	1	490.54	3,493.55	***
T x S	52	415.43	56.90	***
T x P	13	202.31	110.83	***
S x P	4	243.99	434.43	***
T x S x P	52	224.31	30.72	***
Tow (TSP)	140	19.65	2.27	***
Error	280	17.33		
Total	559	2,589.60		

NOTE:

*** - $p \leq 0.001$

TABLE 4.5-13

RESULTS OF ANALYSIS OF VARIANCE FOR ZOEA

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	Significance
Stage 1				
Trip (T)	12	54.39	53.88	***
Station (S)	4	110.57	328.59	***
Period (P)	1	2.15	25.61	***
T x S	48	82.77	20.50	***
T x P	12	17.67	17.51	***
S x P	4	2.94	8.75	***
T x S x P	48	30.25	7.49	***
Tow (TSP)	130	10.93	1.87	***
Error	260	11.67		
Total	519	323.39		
Stage 2				
Trip (T)	6	3.71	30.60	***
Station (S)	4	3.73	46.09	***
Period (P)	1	0.09	4.88	***
T x S	24	4.72	9.73	***
T x P	6	0.98	8.08	***
S x P	4	0.57	7.09	***
T x S x P	24	2.08	4.29	***
Tow (TSP)	70	1.69	1.33	NS
Error	140	2.55		
Total	279	20.15		
Stage 3				
Trip (T)	3	0.508	12.32	***
Station (S)	4	0.651	11.84	***
Period (P)	1	0.001	0.05	NS
T x S	12	0.863	5.24	***
T x P	3	0.349	8.47	***
S x P	4	0.076	1.39	NS
T x S x P	12	0.524	3.18	***
Tow (TSP)	40	0.582	1.09	NS
Error	80	1.067		
Total	159	4.623		

TABLE 4.5-13 (Cont)

NOTES:

NS - not significant at $p > 0.05$.

*** - $p \leq 0.001$

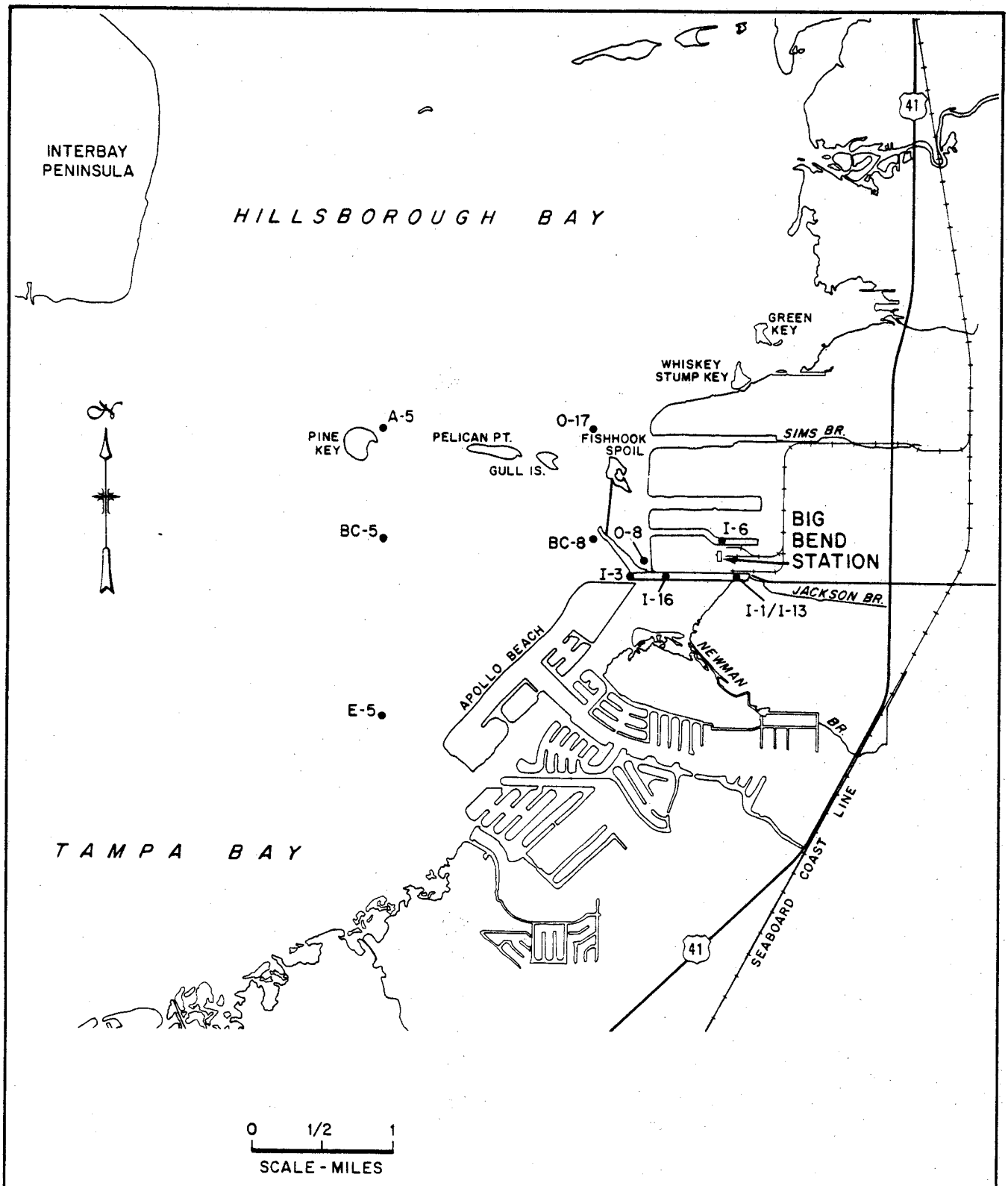


FIGURE 4.5-1
MEROPLANKTON SAMPLING STATIONS 1976-1977
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

SOURCE: Adapted from Appendix to 316 Demonstration for Units 1-3, Volume III, TECO, 1977h, page 5-12

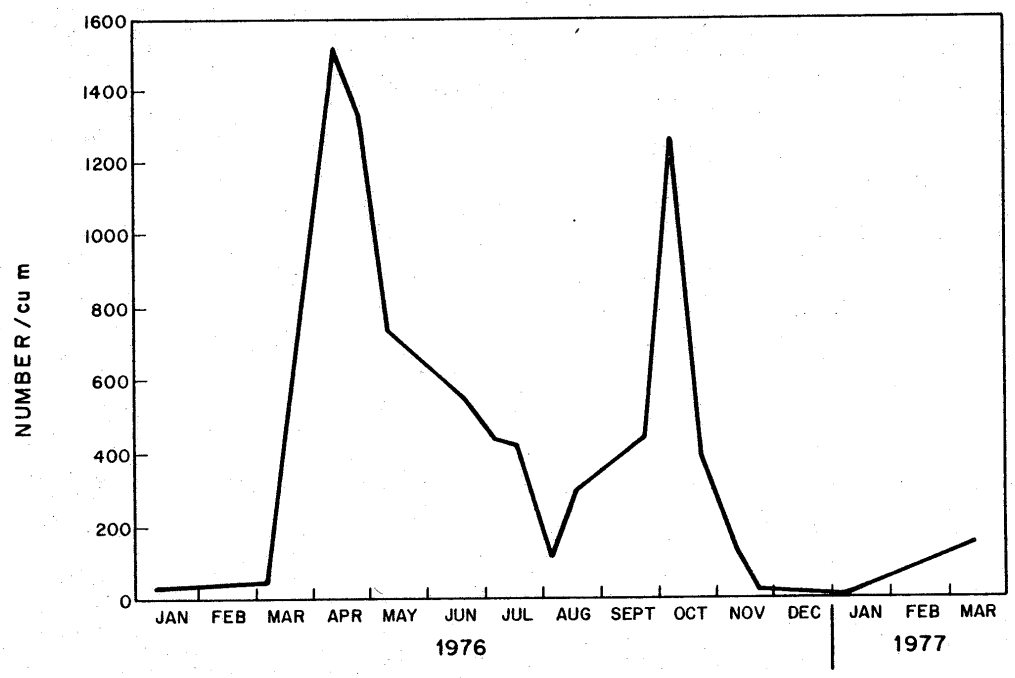
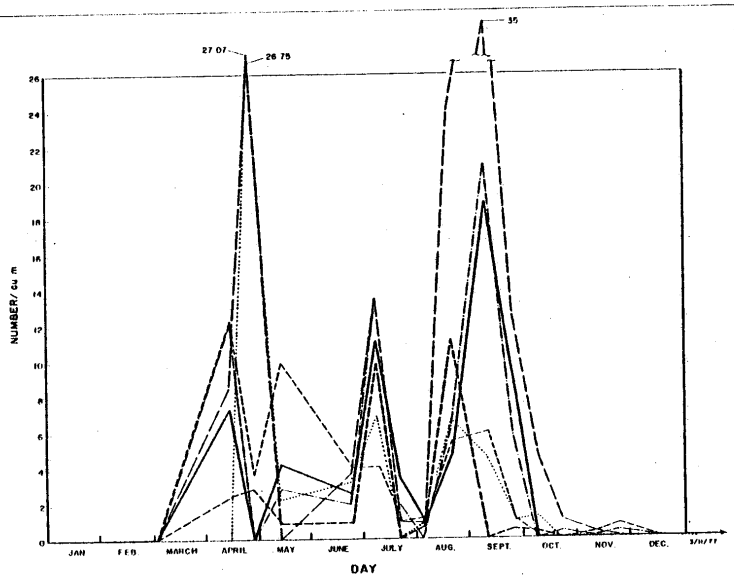
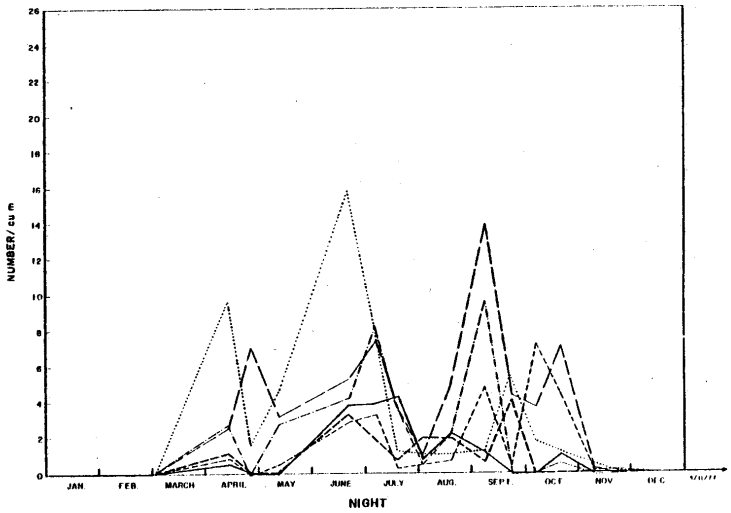


FIGURE 4.5-2
TOTAL MEROPLANKTON ABUNDANCE AVERAGE OF ALL BIG BEND STATIONS (DAY AND NIGHT)
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

SOURCE: TECO, 1977h.
Appendix to 316 Demonstration for Units 1-3
Volume III Page 6-10.

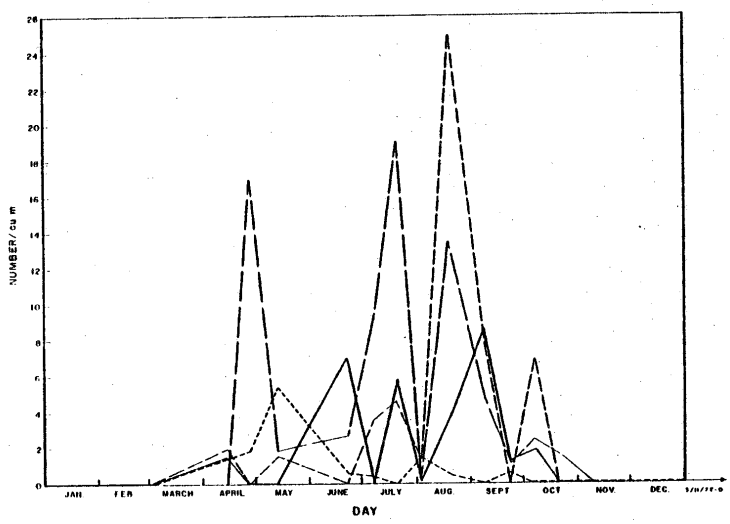


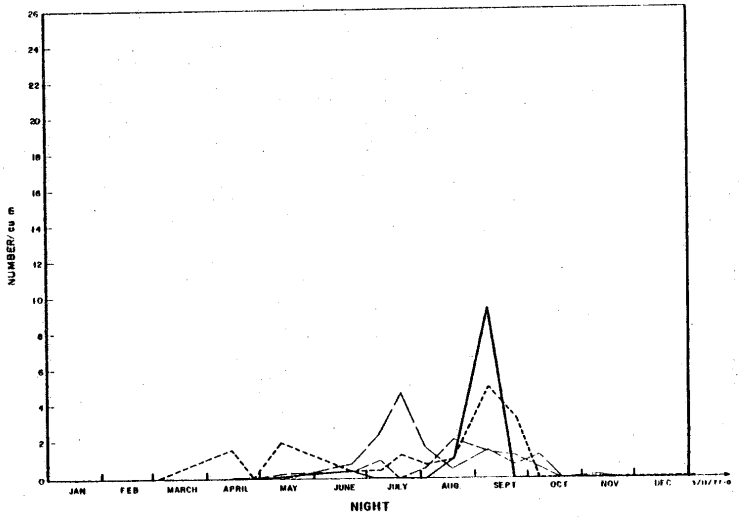


LEGEND

O-A
I-6
I-16
I-3
I-1/I-15
BC-8

FIGURE 4.5-3
DENSITY OF *MENIPPE MERCENARIA* LARVAE AT INSHORE STATIONS 1976-1977
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY





LEGEND

- 0-17
- A-5
- BC-5
- E-5

FIGURE 4.5-4
DENSITY OF *MENIPPE MERCENARIA* LARVAE AT OFFSHORE STATIONS
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

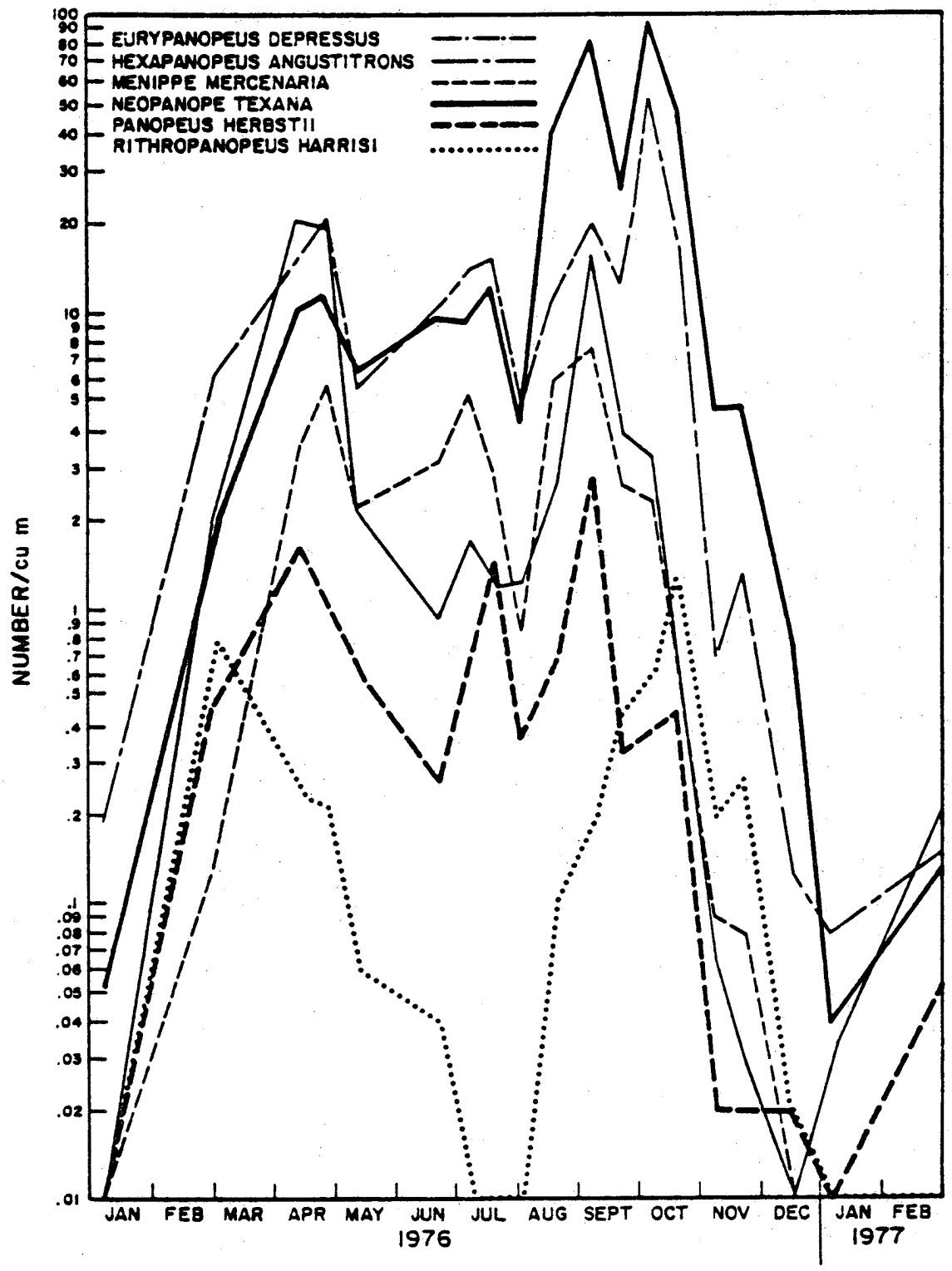
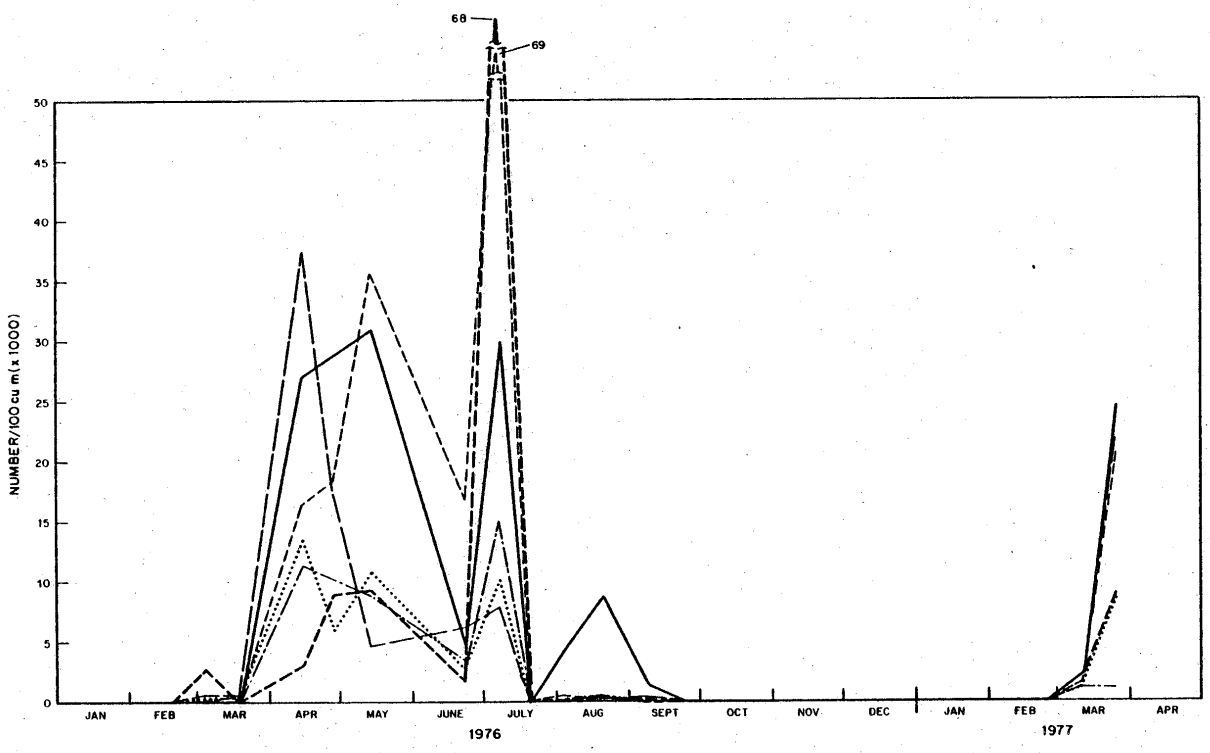


FIGURE 4.5-5
ABUNDANCE OF SIX MOST COMMON TYPES OF XANTHID CRAB LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

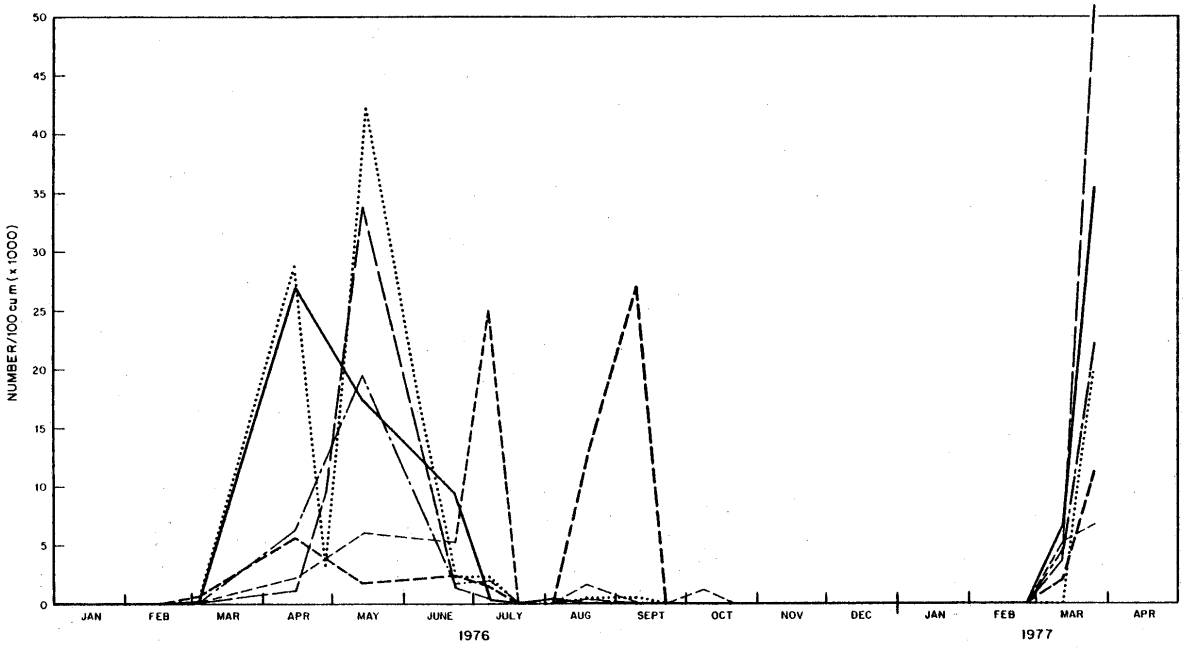
SOURCE: TECO, 1977h. Adapted from Appendix to 316 Demonstration for Units 1-3, Volume III, page 6-26.



LEGEND

0-8	I-16
I-6	I-3
I-1/I-13	BC-8

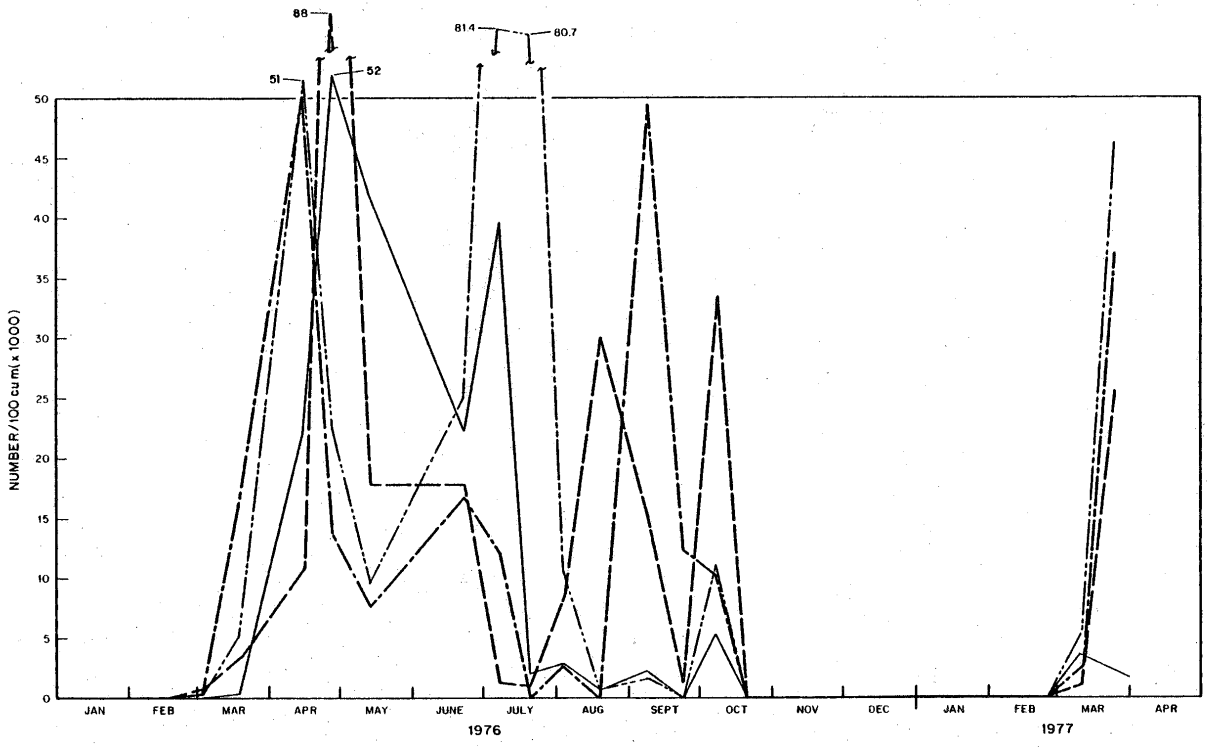
FIGURE 4.5-6
DENSITY OF *ANCHOA MITCHILLI* EGGS
INSHORE STATIONS - DAY
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

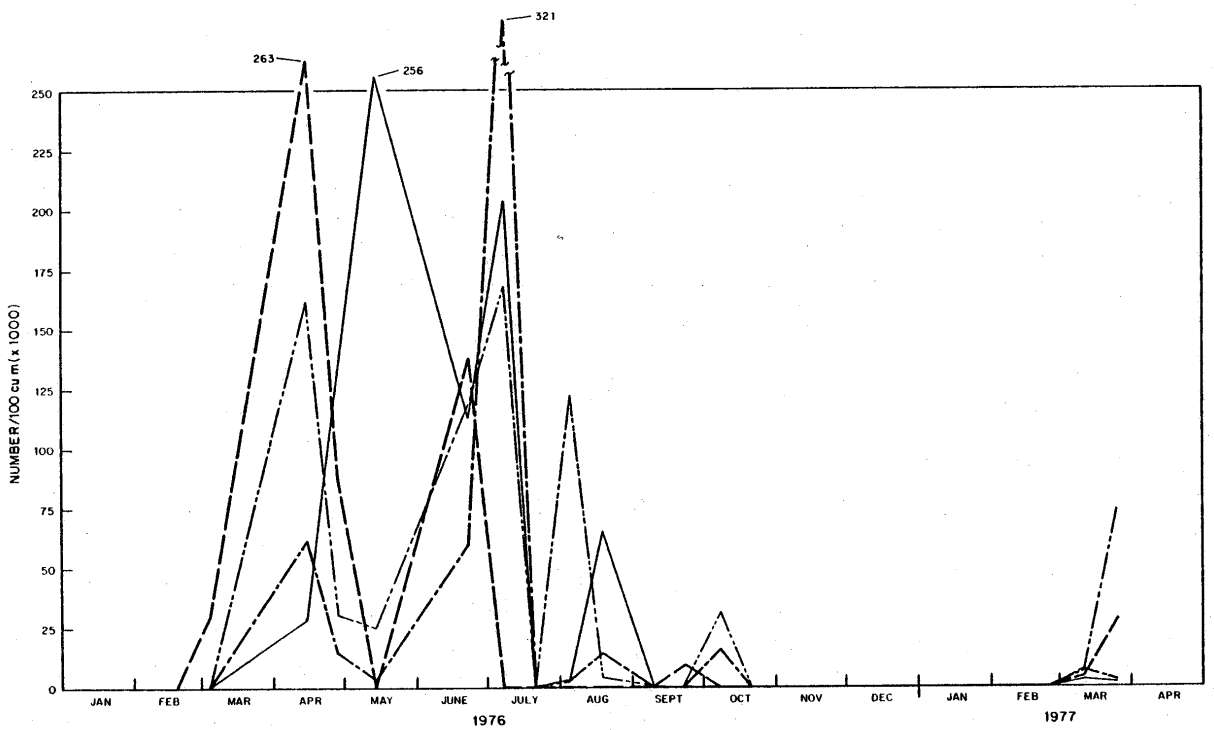
FIGURE 4.5-7
DENSITY OF *ANCHOA MITCHILLI* EGGS
INSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-17
- A-5
- BC-5
- E-5

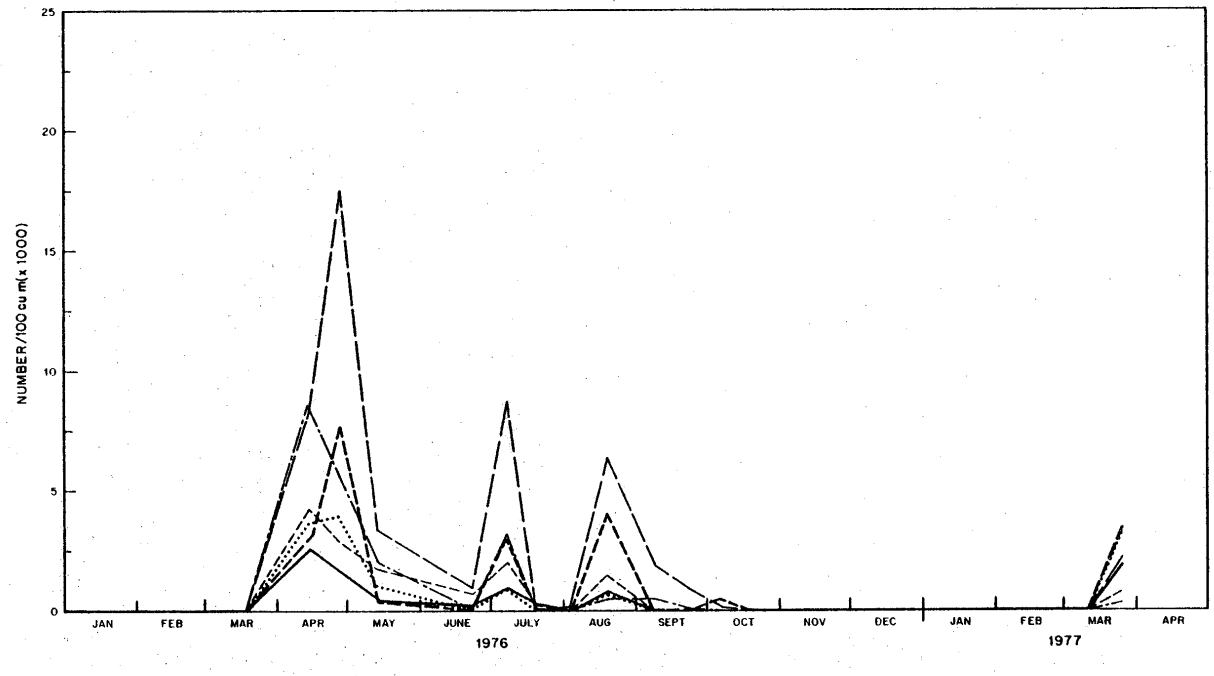
FIGURE 4.5-8
DENSITY OF *ANCHOA MITCHILLI* EGGS
OFFSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-17
- A-5
- BC-5
- E-5

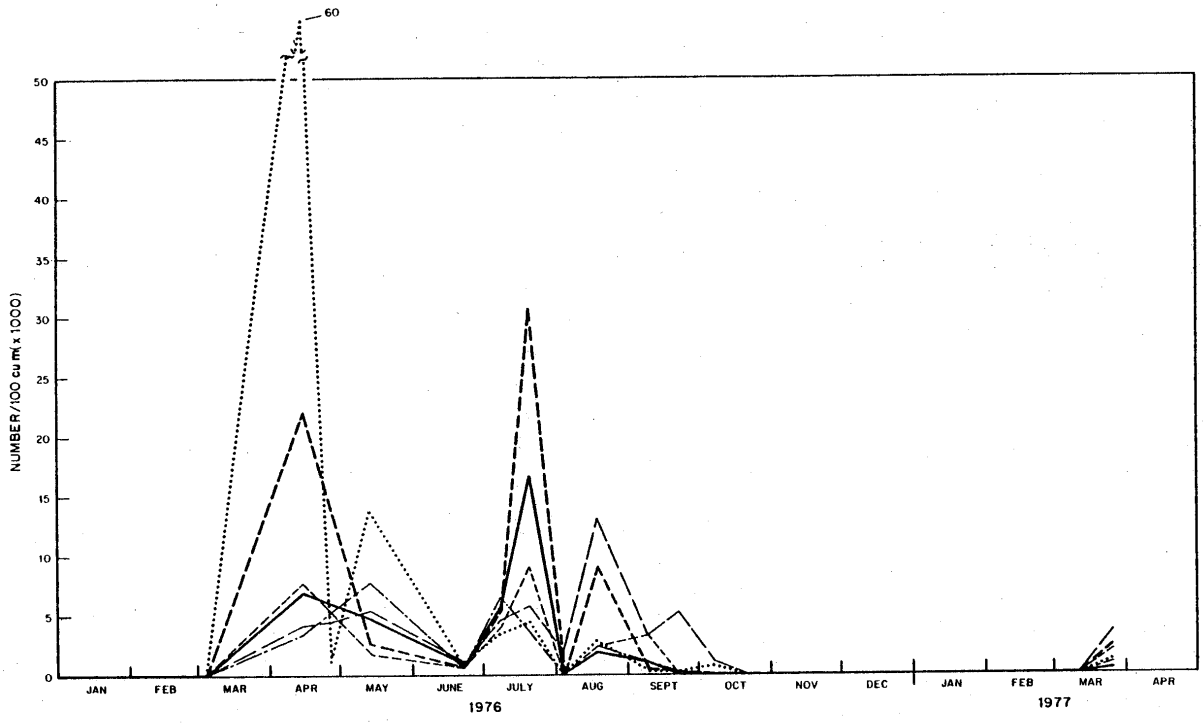
FIGURE 4.5-9
DENSITY OF *ANCHOA MITCHILLI* EGGS
OFFSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

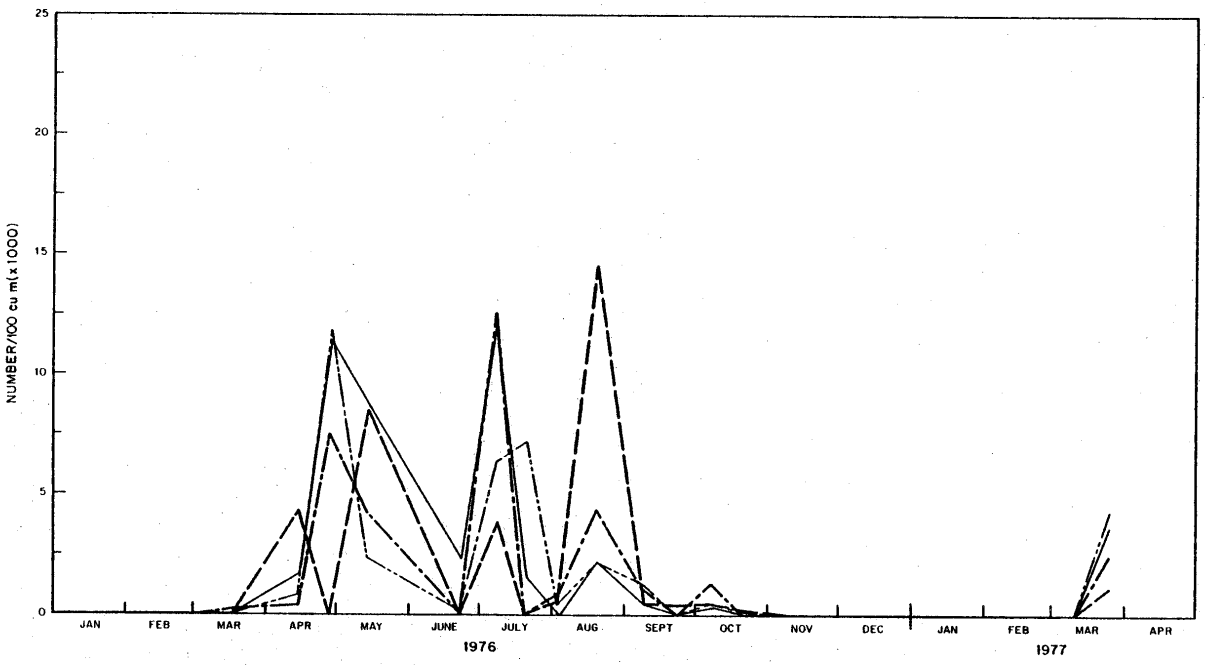
FIGURE 4.5-10
DENSITY OF *ANCHOA MITCHILLI* LARVAE
INSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

O-8	I-16
I-6	I-3
I-1/1-13	BC-8

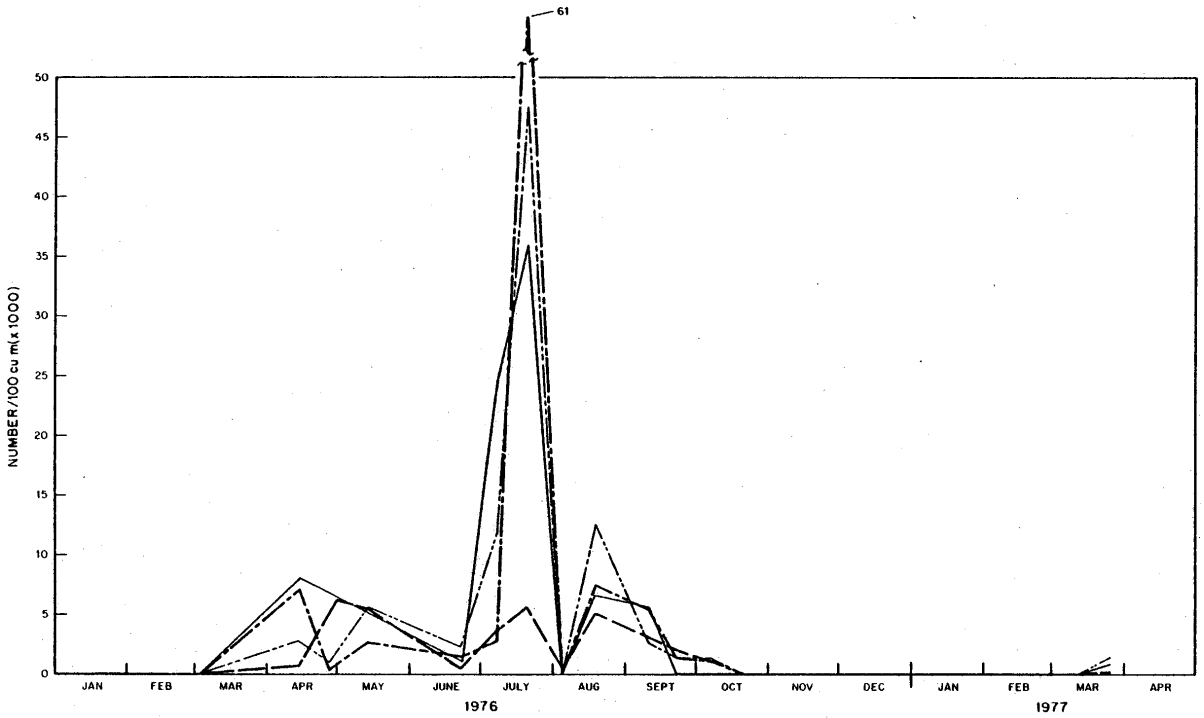
FIGURE 4.5-11
DENSITY OF *ANCHOA MITCHILLI* LARVAE
INSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-17
- A-5
- BC-5
- E-5

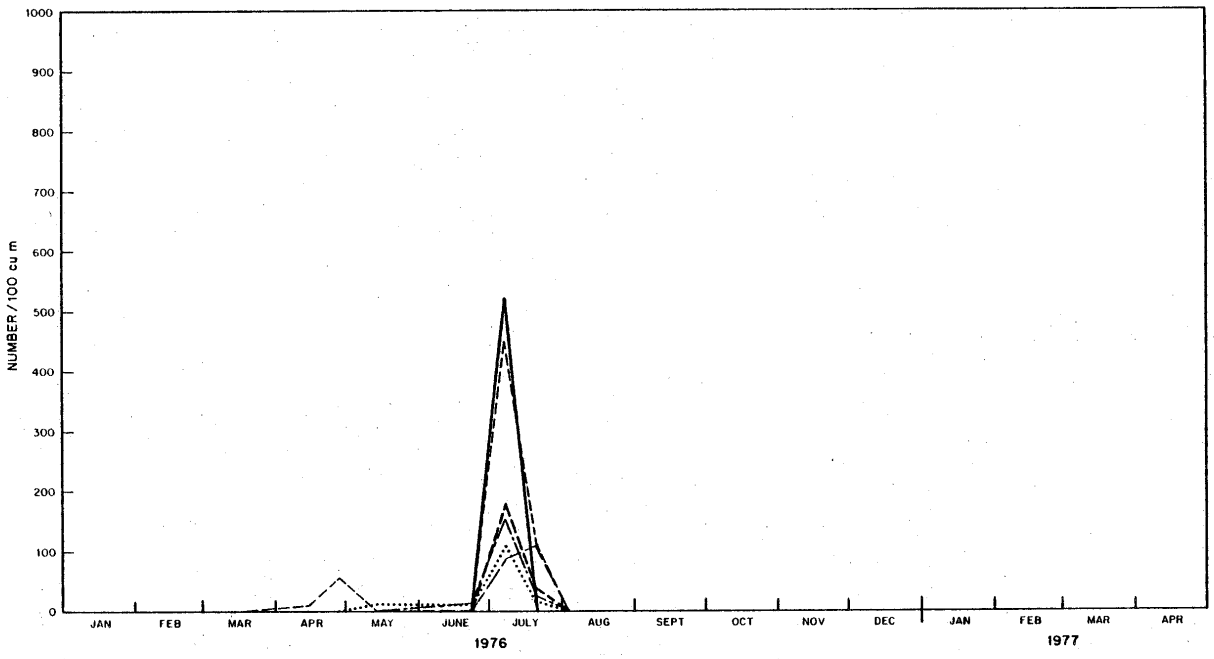
FIGURE 4.5-12
DENSITY OF *ANCHOA MITCHILLI* LARVAE
OFFSHORE STATIONS - DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-17
- A-5
- BC-5
- E-5

FIGURE 4.5-13
DENSITY OF *ANCHOA MITCHILLI* LARVAE
OFFSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

FIGURE 4.5-14
DENSITY OF
HARENGULA JAGUANA EGGS
INSHORE STATIONS - DAY
316 DEMONSTRATION
BIG BEND STATION–UNIT 4
TAMPA ELECTRIC COMPANY

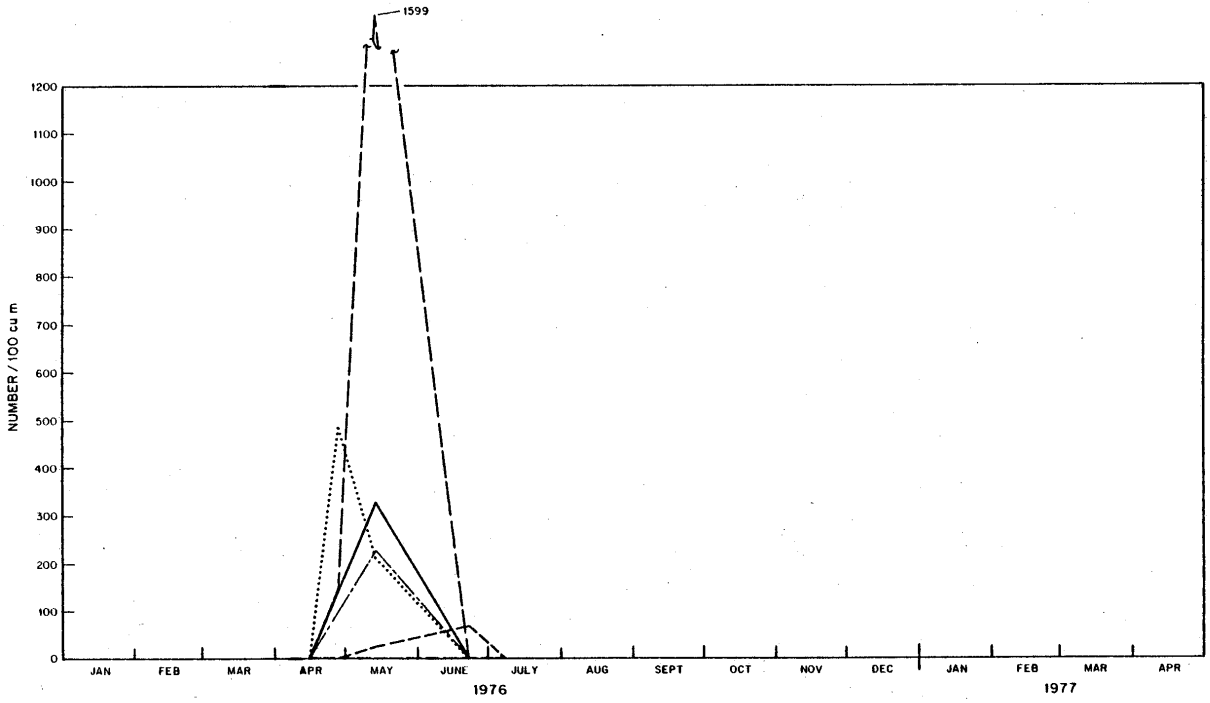
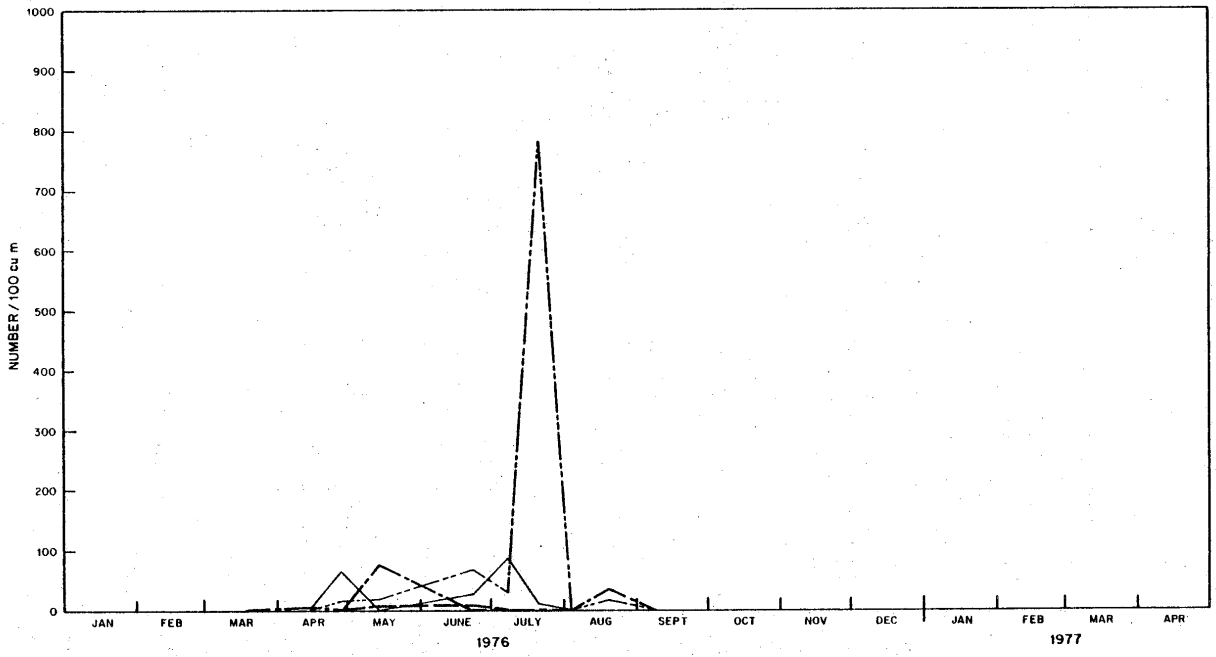


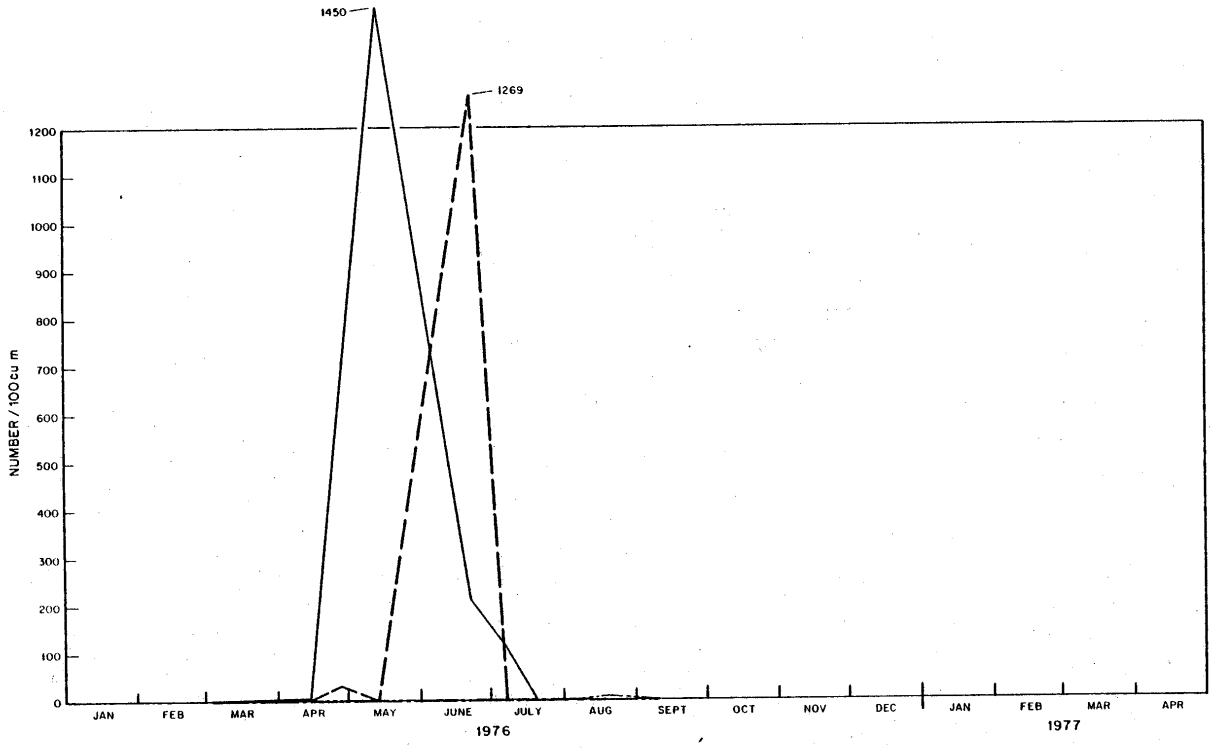
FIGURE 4.5-15
DENSITY OF
HARENGULA JAGUANA EGGS
INSHORE STATIONS-NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-17
- A-5
- BC-5
- E-5

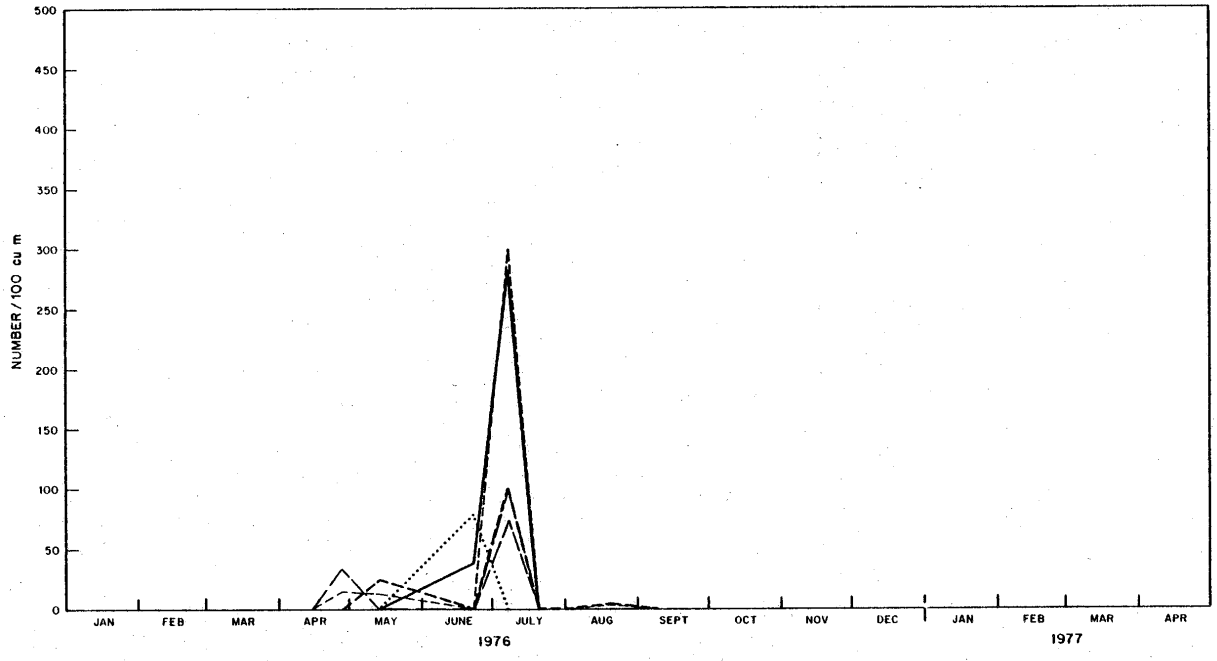
FIGURE 4.5-16
DENSITY OF
HARENGULA JAGUANA EGGS
OFFSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-17
- A-5
- BC-5
- E-5

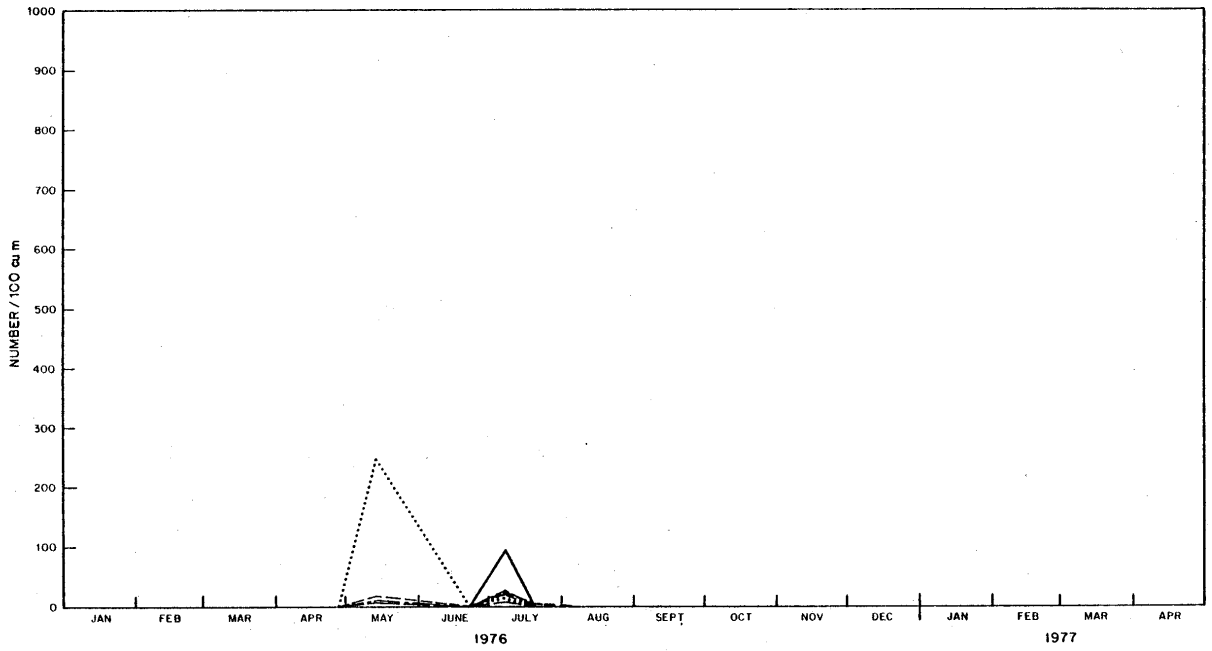
FIGURE 4.5-17
DENSITY OF
HARENGULA JAGUANA EGGS
OFFSHORE STATIONS-NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

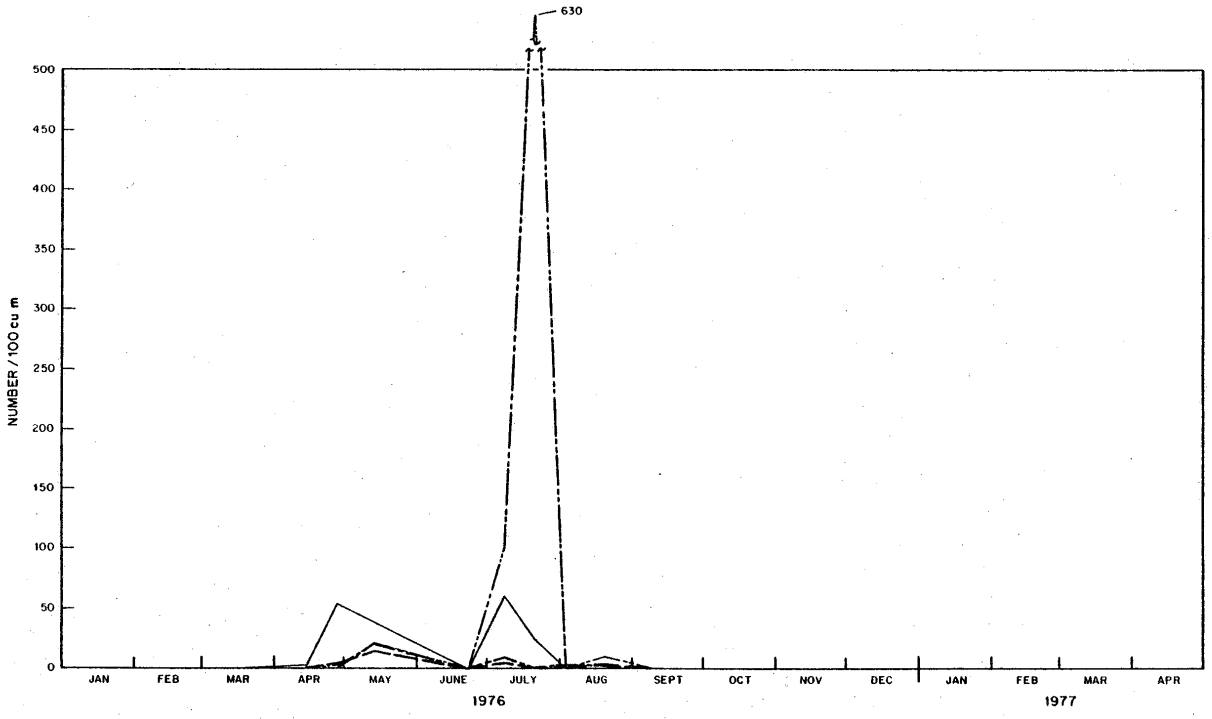
FIGURE 4.5-18
DENSITY OF
HARENGULA JAGUANA LARVAE
INSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

O-8	I-16
I-6	I-3
I-1/I-13	BC-8

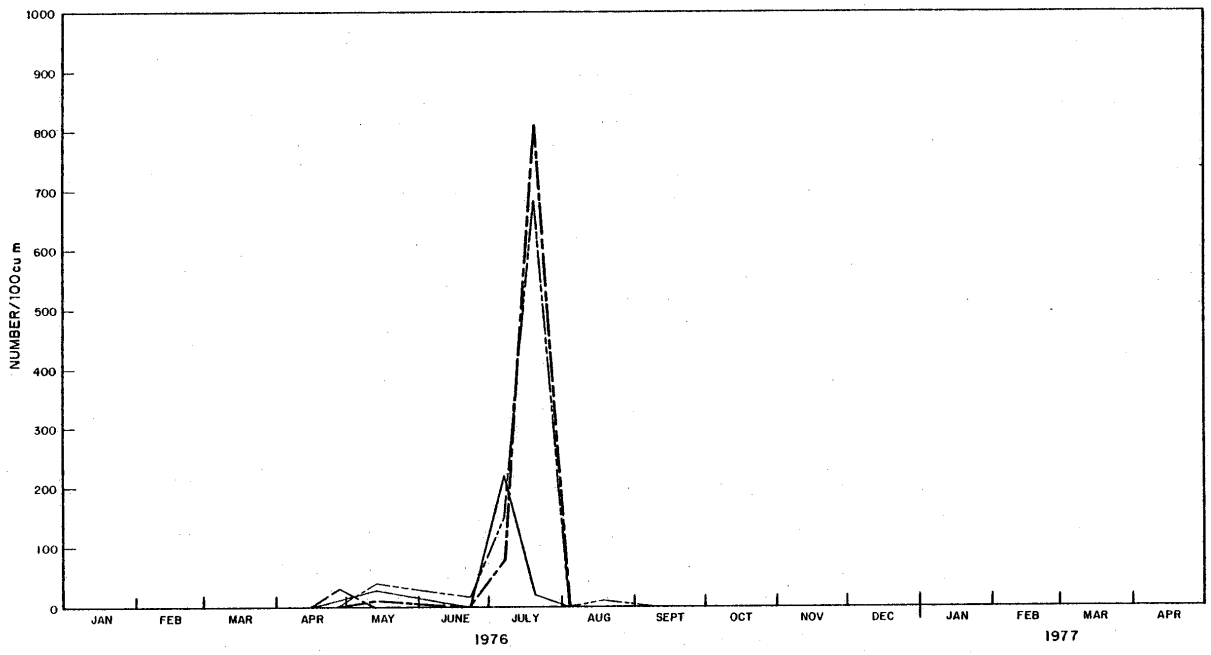
FIGURE 4.5-19
DENSITY OF
HARENGULA JAGUANA LARVAE
INSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-17
- A-5
- BC-5
- E-5

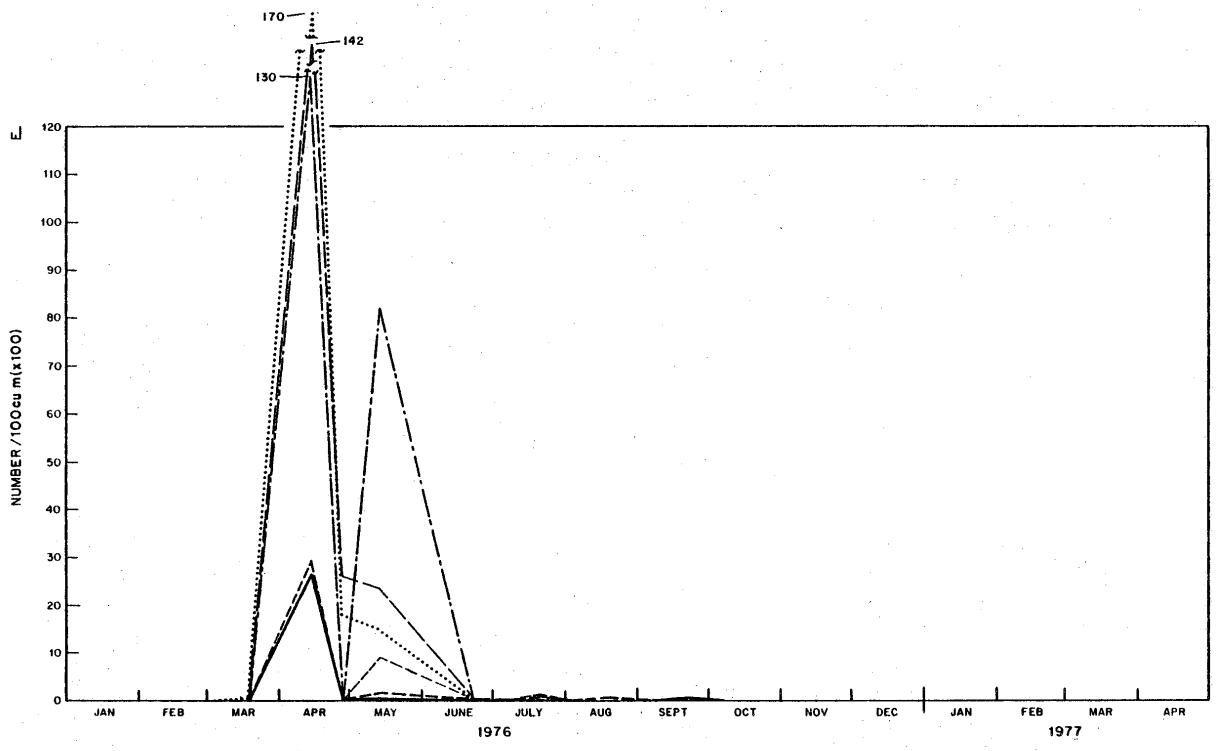
FIGURE 4.5-20
DENSITY OF
HARENGULA JAGUANA LARVAE
OFFSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-17
- A-5
- BC-5
- E-5

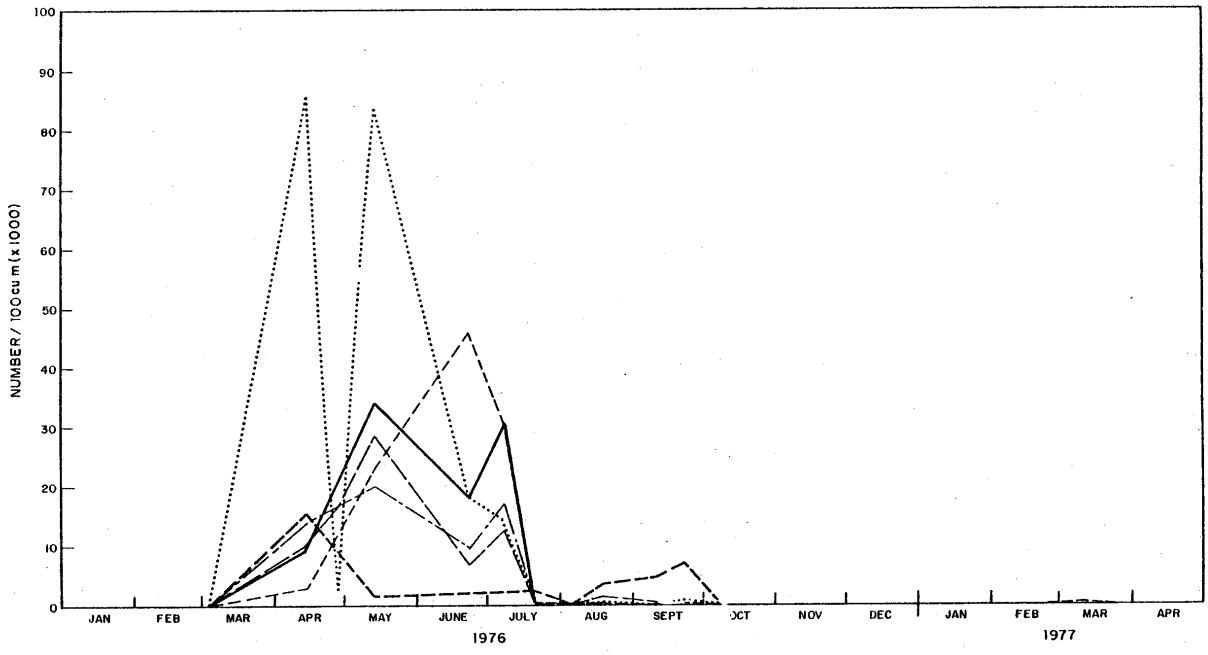
FIGURE 4.5-21
DENSITY OF
HARENGULA JAGUANA LARVAE
OFFSHORE STATIONS-NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-8
- I-16
- I-6
- I-3
- I-1/I-13
- BC-8

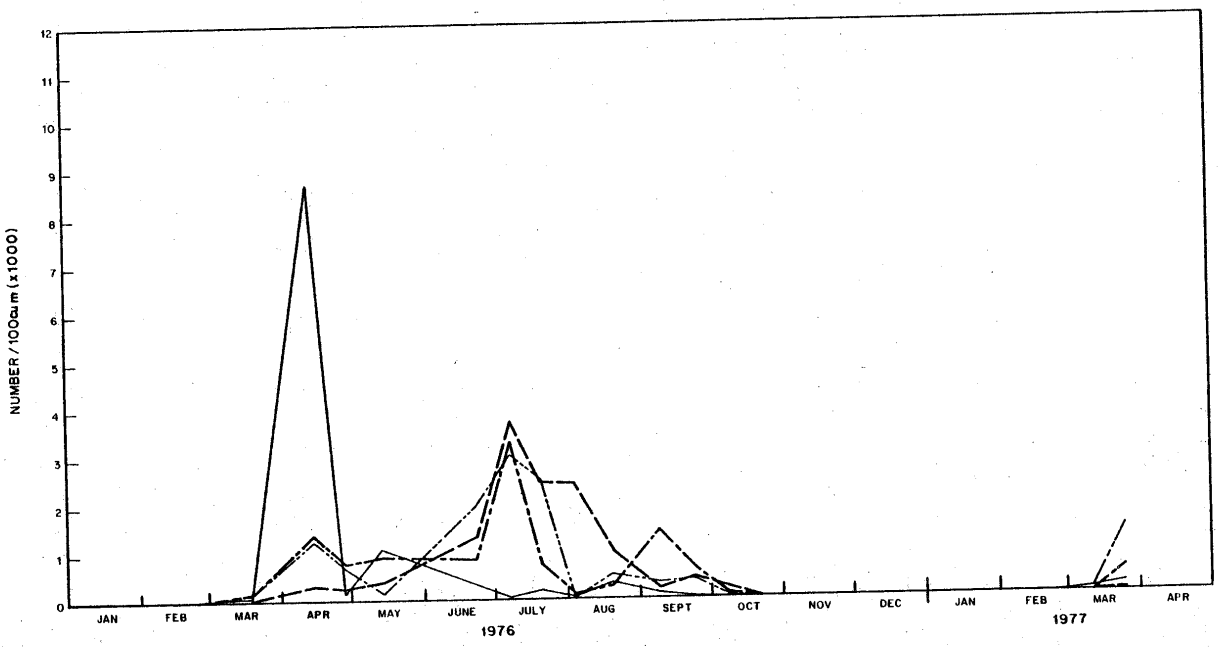
FIGURE 4.5-22
DENSITY OF *SCIAENID* SPP. EGGS
INSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

FIGURE 4.5-23
DENSITY OF *SCIAENID* SPP. EGGS
INSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-17
- A-5
- BC-5
- E-5

FIGURE 4.5-24
DENSITY OF *SCIAENID* SPP. EGGS
OFFSHORE STATIONS-DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

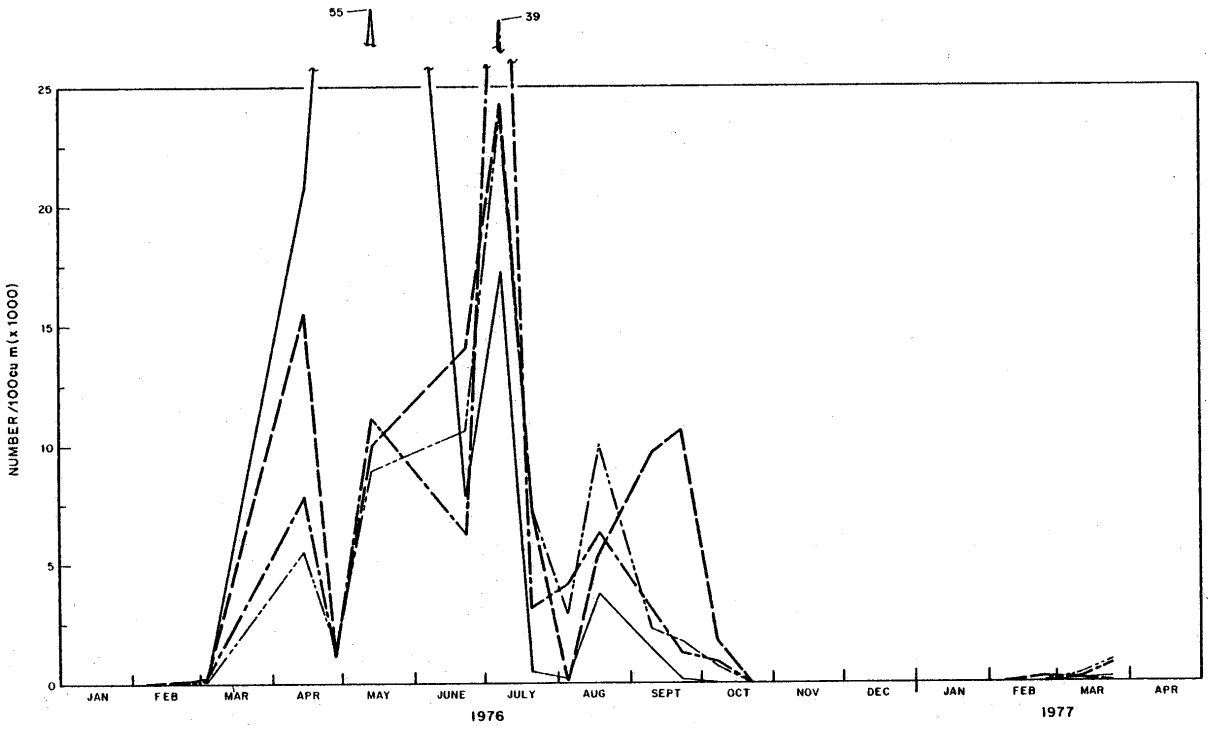
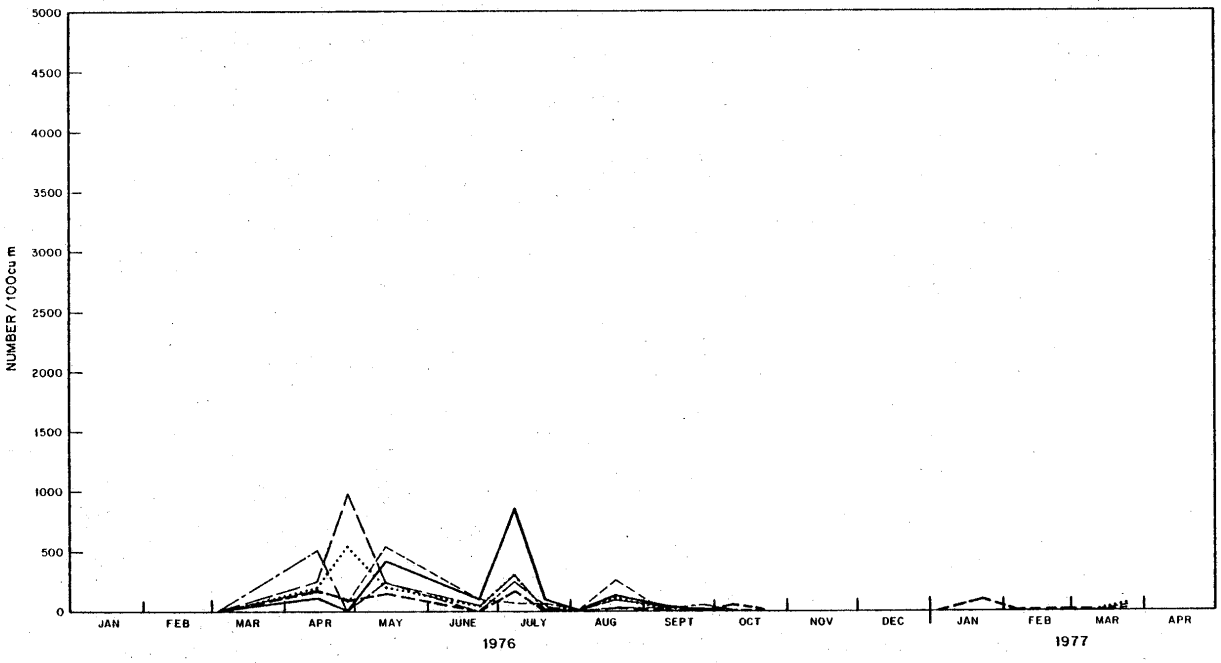


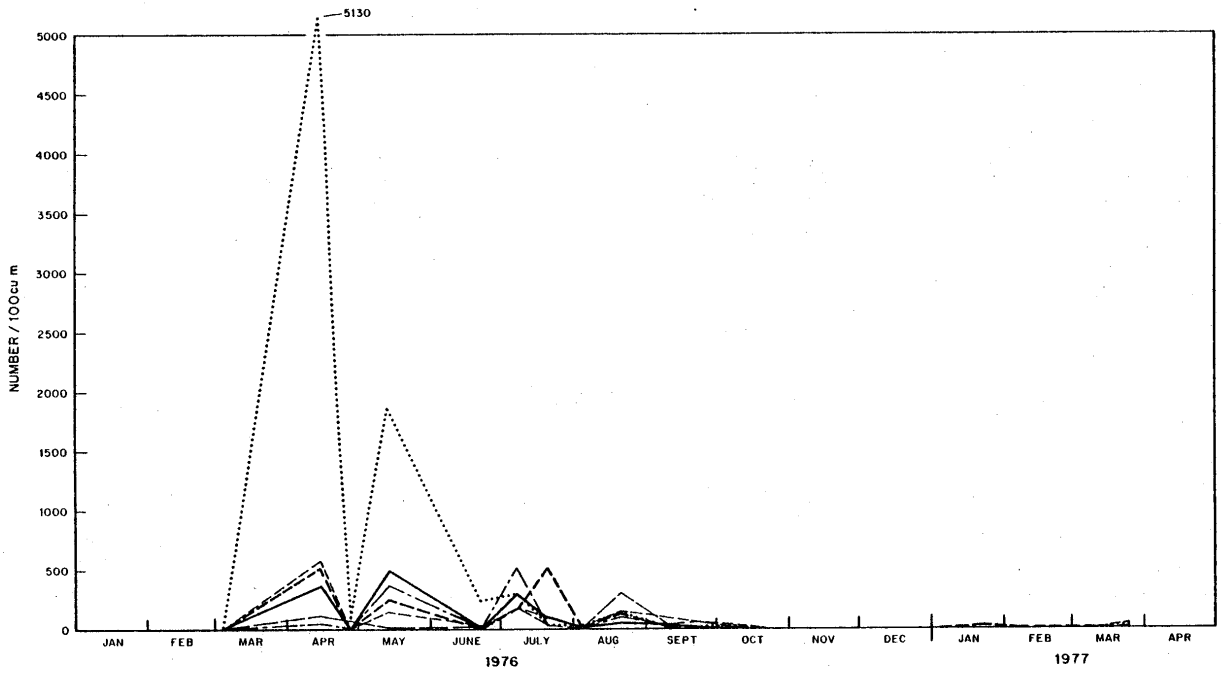
FIGURE 4.5-25
DENSITY OF *SCIAENID* SPP. EGGS
OFFSHORE STATIONS-NIGHT
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

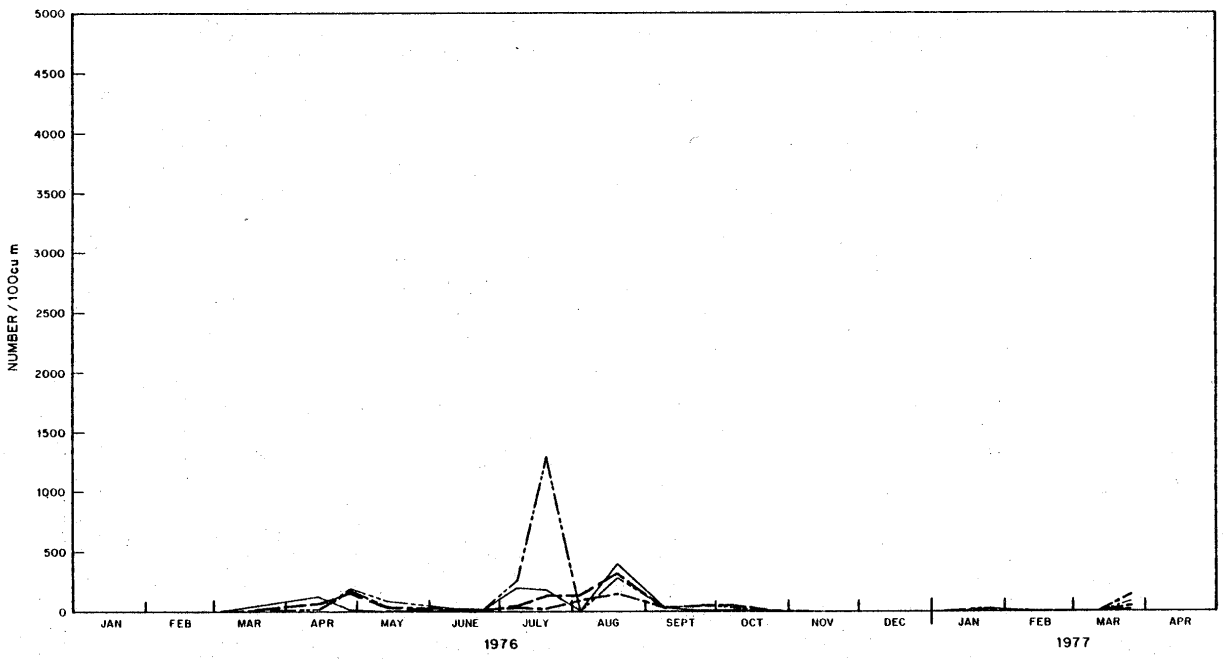
FIGURE 4.5-26
DENSITY OF *SCIAENID* SPP. LARVAE
INSHORE STATIONS - DAY
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-8
- I-6
- I-1/I-13
- I-16
- I-3
- BC-8

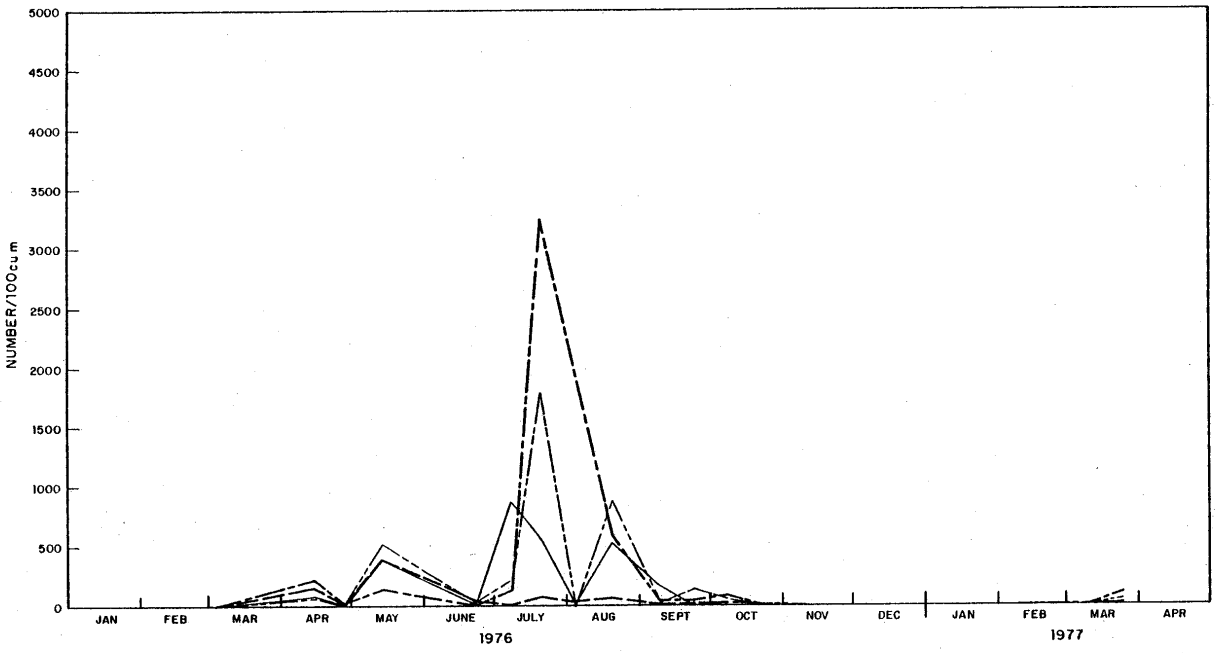
FIGURE 4.5-27
DENSITY OF *SCIAENID* SPP. LARVAE
INSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- 0-17
- A-5
- BC-5
- E-5

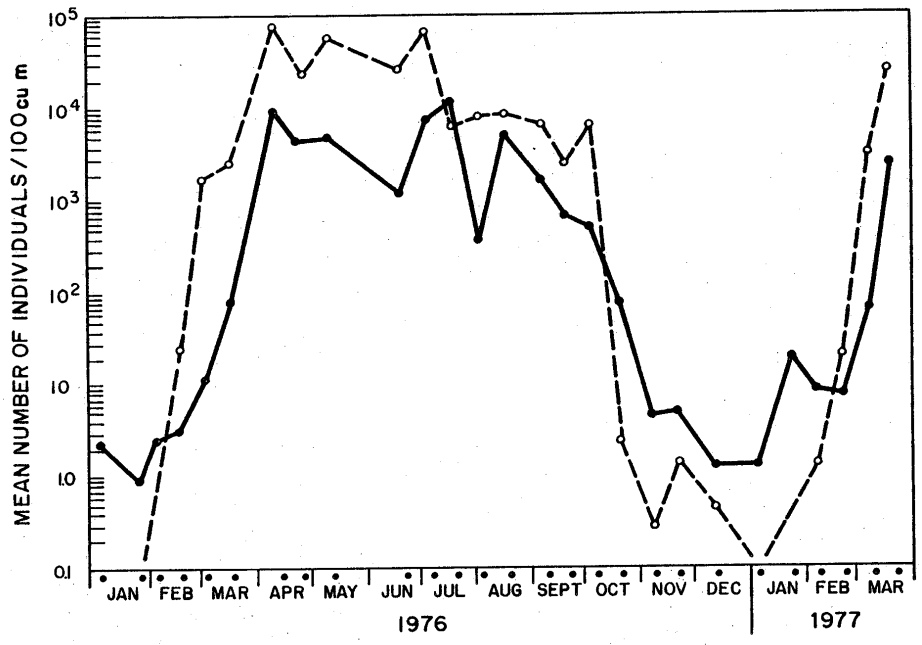
FIGURE 4.5-28
DENSITY OF *SCIAENID* SPP. LARVAE
OFFSHORE STATIONS - DAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



LEGEND

- O-17
- A-5
- BC-5
- E-5

FIGURE 4.5-29
DENSITY OF *SCIAENID* SPP LARVAE
OFFSHORE STATIONS - NIGHT
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

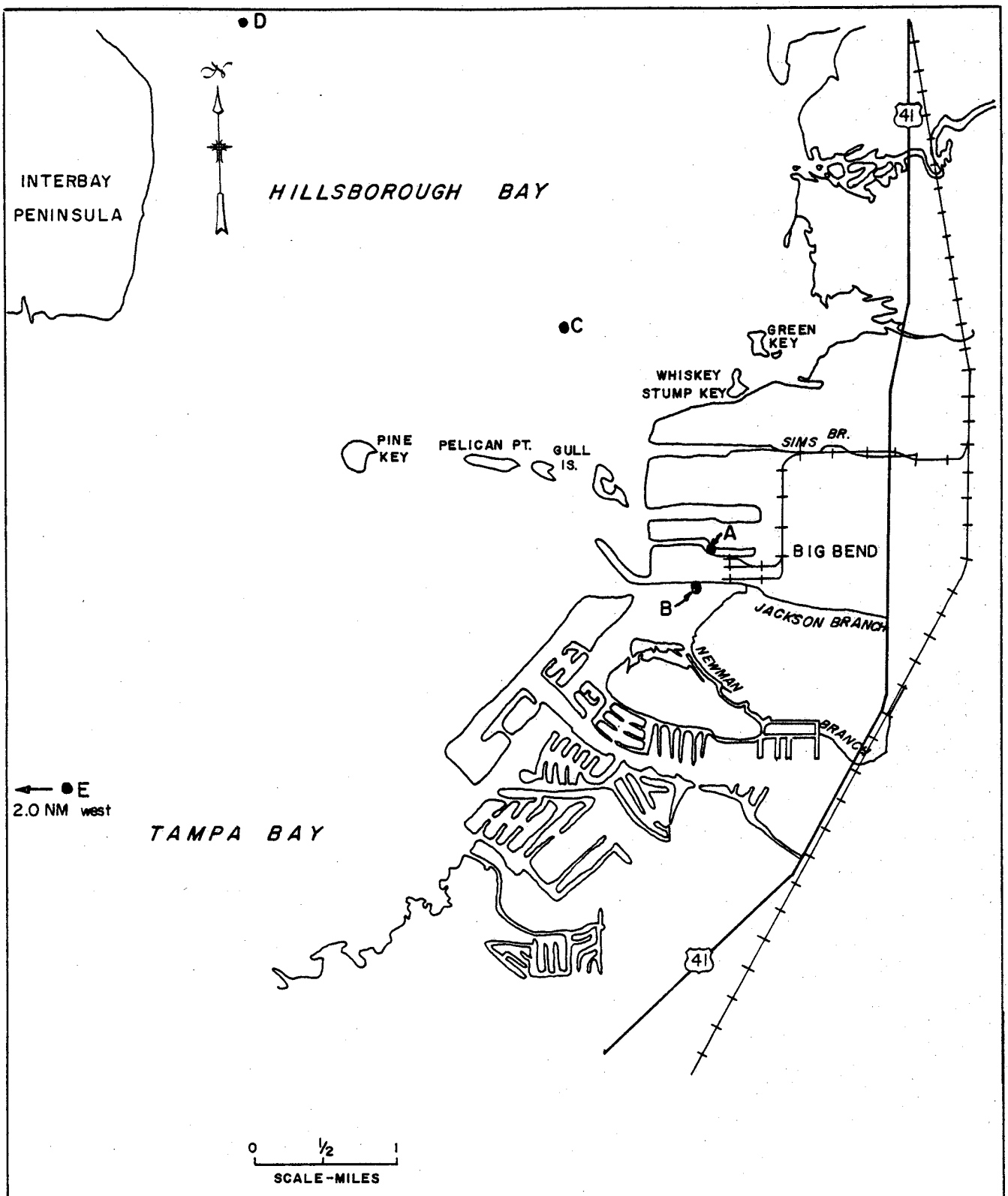


LEGEND

EGGS

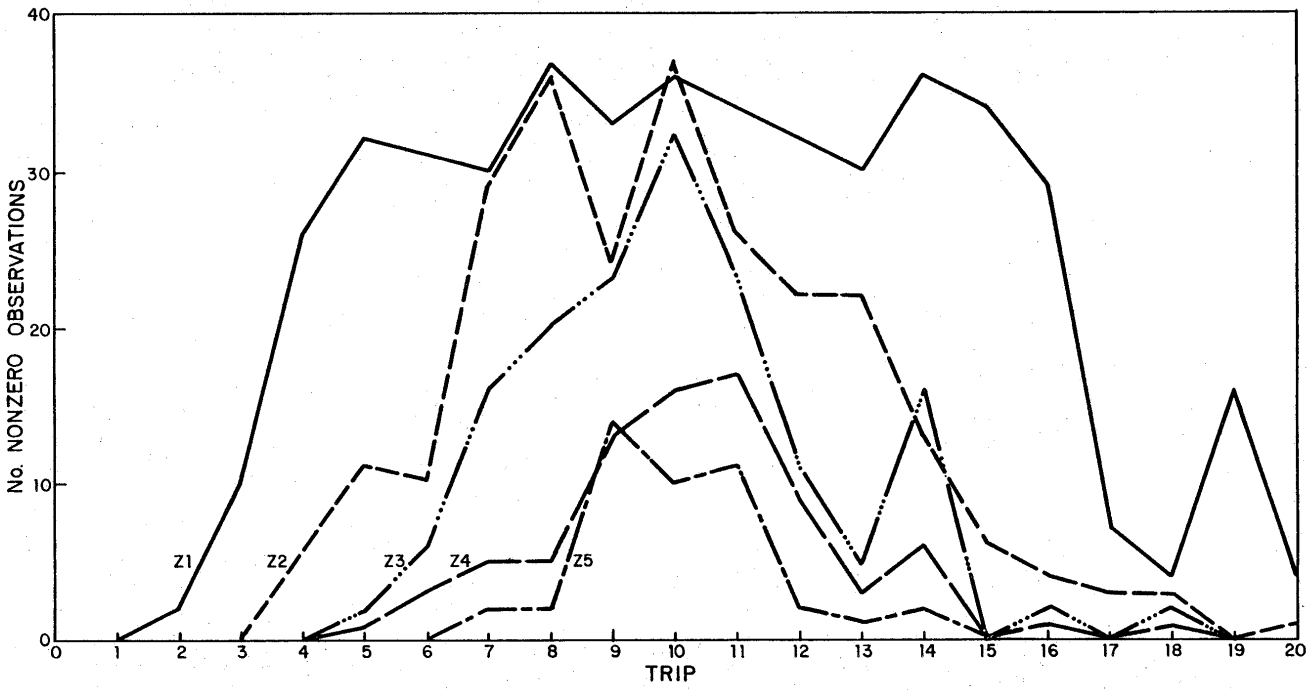
LARVAE

FIGURE 4.5-30
SEASONAL ABUNDANCE OF ICHTHYOPLANKTON
JANUARY 1976 - MARCH 1977
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



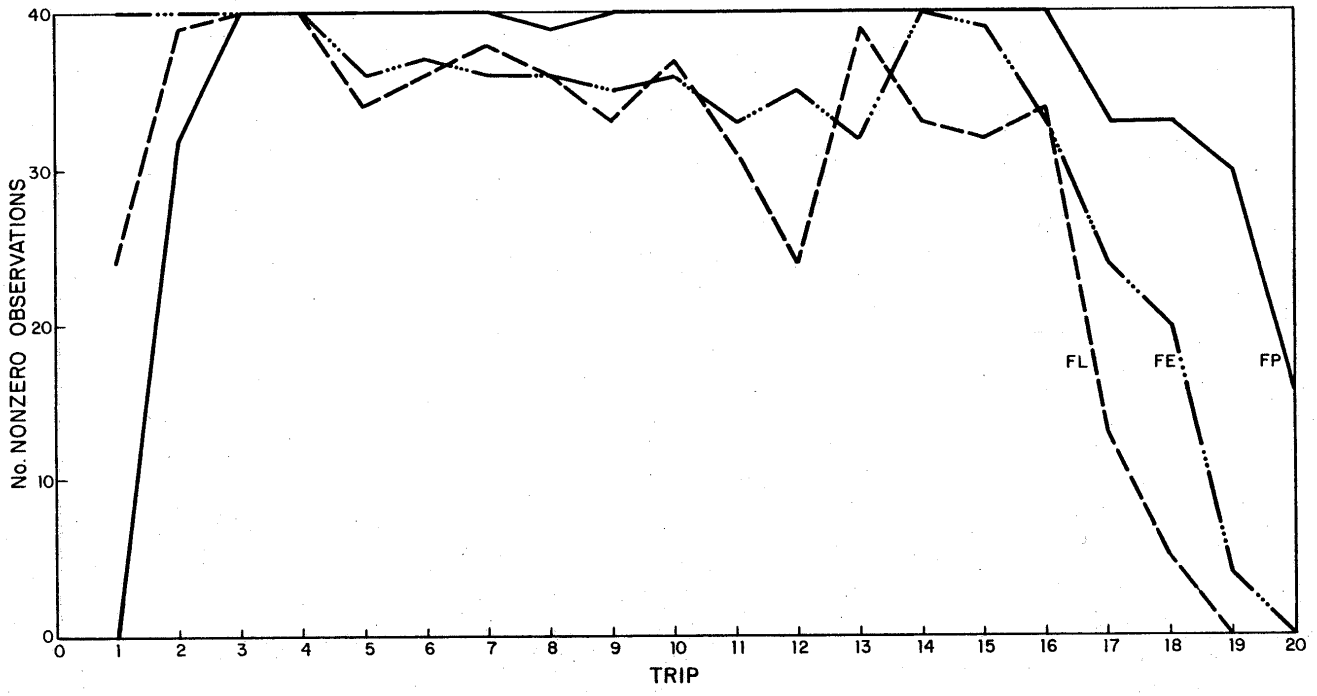
SOURCE: Stone & Webster Engineering Corporation, 1980b. 1979 Aquatic Ecology Program, Big Bend Power Station, Tampa, Florida. Draft Final Report. Selvakumaran Mahadevan (ed), Mote Marine Laboratory, Sarasota, Florida. April 21, 1980.

FIGURE 4.5-31
LOCATION OF MEROPLANKTON SAMPLING STATIONS-1979
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



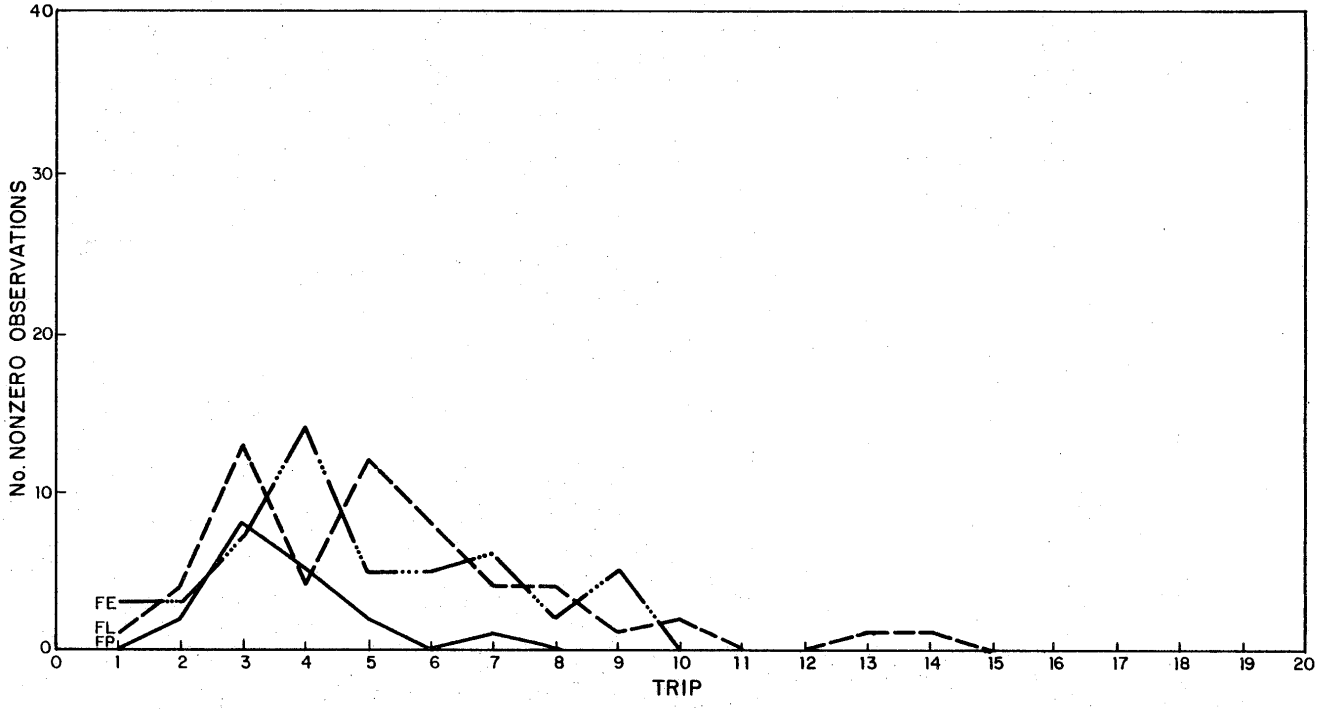
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-32
ZOEA
NUMBER OF NONZERO OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



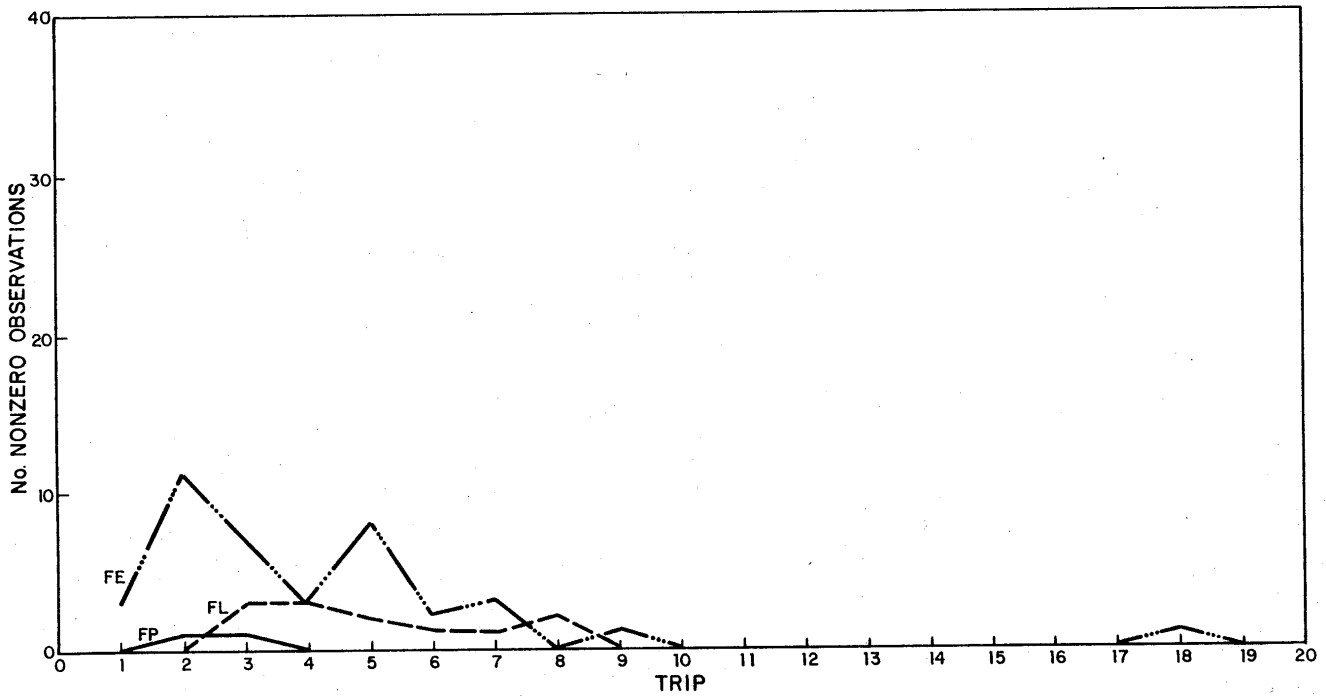
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-33
BAY ANCHOVY
NUMBER OF NONZERO
OBSERVATIONS
316 DEMOSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



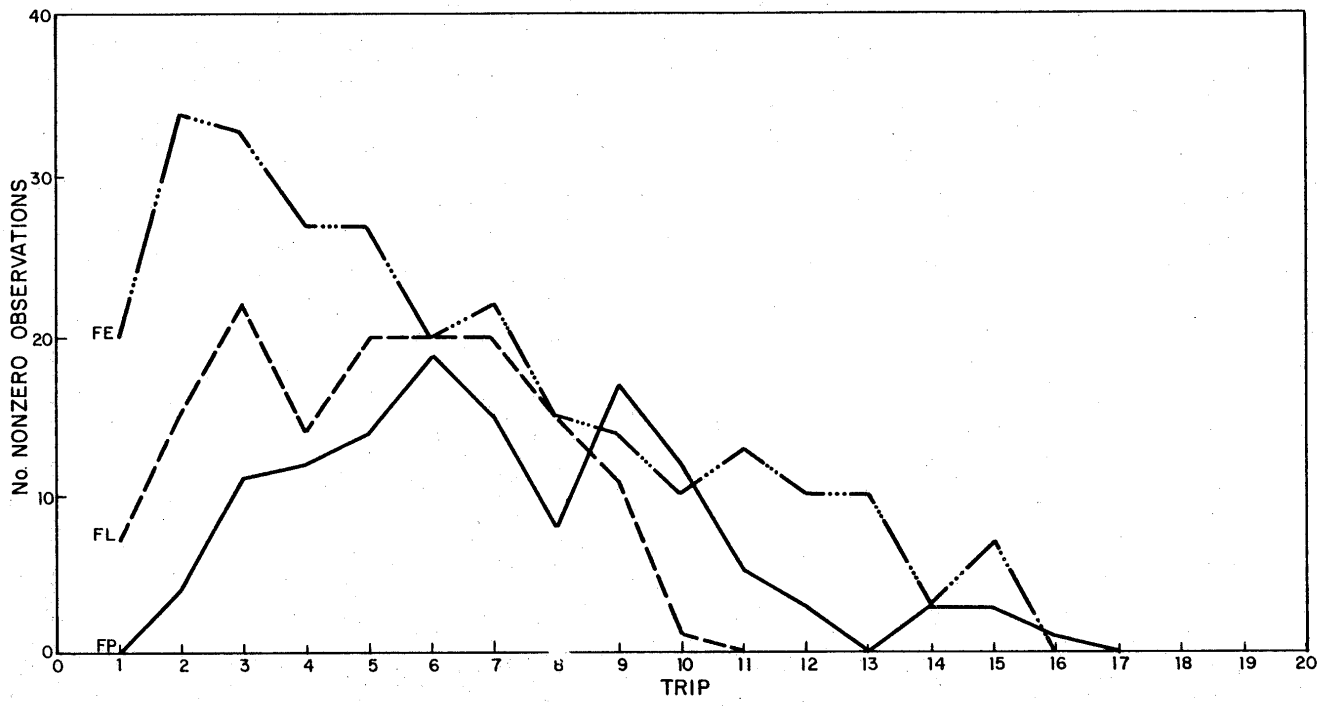
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-34
BLACK DRUM
NUMBER OF NONZERO
OPERATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



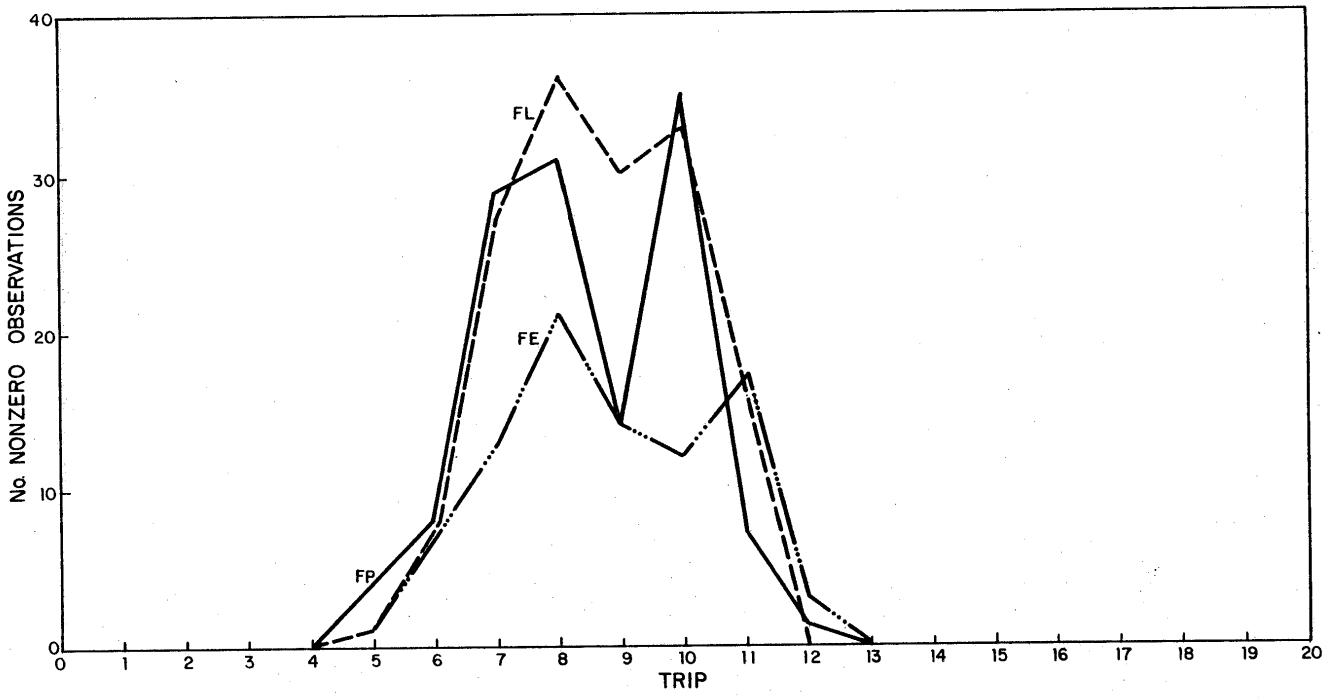
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-35
CYNOSCION SP.
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



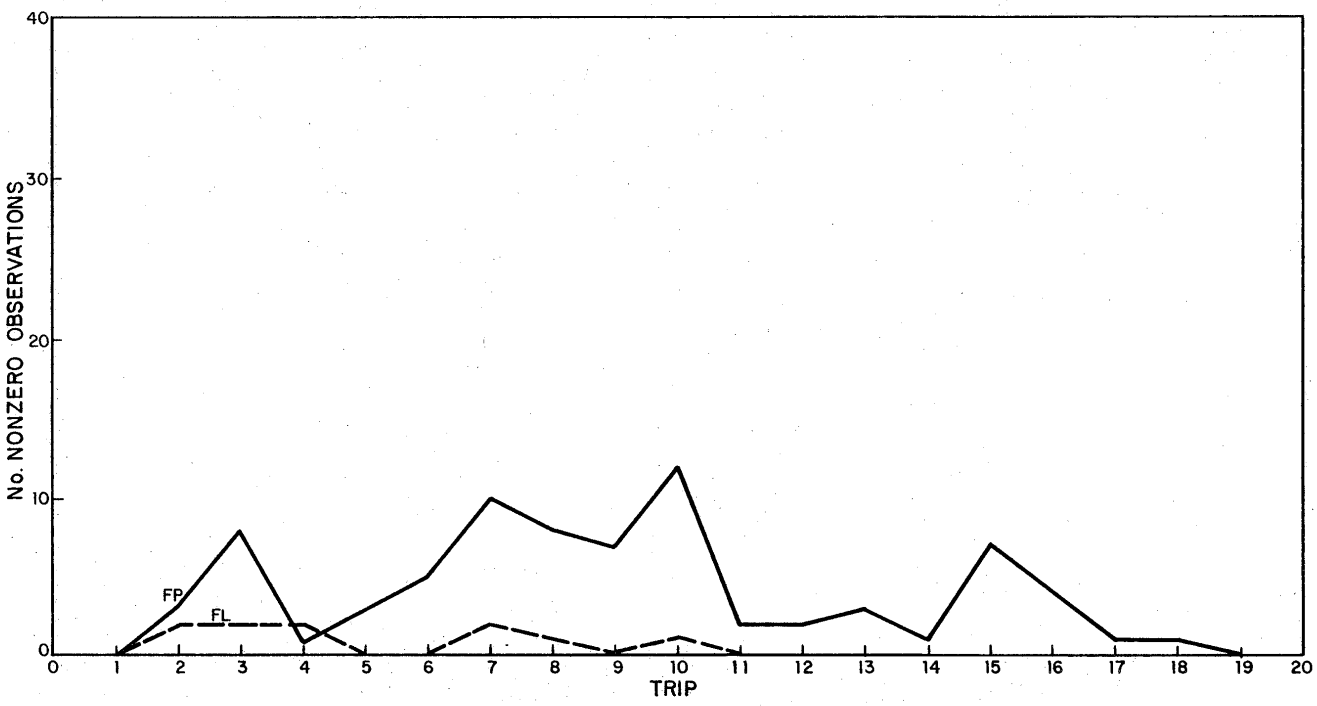
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-36
SILVER PERCH
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



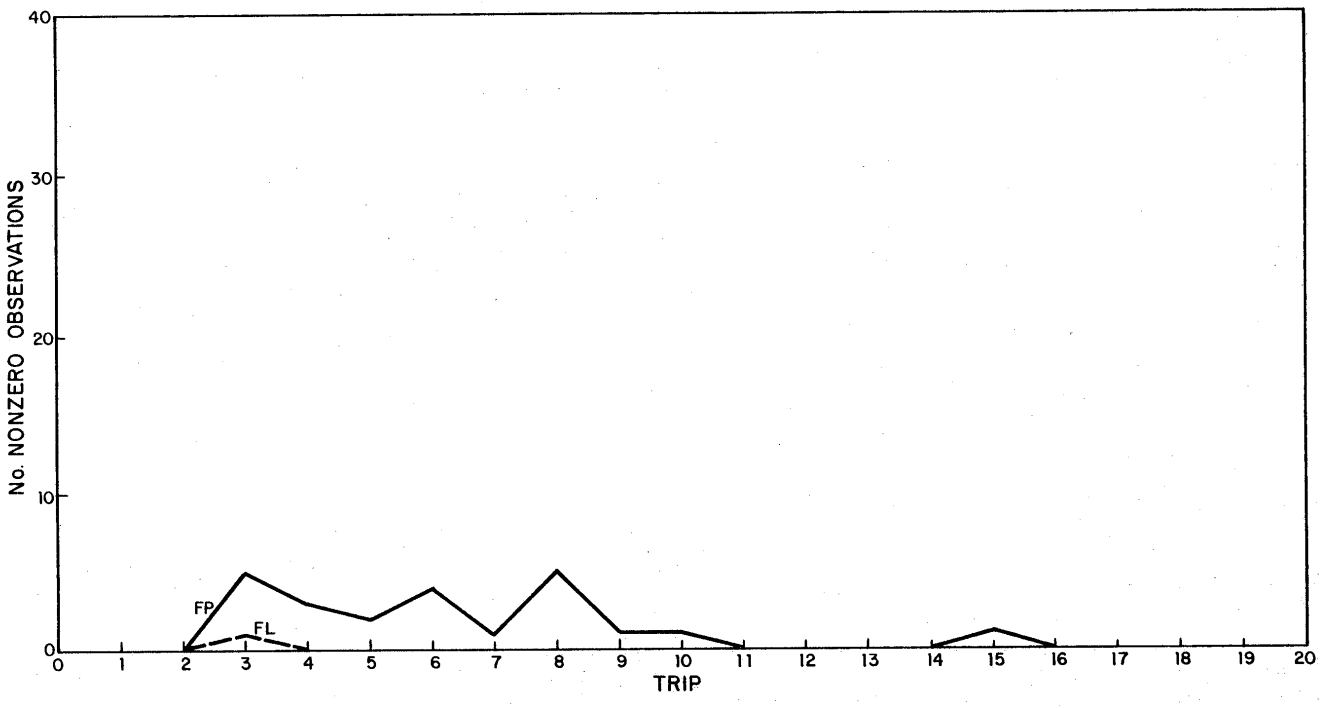
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-37
SCALED SARDINE
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



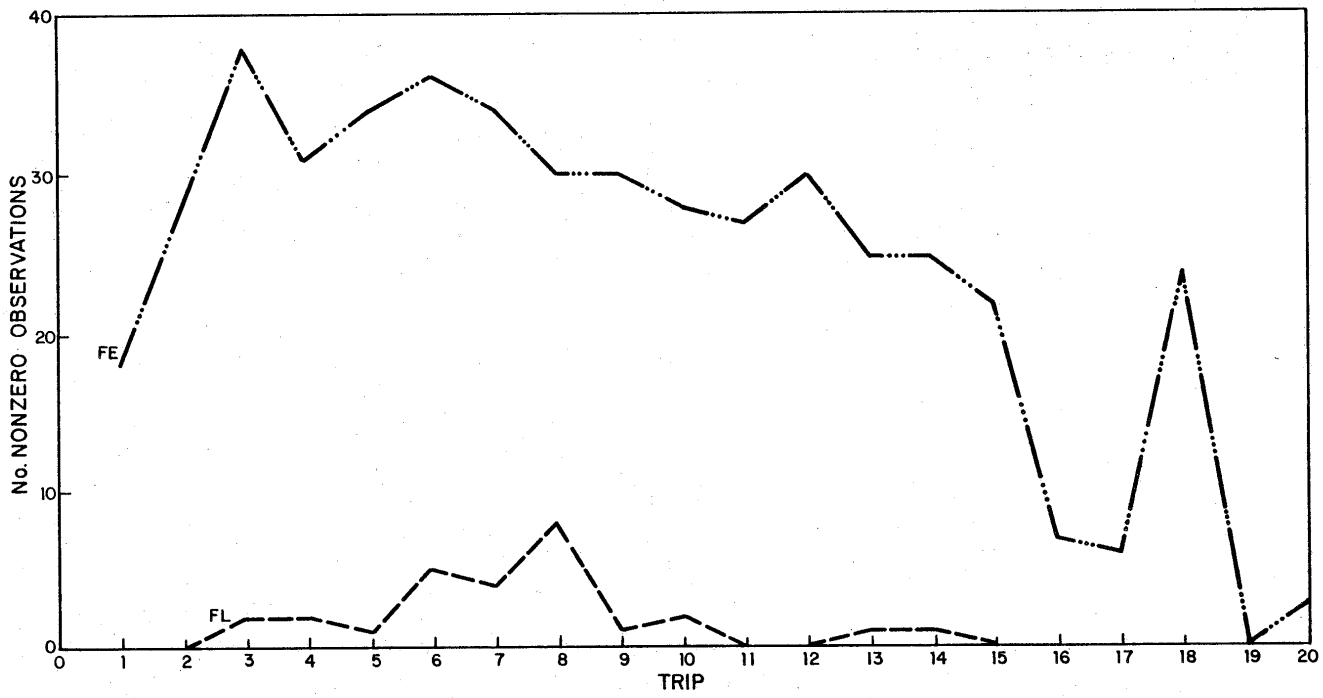
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-38
SPOTTED SEATROUT
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



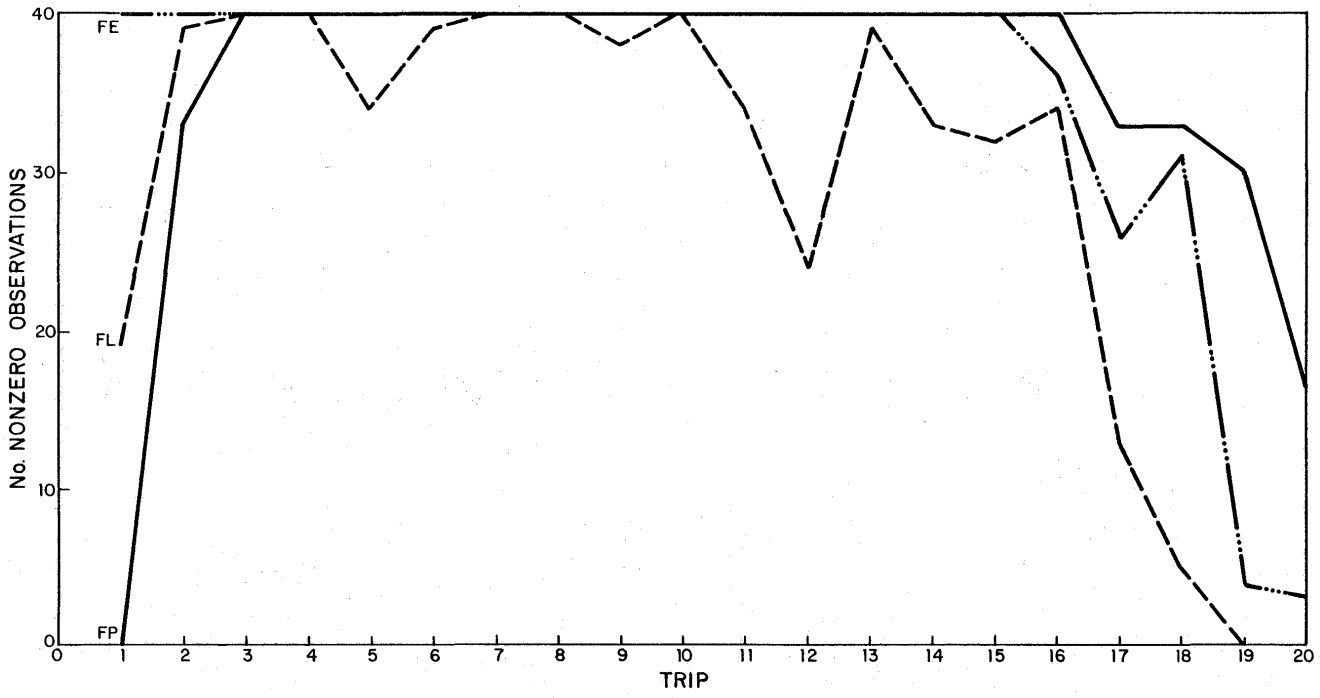
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-39
TIDEWATER SILVERSIDE
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



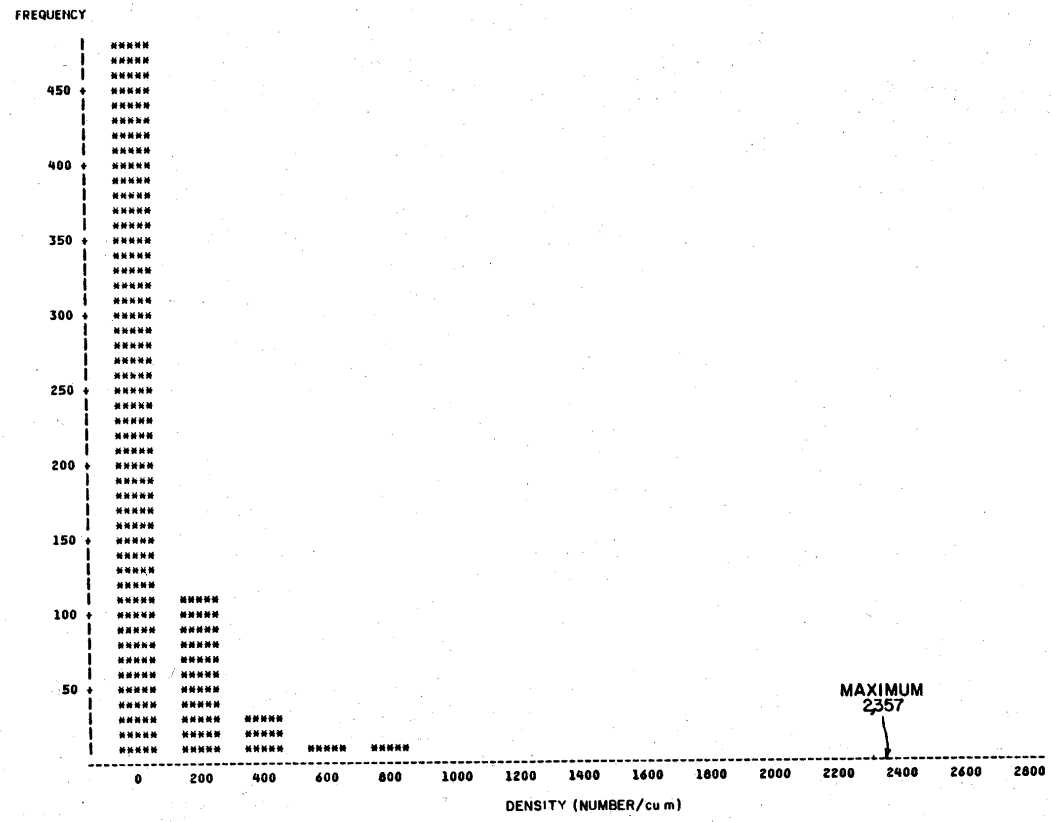
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-40
UNIDENTIFIED SCIAENIDS
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



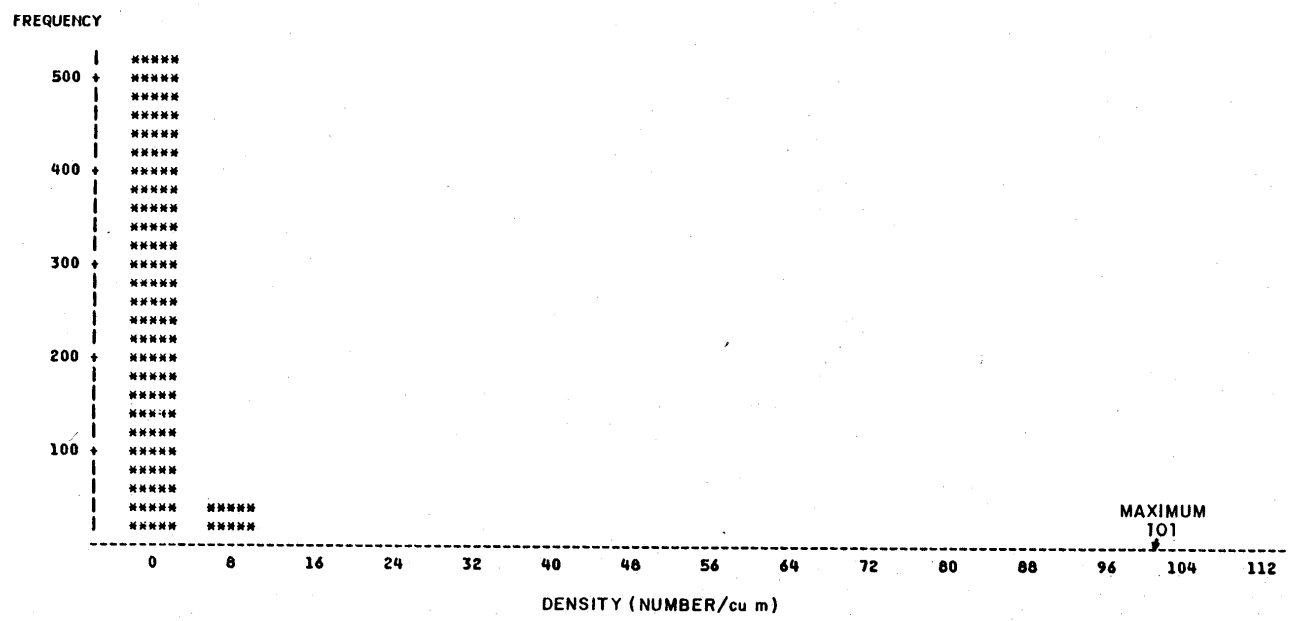
NOTE:
OUT OF 40 PER TRIP

FIGURE 4.5-41
ALL SPECIES COMBINED
NUMBER OF NONZERO
OBSERVATIONS
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



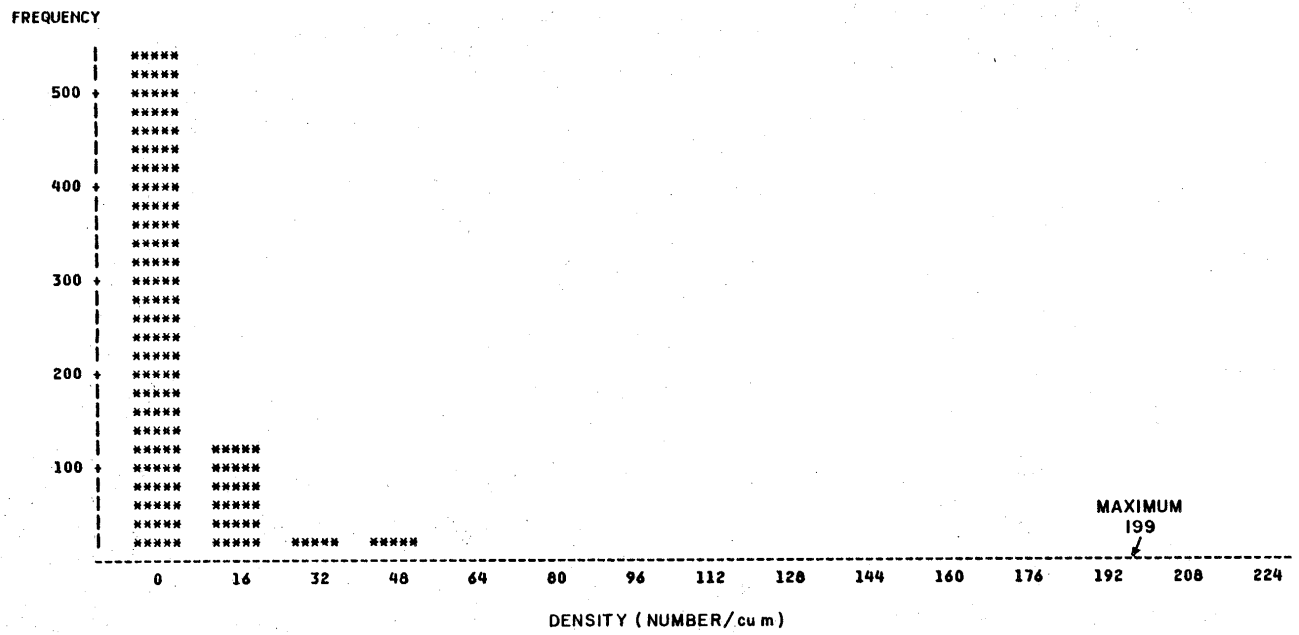
NOTE:
403 ZERO OBSERVATIONS

FIGURE 4.5-42
HISTOGRAM OF
BAY ANCHOVY EGGS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



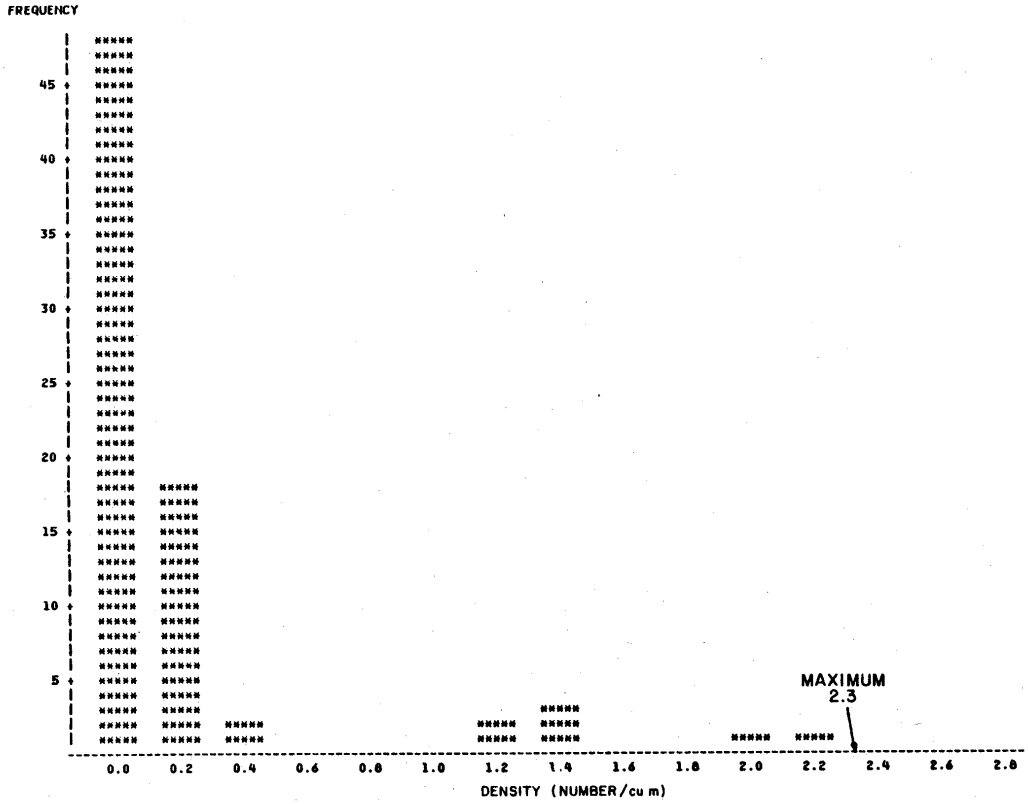
NOTE:
480 ZERO OBSERVATIONS

FIGURE 4.5-43
HISTOGRAM OF BAY ANCHOVY PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



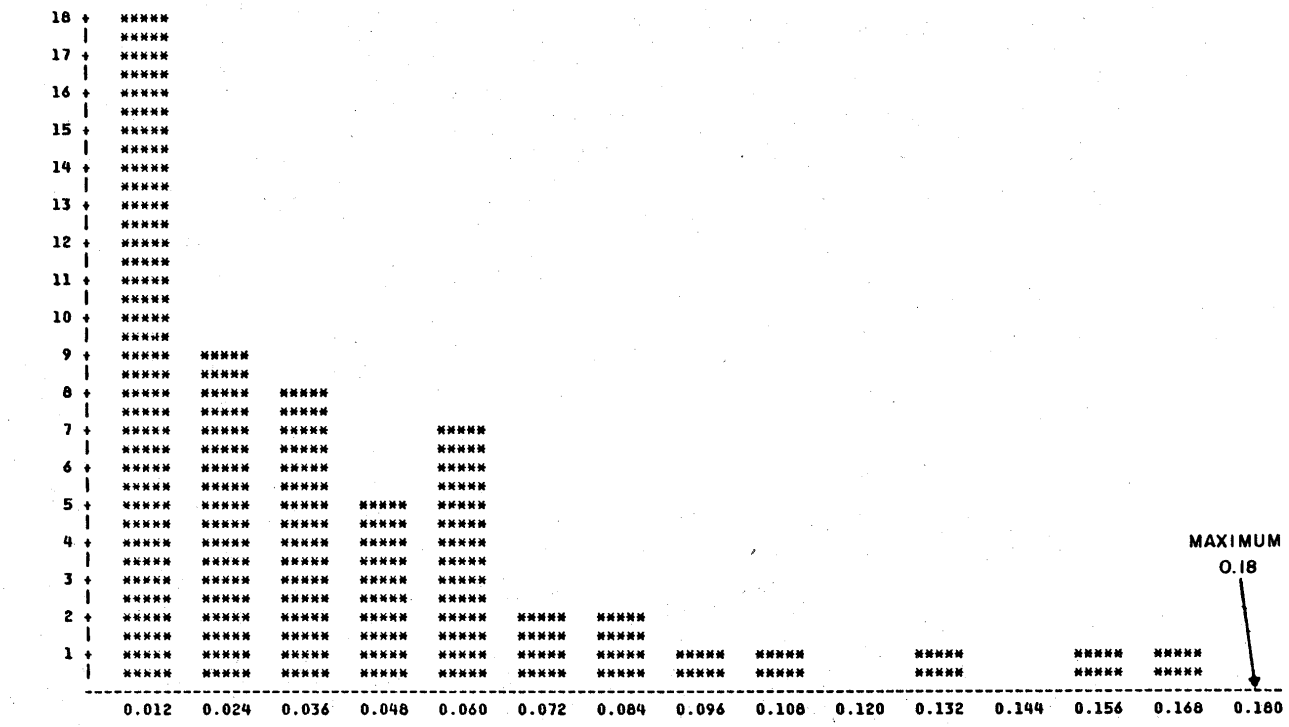
NOTE:
327 ZERO OBSERVATIONS

FIGURE 4.5-44
HISTOGRAM OF
BAY ANCHOVY POST-LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



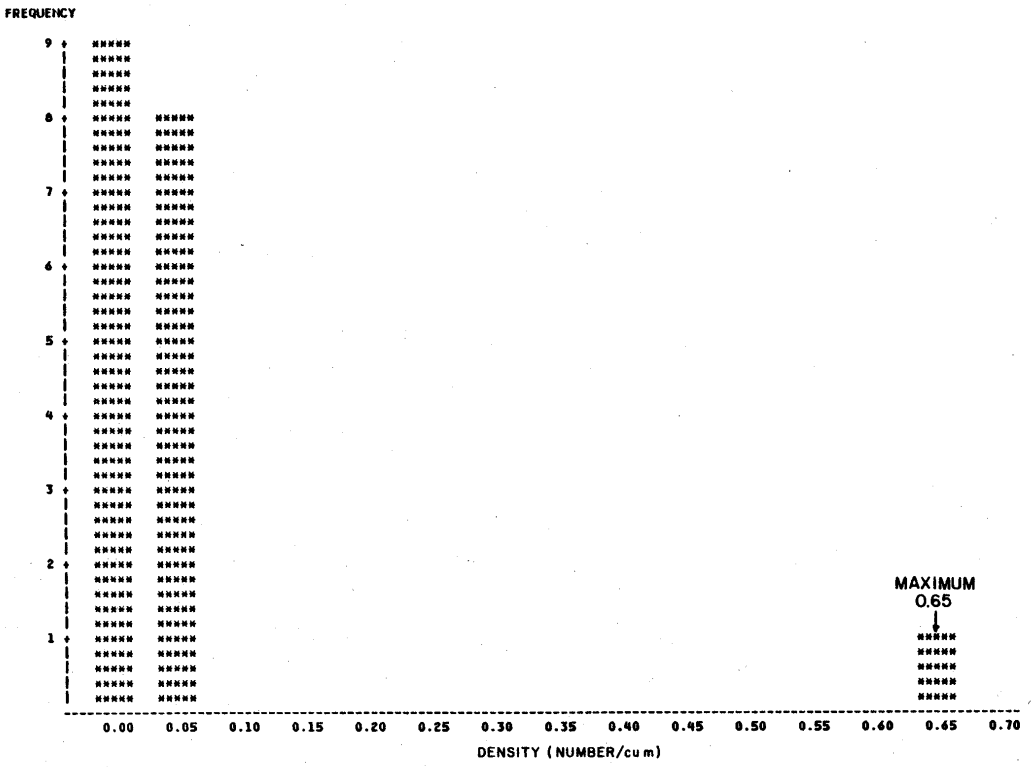
NOTE:
965 ZERO OBSERVATIONS

FIGURE 4.5-45
HISTOGRAM OF
BLACK DRUM EGGS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



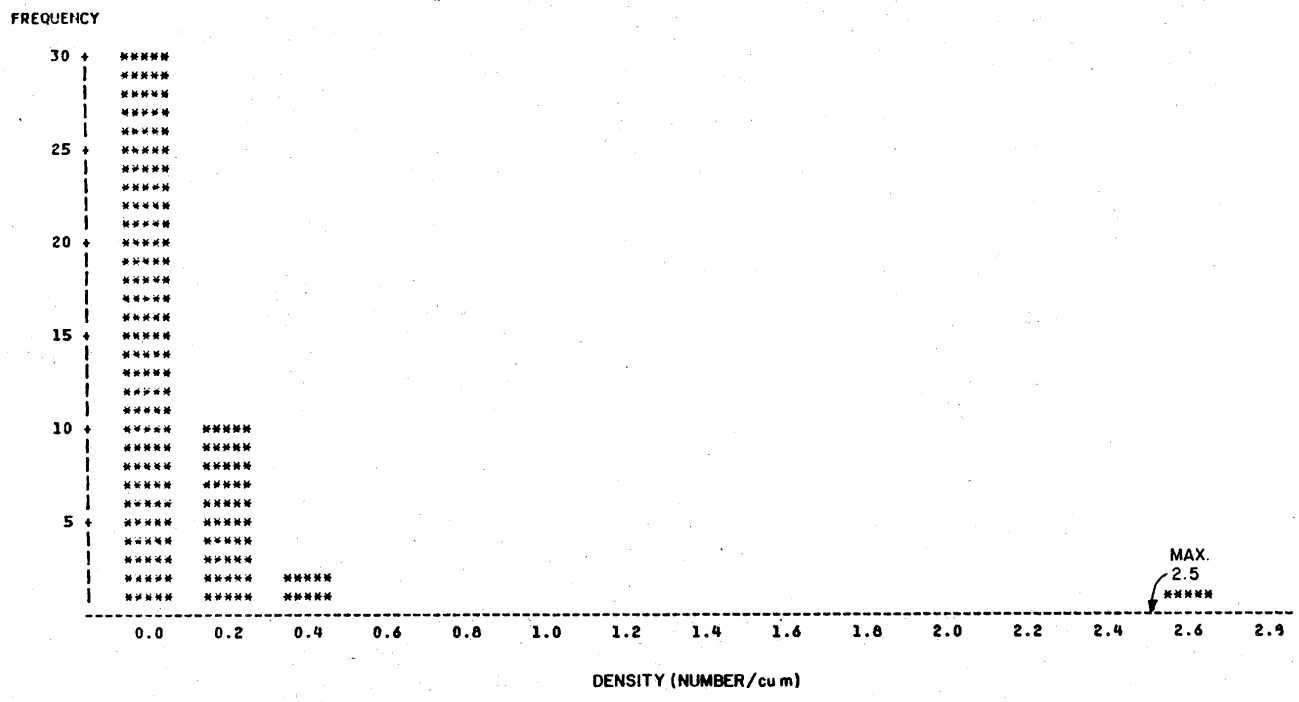
NOTE:
984 ZERO OBSERVATIONS

FIGURE 4.5-46
HISTOGRAM OF BLACK DRUM PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



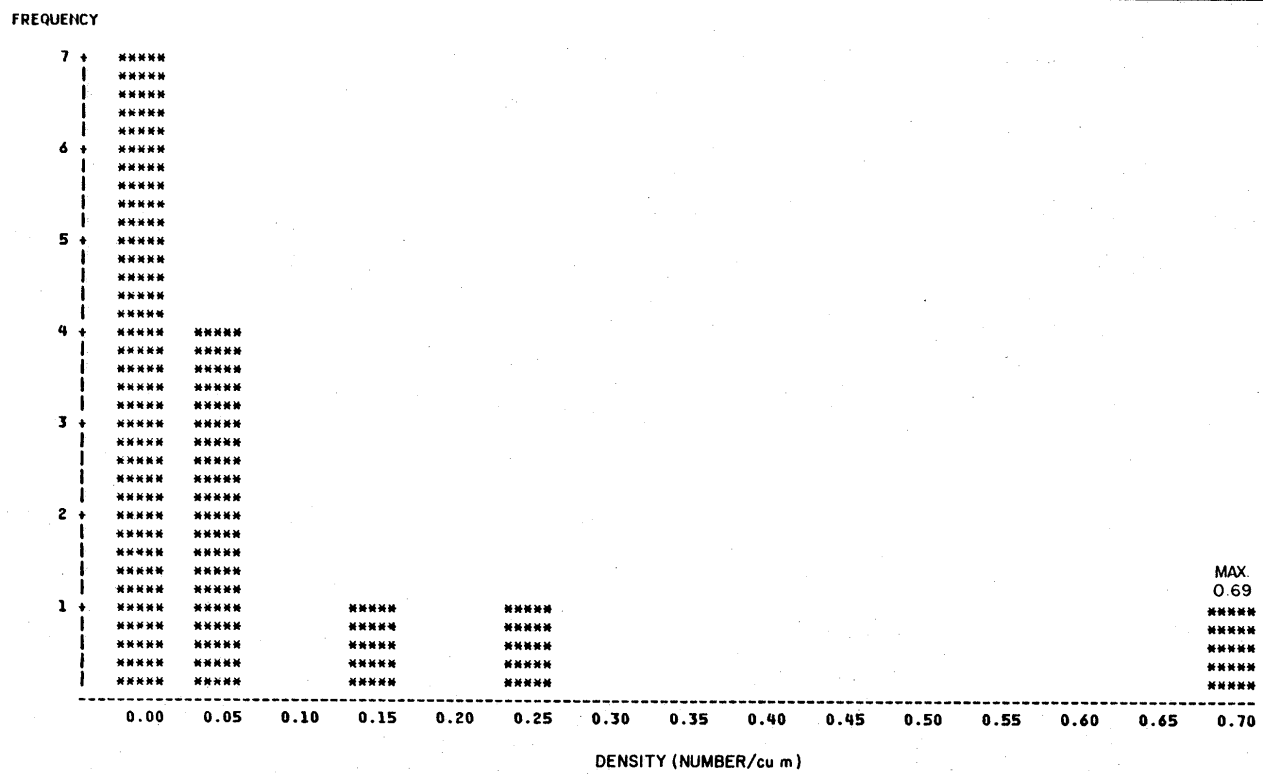
NOTE:
1,022 ZERO OBSERVATIONS

FIGURE 4.5-47
HISTOGRAM OF
BLACK DRUM POST-LARVAE
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



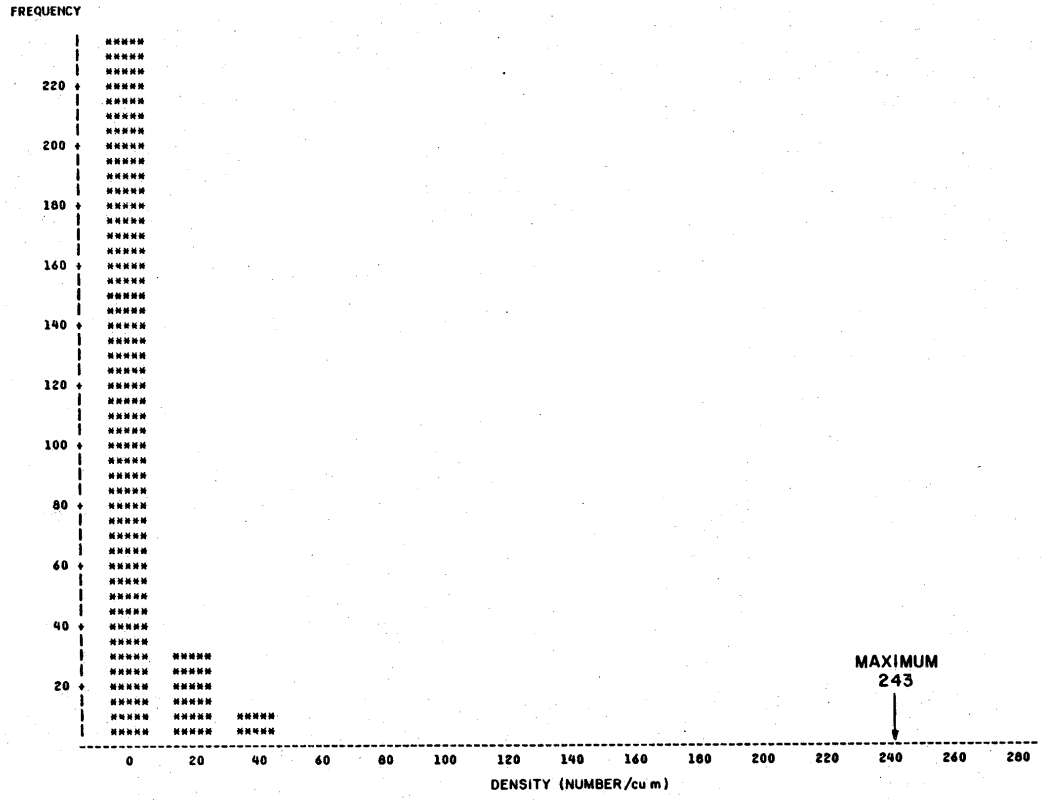
NOTE:
997 ZERO OBSERVATIONS

FIGURE 4.5-48
HISTOGRAM OF CYNOSCION SP EGGS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



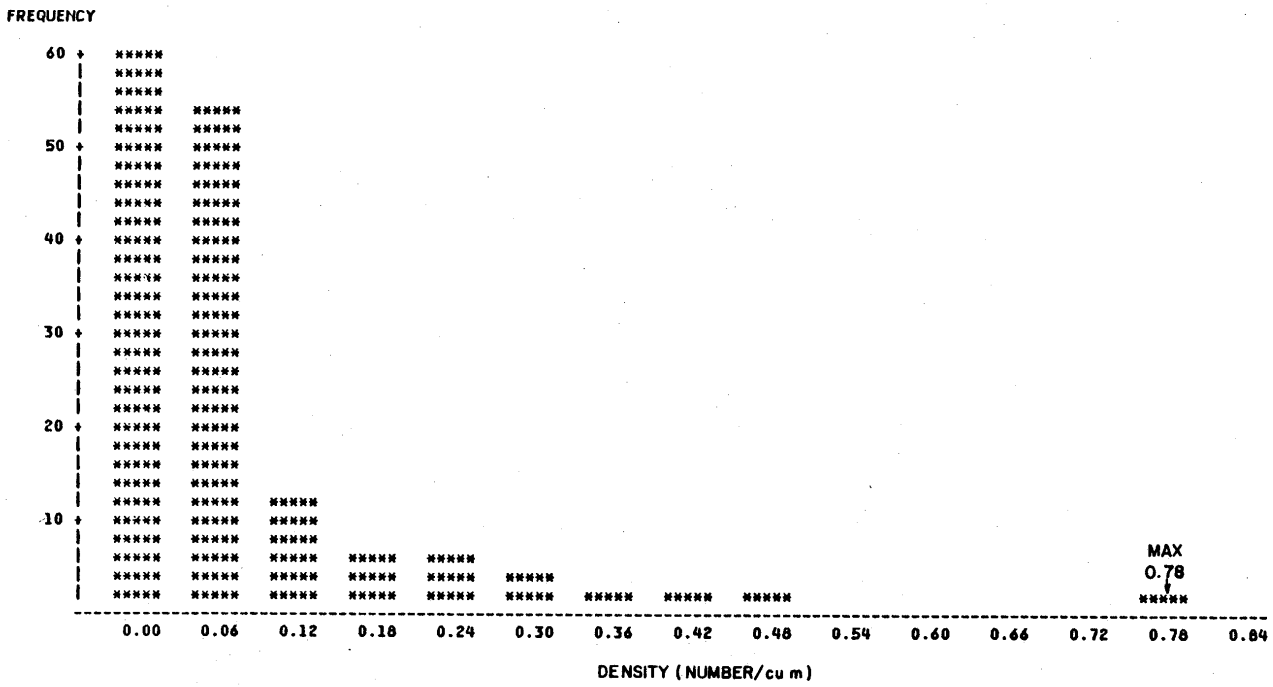
NOTE:
1,026 ZERO OBSERVATIONS

FIGURE 4.5-49
HISTOGRAM OF CYNOSCION SP PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



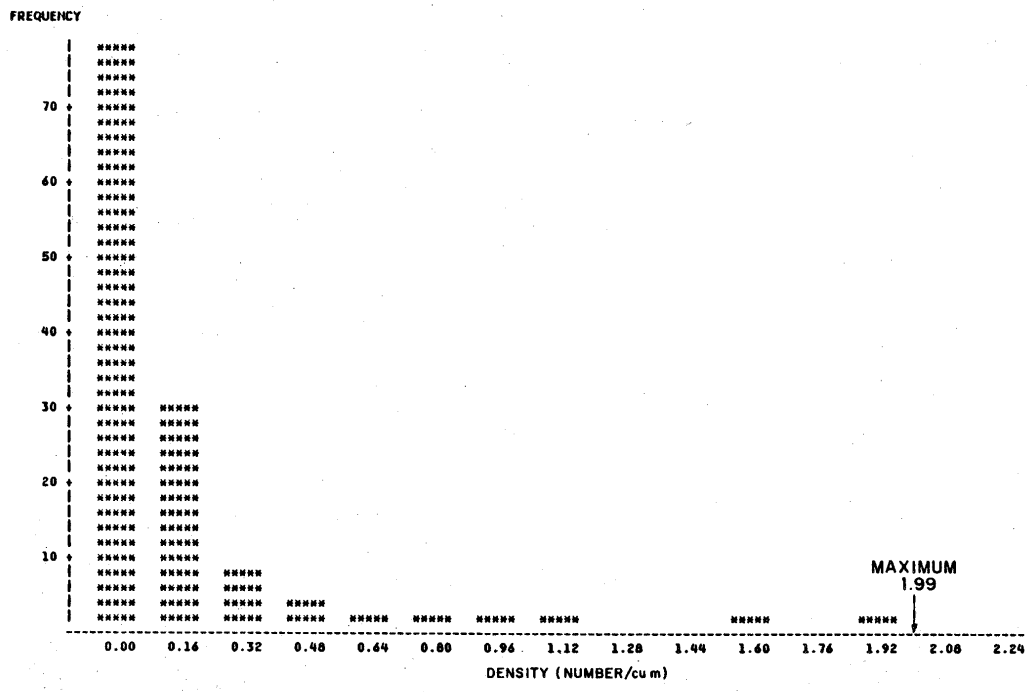
NOTE:
759 ZERO OBSERVATIONS

FIGURE 4.5-50
HISTOGRAM OF
SILVER PERCH EGGS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



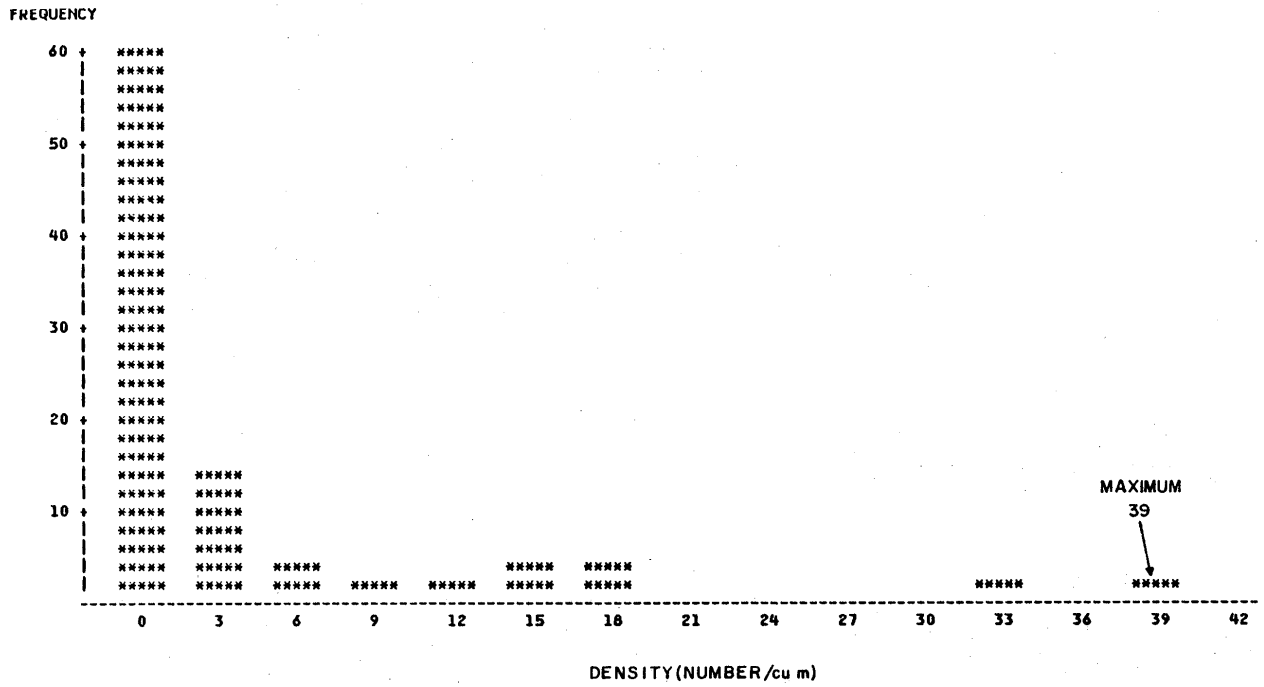
NOTE:
893 ZERO OBSERVATIONS

FIGURE 4.5-51
HISTOGRAM OF SILVER PERCH PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:
913 ZERO OBSERVATIONS

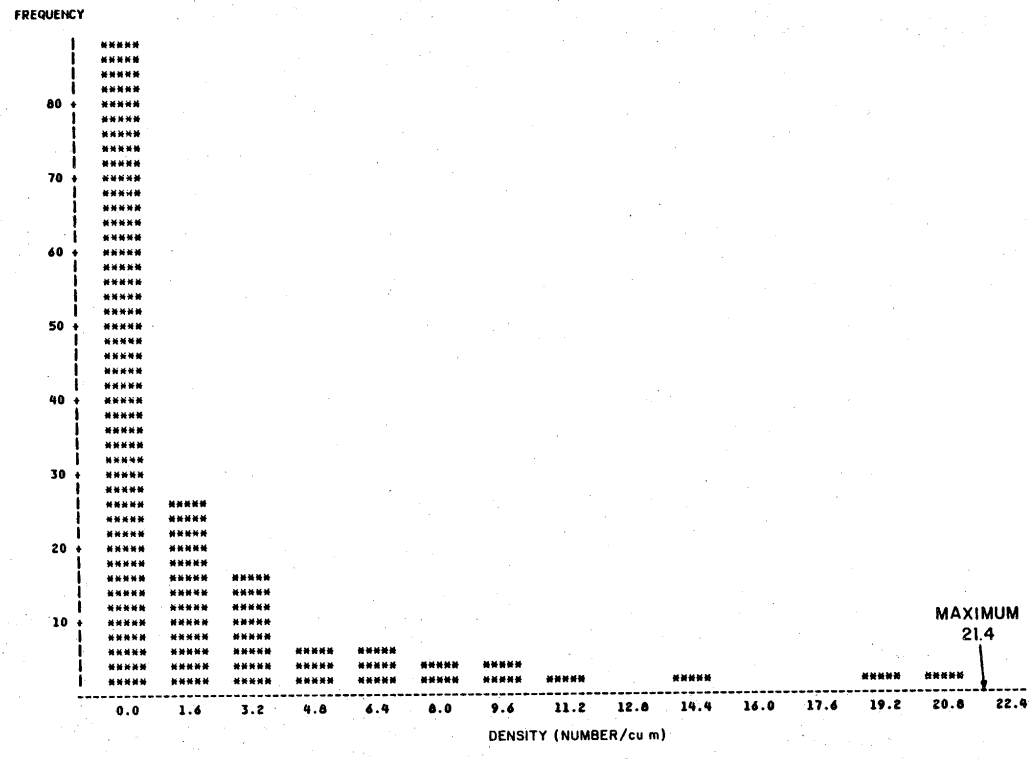
FIGURE 4.5-52
HISTOGRAM OF
SILVER PERCH POST-LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:

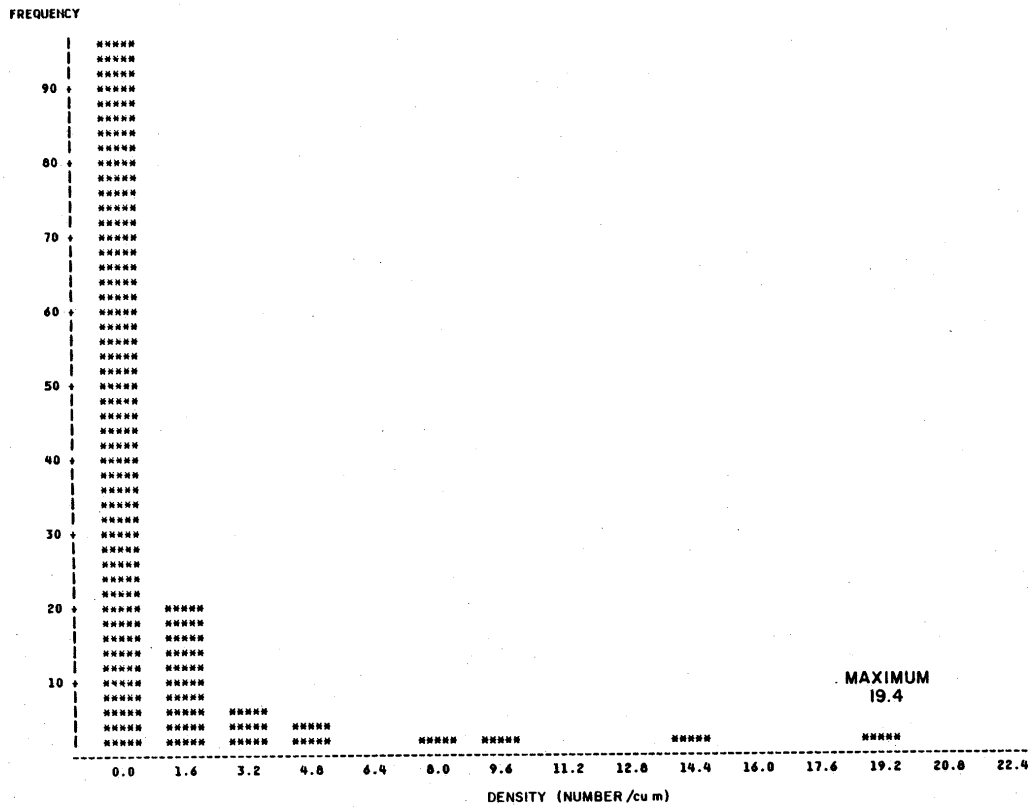
952 ZERO OBSERVATIONS

FIGURE 4.5-53
HISTOGRAM OF
SCALED SARDINE EGGS
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



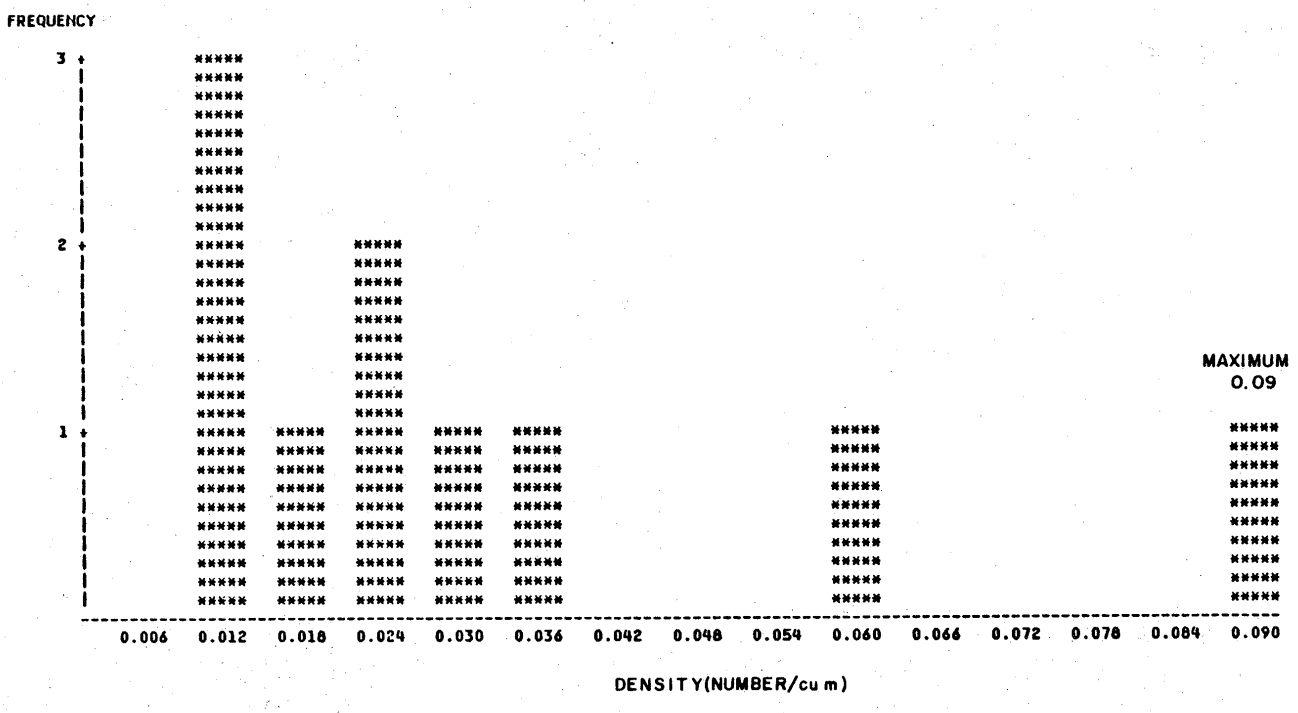
NOTE:
889 ZERO OBSERVATIONS

FIGURE 4.5-54
HISTOGRAM OF SCALED
SARDINE PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY



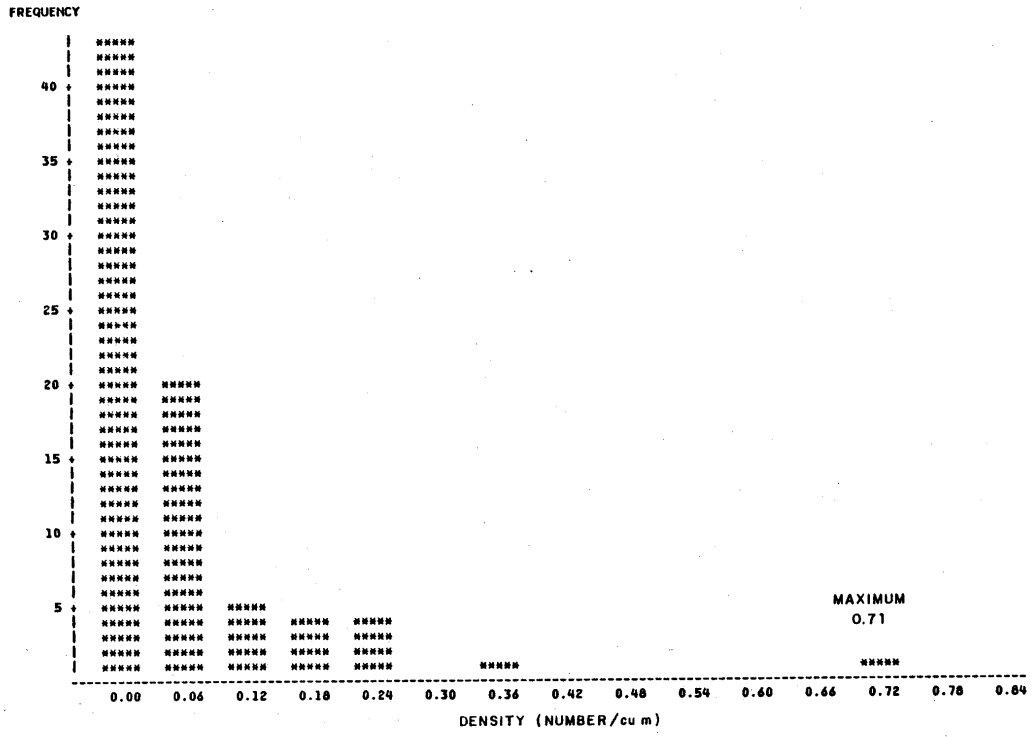
NOTE:
911 ZERO OBSERVATIONS

FIGURE 4.5-55
HISTOGRAM OF
SCALED SARDINE POST-LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



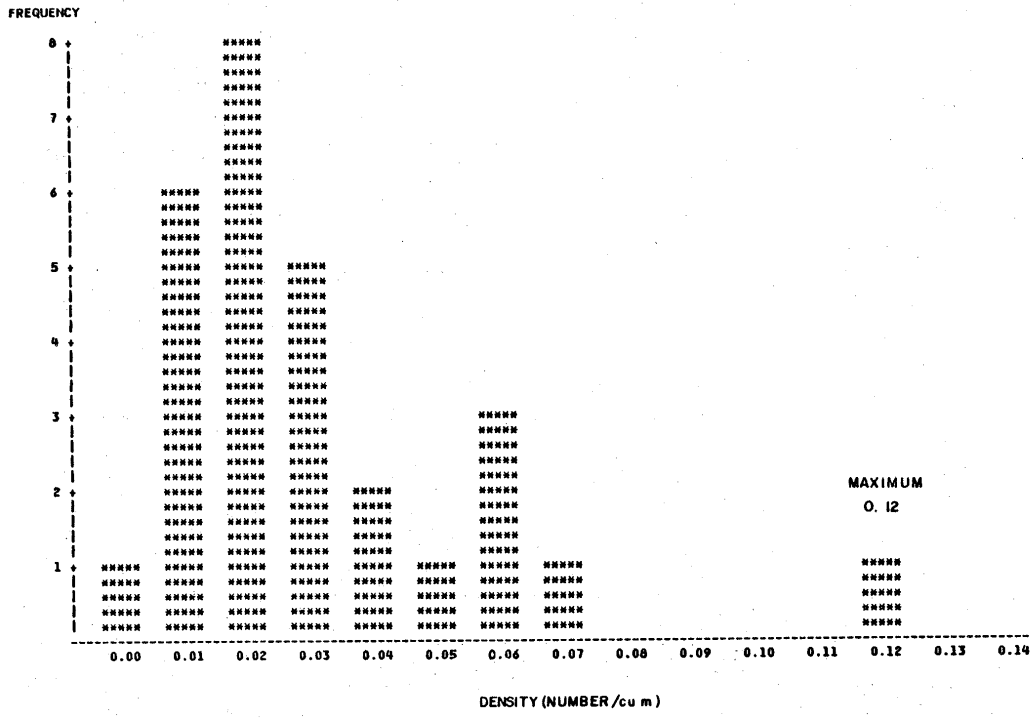
NOTE:
1,030 ZERO OBSERVATIONS

FIGURE 4.5-56
HISTOGRAM OF SPOTTED SEATROUT PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



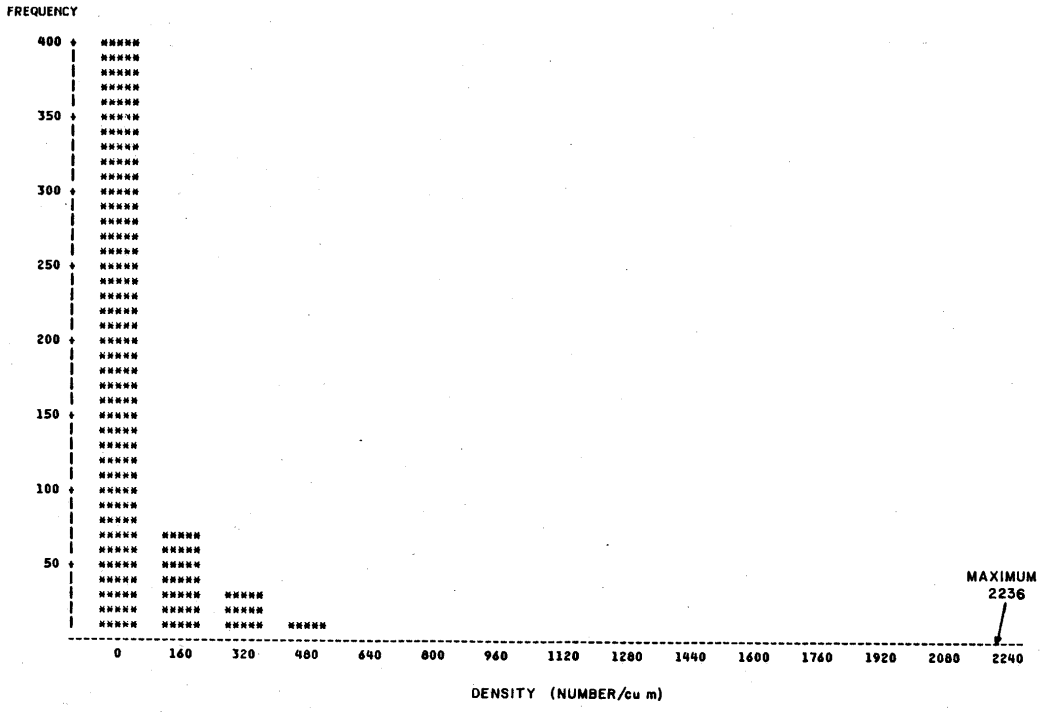
NOTE:
962 ZERO OBSERVATIONS

FIGURE 4.5-57
HISTOGRAM OF
SPOTTED SEATROUT POST-LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



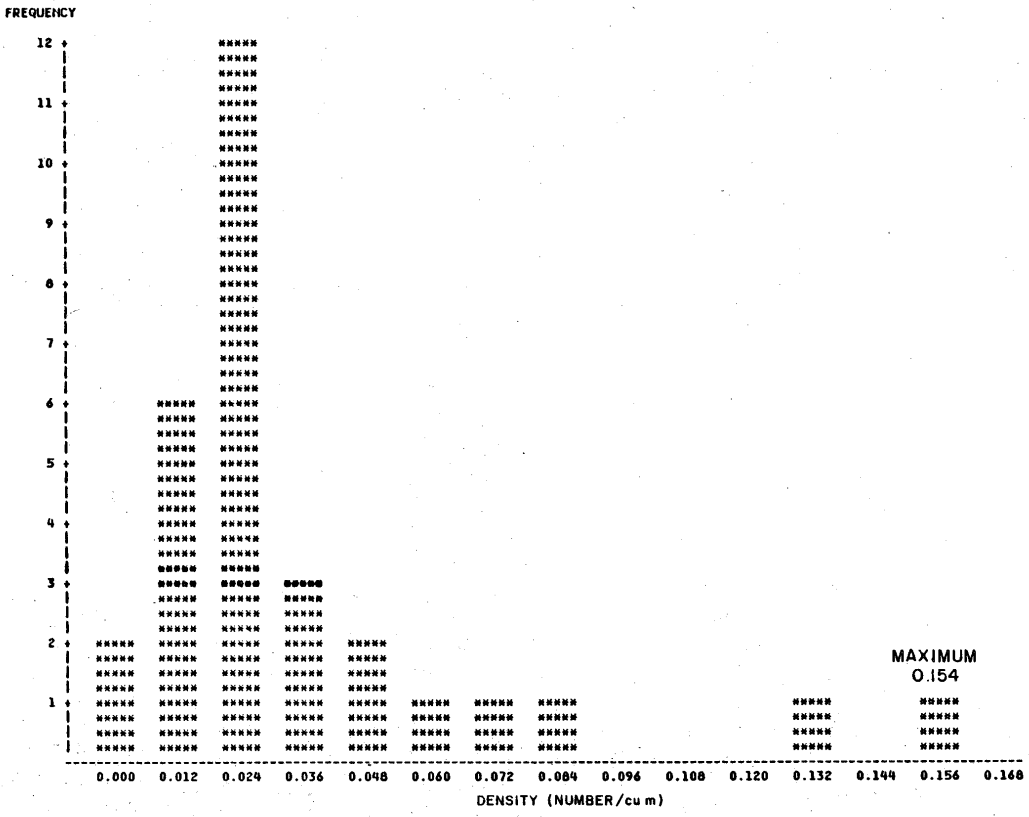
NOTE:
962 ZERO OBSERVATIONS

FIGURE 4.5-58
HISTOGRAM OF
TIDEWATER SILVERSIDE POST-LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



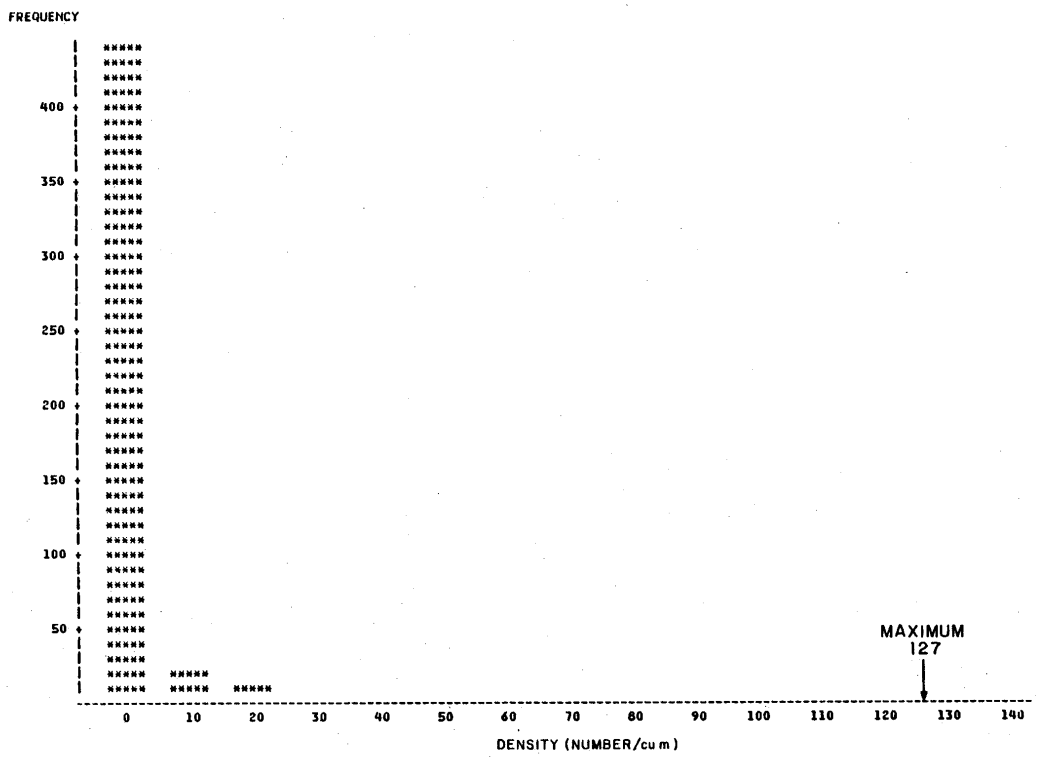
NOTE:
528 ZERO OBSERVATIONS

FIGURE 4.5-59
HISTOGRAM OF
UNIDENTIFIED SCIAENID EGGS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



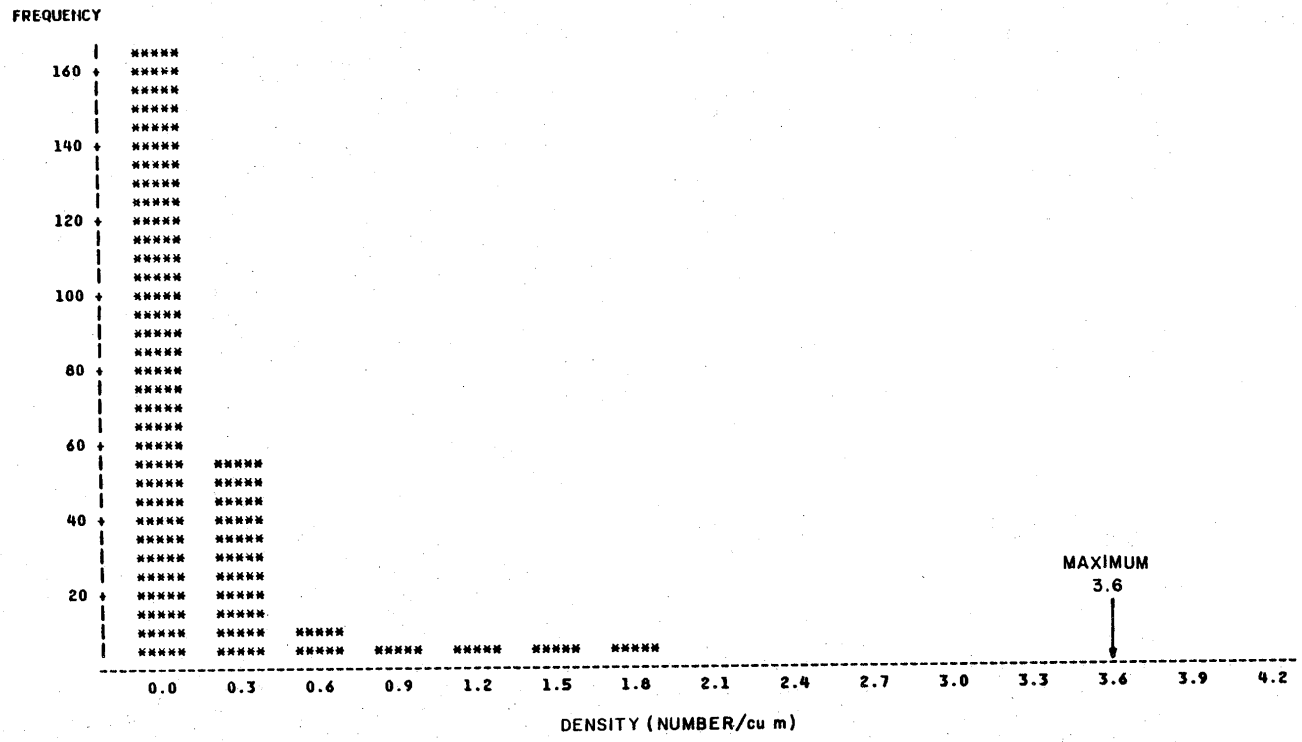
NOTE:
528 ZERO OBSERVATIONS

FIGURE 4.5-60
HISTOGRAM OF UNIDENTIFIED
SCIAENID PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:
560 ZERO OBSERVATIONS

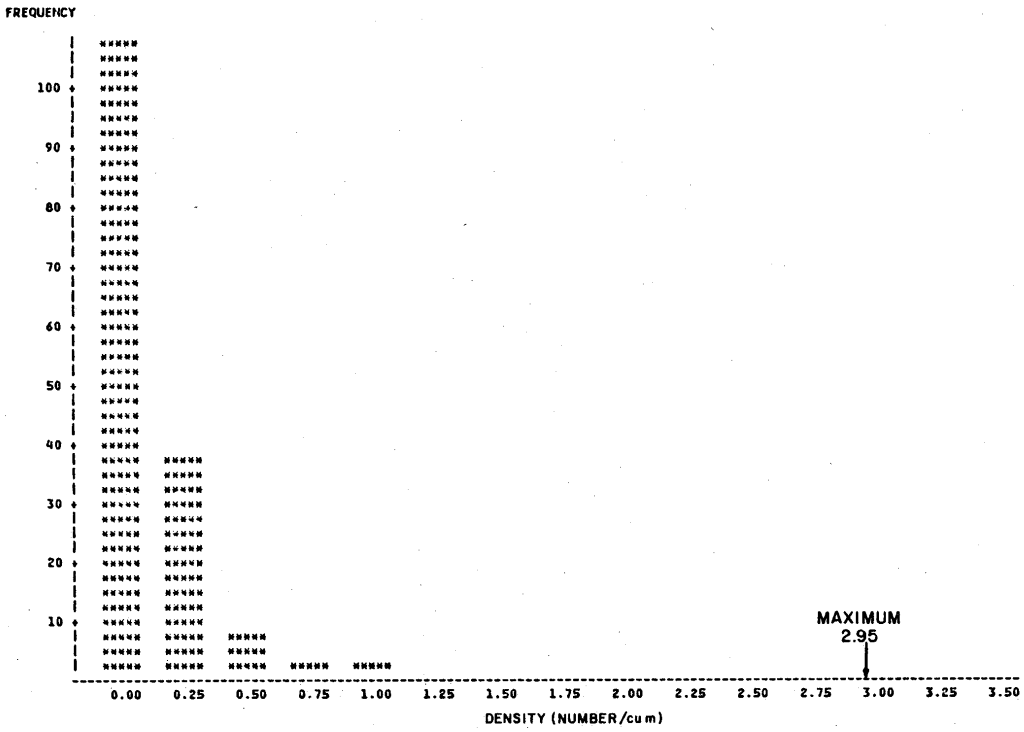
FIGURE 4.5-61
HISTOGRAM OF
STONE CRAB, ZOEA STAGE I
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:

787 ZERO OBSERVATIONS

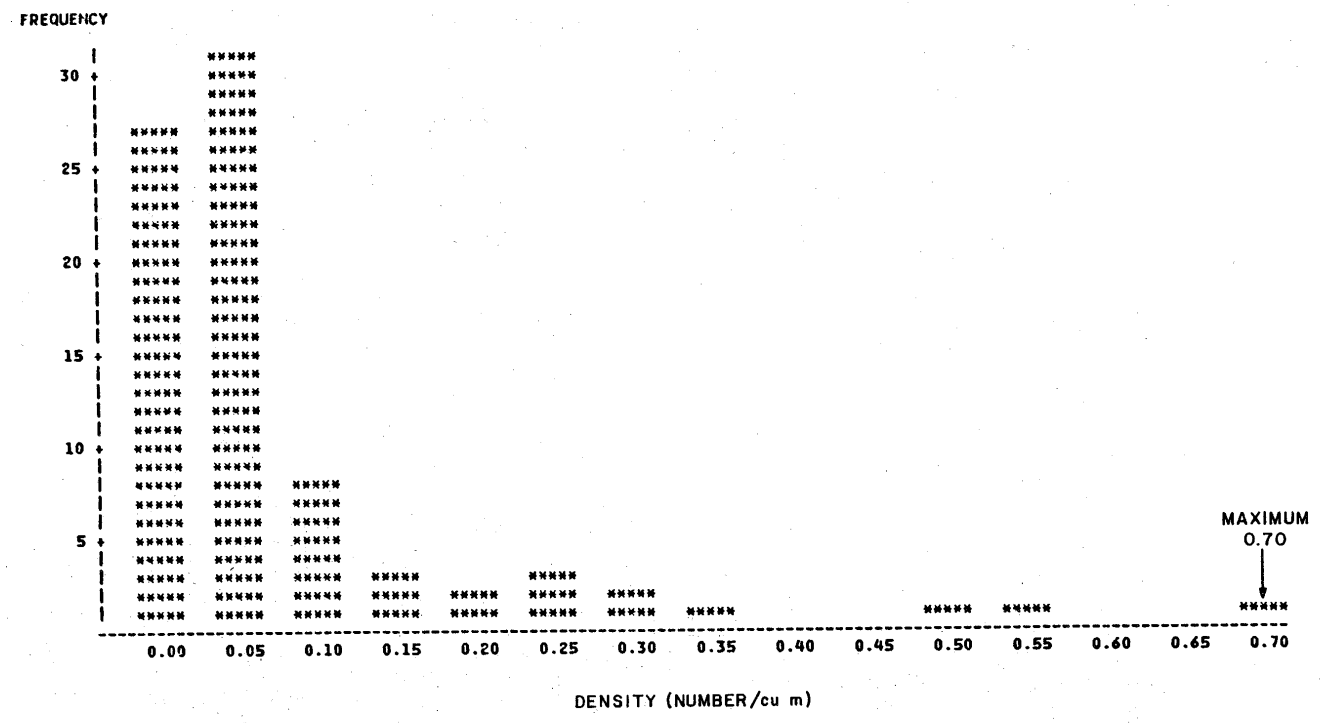
FIGURE 4.5-62
HISTOGRAM OF
STONE CRAB ZOEA STAGE 2
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:

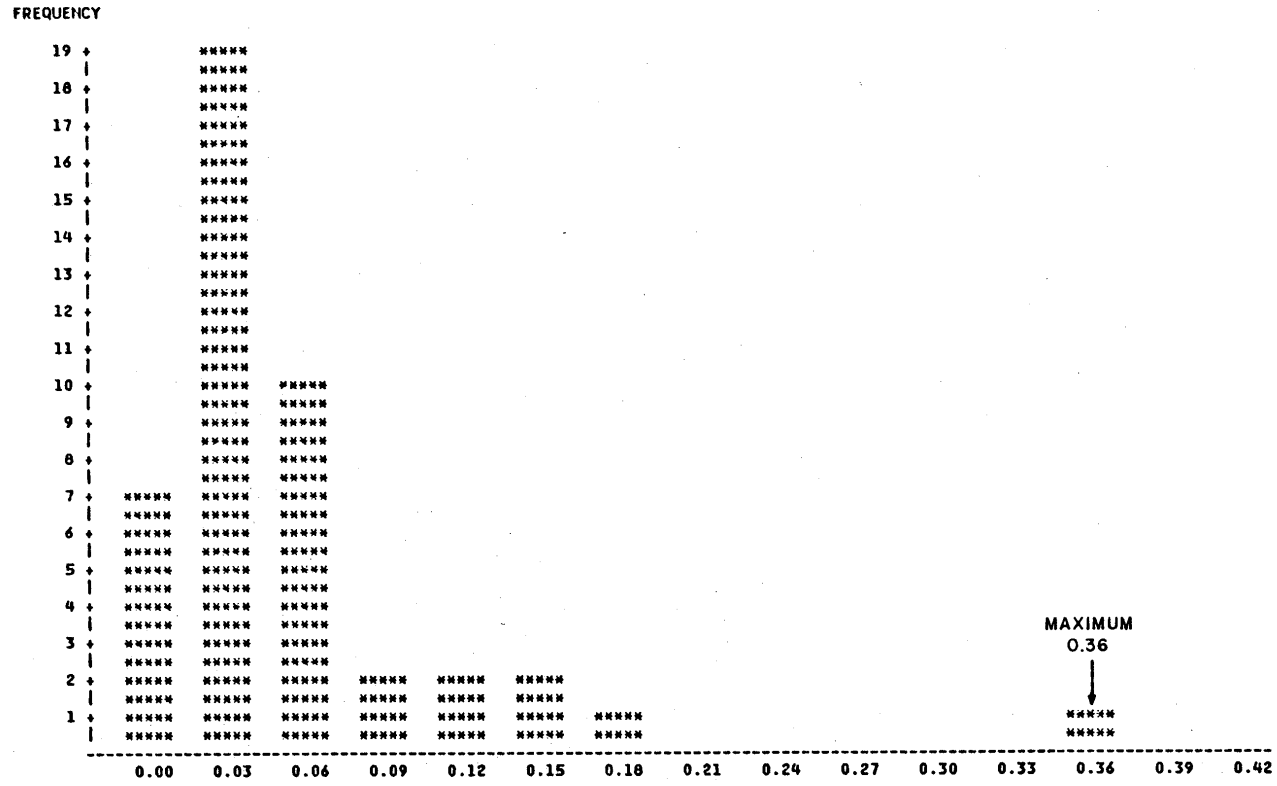
882 ZERO OBSERVATIONS

FIGURE 4.5-63
HISTOGRAM OF
STONE CRAB ZOEA STAGE 3
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:
960 ZERO OBSERVATIONS

FIGURE 4.5-64
HISTOGRAM OF
STONE CRAB ZOEA STAGE 4
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



NOTE:
996 ZERO OBSERVATIONS

FIGURE 4.5-65
HISTOGRAM OF
STONE CRAB ZOEA STAGE 5
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

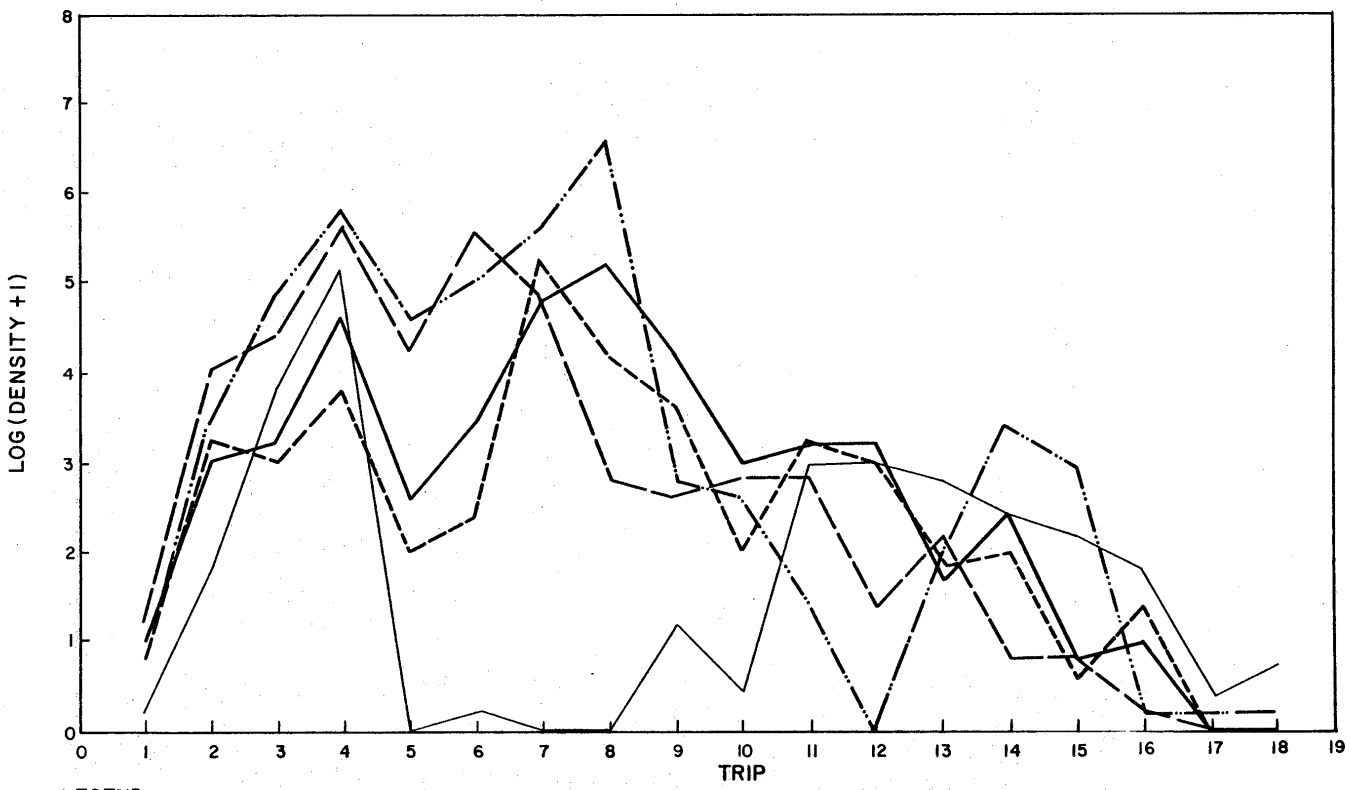


FIGURE 4.5-66
BAY ANCHOVY EGG DENSITY
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

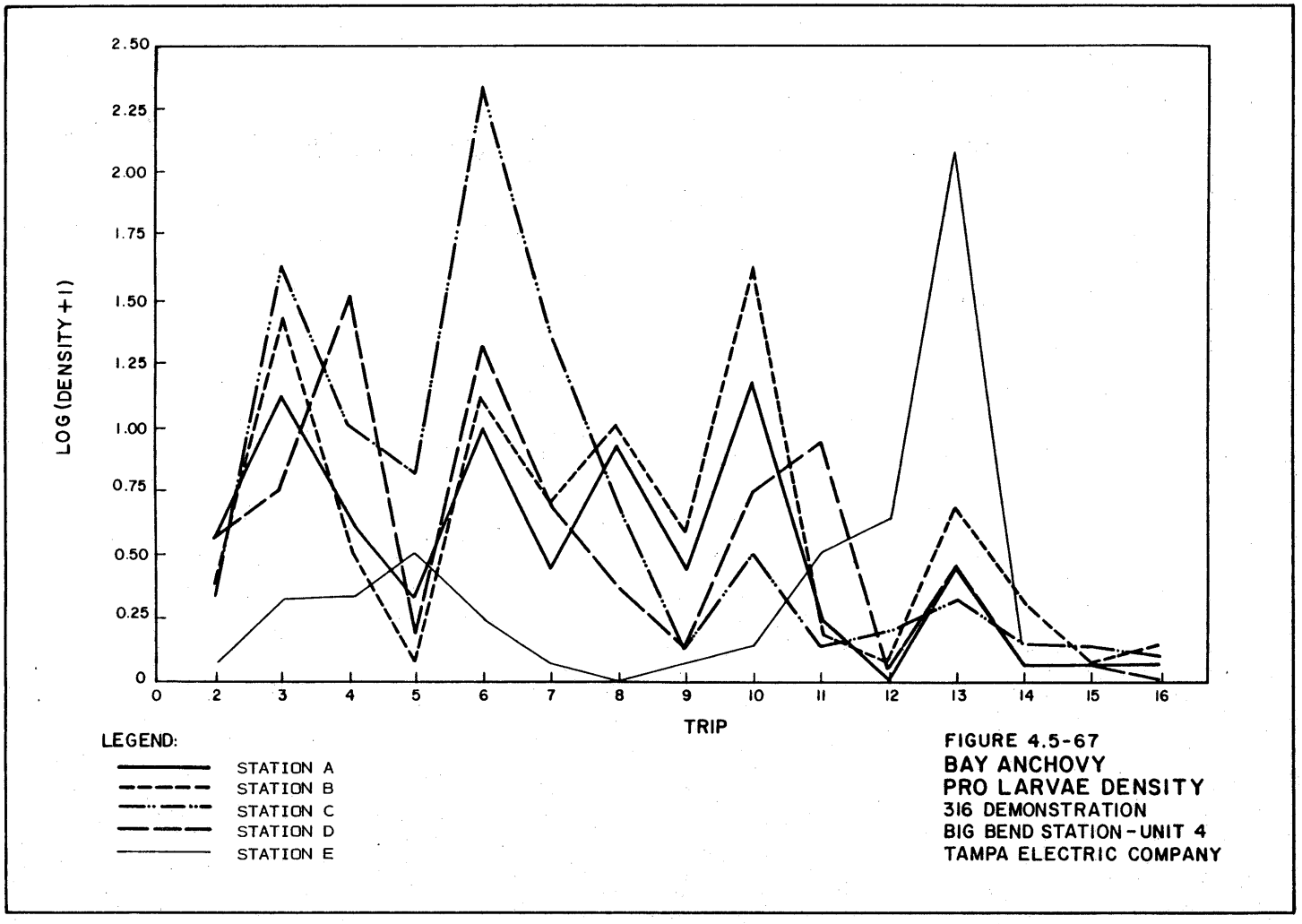


FIGURE 4.5-67
BAY ANCHOVY
PRO LARVAE DENSITY
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

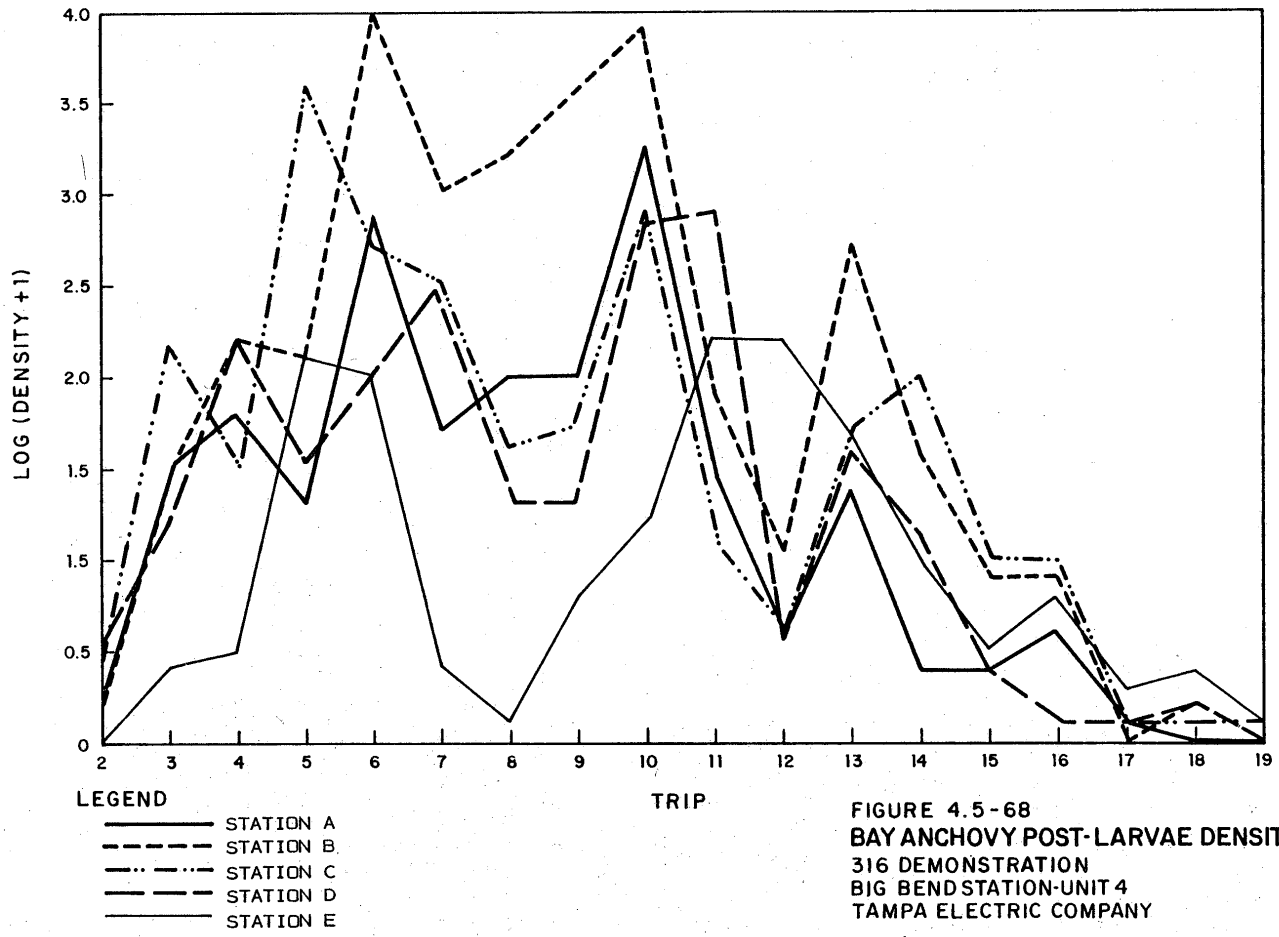


FIGURE 4.5-68
BAY ANCHOVY POST-LARVAE DENSITY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

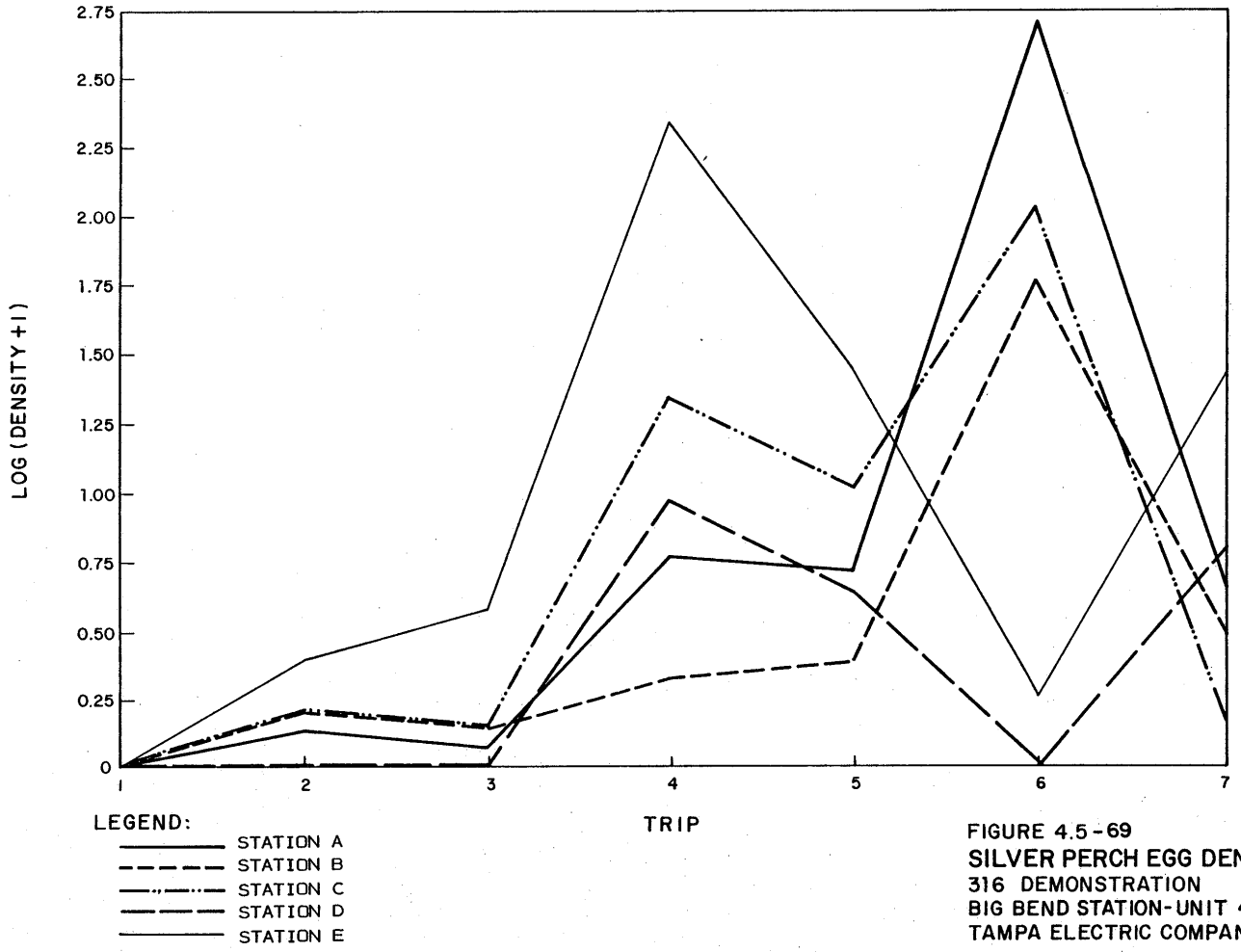


FIGURE 4.5-69
SILVER PERCH EGG DENSITY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

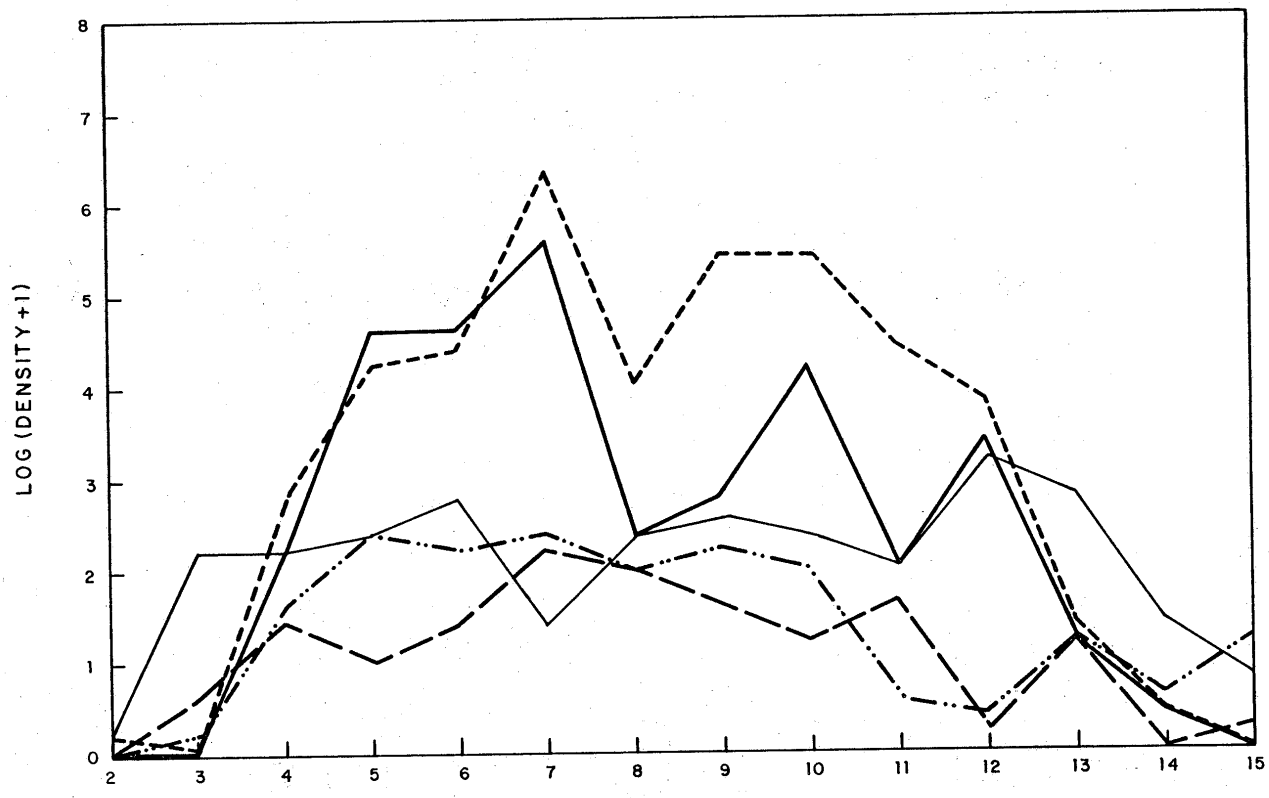


FIGURE 4.5 - 70
UNIDENTIFIED SCIAENID EGGS DENSITY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

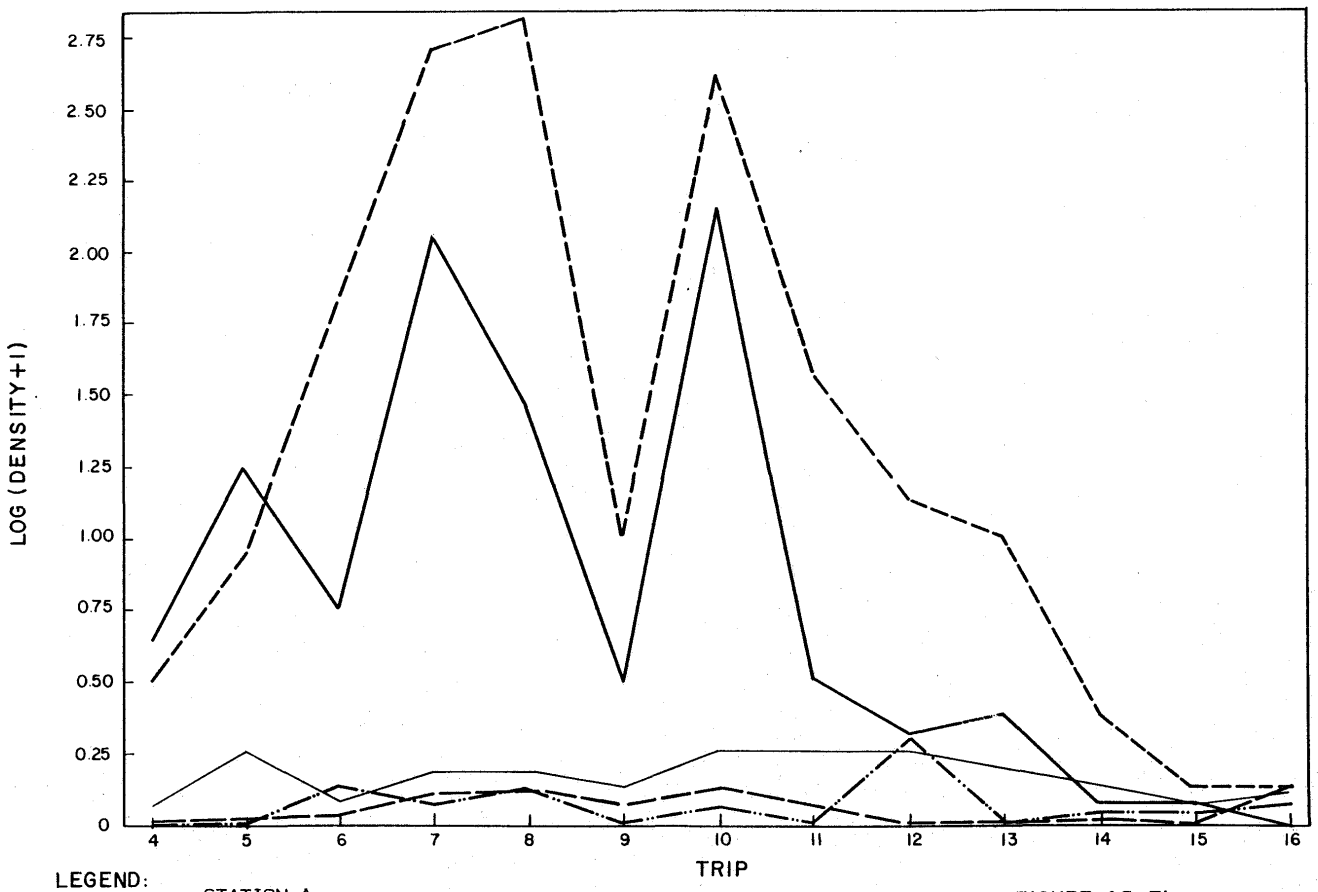


FIGURE 4.5-71
STONE CRAB ZOEA STAGE I DENSITY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

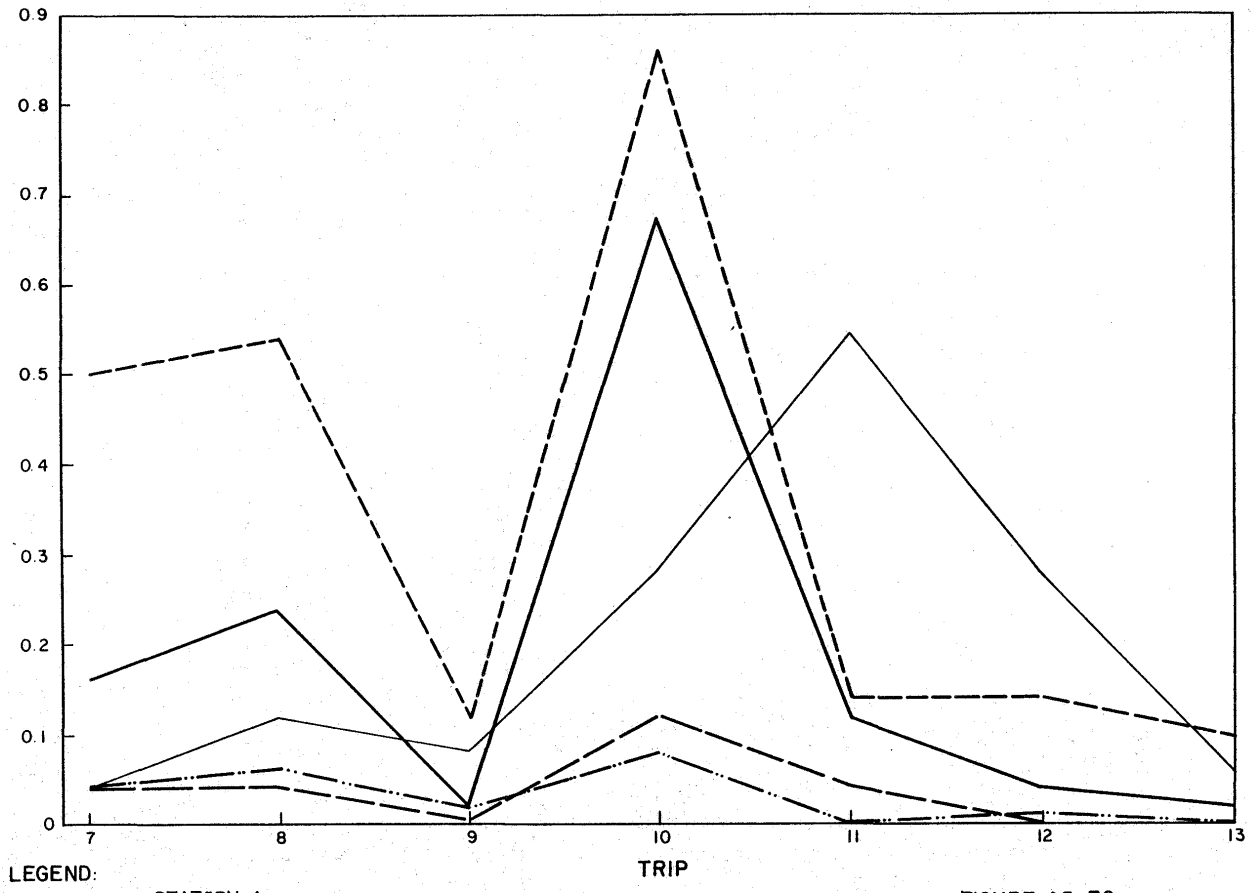


FIGURE 4.5-72
STONE CRAB ZOEA STAGE 2 DENSITY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

4.6 JUVENILE AND ADULT FISH

Trawl and seine studies were conducted at Big Bend Station from 1970 to early 1977 and from February 1979 to February 1980. During the earlier period, the general objectives of the studies were to establish the natural composition of the fish community found in the station's vicinity, incorporating spatial and seasonal variability, and to determine if plant operation significantly affected the community. The 1979 to 1980 study was specifically designed to provide information on Representative Important Species (RIS) for the purpose of assessment of the potential effect of Big Bend Unit 4.

From 1970 to 1975, seines and trawls were used to sample the area on a quarterly basis; sampling station locations varied extensively during the period. From January 1976 to March 1977, a new program, designed with the aid of several regulatory agencies, was conducted (CCI 1975a and 1975b). The study was planned to provide specific ecological information pertinent to the requirements of Section 316 of the Federal Water Pollution Control Act. Seines were deployed monthly at six stations and trawls were conducted quarterly at seven stations; their locations are shown on Figure 4.4-2. Replicate samples and physical measurements, including temperature, were taken for both gears. The description provided below relies mostly on the later study, using the data collected from 1970 to 1975 for corroboration.

Approximately 60,000 fish were collected by seines, representing 56 species of 32 families. The tidewater silverside (Menidia beryllina) was the most abundant species, followed by bay anchovy (Anchoa mitchilli) and longnose killifish (Fundulus similis). The number collected, size range, water temperature range, period of occurrence, and location at which greatest numbers were collected are provided in Table 4.6-1 for tidewater silverside, bay anchovy, longnose killifish, and several other abundant species. All but the sheepshead minnow, spot, and northern kingfish were common in seine collections made from 1973 to 1975. The table shows most fish were collected at shallow inshore areas; one station, SB-10, located in the northern embayment formed by Apollo Beach, accounted for 37.5 percent of the collected specimens. Fish collected at Station SB-10 were predominantly juvenile striped mullet, spot, pinfish, sheepshead minnow, spotfin mojarra, and longnose killifish. Often, juveniles of many different species were collected at the same time. To a lesser extent, the same observations were made at Stations SB-13 and SB-11. Thus, these three shallow, protected stations were probably nursery areas, with the northern embayment being the most important.

Patterns of seasonal abundance were generally similar among the seine stations. With the exception of Station SB-12, highest

abundances were noted in the spring and fall months, and lowest abundances occurred during the winter. Conversely, highest abundance at Station SB-12 occurred during the winter. Seine Station SB-12 is closest to Big Bend's discharge, and the fish community found there may have been attracted by the plant's discharge. Information from other analyses support this conclusion (although the analyses included an inconsequential number of invertebrate specimens - 646 invertebrates versus 61,273 fishes). Correlation between diversity (Shannon-Weaver index) and temperature was highest at this station and more species were collected at this station than at any other (TECO 1977h). However, when abundance levels at this station were compared with those found at Station SB-5 (a station of similar physical habitat but outside the thermal plume), a statistical test revealed no significant difference in number of organisms between stations despite a significant difference in temperatures. This suggests that abundance at Station SB-12 is determined by physical habitat, such as substrate, not by relative proximity to the thermal discharge.

Table 4.6-1 also reveals the transient nature of the fish community in the Big Bend area. In general, most seine catches were numerically dominated by only a few species (two to six), but the dominants changed with time. Seasonal influxes of certain species shifted community structure as the year progressed. The phenomenon was particularly pronounced at the "nursery" stations. For example, young striped mullet, spot, pinfish, and sheepshead minnow dominated the seine catches at Station SB-10 between December and June, and were replaced by juvenile spotfin mojarra and longnose killifish during the remainder of the year.

Because trawls were conducted only four times in daylight during the study period, the descriptive utility of trawl data collected from 1976 to 1977 is restricted. For example, only 2,109 fish were collected from the quarterly sampling conducted at seven stations, as opposed to approximately 60,000 collected from seines during the same period. Moreover, an experimental set of trawls conducted at night during February 1977 yielded 4,349 fish in 14 tows, approximately twice the number collected in daytime tows, but with a quarter of the effort. For these reasons, it is difficult to elucidate abundance and distribution patterns from these data.

Nonetheless, certain trends were apparent. Bay anchovies dominated trawl catches in three quarters, and pinfish were numerically dominant in the remaining sampling period in February 1977. Both were among the most abundant species collected in trawls from 1973 to 1975 (TECO 1977e). Patterns of relative abundance among stations showed that three stations accounted for 72 percent of the fish collected, TB-12, TB-7, and TB-13. Two stations, TB-1 and TB-6, accounted for less than 100 adults

apiece. However, night trawling data suggest these results are misleading, because more specimens were collected during one night at Stations TB-1 and TB-6 than in all the daytime programs at those stations. Consequently, in absence of more frequent trawl data and data collected at night, no conclusions can be reached on the spatial distribution of fish in trawled areas.

The sampling stations for the trawl and seine studies in 1979 are shown on Figure 4.4-2. Seining occurred every 4 weeks at high tide between March 14, 1979, and January 15, 1980. Trawl samples were collected at night every 4 weeks during that period. The numbers of RIS collected are summarized by date in Tables 4.6-2 and 4.6-3. The following discussion is taken from the final report of this study, included as Appendix 1 to this document.

Fewer bay anchovies (Taylor & Saloman 1968a) were collected by seine than in the 1976-1977 study. Most of those collected in this study were adults in spawning condition, while the previous study included additional stations where several thousand juveniles were collected.

A total of 479 bay anchovies were collected by trawl. Adult bay anchovies were collected during each sampling period and were most abundant between November 1979 and January 1980. Most of the specimens were collected in the intake canal during this period.

A total of 862 scaled sardines were collected by seine, most of which (526) were collected in May. Stations W and X accounted for 91 percent of the individuals (Figure 4.4-3).

Schools of immature sardines frequented shallow areas fronting open water beaches. The fact that individuals collected at these areas in May had undeveloped gonads (adults generally spawn in April and May) supports this finding.

No scaled sardines were collected by trawl during this study as they tend to inhabit the upper few meters of the water column and are not susceptible to the gear.

Tidewater silverside was the most abundant (5,639 individuals) and ubiquitous (collected at 2 to 4 stations each month) species collected during the 1979 study. Comprising 85 percent of the total RIS catch, they were least abundant during early June and July. Tidewater silverside dominated all other sample dates. Most individuals (3,319) were collected at Station W. This information supports the findings of previous studies in the Big Bend area. Since this species inhabits the shoreline exclusively, they were not susceptible to the trawl.

Silver perch, a deep-water species, was not collected by seine, but was the most dominant RIS collected by trawl. A total of

1,711 individuals were collected, mostly from Station B. Silver perch were most abundant in June and July as juveniles. Adults became more prevalent in the late fall-early winter catches.

Only 1 small spotted seatrout was collected during this study and was taken by seine at Station Y in October.

A total of 46 black drum, all juveniles and all taken in June at Station Y, were collected by seine. Black drum were never reported at this station in previous studies, but the presence of the young in the embayment suggests this area may have been a nursery.

A total of 49 black drum were collected by trawl. Most were collected in August through October 1979 and 44 were collected at Station B. Black drum are seasonally abundant in both the intake and discharge canals and are often caught by fishermen in large numbers in the canals.

A list of the non-RIS collected appears in Table 4.6-4. A total of 5,416 non-RIS fishes, representing 47 species were collected by seine during this study. The five most abundant species were: Fundulus similis, longnose killifish (1,181); Leiostomus xanthurus, spot (1,018); Lagodon rhomboides, pinfish (794); Cyprinodon variegatus, sheepshead minnow (477); and Membras martinica, rough silverside (386). These species constituted 71.2 percent of the non-RIS seine catch.

The trawl catch included 3,106 non-RIS fishes representing 43 species. The five most abundant species collected were: Cynoscion arenarius, sand seatrout (1,040); Lagodon rhomboides, pinfish (380); Arius felis, sea catfish (301); Leiostomus xanthurus, spot (281); and Orthopristis chrysoptera, pig fish (274). These species made up 73.3 percent of the total catch.

In general, the seasonal trends in relative abundance and species composition observed during this study appear consistent with the patterns observed in previous studies in the Big Bend area. Those differences observed could be attributed to the natural cyclic variations noted for many estuarine organisms.

Local fishermen reported a decline in the spotted seatrout population in the Big Bend area. This could be due either to the normal cyclic patterns of abundance in the population or the loss of seagrass habitat in the area. Mottled mojarra (Eucinostomus lefroyi) were collected for the first time in the study area, but did not appear to replace any indigenous species.

The embayment station (Y) continued to function as a nursery area for several species. Juvenile black drum were collected in this area for the first time during this study.

For detailed results of this study, refer to Chapter 3 of Appendix 1 to this document.

TABLE 4.6-1

SUMMARY OF SEINE STUDY, RESULTS FOR ABUNDANT FISH SPECIES, BIG BEND VICINITY, JANUARY 1976 TO MARCH 1977[1]

Common Name/ Species	Number Collected	Size Range (mm)	Temperature Range (°C)	Approximate Period of Occurrence	Location of Highest Abundance
Tidewater Silverside *Menidia beryllina*	20,256	14-96	12-34.5	Year-round	Ubiquitous
Bay Anchovy *Anchoa mitchilli*	9,171	18-65	16-32	Fall	Inshore Shallows
Longnose Killifish *Fundulus similis*	7,704	9-117	12-34.5	Year-round	Inshore Shallows[2,3]
Spotfin Mojarra *Eucinostomus argenteus*	5,541	11-105	14-34.5	Late Summer, Early Winter	Inshore Shallows
Striped Mullet *Mugil cephalus*	3,005	15-360	12-34	Year-round	Inshore Shallows[4]
Sheepshead Minnow *Cyprinodon variegatus*	2,961	14-58	14-34.5	Late Spring, Summer	North Apollo Embayment
Silver Jenny *Eucinostomus gula*	2,451	31-100	15-34.5	Fall	Inshore Shallows[3]
Scaled Sardine *Harengula jaguana*	1,721	62-138	12-34	Summer, Fall	Open Bay
Pinfish *Lagodon rhumboides*	1,465	16-136	18-34.5	Spring, Summer	Shallow, Sandy Areas
Spot *Leiostomus xanthurus*	1,035	16-104	14-27.5	Late Winter, Spring	Inshore Shallows[5]
Northern Kingfish *Menticirrhus saxatilis*	243	15-137	16-31.5	Summer	Open Bay
Permit *Trachinotus falcatus*	114	15-410	18-33	Summer, Fall	Open Bay[2,3]

TABLE 4.6-1 (Cont)

SOURCES:

1. TECO (Tampa Electric Company). 1977h. Final report of ecological surveys of the Big Bend area. Vol. 3. Appendix to 316 Demonstration, Vol. III. An analysis and summary of studies on the effect of the cooling water system on aquatic fauna. Vol. III. Prepared by Conservation Consultants, Inc., Palmetto, Florida.

2. TECO (Tampa Electric Company). 1977a. Ecological surveys of the Big Bend area. 28th quarterly report. Prepared by Conservation Consultants, Inc., Palmetto, Florida. p 626.

3. TECO (Tampa electric Company). 1977b. Ecological surveys of the Big Bend area. 29th quarterly report. Prepared by Conservation Consultants, Inc., Palmetto, Florida. p 644.

4. TECO (Tampa Electric Company). 1976. Ecological surveys of the Big Bend area. 27th quarterly report. Prepared by Conservation Consultants, Inc., Palmetto, Florida. p 411.

5. TECO (Tampa Electric Company). 1977c. Ecological surveys of the Big Bend area. 30th quarterly report. Prepared by Conservation Consultants, Inc., Palmetto, Florida. p 333.

TABLE 4.6-2

LIST OF RIS FISH COLLECTED BY SEINE BETWEEN MARCH 14, 1979, AND JANUARY 15, 1980

Date of Collection	Species					
	Harengula jaguana	Anchoa mitchilli	Menidia beryllina	Bairdiella chrysura	Cynoscion nebulosus	Pogonias cromis
3/14/79	-	1	249	-	-	-
4/10/79	-	3	194	-	-	-
5/10/79	526	7	802	-	-	-
6/5/79	-	14	30	-	-	46
7/3/79	-	-	20	-	-	-
7/31/79	2	-	431	-	-	-
8/28/79	60	-	875	-	-	-
9/25/79	87	-	371	-	-	-
10/23/79	100	-	1,365	-	1	-
11/20/79	87	-	358	-	-	-
12/18/79	-	-	726	-	-	-
1/15/80	-	-	240	-	-	-
Total	862	25	5,661	0	1	46

TABLE 4.6-3

LIST OF RIS FISH COLLECTED BY TRAWL BETWEEN MARCH 14, 1979, AND JANUARY 15, 1980

Date of Collection	Species					
	Harengula jaguana	Anchoa mitchilli	Menidia beryllina	Bairdiella chrysura	Cynoscion nebulosus	Pogonias cromis
3/14/79	-	27	-	4	-	-
4/10/79	-	8	-	6	-	-
5/10/79	-	15	-	967	-	3
6/5/79	-	28	-	673	-	4
7/3/79	-	7	-	4	-	3
7/31/79	-	20	-	2	-	-
8/28/79	-	10	-	3	-	8
9/25/79	-	25	-	4	-	10
10/23/79	-	28	-	21	-	12
11/20/79	-	148	-	10	-	6
12/18/79	1	46	-	12	-	6
1/15/80	1	118	-	5	-	3
Total	2	480	0	1,711	0	55

TABLE 4.6-4

LIST OF ALL NON-RIS FISH COLLECTED BY SEINE AND TRAWL BETWEEN MARCH 14, 1979, AND FEBRUARY 12, 1980

Species/Common-Name	Seine	Trawl
Dasyatis americana Southern Stingray	X	X
Gymnura micrura Smooth butterfly ray		X
Rhinoptera bonasus Cownose ray		X
Brevoortia smithi Yellowfin menhaden	X	X
Dorosoma petenense Threadfin shad	X	
Opisthonema oglinum Atlantic thread herring	X	X
Anchoa hepsetus Striped anchovy	X	X
Synodus foetens Inshore lizardfish	X	
Arius felis Sea catfish	X	X
Bagre marinus Gafftopsail catfish		X
Opsanus beta Gulf toadfish		X
Porichthys porosissimus Atlantic midshipman		X
Urophycis floridanus Southern hake		X
Hyporhamphus unifasciatus Halfbeak	X	
Strongylura notata Redfin needlefish	X	

TABLE 4.6-4 (Cont)

Species/Common Name	Seine	Trawl
Strongylura timucu Timucu	X	
Cyprinodon variegatus Sheepshead minnow	X	
Floridichthys carpio Goldspotted killifish	X	
Fundulus grandis Gulf killifish	X	
Fundulus similis Longnose killifish	X	
Membras martinica Rough silverside	X	
Hippocampus erectus Lined seahorse		X
Hippocampus zosterae Dwarf seahorse	X	
Syngnathus louisianae Chain pipefish	X	
Syngnathus scovelli Gulf pipefish		X
Centropomus undecimalis Snook	X	X
Diplectrum formosum Sand perch		X
Chloroscombrus chrysurus Atlantic bumper	X	X
Oligoplites saurus Leatherjacket	X	
Trachinotus falcatus Permit	X	
Diapterus plumieri Striped mojarra	X	X

TABLE 4.6-4 (Cont)

Species/Common Name	Seine	Trawl
Eucinostomus argenteus Spotfin mojarra	X	X
Eucinostomus gula Silver jenny	X	X
Eucinostomus lefroyi Mottled mojarra	X	X
Gerres cinereus Yellowfin mojarra	X	
Orthopristis chrysoptera Pigfish	X	X
Archosargus probatocephalus Sheepshead	X	X
Lagodon rhomboides Pinfish	X	X
Cynoscion arenarius Sand seatrout		X
Leiostomus xanthurus Spot	X	X
Menticirrhus americanus Southern kingfish	X	X
Menticirrhus saxatilis Northern kingfish	X	
Micropogon undulatus Atlantic croaker	X	X
Sciaenops ocellata Red drum	X	X
Chaetodipterus faber Atlantic spadefish	X	X
Tilapia sp. Tilapia	X	
Mugil cephalus Striped mullet	X	X

TABLE 4.6-4 (Cont)

Species/Common Name	Seine	Trawl
Mugil trichodon Fantail mullet	X	
Astroscopus y-graceum Southern stargazer	X	
Hypsoblennius hentzi Feather blenny		X
Microgobius gulosus Clown goby		X
Prionotus scitulus Leopard searobin	X	X
Prionotus tribulus Bighead searobin	X	X
Ancylopsetta quadrocellata Ocellated flounder		X
Etropus crossotus Fringed flounder		X
Paralichthys albigutta Gulf flounder	X	X
Achirus lineatus Lined sole	X	X
Trinectes maculatus Hogchoker	X	X
Symphurus plagiusa Blackcheek tonguefish	X	X
Monacanthus hispidus Planehead filefish	X	
Lactophrys quadricornis Scrawled cowfish	X	X
Sphoeroides nephelus Southern puffer		X
Chilomycterus schoepfi Striped burrfish		X

4.7 RARE AND ENDANGERED SPECIES

4.7.1 Manatee (Trichechus manatus)

The Florida manatee is protected by federal, state, and international law. The manatee is listed as an endangered species by the U.S. Fish and Wildlife Service and protected by the Marine Mammal Protection Act of 1972, by Chapter 370.12 (2) of the Florida Statutes, and by Appendix 1 of the 1973 Convention on International Trade in Endangered Species of Wild Fauna and Flora.

Manatees are found in slow moving rivers, estuaries, and salt water bays. Four factors influence their choice of habitat: (1) availability of vascular aquatic vegetation, (2) proximity of channels at least 1.5 m deep for migration, (3) winter warm water refuges, and (4) a source of fresh water (Hartman 1971).

The number of Florida manatees is not certain, but aerial surveys conducted during 1976, 1977, and 1978 have estimated the basic population at between 740 and 1,000, and recorded the areas of greatest abundance (Irvine & Campbell 1978; Rose 1978). More data on summer habitat are needed, but manatees are difficult to locate because they disperse in the summer.

Manatees congregate in warm water refuges from November to March. There are 25 such areas in Florida, 6 natural and 19 man-made (Hartman 1976). Movements between winter congregation areas have been suggested (Hartman 1971 and 1974; Rose 1978), but not verified. Although cold water sensitivity of manatees has been reported many times (Hartman 1971 and 1974; Bangs 1895; Layne 1965; Moore 1951a; Campbell & Irvine 1978; Campbell & Powell 1976), it is not completely understood. The activity of captive manatees decreases at water temperatures below 21°C. Feeding patterns become irregular at 18–19°C, and feeding may stop completely at temperatures below 16°C (Campbell & Irvine 1978). Exceptionally cold winter temperatures can result in manatee deaths, but the lethal level is not known.

Manatee congregations at power plant outflows during cold weather are well documented (Hartman 1971 and 1974; Irvine & Campbell 1978; Rose 1978; Moore 1956; Layne 1965; Campbell & Irvine 1978; Shane 1978). Table 4.7–1 lists the incidence of manatees at Big Bend reported from 1971–1976. No record of manatee sightings exists for the period 1977 through January 1979.

Tampa Electric Company (TECO) contracted Mote Marine Laboratory (MML 1980a) to conduct a study from February 1979 through February 1980 to observe the incidence of manatees in the vicinity of Big Bend Station. The objectives of the study were:

1. To document the manatee's use of the Station's warm-water

effluent as a winter refuge;

2. To determine the significance of the site as a winter refuge, compared to other refuges available in the area.

Surveys were carried on from airplanes, boats, and the plant structure. It was found that the manatees moved into the warm water during cold weather and ventured back out during warming spells. There were 72 observations of manatees in the plant's effluent during the course of the study. However, other warm-water effluents were more heavily utilized by this species. Aerial observations indicated the greatest number of manatees at a phosphate plant on the Alafia River, north of the plant.

The final report of this study appears as Appendix 2 of this document.

4.7.2 Other Species

In addition to manatees, the Marine Mammal Protection Act of 1972 protects porpoises. One species, Delphinus delphis, was sighted on a number of occasions near Big Bend (TECO 1979, Table 2.7-62). Sea turtles have occasionally been washed ashore near Big Bend, but species determinations were not provided. The Atlantic green turtle (Chelonia mydas), Atlantic hawksbill turtle (Eretmochelys imbricata), Atlantic loggerhead turtle (Carretta carreta), Atlantic Ridley turtle (Lepidochelys kempii), and Atlantic leatherback turtle (Dermochelys coriacea) appear on the Federal List of Endangered and Threatened Wildlife and Plants and on the Florida List of Rare and Endangered Species.

During the manatee boat survey (Section 4.7.1), observations were made of other threatened or rare and endangered species. Brown pelicans (Pelecanus occidentalis) were sighted at nearly every station on every sampling day. There were also two incidental sightings of bottlenosed dolphins (Tursiops truncatus) and one American bald eagle (Haliaeetus leucocephalus) (refer to Appendix 2, Section III, of this report).

TABLE 4.7-1

MANATEE SITINGS IN THE VICINITY OF BIG BEND 1971-1976

Date	Number Observed	Location	Discharged Water Temperature (°C)
May 1971	3	Discharge Channel	31
Dec. 31, 1972	5	Discharge Channel	-
Jan. 24, 1973	3	Near #1 Flume	25
Feb. 2, 1973	2	Near #1 Flume	24
Feb. 3, 1973	1	Near boat at mouth of #1 Flume	-
Feb. 6, 1973	1	Discharge Channel	22
Feb. 15, 1973	1	Discharge Channel	21
Feb. 20, 1973	1	Discharge Channel	22
July 25, 1973	5	North of Port Manatee Ship Channel, approximately 1 mile offshore	-
July 1976	3	-	-
Aug. 1976	2	-	-
Nov. 25, 1976	2	-	-

SECTION 5

RATIONALE FOR SELECTION AND LIFE HISTORIES OF REPRESENTATIVE IMPORTANT SPECIES

5.1 RATIONALE FOR SPECIES SELECTION

To determine the Representative Important Species (RIS), a list of species known to exist in the Station's vicinity was compiled together with information on their local patterns of abundance and pertinent ecological characteristics, such as trophic importance. Next, criteria similar to those described in the 316 Demonstration guidance manuals were used to select RIS from the larger list. The selected species may be: (1) of commercial or recreational value, (2) threatened or endangered, (3) important to the structure or function of the ecosystem, (4) susceptible to one or more of the power station's impacts, (5) relatively abundant in the area as determined from literature or field studies, or (6) using the area for spawning or as a nursery. The RIS serve as representatives of a larger array of species and, thus, the analysis of impact for this subgroup provides a meaningful and efficient assessment of the entire ecosystem.

This section describes the rationale for selection of the RIS and their life histories. Table 5.1-1 summarizes the rationale for species selection and life history. Appendix 6 summarizes thermal tolerance data for the RIS. Current data on RIS collected in the 1979-1980 study period are presented in Section 4 and Appendices 1, 2 and 3.

TABLE 5.1-1

CHECKLIST SUMMARY OF RATIONALE FOR SELECTION OF REPRESENTATIVE IMPORTANT SPECIES

	American Oyster	Pink Shrimp	Blue Crab	Stone Crab	Bay Anchovy	Scaled Sardine	Tidewater Silverside	Silver Perch	Spotted Seatrout	Black Drum	West Indian Manatee
Dominant Species					X	X	X	X			
Local Resident	X	X	X	X	X	X	X	X	X	X	X
Migratory		1	1							1	1
Commercial Importance	X	X	X	X		X			X	X	
Recreational Importance	X	X	X	X					X	X	
Community Type											
Marine		X	1		X	X		X	X	X	
Estuarine											
Rock or Firm Substrate	X			X							
Silt/Sand Substrate		X	X	X	X			X		X	X
Open Water		1	1		X	X	X	X	X	X	X
Intertidal	X		X								
Subtidal	X		X	X							
Trophic Level											
Detritivore	X	1	1								
Primary Consumer		1	1		1						X
Secondary Consumer			1	X	1	X	X	1	1	1	
Tertiary Consumer								1	1	1	
Principle Source of Impact											
Entrainment		X		X	X	X	X	X	X	X	
Impingement			X		X			X			
Thermal Plume	X		X	X	X						X
Threatened or Endangered											X

KEY:

X - Category is applicable to species.
1 - Category is applicable to one or more life stages of species.

5.2 REPRESENTATIVE IMPORTANT SPECIES

The RIS are: American oyster (Crassostrea virginica); pink shrimp (Penaeus duorarum); blue crab (Callinectes sapidus); stone crab (Menippe mercenaria); bay anchovy (Anchoa mitchilli); scaled sardine (Harengula jaguana); tidewater silverside (Menidia beryllina); silver perch (Bairdiella chrysura); spotted seatrout (Cynoscion nebulosus); black drum (Pogonias cromis); and West Indian manatee (Trichechus manatus).

5.2.1 American Oyster: Crassostrea virginica (Gmelin); Ostreidae

5.2.1.1 Rationale for Selection

Although the American Oyster is not an important commercial species in Tampa Bay, it is a major commercial species in Florida and was recommended as an appropriate addition to the RIS list by the National Marine Fisheries Service (NMFS 1979). While the early life stages of the oyster are susceptible to entrainment impact, the oyster is primarily susceptible to thermal impact during the sessile stage. They are a predominant biofouling organism at power stations in Tampa Bay and are a major source of biofouling problems at Big bend Station.

American oysters are found in shallow brackish water on firm bottoms. They generally occur near the mouths of rivers and in bays and estuaries. Their eggs hatch into free-swimming (planktonic) forms, and within a few weeks the spat settle on solid objects and become sessile. About 4 years are required for wild oysters to attain marketable size.

Three species of oysters are commercially harvested in the United States. The Florida industry, however, is based solely on the American oyster. Landings of the American oyster from the west coast of Florida declined from 5.3 million pounds in 1968 to 2.1 million pounds in 1975 (NMFS 1971-1978). The decline in oyster fisheries has been attributed to diminished growth caused by pollution, and a reduction in the number of fishermen and boats (Prochaska 1976:46). Methods of data collection have been inefficient and some of the apparent trends are due more to accurate reporting than to actual changes in production (Ingle 1973:3). In the U.S., commercial oyster culture has always been a large component of total production. Much of the growing area in Florida is under lease, but, due to other factors (pollution, red tide, unsuitable oysters), much of the leased acreage lies fallow (Ingle 1973:1). There are approximately 17 leases granted for Tampa Bay, but none are in use because pollution has caused the banning of all commercial harvesting from the Bay. To prevent any serious health problems, all recreational harvesting and small-scale entrepreneur operations are presently being discouraged (Harding 1980a). Tampa Bay has no major, naturally occurring oyster beds, due to the scarcity of suitable substrate.

Oysters are frequently found attached to mangrove roots, piles, and other submerged structures in the Bay.

5.2.1.2 Life History Data

The American oyster ranges along the Atlantic coast (from the Gulf of St. Lawrence to the Gulf of Mexico) into the West Indies (Abbott 1954, cited in Dragovich & Kelly 1964:86) and along the Pacific coast from British Columbia to Morro Bay, California (Palmer & Fowler 1975:418).

The American oyster is commonly found in brackish water near the mouths of rivers or in bays and estuaries. It is found in shallow water from 0.3m above mean low water to 9 to 12m in depth (Butler 1954:479), but is most abundant at depths of 2.4 to 7.6 m (Dunnington 1973, cited in Liden & Burton 1978:30). Individuals present within the tidal zone are exposed to air for 2 to 3 hours (Galtsoff 1964:407). Oysters are located in areas of firm substrate, particularly in shell or coral cultch (Butler 1954:479).

Benthic studies of Tampa Bay were conducted from 1961 through 1964 (Dragovich & Kelly 1964:86); only one specimen of the American oyster was collected, althougn previous studies reported the species in the Tampa Bay area. According to Dawson (1953:5), the scarcity of suitable substrate is a major reason for the absence of wild oyster beds in Tampa Bay.

The American oyster occurs at water temperatures ranging from -2°C (Butler 1954:484) to 36°C (Galtsoff 1964:407). The highest mortalities normally occur during the warmest part of the year due to physiological stress, particularly during or following spawning when the oysters' condition is poor (Collier 1953:19; McHugh & Andrews 1954, cited in Tinsman & Maurer 1973:231).

Short exposure to temperatures well below their critical thermal maximum will cause mortality if the transition occurs too rapidly and the temperature difference is too great. Oysters acclimated at 22°C were found to have a median tolerance limit (TLm) of 45°C with a 25-minute exposure and 42°C with a 117-minute exposure; oysters acclimated at 24°C have a TLm of 41°C with a 0.74°C/hr rate of exposure and a TLm of 47.5°C with a 13.2°C/hr exposure rate (Fingerman & Fairbanks 1957:58-60). The critical thermal maximum for the American oyster is 48.5°C (Henderson 1929, cited in Tinsman & Maurer 1973:230).

Temperature may also have indirect effects. Collier (1953:20) suggests that mortality is not caused by temperature, per se, but under conditions of high temperature (25°C) oysters are more susceptible to attack by predators and parasitic infections. Higher temperatures increase barnacle setting and growth (Cory & Nauman 1969:216), which results in increased competition. In

addition, oysters concentrate heavy metals, and this tends to increase with increased temperature (Quick 1971:173) which may result in harmful effects to the oyster or in contamination to the food product.

Spawning occurs over a temperature range from 15 to 32-34°C; spawning is retarded at a temperature of 35°C or greater (Galtsoff 1964:308). The minimum mass-spawning temperature within the species geographical range tends to decrease southward (Hidu et al 1974:103). Mass spawnings of Gulf populations are clearly defined and typically occur several times during the summer (Ingle 1951:133). Butler (1955:75), observing initial spatfall in Pensacola Bay over a 7-year period, indicates that the initiation of spawning occurs at temperatures of 18 to 27°C. An additional 2°C increase after the initial spawning causes subsequent spawning (Nelson 1928:154). However, Price and Maurer (1971:32) found that the cumulative temperature exposure is more significant in ripening Delaware Bay oysters than exposures to "high" temperatures per se.

The egg of the American oyster is oblong, measuring 0.055 to 0.75 mm (major axis) by 0.035 to 0.055 mm (minor axis) (Galtsoff 1964:327, 338). The eggs hatch within a period ranging from a few hours to greater than a week after fertilization (Bardach et al 1972:677;Nelson 1917:56). Embryo development is impaired by temperatures of 30 to 34°C at a 1- to 16-hour exposure (Roosenburg et al 1970, cited in Liden & Burton 1978:31-33). Hatching under laboratory conditions is less than 50 percent successful at temperatures equal to or less than 17.5°C and equal to or greater than 32.5°C (17.5-32.5°C range tested) and at salinities less than 17.5 ppt (17.5-27.0 ppt range tested) (Davis & Calabrese 1964:647). Eggs acclimated at 24°C for 48 hours exhibited a direct relationship between mortality and duration of exposure up to 2 hours; TLms were 40°C at 10 seconds, 36°C at 1 minute, 34°C at 10 minutes, and 31°C at 1 hour (Hidu et al 1974:106).

Larval stages of the American oyster are free-swimming individuals occurring in the plankton from April through October in Gulf waters (Butler 1954:482). The larva hatches as a trochophore or ciliated gastrula. After a period of 24 to 48 hours, the trochophore transforms into a veliger (Galtsoff 1964:356-368). At 36 hours, the umbo (or shell) appears and encloses the soft body parts within 6 days (Palmer & Fowler 1975:418). The veliger exists in the water column for a period of 2 to 3 weeks and its survival is inversely related to the duration of this stage (Galtsoff 1964:369-371).

Estimates of temperature and salinity optimal for larval growth and survival range from 19 to 32.5°C and 7.5 to 35 ppt (Davis & Calabrese 1964:645, 648; Lough 1975: 86-88; Diaz 1973:933). Mortality is positively correlated with age. The highest

mortality occurs within the first 4 days, and a temperature difference of 20°C at this stage permanently impairs the growth of survivors. Hidu et al (1974:106) found that larvae, as well as eggs, exhibit a direct relationship between mortality and duration of exposure up to 2 hours and a relatively stable mortality rate with exposures from 2 to 16 hours. The upper and lower TLm for larvae are 33 and 20°C, respectively, when acclimated at 24°C for 48 hours. The trochophore exhibits a 1-hour TLm of about 35°C; TLm's at shorter exposures are approximately 3°C greater than those reported for eggs. The veliger exhibits a 1-hour TLm of about 42°C; TLm's at shorter exposures are 8 to 11°C greater than those reported for eggs.

The larva, after about 3 weeks within the water column, attaches itself to the substrate and metamorphoses to the juvenile stage; this process of fixing to the substrate is termed "spatfall" (Bardach et al 1972:677), but may also be referred to as settlement, set, or settling. Spat production is heavy and erratic along the Gulf coast (Butler 1954:482), but mortality is very high due to predation, disease, and effects of crowding (Bardach et al 1972:677). Larvae reared at greater than normal temperatures set at less than normal temperatures, but the success of subsequent metamorphosis decreases with increased temperature differences (Davis & Calabrese 1964:655). Davis and Calabrese (1964:655) found that higher temperatures decreased the settling time: 36 to 40 days at 20°C and 10 to 12 days at 30 to 32°C. Lutz et al (1970:68) found increased percent set after 4-hour exposures as temperatures increased from 24 to 29°C. Diaz (1973:993) found increased percent set at 25°C with a 5-second exposure at 35°C, but a significantly decreased percent set at 25°C with a 5-second exposure at 40 and 45°C; the data indicate a relationship between the temperature difference and the percent of set which is also positively correlated with age.

The growth rate of American oysters reaches a maximum between 15 and 20°C, but decreases significantly at temperatures between 20 and 25°C (Loosanoff & Nomejko 1949, cited in Collier 1953:19). In contrast, Ingle and Dawson (1952:393, 401) found that growth in Apalachicola Bay was remarkably rapid and continuous throughout the year; there was no indication of a decreased growth rate at temperatures of 25 to 30°C as compared to lower temperatures. The oyster grows approximately 5 cm in 82 days (Palmer & Fowler 1975:418). Wild oysters attain a marketable size in about 4 years (Bardach et al 1972:677). The American oyster reaches a maximum age of approximately 9 years (Bardach et al 1972:677). In Gulf waters, maturation is significantly more rapid than in northern portions of the range (Butler 1954:483). Menzel (1951, cited in Butler 1954:483) reported that about one-third of the early summer-settled spat reach sexual maturity 1 month after spatfall; these oysters would measure less than 2.5 cm at maturity.

The American oyster exhibits true hermaphroditism; both sexes are present in a single individual within a few months after set (Coe 1932:439). An individual may function as a different sex from year to year (Galtsoff 1964:316, 317); the sex ratio of 4-year-olds is nearly 1:1, but 1-year-old males outnumber females 2:1 (Galtsoff 1964:324).

Fecundity (eggs/female/season) is about 9 million, according to Palmer and Fowler (1975:418). Galtsoff (1964:313) indicated that fecundity can range from several thousand, if in poor condition, to several million. For individuals measuring 9.4 to 13.3 cm (length) by 6.6 to 10.5 cm (width), estimates range between 15 million and 115 million eggs/female/season (Galtsoff 1930:97, 98).

The American oyster is a filter feeder consuming plankton and suspended organic matter drawn in with water (Bardach et al 1972:677). The trochophore is a non-feeding larval stage (Galtsoff 1964:356-368); feeding begins at the veliger larval stage (Bardach et al 1972:677). Feeding is affected by temperature; feeding ceases at temperatures less than 8°C and greater than 32°C (Galtsoff 1964:407).

Tabular presentation of thermal effect data on the American oyster during various phases of its life cycle is provided in Appendix 6 (Table A6-1).

The American oyster is subject to a large number of parasites and infectious organisms whose effect is enhanced by high temperature and salinity (Mackin 1951, cited in Butler 1954:485). Conch or oyster drills and polyclad flatworms (or oyster "leeches") are a serious threat to the oyster (Butler 1954:485, 486) and are widely distributed in Tampa Bay waters (Dawson 1953:5). Other important predators include the starfish (outside Gulf waters), the stone crab, and the adult blue crab (Butler 1954:485, 486). Oysters may shelter oyster crabs, which are small soft-bodied females of the species Pinnotheres ostreum; the males are hard-shelled and free-swimming (Palmer & Fowler 1975:418). Mud crabs (including the juvenile stage of the blue crab) and oyster crabs feed on spat (Butler 1954:485, 486). In some areas, the black drum is reputed by oyster fishermen to be a pest (Moore 1907:63-65).

5.2.2 Pink Shrimp: Penaeus duorarum Burkenroad; Penaeidae

5.2.2.1 Rationale for Selection

Adult pink shrimp spawn in the ocean, where egg and larval development occurs. They migrate to estuarine habitats arriving as juveniles. They continue their development, emigrating back to the ocean as they approach maturity.

Tampa Bay is a nursery for pink shrimp. Pink shrimp are primarily susceptible to impingement impacts. Few larval pink shrimp were collected in meroplankton sampling studies at Big Bend Station, but juvenile pink shrimp were the most abundant invertebrate impinged.

The Gulf of Mexico is considered to be the center of distribution of the pink shrimp (Perez-Farfante 1969:508). In Florida, it is the single most valuable commercial marine resource (Beardsley 1970:401). The largest catches are off the southwestern coast of Florida from the Tortugas-Sanibel grounds, but shrimp are taken in moderate quantities along the northwestern coast of Florida (Perez-Farfante 1969:520). Pink shrimp accounted for an average of 84 percent of the total number of shrimp landed along the west coast of Florida from 1966 to 1975 (NMFS 1969-1978). Approximately 24 million lbs (heads-on weight) of pink shrimp were landed each year during 1973, 1974, and 1975 (NMFS 1976-1978). Commercial catch statistics for Tampa Bay, per se, are not reported for pink shrimp. Some commercial fishing occurs in Tampa Bay which is seasonal (February through mid-June) except for live bait which can be fished year-round (Harding 1980b). Some recreational fishing for pink shrimp also occurs in Tampa Bay (Godcharles 1980a).

5.2.2.2 Life History Data

The pink shrimp is found on both sides of the Atlantic; along the western Atlantic, its range extends from Chesapeake Bay to Brazil, including the Gulf of Mexico, Bermuda, and the West Indies (Williams 1965:23; Hoestlandt 1967 and LeGuen & Crosmier 1968:343, cited in FPC 1977b:VII.126). The Gulf of Mexico is considered the center of the distribution; dense populations occur in the Tortugas-Sanibel grounds off Florida and the Obergon-Campeche grounds off Mexico (Perez-Farfante 1969:508,520). The northern-most breeding population is in North Carolina waters (Williams 1955:116; Burkenroad 1949 and Broad 1950 and 1951, cited in Eldred et al 1961:86). Pink shrimp were found year-round throughout Tampa Bay (Dragovich & Kelly 1964:79), as well as many other areas of the Gulf (Perez-Farfante 1969:508).

Pink shrimp occur in estuaries and inner oceanic littoral areas, predominantly on sand, shell-sand, and coral-mud bottoms from the shoreline to about 51m, and rarely deeper (U.S. Fish & Wildlife Service 1960, cited in Williams 1965:22). The young are generally found in shallower, somewhat fresher portions of estuaries than are adults (Williams 1965:24). Laboratory observations indicate that the pink shrimp has a strong preference to shell-sand, as opposed to other substrates and combinations; this preference is also significantly different than those of other closely related species (Williams 1958:286,287). The pink shrimp is nocturnal with a strong diel

rhythm; they are inactive or burrow during the day (Wickham & Minkler 1975:21; Williams 1965:24). Light conditions, including those resulting from turbidity, affect pink shrimp. Adults avoid light, while juveniles smaller than 55 mm have been observed swimming and feeding in bright light. The larval stage exhibits strong positive phototropism (Eldred et al 1961:98; Ewald 1965:446).

The occurrence and abundance of the pink shrimp are positively correlated with temperature (Copeland & Bechtel 1974:174). Laboratory observations indicate that a temperature of 37.2°C is lethal to the juvenile/adult stage with prolonged exposure (Marble & Mowell 1971); furthermore, there is no significant difference in adult survival and condition with temperature increases to at least 28°C (Williams 1960:568, 569). Eldred et al (1961:87) reported pink shrimp at water temperatures as high as 35.5°C (during August in the Tampa Bay area).

Pink shrimp prefer the warmer and more stable temperature regime of offshore waters (Perez-Farfante 1969:519; Eldred et al 1961:88), although they have been reported at water temperatures as low as 0°C in Chesapeake Bay and 4.0°C along the North Carolina coast (Williams 1955:138). A sudden cold snap will cause them to move out of shallow areas into deeper water (Tabb et al 1962:16), but under gradual cooling conditions they burrow deeply into the substrate (Perez-Farfante 1969:519). They remain burrowed and undergo little or no activity at water temperatures below 14 to 16°C (Williams 1955:137; Fuss & Ogren 1966, cited in Perez-Farfante 1969:519), and are completely narcotized at temperatures below 10°C (Eldred et al 1961:86).

The occurrence and abundance of the pink shrimp is also strongly correlated with salinity increases from 8 to 35 ppt (Copeland & Bechtel 1974:176). Laboratory observations indicate that adult survival increases with increased salinities from 10 to 30 ppt (Williams 1960:568, 569). Juveniles are good osmoregulators at low temperatures (Williams 1965:24); young pink shrimp apparently have greater salinity tolerances than adults (Tabb et al 1962:27, 28). Joyce (1965, cited in Copeland & Bechtel 1974:186) found post-larvae and juveniles in near-fresh water from the St. Johns River (Florida). In the Tampa Bay area, pink shrimp were collected at salinities ranging from 19.6 to 35.2 ppt (Saloman 1968:1, 2).

Mating occurs year-round with peak spawning generally occurring from April through July (Cummings 1961:466). Eldred et al (1961:83) found impregnated females common in Tampa Bay during spring and summer. There is some evidence that offshore populations spawn to some extent throughout the year (Ingle et al 1959, cited in Perez-Farfante 1969:514); Ewald (1965:439) reported that spawning at the Tortugas occurs year-round, with peaks in spring and summer. Sampling conducted by Eldred et al

(1961:92) in Tampa Bay indicates that peak spawning runs were from April-May through September. Data from the Anclote area indicate a protracted spawning season beginning in winter and lasting through fall (FPC 1977b:VII.130). In warmer, more shallow areas, the spawning season may have two peaks of activity: spring and fall; large females generally spawn when water temperatures begin to drop in the fall, whereas smaller females may also spawn with rising temperatures in the spring (Eldred et al 1961:88). Spawning takes place during the early morning (Ewald 1965:439) in waters 2 to 26 fm deep (Perez-Farfante 1969:514). Temperatures range from 16.1 to 30.6°C (Jones et al 1964a:87; Jones et al 1970:650; Eldred et al 1965:14, 15). Optimum water temperature for spawning is probably 27.0 to 30.2°C (Ewald 1965:439; Roessler et al 1967, cited in FPC 1977b:VII.130; Perez-Farfante 1969:514).

Individual females probably spawn more than once in their lifetime. (Cummings 1961:467, 468; Eldred et al 1961:91). If multiple spawning does occur, fecundity increases with succeeding spawnings (Martosubroto 1974:625). Burukovski (1970, cited in Martosubroto 1974:625) estimates that the pink shrimp has the potential to spawn four times, 2 to 3 months apart. Fecundity is positively correlated with size (Cummings 1961:468); it is more closely correlated with ovary weight than body weight or body length (Martosubroto 1974:625). Fecundity estimates range between 44,000 and 534,000 eggs/female for 10.1 to 66.8 g body weight (Martosubroto 1974:606).

The egg of the pink shrimp is yellow-brown and opaque, measuring 0.23 to 0.37 mm in diameter (Dobkin 1961:325; Eldred et al 1965:12; Cummings 1961:465). The eggs are demersal and hatch in 13 to 14 hours at 27 to 29°C (Hudinaga 1942, cited in Dobkin 1961:325). After hatching, the pink shrimp develops through a total of 11 larval stages (Dobkin 1961:348; Ewald 1965:438) over a period of approximately 15 to 25 days (Perez-Farfante 1969:515; Ewald 1965:442): 5 naupliar stages ranging from 0.35 to 0.61 mm in body length (Dobkin 1961:346); 3 protozoean stages ranging from 0.86 to 2.7 mm in body length (Dobkin 1961:330-335); and 3 mysis stages ranging from 2.9 to 4.4 mm in body length (Dobkin 1961:335-340). Larval survival in the laboratory is dependent on salinities of 27 to 35 ppt (Cook & Murphy 1969:754). The rate of larval development increases with temperatures of 24 to 32°C (Cook & Murphy 1969:753). According to Thorhaug et al (1971b:131), temperatures of 27 to 30°C are considered optimal for mysis development; reasonable survival is exhibited at 33 to 35°C with prolonged exposure, and at up to 36°C under fluctuating conditions. Metamorphosis to the postlarval stage is temperature-dependent, requiring 25 days at 21°C and 15 days at 26°C (Ewald 1965:442). Survival under laboratory conditions from the first protozoean stage to the first post-larval stage is estimated at 4 percent (Ewald 1965:445).

Pink shrimp postlarvae are transported to inshore nursery areas by tidal currents (Tabb et al 1962:15; Hughes 1966:504; Copeland & Truitt 1966:69; Jones et al 1970:645-649), but such movement is not entirely passive (Perez-Farfante 1969:517). Hughes (1969, cited in Perez-Farfante 1969:518) suggested that the tidal transport of post-larvae may be initiated in response to tidal-related salinity changes; post-larvae respond to decreased salinities by dropping to the substrate, and when salinities increase, they become active in the water column. Consequently, postlarvae are moved inshore on flood tide and evade displacement seaward on ebb tide. In Buttonwood Canal (Florida), Roessler and Rehrer (1971:797) found that the occurrence and abundance of postlarvae was greater on flood tide than ebb, greater at night than day, and greater at new moon than other phases. Eldred et al (1961:101) observed similar behavior regarding moon phase, and hypothesized that molting is also related to moon phase. In North Florida Bay, postlarvae (1.8 mm CL) enter the Bay at night on the flood tide (Tabb et al 1962:11, 12, 15). Beardsley (1970:401) found that vertical and lateral distribution of juvenile pink shrimp in Buttonwood Canal could be attributed to moonlight.

Postlarvae enter Buttonwood Canal in April and May with peak abundances occurring in July and August (Roessler & Rehrer 1971:801). The post-larval stage was present in Anclote waters from April to December with peak abundances in July and moderate abundance until October (FPC 1977a:V.172). Joyce (1965, cited in Perez-Farfante 1969:517, 518) reported the occurrence of post-larvae along northeastern Florida from June to December. Post-larvae enter estuarine nursery areas in the Florida Bay area throughout the year with peaks of recruitment varying from year to year: from April to June (Tabb et al 1962:12) and from July to October with secondary peaks in the late fall and winter (Jones et al 1964b, cited in Perez-Farfante 1969:517, 518). Eldred et al (1965:1, 2) also observed that post-larval recruitment to the Tampa Bay area varied year to year; post-larvae were taken in January and from March to November in 1962, and from June to January in 1963. Kelly and Dragovich (1967:218) found pink shrimp postlarvae in lower Tampa Bay most abundant in the summer months.

Postlarvae were most abundant in the Tampa Bay area when water temperatures exceeded 24°C (Eldred et al 1965:2). In the Anclote area, postlarvae were first taken at a mean water temperature of 24°C, and were most abundant at 31°C, the highest mean temperature; densities subsequently declined as temperatures decreased to 24 to 25°C, and the larvae were present only in very low densities after mean temperatures had dropped to 15 to 18°C (FPC 1977a:V.173). Laboratory observations indicate that a 2.5-hour exposure to temperatures between 36.8 and 37.8°C is lethal to the post-larvae (Thorhaug et al 1971b:128).

Tabular presentation of thermal effect data on the pink shrimp during various phases of its life cycle is provided in Appendix 6 (Table A6-2)

The nursery areas are utilized for a period of 2 to 6 months (Costello & Allen 1966, cited in Perez-Farfante 1969:518). Transformation to the juvenile stage occurs at a body length of approximately 18 mm (Perez-Farfante 1969:515). As the juvenile approaches maturity (less than 25 mm CL), they emigrate offshore, predominantly transported by a strong ebb tide (Tabb et al 1962:7; Perez-Farfante 1969:518). Movement out of the inshore areas of Tampa Bay generally occurs from April to July at a body length ranging between 85 and 140 mm, but a smaller size range moves offshore during the fall (Eldred et al 1961:81-85).

Growth is rapid (Williams 1965:23; Costello & Allen 1960:9). Postlarvae (6.9 to 9.4 mm TL) from Biscayne Bay grew at a rate of 0.35 to 0.51 mm TL/day (10.5 to 15.3 mm TL/month) (Ewald 1965, cited in Perez-Farfante 1969:515). According to Tabb et al (1962:26), postlarval/juvenile pink shrimp grow at a rate of approximately 3 to 4 mm CL/month. Older juveniles reportedly grow at a rate of approximately 20 mm TL/month while still in the nursery (Tabb et al 1961:8; Eldred et al 1961:105). Iversen and Jones (1961:14) reported tagged shrimp from the Tortugas grew 21 to 28 mm TL/month (0.2-2.4 mm CL/month). Williams (1955:135) reported a summer growth rate of 52 mm TL/month in North Carolina. At the end of 1 year, pink shrimp from the Tampa Bay area attain an average size of 140 mm TL and a mean weight of 24.0 g; specimens greater than 200 mm TL are about 2 years old (Eldred et al 1961:105). Pink shrimp are believed to live only 15 to 16 months (Christmas et al 1966:179).

The smallest ripe female collected from Tampa Bay measured 85 mm TL, although the usual size at maturity is 92 to 99 mm TL (Eldred et al 1961:83). Cummings (1961:465) reported a mean size of 93 mm TL (22 mm CL).

The population sex ratio is 1:1, but wide variation exists geographically and seasonally (Iversen & Idyll 1960:4; Tabb et al 1962:16; Eldred et al 1961:66-69; Saloman 1965:5). The sexes appear to segregate (Perez-Farfante 1969:514); it has been observed that female abundance increases with depth (Iversen & Idyll 1960:4). Pink shrimp size also increases with depth; the largest shrimp are females (Williams 1955:136, 137; Tabb et al 1961:5; Iversen et al 1960, cited in Eldred et al 1961:69).

The pink shrimp is a nocturnal bottom feeder, which ingests a variety of plant and animal material (Eldred et al 1961:101). Postlarvae (approximately 10 mm) feed on filamentous blue-green algae and diatoms (Flint 1956, cited in Eldred et al 1961:102); they feed in shallow areas among seagrasses and algae (Eldred et al 1961:102). Juvenile pink shrimp are omnivorous like other

penaeids, ingesting algae and fragments of higher plants, as well as sand, mud, and organic debris (Perez-Farfante 1969:516); they also feed on a large variety of animals including foraminiferans, hydroids, nematodes, mollusks, polychaetes, crustaceans, tunicates, and fish larvae (Williams 1955:143; Williams 1958:289; Eldred et al 1961:102).

Predation by fish, and to some extent by aquatic birds, is the major source of juvenile and adult mortality (Tabb et al 1962:16; Perez-Farfante 1969:520). In Texas waters, peak spawning among spotted seatrout corresponds to peak movement of juvenile pink shrimp (Miles 1950, cited in Tabb et al 1962:16). Pink shrimp are one of the most abundant crustaceans consumed by juvenile and young adult spotted seatrout (Klima & Tabb 1959:21; Carr & Adams 1973:525,526).

5.2.3 Blue Crab: Callinectes sapidus Rathbun; Portunidae

5.2.3.1 Rationale for Selection

Spawning occurs in portions of estuaries nearest the ocean. Juveniles migrate to more brackish environments where they mature. Blue crab are susceptible to impingement and thermal impacts. The planktonic stages of blue crab were rarely collected in meroplankton studies at Big Bend. Older specimens were collected in seine studies at Big Bend, and the species was the second most abundant invertebrate collected during impingement monitoring.

The blue crab is a common coastal inhabitant of Florida. The relative ease with which it may be captured, and the delicacy of the meat, makes it a highly prized sport and commercial fisheries species (Oesterling 1976:1). Commercial landings have increased on the west coast of Florida with 9.6, 10.1, and 12.8 million pounds being landed in 1973, 1974, and 1975, respectively (NMFS 1976-1978). The blue crab represents the third largest food fishery in the entire Gulf of Mexico (Perry 1975, cited in Oesterling & Evink 1977:101), even though landings have declined from 43.5 million pounds in 1973 to 38.7 million pounds in 1975 (NMFS 1976-1978). Prochaska (1976:30) has hypothesized that either pollution of estuaries has caused declining landings or the profitability in landing other species may have increased more than that for blue crab.

5.2.3.2 Life History Data

The blue crab has been reported from Nova Scotia to northern Argentina, along the Gulf of Mexico, and in the Caribbean. This species has also been introduced to Europe and Japan, probably by means of ship ballast tanks (Williams 1974:687). The blue crab is found throughout Tampa Bay where it is one of the predominant invertebrate species (Dragovich & Kelly 1964:98).

Found from the intertidal zone to depths of 90 m, the blue crab is especially abundant in bays and mouths of rivers (Powers 1977:78,79; Copeland & Bechtel 1974:180; Gunter 1950:33; Churchill 1919:95). Not only can this organism tolerate a wide range of salinities (0-40 ppt) and temperatures (0-40°C), but it can also tolerate low oxygen conditions, having been found occasionally in polluted and anoxic waters (Powers 1977:78, 79; Copeland & Bechtel 1974:199; Chambers & Sparks 1959:239; Gallaway 1970:85). Tagatz (1969:713) found that blue crabs from North Carolina waters were less tolerant of temperature extremes at low salinity (6.8 ppt) than at high salinity (34 ppt). The upper and lower tolerance limits increased as the acclimation temperature increased. Adult female crabs acclimated to 30°C at 6.8 ppt had a 48-hour thermal tolerance limit of 37°C; juveniles tolerated 37.2°C. Gallaway (1970:85, 86) found blue crabs in a thermal effluent in Texas at similar salinities but at higher temperatures (31-39°C); however, only small crabs (2.0-2.9cm CW) were able to withstand the highest temperatures. Tagatz (1969:714) reported that juveniles were more tolerant to heat and less tolerant to cold than adults. Optimum conditions for blue crab are temperatures between 10 and 35°C and salinities between 10 and 27 ppt (Copeland & Bechtel 1974:199).

Juvenile crabs are usually found in shallow areas with lower salinities, while mature females prefer deeper water and higher salinities (Powers 1977:78,79; Copeland & Bechtel 1974:175; Gunter 1950:33). Tagatz (1969:714) lists a range of temperature-salinity median tolerance limits for adult females and juveniles.

Spawning is thought to be temperature-induced at about 20°C (Sulkin et al 1976:107-111; Copeland & Bechtel 1974:192). Spawning occurs in Florida waters throughout the year, but chiefly from May through November (Nichols & Keney 1963, cited in Futch 1965:8).

An individual female produces from 1 to 3 million eggs about 1/100 inch in diameter at a time. The eggs are yellow or orange when first laid, and turn dark brown as the embryo develops. The eggs attach to swimmerets on the underside of the female to form a mass called a "sponge." Incubation takes 9 to 17 days, and the newly hatched larvae are released into the water column (Williams 1965:170; Churchill 1919:96, 97; Leary 1964:63; Sandoz & Rogers 1944:219).

The larvae metamorphose through 7 zoeal stages while carried by the currents. As they metamorphose to the megalops stage, they begin to sink in the water column and are carried by tidal currents to nursery areas inshore where they metamorphose to the first crab stage. The duration from hatch to the megalops stage ranges from 31 to 49 days, to the first crab stage from 6 to 20 days, and to adult about 7 months (Costlow & Bookhout 1959:395; Churchill 1919:101; Oesterling & Evink 1977:105). The

development rate of the larvae is inhibited by low temperature (≤15°C) particularly at very low or high salinities (<5 ppt, ≥40 ppt), and increases with temperature (Costlow 1967:86; Costlow & Bookhout 1969:254; Leffler 1972:110). The optimum range for larval development is 25 to 30°C and 20.1 to 31.1 ppt (Costlow & Bookhout 1959:395). Pearson (1948:20-25) has postulated that, in Chesapeake Bay, high river discharge during the spawning season may lower the salinity to a level unfavorable to survival of young crabs. This would result in a small year class. Survival of larvae under laboratory conditions is reported by Costlow and Bookhout (1959:395).

Tabular presentation of thermal effect data on blue crab during various phases of its life cycle is provided in Appendix 6 (Table A6-3)

Generally, female blue crab exhibit an onshore/offshore migration pattern (Copeland & Bechtel 1974:193; Daugherty 1952:82, 83; Gunter 1950:37). The Florida Gulf coast populations exhibit an onshore/along-shore movement. After mating in the estuarine areas, the females move into the Gulf and swim northward along the Florida peninsula and westward along the panhandle. Although some spawning takes place along the Florida coast, the Apalachicola Bay region is the major spawning ground for Florida Gulf blue crab. Larvae hatched there are entrained in the Eastern Gulf Current that flows southward at that point. The larvae molt through the successive zoeal stages as they are transported by the current. As they metamorphose into the megalops stage, they are caught up in eddies and are transported by tidal currents into shallow estuarine areas to continue their development (Oesterling & Evink 1977:101-105; Oesterling 1976:6-9).

The adult stage is reached less than a year after hatching in the St. John's River and in 12 to 18 months in Chesapeake Bay; 3 years is the normal maximum age for this species (Williams 1965:170; Oesterling & Evink 1977:101; Tagatz 1968b:287). Maximum size (carapace width) for male crabs is about 215 mm, for females about 175 mm (Churchill 1919:101). In laboratory studies (Tagatz 1968b:287), summer mortality for crabs 20 to 79 mm wide was 8 percent, and for crabs 80 to 139 mm 19 percent; winter mortality was about 3 percent. However, these laboratory animals were not subject to predation during the studies.

Blue crabs consume a wide variety of materials. Zoea feed on diatoms, dinoflagellates, and larvae of other animals (Sandoz & Rogers 1944:225). Adults feed on crabs (including C. sapidus), other crustaceans, mollusks, fish, vegetation, detritus, occasional aquatic insects, barnacles, decaying fish, and other animals. This species can be called a detritivore, bottom predator, and general scavenger (Darnell 1958:409-411; Churchill 1919:114, 115; Hoese 1960:330). In turn, blue crab is preyed

upon by several species of fish and invertebrates, including its own species, being most vulnerable during its "soft-shell" stage.

5.2.4 Stone Crab: Menippe mercenaria (say); Xanthidae

5.2.4.1 Rationale for Selection

Although the stone crab is not one of the most abundant xanthids in Tampa Bay, it is susceptible to entrainment and thermal impacts. The planktonic larval stages were found in both open bay trawl sampling and entrainment monitoring studies. Juveniles migrate to shallower water as they grow. A few adults were collected in the seine and impingement monitoring studies.

The U.S. fishery for stone crabs is exclusive to Florida (Savage et al 1975:1). Stone crabs are presently trapped commercially from Franklin County on Florida's northwest coast to the Indian River in Brevard County on the east coast. Most stone crabs harvested commercially are landed in west coast counties (Savage et al 1975:1). The value of the stone crab fishery to the State of Florida is considerable, ranking third in crustacean fisheries behind the shrimp and lobster industries in total revenues (Savage & Sullivan 1978:1). Commercial landings of stone crab from Florida's west coast declined from 2.5 million pounds in 1974 to 2.1 million pounds in 1975 (NMFS 1977-1978). With the exception of 1974-1975, stone crab landings and dollar values increased steadily from 1966 to 1973 (NMFS 1969-1978). A recreational fishery, of unknown magnitude, also exists for the stone crab in Tampa Bay.

5.2.4.2 Life History Data

Geographically, the stone crab ranges from North Carolina to southern Florida, the Florida Keys, and southwest Florida to southern Texas; the species also occurs off the Yucatan Gulf Coast, the Bahamas, Jamaica, and the northern coast of Cuba (Rathbun 1930:472-477; Williams 1965:185; Powers 1977:96).

The stone crab inhabits the brackish waters of estuaries and the shoreline of bays to depths of 51 m (Powers 1977:96). The species occurs throughout the Tampa Bay area, primarily in deeper waters; temperature and salinity ranges associated with the collection of juveniles and adults were 15.4 to 29.7°C and 23.6 to 33.2 ppt (Dragovich & Kelly 1964:83). Ovigerous females migrate offshore to spawn throughout spring and summer (Futch 1966:4); however, in the Cedar Key area it appears that females remain in their grass-flat habitat, spawning March through October (Bender 1971:ix). In North Carolina waters, spawning occurs from May through July or August (Williams 1965:185).

The stone crab female is known to produce as many as 6 egg masses within a period of 69 days, each containing 0.5 to 1.0 million

eggs (Binford 1912:18). Laboratory observations by Porter (1960:169) indicate that a stone crab can produce as many as four egg masses as little as 1 week apart; during this period temperatures ranged from 27 to 31°C, and no intervening molts or matings were observed. Thorhaug et al (1971a; 1972:IX.2) indicate that egg mortality occurs at temperatures above 36°C. Stone crab larvae hatch approximately 2 weeks after spawning (Porter 1960:169).

The first larval stage, protozoea, has a relatively short duration, ranging from several seconds to a few minutes (Hyman 1925:14; Porter 1960:169). The stone crab larva then passes through five or six zoeal stages, each lasting 3 to 6 days (Porter 1960:169). Transformation to the megalopal stage occurs 14 to 19 days after hatching (Ong & Costlow 1970:29; Porter 1960:169). Upon molting of the megalopa 21 to 27 days after hatching, the true crab form is assumed; this is the early juvenile or first crab stage (Ong & Costlow 1970:29; Porter 1960:169).

During the period of larval development, molting larvae are fragile and intolerant of sudden fluctuations of temperature and salinity (Futch 1966:4); upper lethal limits (24-hour exposure) during metamorphosis are 30.5 to 31.4°C for zoea/megalopa and 28.9 to 30.5°C for megalopa/juveniles (Thorhaug et al 1972:IX.1). Larval survival increases with increased temperature (20-30°C) and salinity (10-40 ppt) (Ong & Costlow 1970:28). At temperatures below 26°C and salinities less than 27 ppt, larval development may not be completed (Porter 1960:170, 176). Ong and Costlow (1970:29) indicate 30°C and 30 to 35 ppt as optimal for the survival and development of stone crab larvae. Thorhaug et al (1971a; 1972:IX.1) indicate temperatures above 33°C are lethal to the larval stages.

Stone crab larvae have been collected in the Anclote area at water temperatures ranging from 16 to 31°C (salinities 27 to 35 ppt) with peak densities occurring at temperatures ranging from 29 to 31°C (salinities 31 to 34 ppt) (FPC 1977a:V.170-V.171).

In the Anclote area, zoea were collected March to November with peak densities July to September, and megalops were collected May to November with peak densities in July (FPC 1977a:V.170). Menippe zoea were present May to October in the lower St. Johns River (Tagatz 1968a:25). Maturo et al (1974:IV.19) found "stone crab-like" larvae most abundant in the summer.

Juveniles continue to molt and grow as they move inshore; upon attaining a carapace width of about 10 mm, they migrate into bays and estuaries where the water is shallower and less saline (Williams 1965:184; Futch 1966:5). Here, they may be found among oyster shells, and on rocks and pilings (Hay & Shore 1918:439).

A preference for turtle grass has been reported in northwestern Florida waters (Wass 1955, cited in Williams 1965:184). Other xanthid crabs are similar in appearance to the juvenile stone crab; these are sometimes collectively known as mud crabs or oyster crabs (Futch 1966:3,4). Juveniles maintained in the laboratory have an average intermolt of 40 days (Savage & McMahan 1968:2). Molt inhibition occurs at a threshold temperature of 15°C (Cheung 1969:343). Bender (1971:32) found juvenile survival enhanced by temperatures greater than 20°C and salinities above 23 ppt. Transition to the adult stage is reached when the juvenile has a carapace length measuring 20 to 30 mm (Savage & McMahan 1968:2, 3; Manning 1960:273).

Tabular presentation of thermal effect data on the stone crab during various phases of its life cycle is provided in Appendix 6 (Table A6-4).

As adults, they move into shoals just below the low-tide mark and burrow obliquely 25 to 50 cm into the substrate (Williams 1965:184; Futch 1966:5). Within colonized areas, these burrows can be quite closely spaced, some no more than 20 to 30 cm apart (Powell & Gunter 1968:286). Powell and Gunter (1968:288) observed that many commensal organisms are found in or adjacent to these burrows; these include mollusks, decapods, and tube worms, as well as some fishes.

The growth rate of adult stone crab decreases with increased size (Savage & Sullivan 1978:10). Sexual maturity is attained approximately 10 months after hatching, and the adult reaches commercial size within 30 months (Savage & Sullivan 1978:13). Males may greatly outnumber females; in the vicinity of Port Aransas, Texas, stone crabs were collected December through August with sex ratios ranging from 2.6:1 to 5.2:1 (Powell & Gunter 1968:289).

The food of the stone crab consists principally of mollusks, including oysters and clams (Williams 1965:185). Laboratory observations by Menzel and Hopkins (1956, cited in Williams 1965:185) indicate an average of 219 oysters per adult crab per year; a spawning female consumes about 40 clams during a 32-day period. It is not uncommon for stone crabs to take chunks of meat used as bait, and, therefore, it is inferred they are scavengers (Powell & Gunter 1968:297). Cannibalism has been observed, at least in the laboratory (Powell & Gunter 1968:296).

5.2.5 Bay Anchovy: Anchoa mitchilli (Valenciennes); Engraulidae

5.2.5.1 Rationale for Selection

The species was abundant in all studies at Big Bend. Bay anchovies are susceptible to entrainment and impingement impacts as well as thermal impact. Its eggs and larvae were collected more often than those of any other fish species in both open bay ichthyoplankton sampling and entrainment monitoring studies. Bay anchovies were more abundant in trawl catches than in seine catches, and were the second-most abundant RIS collected during fish impingement studies.

The bay anchovy is the most abundant fish species in Tampa Bay and the Gulf of Mexico but has no commercial value (Godcharles 1980b; Rounsefell 1975:356). It is not an important food fish in the U.S. (Hildebrand & Cable 1930:388). The bay anchovy's importance is derived from the fact that it is an abundant forage species and constitutes an important portion of the diet of many larger commercially harvested fishes (FPC 1977b:VII.124; Rounsefell 1975:356).

5.2.5.2 Life History Data

The bay anchovy ranges along the Atlantic coast from Maine to Florida and through the Gulf of Mexico (Briggs 1958:254; Hoese & Moore 1977:137). The species is rarely found north of Massachusetts (Hildebrand & Schroeder 1928:110); individuals north of Cape Cod are described as "stragglers" by Bigelow and Schroeder (1953:119). In Gulf waters, the bay anchovy is rarely found in the Florida Keys and Yucatan (Hoese & Moore 1977:137).

The bay anchovy is extremely common, but somewhat restricted to bays and inshore areas (Hoese & Moore 1977:137). It is abundant along inshore areas with silt and sand bottoms (Gallaway & Strawn 1974:95; Bigelow & Schroeder 1953:119; Simmons 1957:182), in muddy coves and even freshwater streams (Hildebrand & Schroeder 1928:110), and around islands and tidal flats (Simmons 1957:182). Other investigators have reported the bay anchovy to be common in open waters (Joseph & Yerger 1956:122; Gunter 1945:34, 35; Reid 1954:18), but these observations are contradicted by Tampa Bay data (Springer & Woodburn 1960:21).

No extensive migratory patterns are exhibited by the bay anchovy; generally, only inshore-offshore movements occur (Hildebrand 1963:178, cited in FPC 1977b:VII.124). Bay anchovies are considered a year-round resident throughout most of their range. They are generally most abundant during the summer and fall as a result of juvenile recruitment, and least abundant inshore during the winter due to their movement to deeper waters.

The bay anchovy has been collected at water temperatures ranging from 0°C (Dovel 1971:47) to 34.9°C (Perret et al 1971:44, cited in FPC 1977b:VII.125). The species occurs within Tampa Bay at temperatures between 10.8 and 32.5°C (Springer & Woodburn 1960:21). In studies conducted in the area of a thermal discharge in Galveston Bay (Texas), bay anchovies were most abundant at temperatures between 24.5 and 33°C with reduced numbers up to 37°C (Gallaway & Strawn 1974:95). Laboratory experiments indicate higher temperature preferences at low salinities (4.0-4.5 ppt) than at high salinities (27-29 ppt) (Meldrim & Gift 1971:27; Terpin et al 1977:26). At high salinities (27-29 ppt), the acclimation temperature does not significantly affect the preference temperature (Terpin et al 1977:10). Salinity apparently does not affect avoidance temperatures (Meldrim & Gift 1971:34; Meldrim et al 1974:41; Terpin et al 1977:37). Avoidance temperatures increased directly in relation to acclimation temperatures below 20°C, but avoidance temperatures (30-33°C) were unrelated to their acclimation temperatures (20-27°C) (Meldrim & Gift 1971:34; Meldrim et al 1974:41; Terpin et al 1977:37).

The bay anchovy is found in a range of salinities from freshwater to saltwater. Simmons (1957:182) found bay anchovies in salinities up to 75-80 ppt, but most were taken at salinities below 50 ppt. Gunter and Hall (1965:21, 22) reported taking bay anchovies from the Caloosahatchee River estuary at salinities less than 0.2 ppt. According to Massmann (1954:76, cited in Mansueti & Hardy 1967:86), bay anchovies were present in freshwater approximately 64 km upstream of brackish water. In Tampa Bay, the species occurs at salinities between 5.0 and 35.0 ppt (Springer & Woodburn 1960:21).

Spawning is protracted year-round in warmer waters (Hoese & Moore 1977:275), but is restricted to the warmer months (April-June through August-September) in its northern range (Austin 1974:22; Dovel & Wiley 1973, cited in Liden & Burton 1978:23; Lippson & Moran 1974:60). Spawning generally occurs in the evening, between 1800 and 2100 hour (Kuntz 1914:13; Hildebrand & Cable 1930:389) at temperatures from 9 to 31°C (Dovel 1971:44). Bay anchovy eggs were collected in Tampa Bay from February through November (TECO 1977e:5.56).

The egg of the bay anchovy is perfectly transparent with no oil globule and is slightly elongated in shape (Kuntz 1914:14). Egg size decreases as salinity increases: mean measurements (major axis x minor axis) range from 1.12 x 1.04 mm at 5 ppt to 0.95 x 0.89 mm at 20 ppt (Dovel 1971:61). The eggs are buoyant when spawned, but 12 to 16 hours after fertilization, they begin to sink (Kuntz 1914:14); the eggs are most abundant at depths less than 20 m (Richards 1959:109). The eggs hatch within 24 hours at temperatures between 20 and 28°C (Hildebrand 1963:178, cited in FPC 1977b:VII.125; Detwyler & Houde 1970:214;

Kuntz 1914:3). Bay anchovy eggs have been collected at temperatures from 9.7°C (Dovel 1971:8) to 30°C (Dovel & Wiley 1973, cited in Liden & Burton 1978:23), although most eggs are found at temperatures greater than 20°C (Dovel 1971:6).

The larva is highly transparent and measures 1.8 to 2.7 mm in length at hatching (Kuntz 1914:16; Detwyler & Houde 1970:215). The yolk sac is absorbed 15 to 25 hours after hatching (Houde 1974:271; Kuntz 1914:16). Laboratory observations indicate growth rates ranging from 0.48 to 0.54 mm/day (Saksena & Houde 1972:249) to 0.70 mm/day (Detwyler & Houde 1970:216) and 9 to 10 mm/month (Perlmutter 1939:18; Stevenson 1958:21). Bay anchovy larvae occur in salinities ranging from 1 ppt (Dovel 1971:6) to 35 ppt (Jones et al 1978:160). Laboratory experiments indicate survival at incubation and maintenance temperatures greater than 15.1°C and less than 35.8°C; no significant difference between temperature and survival was observed at temperatures ranging from 18.6 to 32.5°C (Rebel 1973:22).

Tabular presentation of thermal effect data on the bay anchovy during various phases of its life cycle is provided in Appendix 6 (Table A6-5).

Transformation to the juvenile stage is completed before the individual reaches 22.5 mm SL (Jones et al 1978:161). Their rate of growth is estimated at 3 to 4 mm/week (Stevenson 1958:1). Young-of-year length frequency distribution is confounded by the protracted spawning, as evidenced by data from Long Island Sound (Perlmutter 1939:40), Delaware Bay (Stevenson 1958:16-21), Corpus Christi Bay (Gunter 1945:34, 35), and Tampa Bay (Springer & Woodburn 1960:21). Hildebrand (1963:177, cited in FPC 1977b:VII.125) suggests that the bay anchovy attains a greater maximum size in northern populations (100 mm from North Carolina waters) than southern populations (75 mm from Gulf waters); however, more recent investigations (Gallaway & Strawn 1974:90) report a maximum length of 94 mm from a Galveston Bay, Texas, study; whereas 86 mm was the maximum length recorded from an extensive Delaware Bay study (Stevenson 1958:20).

Two and sometimes three-year classes are found year-round in Gulf waters (Gunter 1945:35; Springer & Woodburn 1960:21), indicating they live to age II and possibly beyond. Sexual maturity is attained at a length of 35 to 40 mm in Delaware Bay (Stevenson 1958:2), 40 to 50 mm in Chesapeake Bay (Hildebrand & Cable 1930:395; Dovel 1971:9), 45 to 60 mm in North Carolina waters (Hildebrand 1963:178, cited in FPC 1977b:VII.125), and 56.3 mm (male) and 60.0 mm (female) in Texas waters (Gunter 1945:34). In northern waters, there is evidence that all fish spawned during the previous summer mature sometime during the next summer (Stevenson 1958:22); some individuals which spawned early in the season may possibly breed at the end of the season (Dovel

1971:10), 2.5 to 3 months after hatching (Hildebrand & Cable 1930:395).

Fecundity is positively correlated (significantly) to body size (Stevenson 1958:32); the mean fecundity of bay anchovy examined by Stevenson is estimated at 34,300 eggs/female, though Stevenson indicated that only 7 percent of these (2,400 eggs) are actually spawned. Generally, females outnumbered the males, but as spawning approached, the sex ratio narrowed to about 1:1 (Stevenson 1958:2).

The bay anchovy is a planktivorous schooling fish. Larval feeding experiments by Detwyler and Houde (1970:216) indicate that the average size of food increases exponentially as larval length increases. Bay anchovy larvae at a length of 3.4 mm begin feeding on copepod nauplii, but at a length less than 9 mm they cease feeding on nauplii and select larger prey. At 15 to 20 mm their diet is predominantly veliger larvae, but copepods become increasingly important (Detwyler & Houde 1970:217). Young bay anchovies (20-30 mm) feed principally on copepods (Hildebrand & Schroeder 1928:110; Stevenson 1958:2; Darnell 1958:365, 367), but this may be supplemented by rotifers, mysids, crab larve, small gastropods, and ostracods (Hildebrand & Cable 1930:395; Carr & Adams 1973:515; Darnell 1958:365, 367; Stevenson 1958:2). Adults continue to feed on copepods, but other food items are consumed in progressively greater amounts: gastropods, ostracods, annelids, mysids, pelecypods, amphipods, schizopods, larval and postlarval penaeids, and larval fishes (Darnell 1958:365, 367; Subrahmanyam & Drake 1975:456; Reid 1954:18; Springer & Woodburn 1960:21; Hildebrand & Schroeder 1928:110; Stevenson 1958:2, 3; Hildebrand & Cable 1930:395). An analysis comparing the size of organisms contained in the stomachs of captured juvenile and adult specimens to the morphology of their gill rakers indicates that the bay anchovy may actively select larger food organisms (Stevenson 1958:3).

The bay anchovy is an important link in the food chain because it constitutes a major portion of the diet of species at higher trophic levels (Rounsefell 1975:356; Hildebrand & Schroeder 1928:110; Dovel 1971:10). It is considered a warm water forage species frequently preyed on by aquatic birds and predatory fishes (Dovel 1971:10) including the spotted sea trout (Carr & Adams 1973:525; Tabb 1961:19) and the silver perch (Chao & Musick 1977:691; Hildebrand & Schroeder 1928:280).

5.2.6 Scaled Sardine: Harengula jaguana Poey; Clupeidae

5.2.6.1 Rationale for Selection

The scaled sardine is very common in the Tampa Bay area. Adults spawn in the ocean and their young mature there and in estuaries. Scaled sardines are susceptible to entrainment and, to a lesser

extent, thermal impacts. They were common in both open-bay ichthyoplankton sampling and entrainment studies at Big Bend. Though abundant in seine studies, the number collected during impingement monitoring at Big Bend was considered negligible.

The scaled sardine is commonly used as bait by sport fishermen in Florida, and supports a small commercial fishery for that purpose (Martinez & Houde 1975:35). In the Miami area they are caught with lift nets around piers and bridges in the fall and winter and sold as live bait (Klima 1959, cited in Klima 1971:23). Commercial catch statistics for the U.S. are not reported (NMFS 1973-1978), but according to Houde (1977a:613) a small amount, probably less than 500 tons annually, is landed in Florida for bait in commercial and recreational fishing. Because of its abundance, the scaled sardine is an important latent fishery resource in the Gulf of Mexico and Caribbean region (Klima 1971:23; Martinez & Houde 1975:35). The scaled sardine is also an important forage fish (Klima 1959, cited in Houde et al 1974:1106).

5.2.6.2 Life History Data

The scaled sardine is a common clupeid in tropical western Atlantic waters (Rivas 1963:395, cited in Berry 1964:728); it occurs in coastal waters from New Jersey to Brazil, and is abundant within the Gulf of Mexico (Briggs 1958:253; Berry 1964:728; Klima 1971:21).

The scaled sardine is one of the most common species within Gulf estuaries (Gunter 1945:26; Springer & Woodburn 1960:18; Roessler 1970:867). The species is usually found within the 36-meter depth contour (Klima 1971:21). Springer and Woodburn (1960:18) indicate that the scaled sardine is one of the most abundant fish within the Tampa Bay area. Scaled sardine often school near the surface (Reid 1954:17; Klima 1971:21) and may be found in mixed schools with Atlantic thread herring (Fuss et al 1968, cited in Carr & Adams 1973:515). Along the Texas coast, larger fish are found in high-salinity open waters, while smaller fish are found in surf areas (Gunter 1945:25, 26). In the Biscayne Bay area, the species is present year-round (Low 1973:100); young scaled sardines occur in large schools over grassbed areas during spring and summer (Low 1973:107).

Adult/juvenile scaled sardine have been collected at water temperatures ranging from 15.5 to 34.0°C (Roessler 1970:883), although infrequently below 24°C (Gunter 1945:26). In the Tampa Bay area, scaled sardine have been collected at temperatures from 21.0 to 32.4°C, although a few specimens were taken incidentally at temperatures as low as 16.8°C (Springer & Woodburn 1960:19). Those captured near the Big Bend area at 14°C exhibited no apparent ill effects (TECO 1977e:5.63), even though this temperature is probably close to their minimum lethal

temperature. Scaled sardine have been collected in salinities ranging from 4.8 to 45.2 ppt (Gunter 1945:26; Roessler 1970:883), although very infrequently below 25 ppt (Gunter 1945:26; Springer & Woodburn 1960:19; Roessler 1970:864).

Mature adults, generally abundant in estuarine waters during the winter, move offshore to spawn during the spring and summer. In Tampa Bay, adults were absent from January to April; the young-of-the-year first appeared during May or June (Springer & Woodburn 1960:19). Similar observations have been made along the Texas coast (Gunter 1945:26) and near Cedar Key (Reid 1954:17). Adults were abundant within the Biscayne Bay area from October to May, moving to deeper waters from June through September (Martinez & Houde 1975:44). Spawning probably occurred principally offshore since eggs were collected from March to August off Miami near the edge of the Florida Current, though spawning was also observed within the Biscayne Bay area from late February through early May (Houde et al 1974:1108; Houde & Fore 1973:4; Martinez & Houde 1975:39, 44). This spawning period is also supported by gonad indices, which indicate spawning occurs from February to August with peak spawning occurring in April and May (Martinez & Houde 1975:39). In the eastern Gulf, eggs occur from January to September with peak abundance from May to August (Houde 1977a:614). Densities offshore were statistically greater than nearshore densities; most eggs occurred within 33 km of the coast in water 20 m or shallower and no eggs were found in waters exceeding a 30-m depth (Houde et al 1976:20; Houde 1977a:614).

Presumably, the scaled sardine spawns at night, since recently fertilized eggs are collected only at night (Houde et al 1974:1107; Houde 1977a:620). Although Martinez and Houde (1975:39) indicate that spawning occurs only once per season based on gonad indices, Gunter's (1945:27) data suggest two spawning peaks, spring and fall; this is supported, in part, by data from Tortugas (Longley & Hildebrand 1941:10, 11) and Tampa Bay (Springer & Woodburn 1960:19).

The eggs of the scaled sardine are buoyant, translucent, and colorless (Matsuura 1972:130). Spherical in shape (Matsuura 1972:130), the fertilized egg measures between 1.55 and 1.85 mm in diameter (Houde & Fore 1973:4; Houde et al 1974:1107). Upper and lower incipient lethal temperatures of the embryo are 35 and 20°C, respectively, according to Saksena et al (1972:693), and 36.5 and 14.9°C, respectively, according to Rebel (1973:17). Scaled sardine eggs have been collected at temperatures ranging between 19.2 and 30.7°C, but most are taken at temperatures greater than 24°C and salinities greater than 35 ppt (Houde 1977a:615, 616; Matsuura 1972:135). Hatching occurs within 24 hours at temperatures greater than 24°C (Houde 1977a:619). Survival from spawn to hatch is estimated at 9 to 15 percent (Houde 1977a:626).

Newly hatched larvae are pelagic, are 2.4 mm TL at hatching, and grow to about 4.0 mm TL within 15 hours (Houde et al 1974:1108; Houde 1977a:623). Yolk-sac absorption occurs within 36 to 48 hours after hatching, depending on temperature (Detwyler & Houde 1970:215; Houde et al 1974:1108). The growth rate is slow during the first 3 days, then rapid and temperature-dependent, ranging from 0.5 to 1.0 mm/day (Houde et al 1974:1108; Saksena et al 1972:693; Saksena & Houde 1972:249; Detwyler & Houde 1970:215, 216). Growth is linear to at least 32°C and considered optimal between 26 and 32°C (Saksena et al 1972:293, 294). Laboratory observations have indicated larval scaled sardine survive temperatures at least as high as 33.5°C (Saksena et al 1972:693). Rebel (1973:17, 19) reported larval survival at incubation and maintenance temperatures greater than 19.7°C and less than 35.0°C; upper and lower median tolerance limits were established as 31.4 and 24.6°C, respectively. Scaled sardine larvae (5 mm TL or less) have been collected at temperatures ranging between 18.4 and 30.5°C, but most are taken at temperatures greater than 24°C and salinities greater than 35 ppt (Houde 1977a:615, 616). Larval survival from spawn is estimated at 2 percent by 5.5 mm TL and less than 0.1 percent by 15.5 mm TL (Houde 1977a:626). Transformation to the juvenile stage occurs at 22 to 24 mm SL (Houde et al 1974:1120).

Tabular presentation of thermal effect data on the scaled sardine during various phases of its life cycle is provided in Appendix 6 (Table A6-6).

Growth is rapid; during the first year, individuals grow to an average of about 95 mm SL in Tampa Bay (Springer & Woodburn 1960:19) and between 100 and 130 mm in Buttonwood Canal (Roessler 1970:877). Based on gonad index values for both sexes, scaled sardines mature at between 78 and 85 mm SL (Martinez & Houde 1975:40). Most scaled sardines reach sexual maturity by age I, some during age 0, but all by age II (Martinez & Houde 1975:41); no specimens of age IV have been collected by previous investigations. Fecundity estimates range between 5,563 (85 mm SL) and 52,753 (143 mm SL) eggs per female (Martinez & Houde 1975:41); such estimates are correlated to age, growth, and weight (Martinez & Houde 1975:43). The sex ratio appears to be 1:1 (Martinez & Houde 1975:41).

Scaled sardines apparently feed at night (Starch & Davis 1966:316, cited in Moe 1972:9). Food of the scaled sardine includes principally zooplankton and small benthic organisms (Reid 1954:17). The stomach contents of juvenile/adult fish from Tampa Bay were found to consist primarily of mysids, gammarids, copepods, ostracods, and small mollusks (Springer & Woodburn 1960:19). In 21- to 30-mm SL specimens from the Crystal River area, Carr and Adams (1973:514, 515) indicated that diet consisted primarily of veliger larvae and increasing amounts of megalops larvae with the increasing size of the fish. In

Biscayne Bay, the diet of juveniles and adults was principally caridean shrimp (Low 1973:104).

Scaled sardine are important prey for larger fish (Martinez & Houde 1975:35). Roessler (1970, cited in Martinez & Houde 1975:35) indicates a positive correlation between catches of mangrove snappers and scaled sardine abundance. Klima (1959, cited in Martinez & Houde 1975:35) indicates that the fall run of Spanish mackeral coincided with peak seasonal abundance of clupeids; their diet consisted mainly of clupeids, particularly scaled sardine.

5.2.7 Tidewater Silverside: Menidia beryllina (Cope); Atherinidae

5.2.7.1 Rationale for Selection

It is one of the more common and ubiquitous species within Tampa Bay. Spawning preferences appear to be specific: ripe adult females and their eggs have been found in the brackish portions of estuaries in heavy vegetation and tree roots. Developing individuals do not appear to migrate far from these habitats, and adults are found in shallow estuarine areas.

The species was abundant in all parts of the sampling study, except impingement monitoring. Tidewater silversides are susceptible to entrainment, and to a lesser extent, thermal impacts.

Because of its small size, the tidewater silverside has no commercial importance; its chief value is as food for larger predatory fish (Hildebrand & Schroeder 1928:191).

5.2.7.2 Life History Data

This species occurs along the Atlantic coast from Massachusetts to Florida, and along the Gulf coast to Veracruz, Mexico (Briggs 1958:293; Hoese & Moore 1977:157; Hildebrand & Schroeder 1928:191). The tidewater silverside is an inshore species (Briggs 1958:293) inhabiting the shallows of bays (Gunter 1945:49); it is common in open waters, but prefers some form of shelter such as islands, piers, or oyster bars (Reid 1954:30). Along the Atlantic coast M. beryllina is occasionally found in association with M. menidia, the Atlantic silverside (Hildebrand & Schroeder 1928:191).

The species is considered euryhaline, capable of tolerating a wide range of salinities (Gunter & Hall 1965:30; Joseph & Yerger 1956:131). It occurs along the Texas coast at salinities between 0 and 75 ppt (Gunter 1945:49; Simmons 1957:183), but is more abundant at salinities less than 45 ppt (Simmons 1957:183). They are found in the Gulf at temperatures ranging from 5.0 to 34.9°C

(Martin & Drewry 1978:99) and have been collected in Galveston Bay (Texas) from a thermal discharge at temperatures as high as 39°C (Gallaway & Strawn 1974:104).

Spawning is protracted (Hoese & Moore 1977:277). Ripe specimens have been collected year-round in the Laguna Madre on the Texas coast (Simmons 1957:183) and all months except January and August in Tampa Bay (Springer & Woodburn 1960:81). Some reports of spring and fall spawning (Gunter & Hall 1965:29; Gunter 1945:49) suggest that this species may be capable of multiple spawnings, as also suggested by investigations along the Atlantic coast (Hildebrand 1922:118; Hildebrand & Schroeder 1928:191; Springer & Woodburn 1960:81). The spawning habitat is shallow with abundant vegetation (Hildebrand 1922:118). The spawning temperatures probably range between 18 and 30°C (Gunter 1945:49; Reid 1954:30; Garwood 1968:320).

Fecundity of the tidewater silverside is unknown (Martin & Drewry 1978:100); estimated mean fecundities for closely-related species range from an average of 500 eggs/female for M. menidia (Hildebrand 1922:114) to an estimated 984 eggs/female for M. audens (Mense 1967:20, 21). The female spawns the eggs in a transparent gelatinous mass with adhesive strands (Hildebrand 1922:120); these eggs are demersal and attached (Dovel 1971:10). The egg is not quite spherical, measuring 0.75 mm in diameter (Hildebrand 1922:120). Incubation time is temperature dependent; eggs hatch within 5 to 12 days at temperatures between 21 and 29°C (Martin & Drewry 1978:101; Rubinoff 1961:242-244; Hildebrand 1922:120; Hubbs & Drewry 1959:80; Hubbs 1967:53). The larvae measure 3.5 mm in length at hatching (Hildebrand 1922:120) and are very slender and highly transparent (Hildebrand & Schroeder 1928:191). In the Chesapeake Bay, larvae are common in the surface waters of offshore portions of the Bay, while the juveniles prefer low salinity areas inshore (Dovel 1971:10).

Tabular presentation of thermal effect data on the tidewater silverside during various phases of its life cycle is provided in Appendix 6 (Table A6-7).

Growth is rapid; a length of 75 to 85 mm is attained by the end of the first year (Springer & Woodburn 1960:81). Maximum length is approximately 95 mm in Florida waters (Springer & Woodburn 1960:81; Kilby 1955, cited in Texas Instruments, Inc. 1977:VII.12.51), only 72 mm along the North Carolina coast (Hildebrand 1922:118), and greater than 120 mm in the Laguna Madre area of Texas (Simmons 1957:183). The average length for females is greater than that for males (Hildebrand 1922:118; Hildebrand & Schroeder 1928:191). The sex ratio appears to be equal (Hildebrand 1922:118). The species matures within 1 year and lives through its second summer (Joseph & Yerger 1956:131) though few reach age II (Springer & Woodburn 1960:81).

Planktonic organisms, particularly small crustaceans, comprise the bulk of the tidewater silverside diet (Hildebrand 1922:118; Hildebrand & Schroeder 1928:191). As larvae and early juveniles, the tidewater silverside may be very dependent on veliger larvae (Carr & Adams 1973:530-532). Darnell (1958:375-378) and Carr and Adams (1973:530-532) found amphipods, isopods, mysids, insects, and crab megalops increasingly important to the diet of the tidewater silverside as it increases in size. Other researchers have found small mollusks, annelid worms, algae, and small fish (Hildebrand 1922:118; Hildebrand & Schroeder 1928:191; Springer & Woodburn 1960:83; Reid 1954:30).

The tidewater silverside is reported to be a common food item in the diet of other estuarine fishes (Simmons 1957:183); according to Breuer (1957:149), it represents a major portion of the 2- to 4-year-old spotted seatrout diet. Some aquatic birds may also be important predators; Allen (1942, cited in Gunter 1945:49) observed spoonbills feeding extensively on the killifish and tidewater silverside.

5.2.8 Silver Perch: Bairdiella chrysura (Lacepede); Sciaenidae

5.2.8.1 Rationale for Selection

The silver perch is a moderately abundant inhabitant of Tampa Bay. The adults spawn in estuaries where development of young also occurs. Silver perch are susceptible to entrainment and impingement impacts and, to a lesser extent, to thermal impact. Entrainment monitoring studies at Big Bend suggest the eggs of this species were entrained in larger numbers than those of any other sciaenid. Larvae were also numerous. This species was the most abundant RIS collected during fish impingement studies.

Because of its relatively small size, commercial landings of silver perch are relatively small (Chao & Musick 1977:675), and since it is not highly thought of as a food fish, its economic value is slight (FPC 1977b:VII.97). The major importance of silver perch lies in its position as a higher level predator in the food chain (FPC 1977b:VII.97).

5.2.8.2 Life History Data

The silver perch is distributed in the western Atlantic and Gulf of Maine from Massachusetts to Texas, widespread in the Gulf of Mexico, and very abundant from New Jersey to North Carolina (Hildebrand & Schroeder 1928:281; Hildebrand & Cable 1930:411; Briggs 1958:281; Hoese & Moore 1977:206). Adults are most common in bays and quiet lagoons, especially around estuaries (DeSylva 1965:223), and over mud and sand bottoms (Robins & Tabb 1965:497). Silver perch move to deeper bay waters and offshore

waters in winter, returning in spring to spawn (Gunter 1945:326; DeSylva 1965:223).

Investigations along Florida's west coast indicate for the silver perch a varied pattern of seasonal abundance (Reid 1954:48, 49; Joseph & Yerger 1956:137; Tabb et al 1962, cited in Johnson 1978:172; Roessler 1970:865; FPC 1977b:VII.94; Grimes & Mountain 1971:19). The species ranked third in abundance in investigations offshore Tampa Bay (Moe & Martin 1965:138). In Tampa Bay, it was most abundant from May through October but absent during April (Springer & Woodburn 1960:49).

The species is collected at temperatures ranging from 7.5°C (Dahlberg 1972:341) to 34.0°C (Roessler 1970:884); however, cold kills have been reported at temperatures even within the species' known tolerances (Gunter & Hildebrand 1951; Gunter 1945:66; Springer & Woodburn 1960:50; Moore 1976:462). Laboratory observations indicate a critical thermal maximum at temperatures greater than 34°C (Gift & Westman 1971:47). Adults are considered euryhaline (Gunter 1945:66; DeSylva 1965:223), and are taken in salinities between 0 and 48 ppt (Roessler 1970:884).

Spawning occurs May-June through September in northern Florida (Kilby 1955, cited in Jannke 1971:30; Joseph & Yerger 1956:137; Reid 1954:48, 49); similar observations have been made in other parts of Florida (Springer & Woodburn 1960:49, 50; Grimes & Mountain 1971:19-22; FPC 1977b:VII.95; Moe & Martin 1965:138). Sciaenid eggs were found in peak abundance in the March to September period in the Big Bend area (TECO 1977e).

Spawning occurs primarily in bays and coastal lagoons (Thomas 1971:40; Gunter 1945:66; Springer & Woodburn 1960:49, 50; Hildebrand & Cable 1930:411) and to some extent offshore, as eggs have been taken as far as 19 to 24 km off North Carolina (Hildebrand & Cable 1930:411). Spawning apparently occurs in the evening (Kuntz 1914:3). Ripe individuals or eggs are taken at temperatures from 19.4 to 28°C (Miller 1965:91; Kuntz 1914:3) and salinities 14.3 to 26 ppt (Gunter 1945:66; Thomas 1971:40).

The eggs are pelagic and spherical in shape, measuring between 0.66 and 0.88 mm in diameter (Welsh & Breder 1923:171; Joseph et al 1964:432; Kuntz 1914:4). Hatching requires approximately 18 hours at 27°C in the laboratory (Kuntz 1914:3). The incubation period is temperature-dependent; 40 to 50 hours at 18 to 21°C (Welsh & Breder 1923:171, 174) as compared to 18 hours at higher temperatures (Kuntz 1914:4). Larvae measure between 1.5 and 1.9 mm in length (Welsh & Breder 1923:171; Kuntz 1914:9). The yolk sac is absorbed by the second day at a length of 2.5 to 2.8 mm (Kuntz 1914:11). Larvae are taken at temperatures between 16.4 and 31.8°C (Jannke 1971:71) and salinities between 2 and 37.4 ppt (Dovel 1971:37; Jannke 1971:69). Transformation to the

juvenile stage occurs at a length of about 30 mm (Welsh & Breder 1923:174; Kuntz 1914:13).

Juveniles are generally taken along the shore zone of rivers, in ditches, and in lower portions of marsh creeks over mud or mud-sand bottoms (Hoese 1973:83; Merriner et al 1976:285; Thomas 1971:44, and often in very turbid water with heavy detritus (Hildebrand & Cable 1930:411). They enter estuaries from late spring to early summer (Hildebrand & Schroeder 1928:280; Markle 1976:55). Juveniles are taken at temperatures between 4.8 and 32.5°C at salinities between 0 and 35 ppt (Thomas 1971:44; Springer & Woodburn 1960:50).

Silver perch attain a length of about 140 mm SL by the end of their first year, and perhaps an additional 60 mm during their second year. Sexual maturity is reached after the second year at a length of 150 to 210 mm SL (Welsh & Breder 1923:174; Hildebrand & Schroeder 1928:280). Fecundity of a mature female (140 mm SL) is estimated at 52,800 eggs (Hildebrand & Schroeder 1928:280). According to Moe and Martin (1965:138), longevity is slightly more than 2 years; however, older fish, including a 230 mm specimen (age VI), have been reported (Welsh & Breder 1923:174).

Tabular presentation of thermal effect data on silver perch during various phases of its life cycle are provided in Appendix 6 (Table A6-8).

Silver perch are strictly carnivourous and appear to be noctural feeders (Adams 1976:516). They feed primarily near the bottom, consuming large quantities of small crustaceans and smaller quantities of insect larvae, annelids, mollusks, and small fish (Thomas 1971:50; Linton 1905, McLane 1955, and Odum 1971, cited in Carr & Adams 1973:523; Darnell 1958:381,382; Hildebrand & Schroeder 1928:280; Adams 1976:516; Welsh & Breder 1923:175; Reid 1954:49; Springer & Woodburn 1960:52). The diet of young silver perch (less than 50 mm) is composed almost exclusively of planktonic copepods, but these are replaced by mysids, larval shrimp, and polychaetes as perch size increases; in larger silver perch (greater than 50 mm), gammarid amphipods, small crabs, annelids, shrimp, and small fish become increasingly important (Stickney et al 1975:110; Hildebrand & Cable 1930:415; Carr & Adams 1973:524; Darnell 1958:381, 382). Bay anchovies are frequently among the small fish consumed by silver perch (Chao & Musick 1977:691; Hildebrand & Schroeder 1928:280); cannibalism has also been noted (Carr & Adams 1973:524).

5.2.9 Spotted Seatrout: Cynoscion nebulosus (Cuvier); Sciaenidae

5.2.9.1 Rationale for Selection

The sciaenid species is an estuarine breeder, preferring grassy areas or channels. Spotted seatrout are susceptible to entrainment and, to a lesser extent, thermal impacts. The species was abundant in open bay ichthyoplankton and entrainment collections. Spotted seatrout were not frequently collected in seines, and were not among the most abundant fish impinged during the monitoring study.

The spotted seatrout is the most valuable sciaenid landed in Florida. Approximately 65 percent of all spotted seatrout landed in the U.S. comes from Florida, with 80 percent of this production coming from Florida's west coast (Futch 1970:1). Commercial landings of spotted seatrout from the west coast of Florida remained relatively constant averaging 2.2 million pounds from 1970 to 1975 (NMFS 1973-1978). Landings from the Gulf of Mexico declined from 7.4 million pounds in 1973 to 6.2 million pounds in 1975 (NMFS 1976, 1978). In addition to being commercially valuable, the spotted seatrout is highly prized as a game fish (Moffett 1961:7). Anglers land more spotted seatrout than any other fish from Florida waters (Futch 1970:1; Moffett 1961:7).

5.2.9.2 Life History Data

The spotted seatrout occurs on both sides of the Atlantic. Along the western Atlantic, the species ranges from New York to Florida and throughout the Gulf of Mexico (Briggs 1958:281; Hoese & Moore 1977:204,205; Hildebrand & Schroeder 1928:299). They are abundant inshore and in estuarine areas, usually over grass flats or deeper areas, sometimes over oyster reefs, but relatively uncommon in bayous (Reid 1954:53; Hoese & Moore 1977:204, 205; Tabb 1958:3; Springer & Woodburn 1960:52; Moody 1950:156). They are rarely taken in turbid waters (Gunter & Hall 1965:42) or from depths greater than 20 m (Tabb 1958:2). They are present from May to January in Tampa Bay (Springer & Woodburn 1960:52).

Spotted seatrout have been reported in salinities ranging from freshwater (Herald & Strickland 1949:107; Tagatz & Dudley 1961:9) to hypersaline conditions at 75 ppt (Simmons 1957:185). Despite this wide range, Breuer (1957:149) reported their absence at salinities greater than 55 ppt, and Tabb (1966:63) noted that they were most abundant in salinities between 15 and 53 ppt, and moved offshore when salinities dropped below 5 ppt. Spotted seatrout are found in temperatures ranging from 4°C (Simmons 1957:185) to 34.9°C (Reid 1954:53; Gunter 1945:76). In the Tampa Bay area, the species has been collected at temperatures between 14 and 33°C (Springer & Woodburn 1960:52). Occasional mass mortalities have resulted from exceptionally severe cold waves

(cold kills), possibly as a result of poor access to deeper water (Moore 1976:462; Schwartz 1964:184; Hildebrand & Cable 1934:92; Stewart 1961:25; Tabb 1958:398 and 1966:64; Guest & Gunter 1958, cited in Johnson 1978:181 Miles 1951:8). They are said to prefer stable temperatures between 15 and 26°C (Tabb 1958:399).

The species is essentially nonmigratory (Futch 1970:5; Moffett 1961:6; Tabb 1966:66). Several tagging studies have been conducted along the Gulf coast of Florida; in each of these studies, most of the spotted seatrout were recaptured within 5 miles of the release point and nearly all within 48 km (Beaumariage 1969:28; Ingle et al 1962:19, 36, 48; Topp 1963:22). The results of these tagging studies have led several researchers to suspect the existence of localized subpopulations (Iversen & Tabb 1961, cited in Ingle et al 1962:36; Topp 1963:22).

The spotted seatrout spawns in less turbid portions of estuaries and nontidal lagoons along the deeper channels adjacent to vegetated shallows (Futch 1970:3; Gunter 1945:77; Tabb 1961:19; Breuer 1957:150); however, there is some indication that the species sometimes wanders into brackish areas and may even prefer areas close to the entrances of bays and lagoons (Pearson 1929:180,181, 190,191). Larger fish are sometimes found in small schools prior to, or during, spawning (Pearson 1929:191). Spawning is known to occur at water temperatures ranging from 24 to 30°C (Jannke 1971:71,72; Stewart 1961:77). Tabb (1958:397) reported that spawning was first observed when water temperatures averaged 25.5°C and was completed at an average temperature of 28.5°C.

Peak spawning in the Indian River area occurs during the dry spring months when salinities have risen to 30-35 ppt in the estuaries and lagoons. Spawning generally occurs from March through October in Florida waters (Klima & Tabb 1959:19; Moffett 1961:28; Moody 1950:157; Tabb, unpublished citation in Klima & Tabb 1959:19), although there is some indication that spawning may occur year-round (Jannke 1971:38). Peak spawning generally occurs within the first 2 or 3 months of the spawning period (Jannke 1971:33; Moffett 1961:28; Pearson 1929:180,181). Each individual probably spawns over a period of several weeks (Pearson 1929:180,181).

The eggs of the spotted seatrout are initially buoyant (Pearson 1929:180,181), but the specific gravity increases with development and they begin to sink (Guest & Gunter 1958:12). The eggs become demersal after about 12 hours (Miles 1951:4; Fable et al 1978:66). The egg measures between 0.7 and 1.1 mm in diameter (Guest & Gunter 1958:12; Tabb 1966:62; Miles 1951:4). The incubation time probably decreases as the temperature increases: 21 hours at 23°C, 18 hours at 25°C, and 15 hours at 27°C (Fable et al 1978:66), but Smith (1907:312) reported 40 hours at 25°C. Larval length ranges between 1.46 mm (Fable et al 1978:67) and

1.75 mm (Guest & Gunter 1958:12) at hatching. Absorption of the yolk sac occurs about 64 hours after hatching at a length of 2.1 mm SL (Fable et al 1978:68). Transformation to the juvenile stage occurs at a length of 10 to 12 mm SL (Johnson 1978:183).

Larvae are collected at water temperatures ranging from 16.4 to 31.8°C (Jannke 1971:72). In the Anclote area, larvae are collected from March to September (NUS 1977, cited in FPC 1977b:VII.99). Small larvae (less than 5 mm) are collected predominantly offshore, while larger larvae occur more inshore (Hildebrand & Cable 1934:101,102) scattered over aquatic vegetation or shell rubble for a period of several weeks (Tabb 1966:63). The young often spend their first year in or near grass beds (Hoese & Moore 1977:204, 205; Moody 1950:156; Futch 1970:3; Pearson 1929:182). Approximately 6 to 8 weeks after hatching, the young spotted seatrout begin to form small schools (Moody 1950:156; Tabb 1966:63). In Alligator Harbor, Florida, young are commonly taken in open water and tidal streams (Joseph & Yerger 1956:136). The young are generally first collected during June in Tampa Bay (Springer & Woodburn 1960:52).

Tabular presentation of thermal effect data on spotted seatrout during various phases of its life cycle is provided in Appendix 6 (Table A6-9).

The growth rate for spotted seatrout varies throughout its range (Futch 1970:4; Tabb 1958:398). The rate of growth is greater for females than for males (Moffett 1961:6; Tabb 1961:14; Moody 1950:164). Most individuals weighing more than 2.7 kg are female (Tabb 1961:14). The spotted seatrout measured 11 to 16 cm in length by the end of the first year, 23 to 28 cm by the end of the second year, 30 to 37 cm by the end of the third year, and grow perhaps 5 to 7 cm/year thereafter (Welsh & Breder 1923:165; Pearson 1929:189; Sundararaj & Suttkus 1962:85; Tabb 1961:6; Tabb 1958:398). Mean adult length is estimated at 28.5 cm for females and 26.5 cm for males (Moody 1950:164).

Most of the males have died by the age of 5 or 6 years (Moffett 1961:6). Female longevity is estimated at 8 to 9 years (Moffett 1961:6; Pearson 1929:182), or perhaps 10 years (Tabb 1961:14). Sundararaj and Suttkus (1962:84, 85) estimate longevity at 5 years for females and 3 years for males. Excluding the first year (age group 0), about 90 percent of the females are evenly distributed between age groups I and III (Sundararaj & Suttkus 1962:87); these also represent the largest spawning classes (Guest & Gunter 1958:15).

Tabb (unpublished citation in Klima & Tabb 1959:16) reports a sex ratio of females to males of 1:7 for yearlings, but the ratio is nearly 1:1 by age III. A marked change in the sex ratio occurs after age III, in which the number of males diminishes rapidly (Tabb 1961:15); the ratio of females to males is nearly 8:1 by

age VI (Klima & Tabb 1959:16). For most of the population, it appears that the ratio of females to males is approximately 2:1 (Klima & Tabb 1959:16; Pearson 1929:190).

Sexual maturity occurs at the end of the second year or the beginning of the third year at 25 to 35 cm SL (Futch 1970:4; Tabb unpublished citation in Klima & Tabb 1959:20; Tabb 1961:17; Moody 1950:161-164; Pearson 1929:189). Approximately 10 percent of 1-year-olds mature at an average length of 16 cm SL, and 50 percent of the 2-year-olds at an average length of 25 cm SL (Guest & Gunter 1958:14; Tabb, unpublished citation in Klima & Tabb 1959:20). All females reach sexual maturity by the end of the second year at an average length of 27 cm SL, and all males at the end of the first year at an average length of 25 cm SL.

Fecundity of the spotted seatrout is highly variable, and generally increases with age, weight, and length. According to Miles (1951:4), only about one-third of the ova are fully developed and capable of being fertilized. Fecundity has been estimated at 464,000 (39.7 cm SL) in the Cedar Key area (Moody 1950:161); 15,000 to 1,118,000 (31.5-62.5 cm SL and age II-IX) in the Punta Gorda area (Pearson 1929:190; Tabb 1958:398; Tabb 1961:15); 100,000 to 1,500,000 eggs (from 25.4 cm SL and age II-VIII) in Texas waters (Miles 1951:4; Guest & Gunter 1958:13); and 140,000 to 1,444,000 eggs (28.3-50.4 cm SL and age I-IV) in Louisiana waters (Sundararaj & Suttkus 1962:85).

The spotted seatrout is carnivorous (Carr & Adams 1973:524); its diet is determined by the size and seasonal availability of food items (Futch 1970:4; Tabb 1961:19). In general, the diet is composed of crustaceans, with progressively increasing amounts of fish in the diet as growth occurs (Hildebrand & Schroeder 1928:296; Stewart 1961:86; Breuer 1957:150; Simmons 1957:185).

Small spotted seatrout (less than 15 cm) consume mysids, postlarval penaeids, copepods, carideans, and small fish including anchovies and silversides (Springer & Woodburn 1960:52, 53; Carr & Adams 1973:525; Futch 1970:4; Tabb 1961:19). In the Anclote area, 2- to 7-cm individuals fed on carideans and juvenile penaeids, while fish became increasingly important in the diet of 7- to 15-cm individuals (Dietz & Feinstein 1975:421). In Louisiana waters, 4- to 10-cm individuals fed on fish and secondarily on mysids and amphipods, while 10- to 15-cm individuals fed on fish and secondarily on penaeids (Darnell 1958:384-389).

In larger spotted seatrout (greater than 15 cm), the diet consists of copepods, mysids, carideans, penaeids, blue crab, and fish (Tabb 1966:61; Miles 1949:145, 146; Moody 1950:164-168; Gunter 1945:77; Breuer 1957:149; Pearson 1929:191, 192; Darnell 1958:384-389). The largest individuals feed most exclusively on fish (Darnell 1958:384-389), particularly mullet (Hoese & Moore

1977:205) and anchovy (Carr & Adams 1973:525; Tabb 1961:19). Breuer (1957:149) indicates that the tidewater silverside represents a major portion of the 2- to 4 year-old spotted seatrout diet. Large penaeids occassionally form part of their diet (Futch 1970:4). Cannibalism is also noted (Simmons 1957:185).

Competitors of the spotted seatrout include the sea catfish, grouper, red drum, spot, croaker, and southern rock bass. Predators include the bluefish, snook, tarpon, barracuda, Spanish mackeral, and king mackeral. The silver perch is considered both competitor and predator of young spotted seatrout (Klima & Tabb 1959:22).

5.2.10 Black Drum: Pogonias cromis Linnaeus; Sciaenidae

5.2.10.1 Rationale for Selection

Black drum are susceptible to entrainment and, to a lesser extent, thermal impacts. This sciaenid species was relatively abundant in ichthyoplankton collections in the vicinity of Big Bend, and was also numerous in the entrainment study. Only one specimen was collected during impingement monitoring, and a negligible number were found in seine and trawl studies performed at Big Bend (TECO 1977e).

The black drum attains its greatest abundance in the Gulf states, although it occurs in commercial quantities as far north as New York (Pearson 1929:175). The fishing industry has always avoided the drum because the larger adults are likely to become infested with parasitic worms, which virtually destroy the marketability of the fish unless the flesh is cut into fillets or steaks (Pearson 1929:175). Commercial landings from the Gulf Coast remained relatively constant from 1971 to 1974 averaging 1.9 million pounds, but dropped to 1.5 million pounds in 1975 (NMFS 1974-1977). Commercial landings from the west coast of Florida steadily declined from 96,000 pounds in 1972 to 35,000 pounds in 1975 (NMFS 1975-1978). According to the records of the U.S. Department of Transportation, there has been a decline of fishing vessels with home ports in the Gulf of Mexico from 317 vessels in 1971 to 121 vessels in 1975, which was a major factor in the decline of commercial landings (NMFS 1974-1978). The black drum is frequently taken by hook and line and provides a favored sport fishery (Springer & Woodburn 1960:63; TECO 1979: 2.7-54).

5.2.10.2 Life History Data

The species ranges along the western Atlantic from Massachusetts to Argentina (Briggs 1958:281; Hoese & Moore 1977:204; Hildebrand & Schroeder 1928:289), straying as far north as the Bay of Fundy (Bleakney 1963:173). They are most abundant off the Texas coast in the Corpus Christi Bay-Laguna Madre area

(Simmons & Breuer 1962:194; Breuer 1957:46). Black drum is the largest species of the drum family (Hoese & Moore 1977:204).

The species is found in bays and lagoons, as well as offshore waters (Simmons & Breuer 1962:194). Black drum prefer shallow, warm, and turbid waters with sandy or muddy bottoms (Jordan & Evermann 1896-1900:1482, 1483; Schwartz 1964:185).

Black drum are known to occur in waters ranging from 3 to 35°C (Simmons & Breuer 1962:200). Simmons and Breuer (1962:200) have noted that black drum move to deeper water with sudden temperature drops; cold kills are not uncommon to this species with sudden and prolonged cold waves. Meldrim and Gift (1971:29) reported a preference temperature as high as 36.0°C for young black drum. The species is considered euryhaline, (Simmons & Breuer 1962:200).

Black drum migrate northward and inshore along the mid-Atlantic coast each spring, retreating southward and offshore by late fall (Richards 1973:589). Tagatz and Dudley (1961:12, 17) collected black drum only offshore and during January. The Delaware and Chesapeake Bays are considered the northern spawning limit of the species (Frisbie 1961:99) where black drum occur from April to December (Hildebrand & Schroeder 1928:289).

In Gulf waters along the Texas coast, black drum are abundant within bays and lagoons during the fall and winter until nearly ripe and then migrate toward the entrances to spawn; after spawning, they quickly return to the bays and lagoons (Hoese 1965:37, 38; Miles 1950 and 1951, cited in Simmons & Breuer 1962:194; Pearson 1929:160). According to Simmons and Breuer (1962:194), spawning occurs in or near entrances to bays, in the Gulf, and all bay areas. Spawning is apparently protracted, from February to May or later (Gunter 1945:75; Pearson 1929:160; Breuer 1957:153). Ripe fish occur as early as December and as late as June (Simmons & Breuer 1962:194). It is estimated that 90 percent of the known spawning occurs during February and March (Simmons 1957:186; Simmons & Breuer 1962:194). However, length frequency analyses suggest a possible second spawning season in June and July or later (Pearson 1929:160; Simmons & Breuer 1962:195).

Tagging studies (Breuer 1957:153) indicate most black drum in Texas spawned in the locale, although some individuals migrated great distances to other recognized spawning grounds. Other tagging studies in this region found that nearly 60 percent of the returns were recaptured after 2 years within 5 miles of their release (Simmons & Breuer 1962:198, 200). Tag returns from Florida waters indicate less than 5 percent of the returns exhibited any significant movement (Beaumariage 1969:31, 34).

Eggs of the black drum are pelagic, measuring 0.8 to 1.0 mm in diameter (Joseph et al 1964:428). Hatching occurs in 24 hours at 20°C (Joseph et al 1964:428). Larvae measure 1.9 to 2.4 mm in length (0.7 to 0.8 mm width) at hatching (Joseph et al 1964:428). Absorption of the yolk sac occurs after the fourth day (Joseph et al 1964:428). At about 15 mm in length, the general adult shape is attained (Pearson 1929:156, 160; Johnson 1978:238).

Tabular presentation of thermal effect data on black drum during various phases of its life cycle is presented in Appendix 6 (Table A6-10).

The young appear to disperse inshore and upriver, and congregate over mud bottoms in areas with little or no current (Thomas & Smith 1973:129; Breuer 1957:153; Richards 1973:590; Baird et al 1972, cited in Texas Instruments, Inc. 1977:VII.12.98; Richards & Castagna 1970:235). Their movements are quite limited when food is abundant, and they often travel in large schools in search of food (Simmons & Breuer 1962:198). In Gulf waters, the young move to deeper portions of the bay and, to some extent, into the Gulf at about 100 mm SL (Pearson 1929: 172,173). In the Chesapeake and Delaware Bays, the young disperse downstream and throughout the bay during late summer (Thomas & Smith 1973:129), and the young apparently move offshore during late fall in response to low temperatures occurring within the bay (Frisbie 1961:99).

By age I, black drum average 160 to 250 mm SL; by age II, 310 to 406 mm SL; and by age III, 415 to 562 mm SL (Pearson 1929:162-170; Richards 1973:589; Simmons & Breuer 1962:196). Tagging returns indicate a net growth of at least 50 mm per year after the third year (Simmons & Breuer 1962:196). Longevity in the black drum may be 35 years or more (Richards 1973:590).

Sexual maturity is obtained within 1.5 to 2 years at an average length of 320 to 350 mm SL (Pearson 1929:170,171; Simmons & Breuer 1962:194; Breuer 1957:154; Miles et al 1952, cited in Breuer 1957:154). Fecundity is believed to be relatively high; for example, a female measuring 1,110 mm SL contains approximately 6,000,000 eggs (Pearson 1929:171).

Black drum are bottom feeders and their strong pharyngeal teeth enable them to crush shells (Simmons & Breuer 1962:198). Adults and older juveniles feed upon mollusks, crabs, and shrimp, whereas young juveniles feed on polychaetes, small fishes, and crustaceans (Gunter 1945:75; Breuer 1957:151; Simmons & Breuer 1962:196-198; Pearson 1929:174,175; Darnell 1958:398-400; Smith 1907; Welsh & Breder 1923:197). In Texas waters, Mulinia lateralis is a very abundant mollusk and is heavily fed upon by black drum (Breuer 1957:151; Pearson 1929:174,175). Black drum are also known to feed upon oysters (Welsh & Breder 1923:197) and are considered by oyster fishermen in some areas to be a serious pest (Moore 1907:63-65).

5.2.11 West Indian Manatee: Trichechus manatus Linnaeus; Trichechidae

5.2.11.1 Rationale for Selection

The manatee is a massive aquatic mammal that once ranged widely throughout the southeastern waters of the United States. Today its numbers are reduced to probably less than 1,000 individuals, and it has been placed on the Federal Endangered Species List.

Cold air temperatures seem to stimulate the formation of manatee congregations in warm water areas. Historically, manatees have used springs or spring-fed rivers for winter refuge; these areas have become subject to heavy recreational use and development. Increasingly, manatees are using artificial sources, such as the thermal discharges of power plants and other industry, as warm-water refuges. Manatees have been observed during winter months in the discharge canal at the Big Bend Power Station and at other times of the year in areas near the plant (TECO 1979:2.7-57).

Considering the manatees' sensitivity to cold, their dependence on warm water refuges makes them vulnerable to changes in the artificial source. Severe changes, such as plant shutdown when ambient water temperatures are minimal, could be potentially detrimental to the manatee.

5.2.11.2 Life History Data

Manatees are found in slow moving rivers, estuaries, and salt water bays. Four factors influence their choice of habitat: (1) availability of vascular aquatic vegetation, (2) proximity of channels at least 1.5 m deep for migration, (3) winter warm-water refuges, and (4) a source of fresh water (Hartman 1971).

The number of Florida manatees is not certain, but aerial surveys conducted during 1976, 1977, and 1978 have estimated the basic population at between 740 and 1,000, and have recorded the areas of greatest abundance (Irvine & Campbell 1978; Rose 1978). More data on summer habitat are needed, but manatees are difficult to locate because they disperse in the summer.

Sexually mature manatees range in size from 2.8 to over 4.5 m (9.2 to 14.8 ft) and weigh from 200 to 600 kg (440 to 1,325 lb) or more. The largest manatee recorded in recent years measured 3.8 m (12.5 ft) and weighed 881 kg (1,950 lb) (Hartman 1976; Applied Biology 1977).

Manatees apparently breed year-round because calves are found during all seasons (Hartman 1976; Moore 1953; Moore 1956). Moore (1951b) suggested a breeding season from December to August, but no recent data confirm this. However, calving peaks may occur in spring and early summer (Irvine & Campbell 1978;

Campbell 1976), or fall (Irvine et al 1978). The gestation period may be as long as 13 months (Applied Biology 1977), and a female will have one or two calves every 2 to 5 years (Hartman 1971; Campbell 1976; Hartman 1969; Powell 1978; Powell & Waldron 1978). The calf remains with its mother for 1 to 2 years (Hartman 1971). Female manatees are sexually mature when they are 7 or 8 years old, and males mature when 9 to 10 years old. Manatees can live over 25 years in captivity (Hartman 1976).

Manatees feed for 6 to 8 hours a day and eat a wide variety of plants (Hartman 1971); captives can eat 30 to 50 kg (66 to 110 lb) of vegetation a day (Hartman 1968). Calves begin to eat vegetation long before they are weaned. Manatees prefer submerged, emergent, and floating vegetation (Hartman 1971). They are also known to eat green algae (Hartman 1974). They will eat a wide variety of foods, including fish, when preferred foods are unavailable (Bertram & Bertram 1973; Spurgeon 1974). Manatees have passed by rafts of water hyacinth (Eichhornia crassipes) to feed in shallow water on eel grass (Vallisneria americana). Although they are at home in fresh and saltwater, they need a source of fresh water (Hartman 1974).

Manatees congregate in warm-water refuges from November to March, stimulated by air temperatures of 10 to 15°C (Hartman 1979; Applied Biology 1977). There are 25 such areas in Florida, 6 natural and 19 man-made (Hartman 1976). Manatee congregations at power plant outflows during cold weather are well documented (Hartman 1971; Irvine & Campbell 1978; Rose 1978; Moore 1956; Hartman 1974; Layne 1965; Campbell & Irvine 1978; Shane 1978). Movements between winter congregation areas have been suggested (Hartman 1971; Rose 1978; Hartman 1974), but not verified. Although cold water sensitivity of manatees has been reported many times (Hartman 1971; Hartman 1974; Bangs 1895; Layne 1965; Moore 1951a; Campbell & Irvine 1978; Campbell & Powell 1976), it is not completely understood. The activity of captive manatees decreases at water temperatures below 21°C. Feeding patterns become irregular at 18–19°C; feeding may stop completely at temperatures below 16°C, but resumes at 17°C (Campbell & Irvine 1978; Brownell et al 1978). Captive manatees will not tolerate water temperatures below 15°C according to Brownell et al (1978), but Hartman (1979) has observed them moving out of a warm-water refuge into 13.5 to 15.0°C or colder water. Exceptionally cold winter temperatures can result in manatee deaths, but the lethal level and contribution circumstances are not known.

A bibliography and additional information concerning the life history of the manatee can be found in Appendix 2.

SECTION 6

ENGINEERING DESIGN

6.1 EXISTING GENERATING CAPACITY - UNITS 1, 2, AND 3

Big Bend Station is located 5 miles (8.1 km) north of Ruskin, Hillsborough County, Florida, on the eastern shore of Hillsborough Bay. Hillsborough Bay is the northeasterly extension of Tampa Bay about 26 miles (41.8 km) from Egmont Key, which is located at the entrance to Tampa Bay from the Gulf of Mexico. The site is about 10 miles (16.1 km) south of the City of Tampa and 14 miles (22.5 km) east of St. Petersburg, across Tampa Bay. Figure 6.1-1 shows the general site location.

An extension of the Tampa Bay Channel System permits access to the site by water. Fuel and large equipment are delivered by barges which approach the site through a dredged, ship-access channel.

The site presently consists of three coal-fired, steam-electric generating units. Units 1, 2, and 3 have a total nameplate rating of 1,336.5 megawatts (445.5 MW each). The units utilize a once-through cooling system discharging to Hillsborough Bay, as illustrated on Figure 6.1-2. Each unit has a main condenser, cooled by water withdrawn from the intake channel.

6.1.1 Intake System

Units 1, 2, and 3 each draw 537 cfs of circulating water from an intake channel that is 25-feet (7.6 m) deep. The intake channel draws water from a 34-feet (10.4 m) deep ship access channel. Each unit is equipped with a screenwell structure containing two 268.5 cfs capacity circulating water pumps. Figure 6.1-3 illustrates the screenwell arrangement.

Water is drawn through 3/8-inch (9.5 mm) mesh traveling water screens, and is pumped through two 72-inch (1.8 m) diameter pipes to a condenser for each unit. The average water velocity measured immediately in front of the screenwells at the traveling water screens is 1.45 fps. Flows in the intake channel and their respective velocities are presented in the following table:

	Unit 1	Unit 2	Unit 3
Intake Channel			
Flow rate, cfs	537	537	537
Cumulative flow, cfs	537	1,074	1,611
Velocity, fps	0.14	0.28	0.42

6.1.2 Discharge System

Pipes from the two outlet water boxes connect to a 9-foot (2.7 m) diameter pipe leading to the discharge structure. The warm circulating water from each unit exits to the discharge channel via the circulating water discharge structures. The discharge structure is shown on Figure 6.1-4. Flow from the discharge pipe enters the structure at approximately 8 fps and exits the structure to the discharge channel at less than 2 fps. The circulating waters exiting the three discharge structures flow west through the common discharge channel and return to Hillsborough Bay.

6.1.3 Biocide Additions

The three Big Bend units utilize chlorine to control condenser biofouling in the once-through cooling system. Big Bend is equipped with a chlorinator which serves one generating unit at a time. It has a maximum feed rate of 10,000 lb/day (4,536 kg/day) and has a 100 percent backup chlorinator available. For each unit, actual feed rates range from 5,000 to 8,000 lb/day (2,268 to 3,629 kg/day), with an average of 6,000 lb/day (2,722 kg/day).

Liquid chlorine is evaporated and fed by water injection to the screenwell prior to entering the cooling water pumps. The solution is added to the cooling water through rubber-lined diffusers. Chlorine is not fed to a unit unless both pumps are operating. The normal chlorination cycle is 20 minutes of feed, three times a day, for each unit. Chlorine concentration is measured during chlorination, at the outfall of each unit.

The intake pipes of the three units at Big Bend are cleaned approximately twice per year to remove shellfish and marine plant growth. Condenser tubes are cleaned manually using plastic plugs which are blown through the tubes using water and air. Units 1 and 2 have plugs blown about every 2 weeks, and Unit 3 has plugs blown weekly.

A report entitled "Chlorine Minimization Study for Big Bend Station and F.J. Gannon Station of Tampa Electric Company" was prepared by TECO in January 1980, and submitted to EPA (Region IV) in response to a NPDES permit requirement (TECO 1980). The purpose of the study was to investigate the chlorine decay within the discharge channel at TECO's Big Bend Station. The study concluded that intermittent chlorination, along with manual cleaning, is an effective, acceptable means of controlling biofouling and maintaining thermodynamic efficiency.

The study found that chlorine residuals at Big Bend are below the permitted levels of 0.2 mg/1 for free available chlorine, and 0.5 mg/1 for a maximum instantaneous concentration at the outlet

of an individual unit. Once discharged, the chlorine residuals decay within a short distance to levels approaching analytical sensitivity.

6.1.4 Plume Characteristics

Hydrothermal modeling was performed to determine the effects of the thermal discharge on the temperature of Tampa Bay. Two types of models, near-field and far-field, were used to perform this task. Detailed descriptions of these models and their application to Tampa Bay are presented in Appendix 5.

The near-field model was used to predict detailed temperatures near the station where the hydrodynamic characteristics of the discharge plume are more important than those of the receiving water body. This model is the same one used for the 316 Demonstration for Big Bend Station Units 1-3 (TECO 1977e), with minor modifications (principally in the coefficient which determines the amount of entrainment of ambient water).

The far-field model was used to determine the long-term buildup of heat (residual heat) in the vicinity of the Station. This model also determined temperatures at distances from the Station where the near-field model was not applicable. This model, a finite element dispersion model named DISPER-1, was developed at the Massachusetts Institute of Technology (MIT). DISPER-1 was used in conjunction with a finite element hydrodynamic model named CAFE-1, which was also developed at MIT. CAFE-1 calculates current velocities and tide heights for use in DISPER-1.

The final results of the hydrothermal modeling were obtained by adding the far-field residual heat to the near-field results for the area near the plant where the near-field model was applicable. For areas farther from the plant, where the near-field model was not applicable, the far-field results were used.

Results of the hydrothermal modeling are shown on Figures 6.1-5 and 6.1-6 and presented in Tables 6.1-1 to 6.1-3. Figures 6.1-5 and 6.1-6 show the surface plume at 100 percent and 64 percent load, respectively. Table 6.1-1 presents associated surface areas enclosed by various ΔT isotherms. Table 6.1-2 presents areas that the surface plume will sweep over a complete tidal cycle. Table 6.1-3 gives the distance from the point of discharge to the point of bottom detachment of the thermal plume. This table also gives the area of bottom contact of the thermal plume.

TABLE 6.1-1

SURFACE AREA ENCLOSED BY ΔT ISOTHERMS -
3 UNITS WITHOUT DILUTION PUMPS

ΔT (°C)	Area (Hectares)	
	100% Load	64% Load
1	1,408	923
2	692	437
3	409	219
4	190	109
5	97	55
6	55	31
7	32	19
8	20	11
9	11	6

TABLE 6.1-2

SURFACE AREA SWEPT OVER TIDAL CYCLE BY ΔT ISOTHERMS
3 UNITS WITHOUT DILUTION PUMPS

ΔT (°C)	Area (Hectares)	
	100% Load	64% Load
1	1,854	1,408
2	923	761
3	875	397
4	356	182
5	178	89
6	91	49
7	51	25
8	26	12
9	15	6
10	7	-

TABLE 6.1-3

BOTTOM CONTACT DATA FOR THERMAL PLUME
3 UNITS WITHOUT DILUTION PUMPS

Station Load (Percent)	ΔT (°C)	Distance to Isotherm (m)	Area Enclosed by Isotherm (Hectares)
100	9.8	361	7
64	9.4	301	5

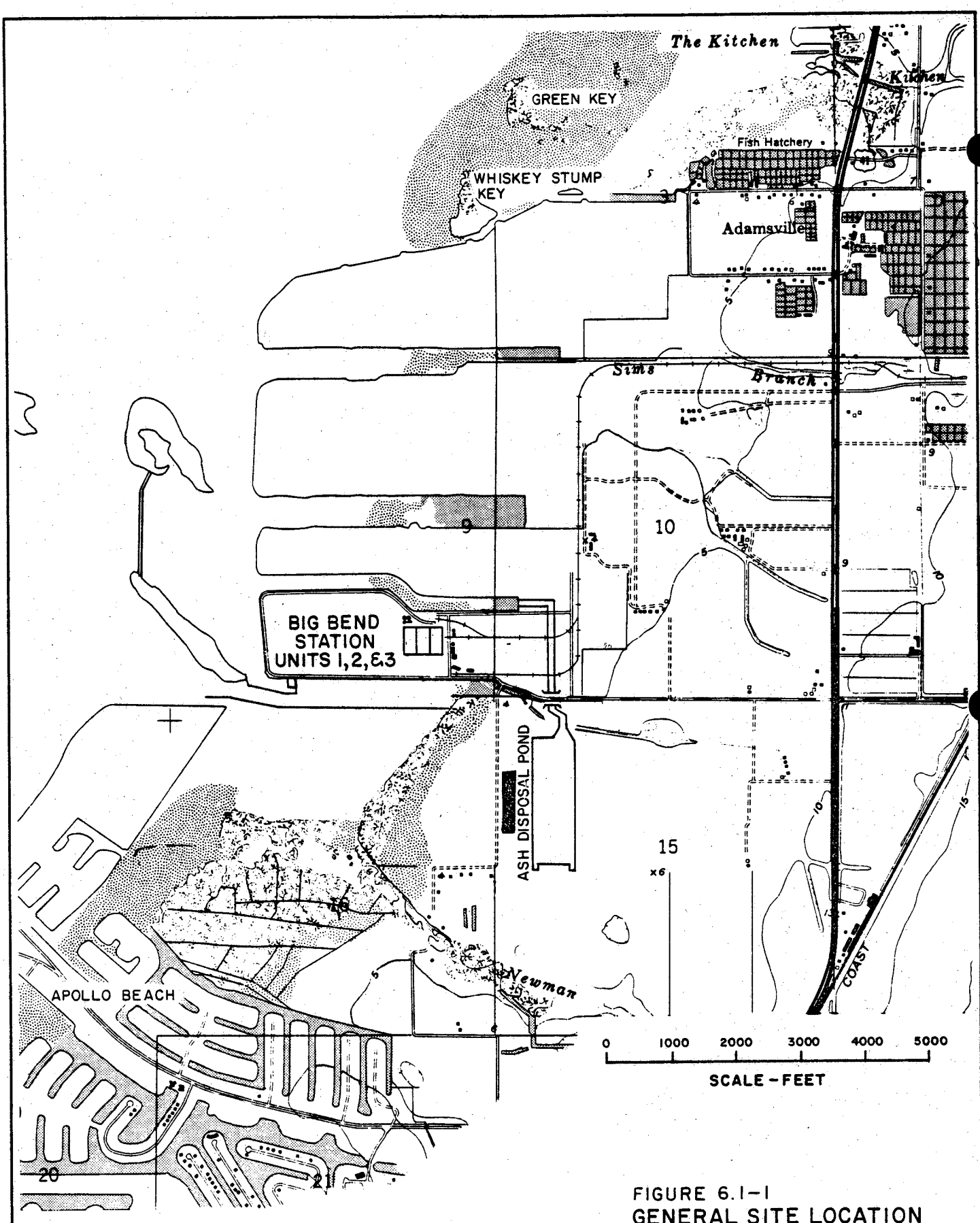


FIGURE 6.1-1
GENERAL SITE LOCATION
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

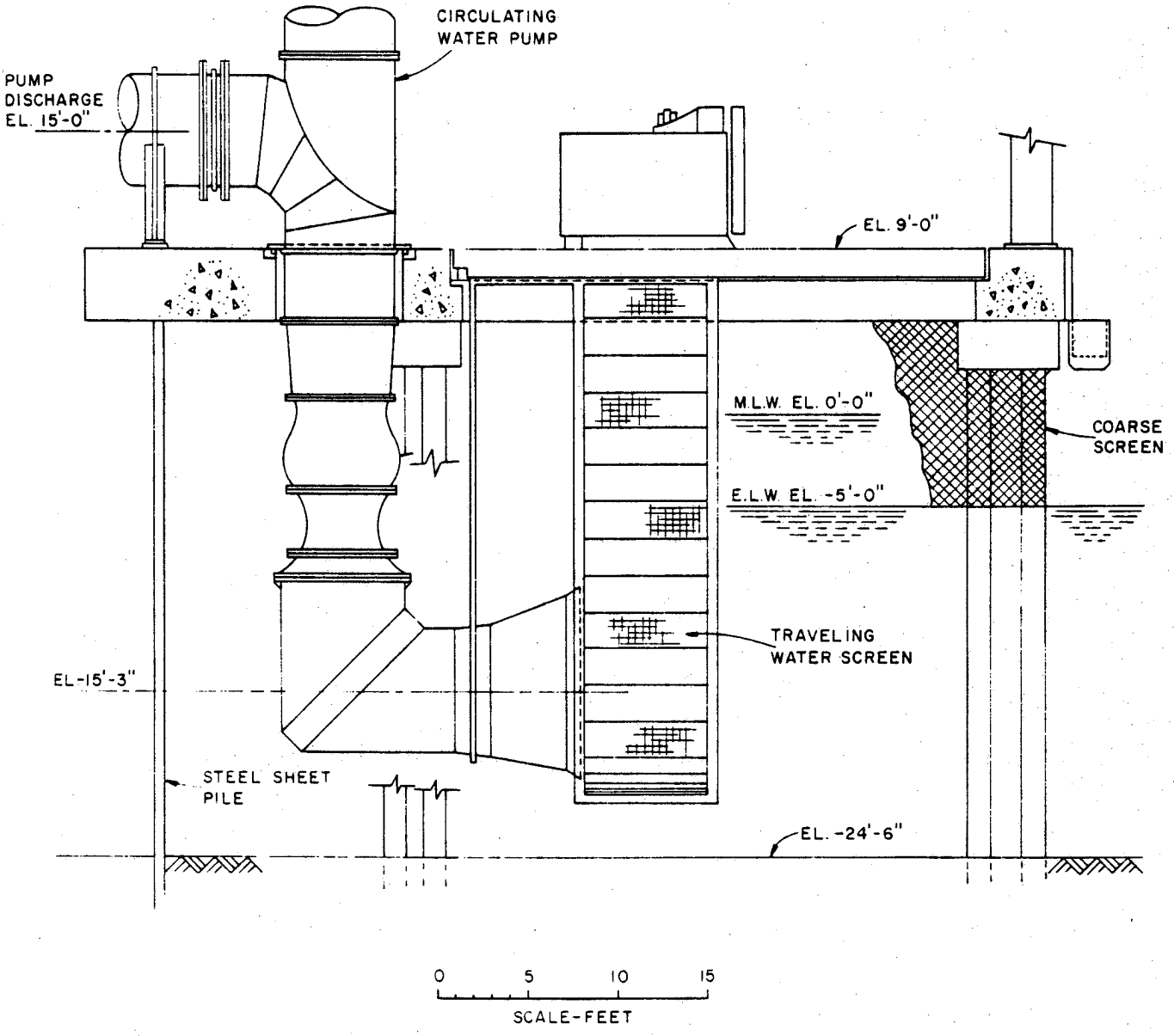


FIGURE 6.1-3
CIRCULATING WATER
INTAKE SYSTEM
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

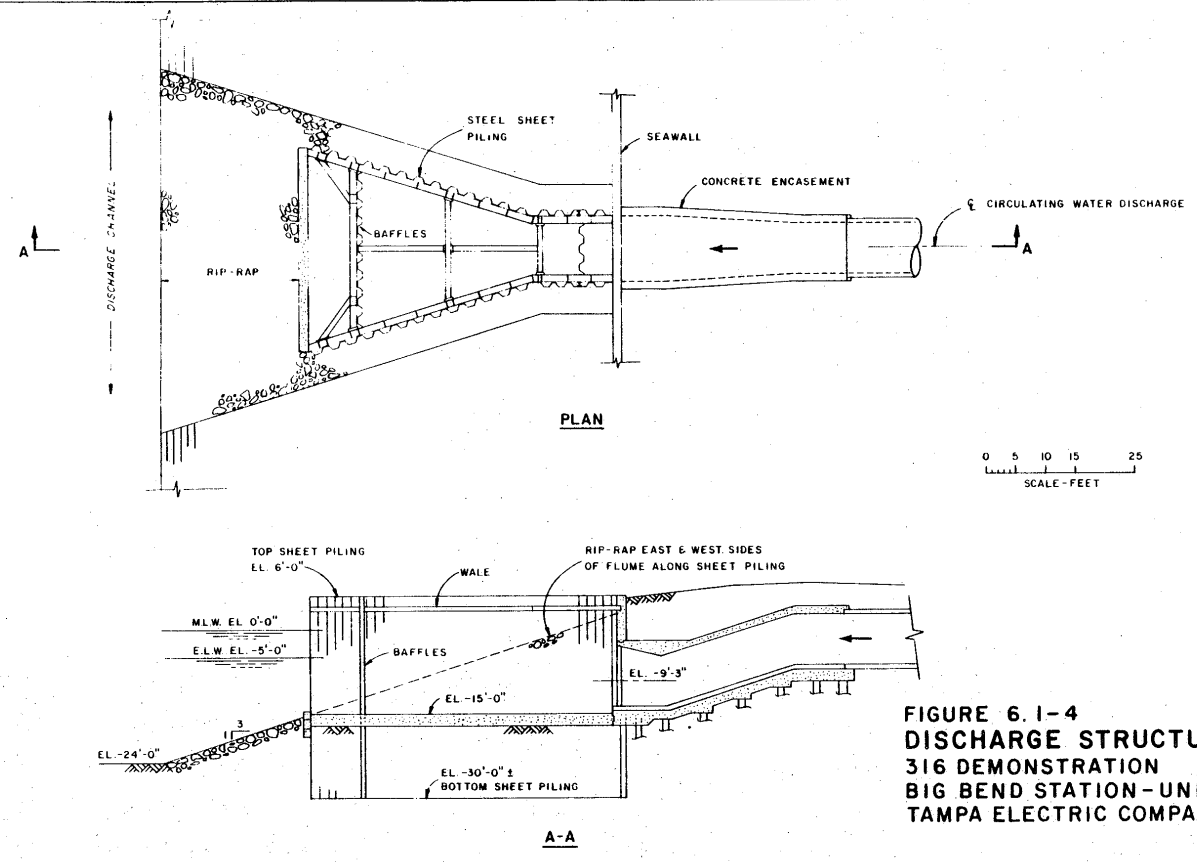


FIGURE 6.1-4
DISCHARGE STRUCTURE
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

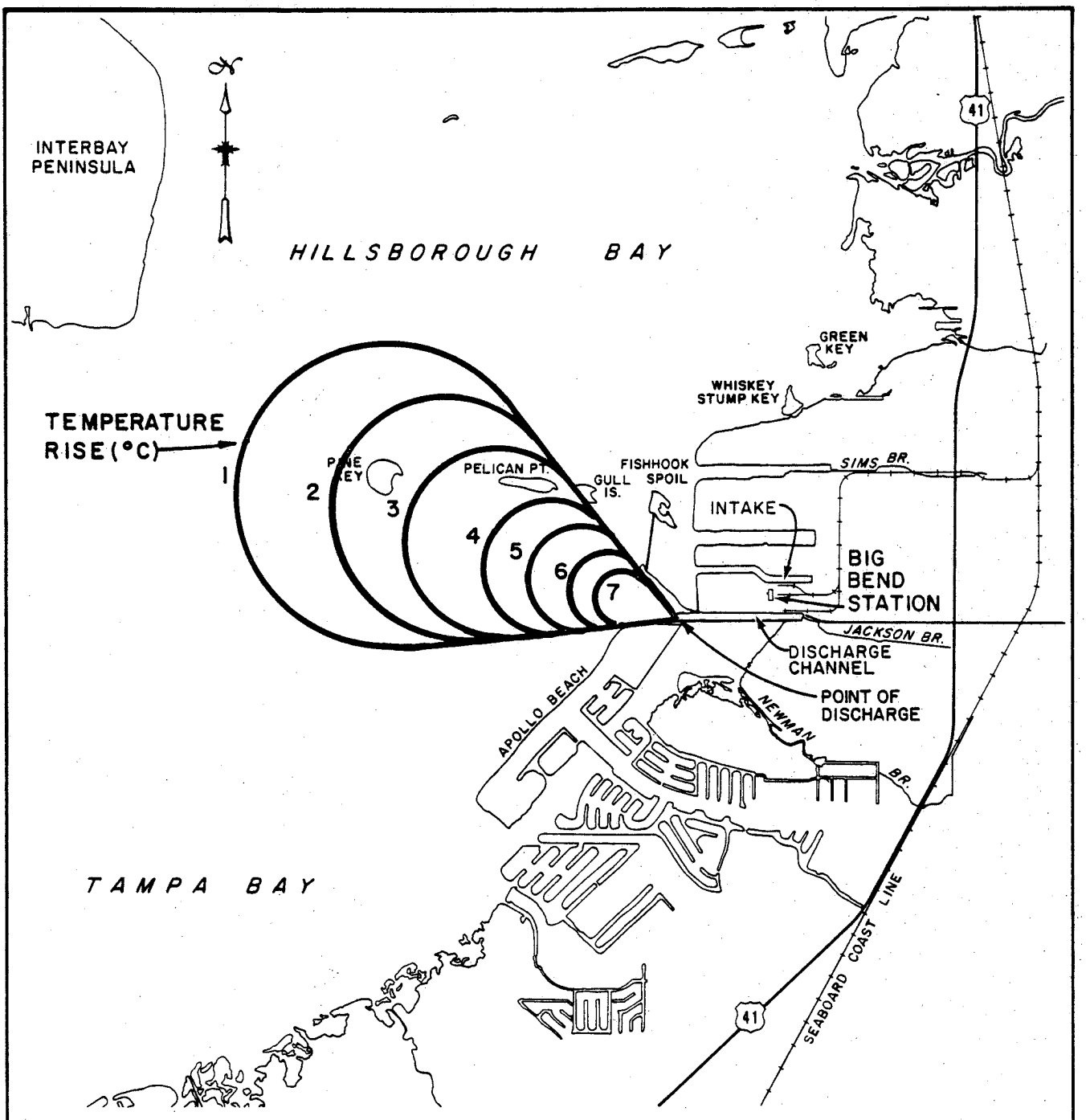


FIGURE 6.1-5
ISOTHERMAL CONTOUR MAP
3 UNITS, 100% LOAD, NO DILUTION PUMPS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

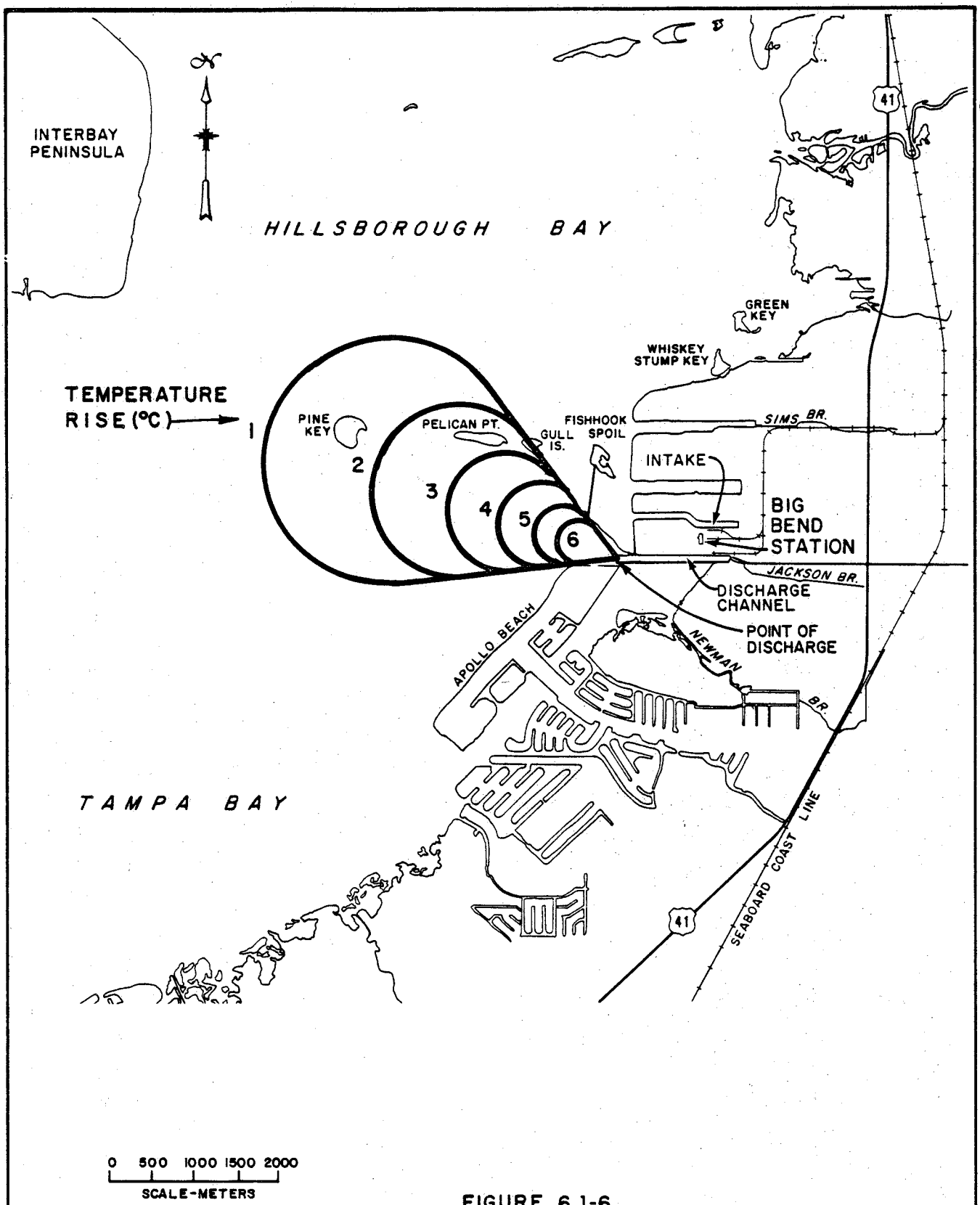


FIGURE 6.1-6
ISOTHERMAL CONTOUR MAP
3 UNITS, 64% LOAD, NO DILUTION PUMPS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

6.2 PROPOSED GENERATING CAPACITY - UNIT 4

The proposed Big Bend Station Unit 4 is scheduled for commercial operation in March 1985. It will be constructed adjacent to Unit 3, which began commercial operation on May 1, 1976. This new, coal-fired steam electric generating unit will have a net capacity of 417 MW. The following table shows the average capacity factor of Units 1-4 of Big Bend Station beginning in 1985:

Year	Capacity Factor (percent)
1985-1989	64
1990-1994	63
1995-1999	63
2000-2004	50
2005-2009	40
2010-2014	33

It is proposed that Unit 4 also have a once-through cooling system. Unit 4 will have a condenser, independent of Units 1, 2, and 3, which will be cooled by water withdrawn from Hillsborough Bay via the existing intake channel. Figure 6.2-1 illustrates the cooling water system of the existing three units and that proposed for Unit 4.

After passing through the Unit 4 condenser, the water will exit to the existing discharge channel and combine with water discharged from Units 1, 2, and 3. The mixture will flow westerly, returning to Hillsborough Bay.

6.2.1 Intake System

Unit 4 will draw approximately 537 cfs of circulating water from the existing, 25-feet (7.6 m) deep intake channel. Unit 4 will be provided with a screenwell structure equipped with two 268.5 cfs capacity circulating water pumps, each with its own traveling water screen. The structure will be similar to those used for the existing units, shown on Figure 6.1-3. The cooling water will be drawn through the traveling water screens and pumped through two 72-inch (1.8 m) diameter pipes to the Unit 4 condenser. The average water velocity immediately in front of the screenwell at the traveling screens will be about 1.45 fps. The combined circulating water flow rate for the four units will total 2,148 cfs. Flows in the intake channel for the units, and their respective velocities, are as follows:

	Unit 1	Unit 2	Unit 3	Unit 4
Intake Channel				
Flow rates, cfs	537	537	537	537
Cumulative flow, cfs	537	1,074	1,611	2,148
Velocity, fps	0.14	0.28	0.42	0.56

6.2.2 Discharge Structure

Pipes from the condenser will connect to a 9-foot (2.7 m) diameter pipe leading the water to the discharge structure. The Unit 4 discharge structure will resemble those for Units 1, 2, and 3, shown on Figure 6.1-4. The warm circulating water from Unit 4 will also exit to the discharge channel. The structure, designed to reduce the velocity of the discharged water, will control erosion of the far bank of the dredged discharge channel. Flow from the Unit 4 discharge structure will combine with the discharge water from the three existing units, and move westerly through the channel to the point of discharge to Tampa Bay.

6.2.3 Biocide Additions

As described in Section 6.1.3, Big Bend is equipped with one chlorinator to which Unit 4 will be connected. Liquid chlorine will be fed to the Unit 4 cooling water at a similar rate and in the same manner that it is being fed to the existing units.

The chlorine for Unit 4 will be injected for 20 minutes three times a day. Only one unit at a time will be chlorinated. The feed rate is expected to range from 5,000 to 8,000 lb/day (2,268 to 3,629 kg/day) with an average feed rate of 6,000 lb/day (2,722 kg/day).

6.2.4 Plume Characteristics

Hydrothermal modeling was performed to determine the effects of the thermal discharge on the temperature of Tampa Bay. The two types of models discussed in Section 6.1.4 were used to perform this task. Detailed descriptions of these models are presented in Appendix 5.

The final results of the hydrothermal modeling were obtained by adding the far-field residual heat to the near-field results for the area near the plant where the near-field model was applicable. For areas farther from the plant, where the near-field model was not applicable, the far-field results were used.

Results of the hydrothermal modeling are shown on Figures 6.2-2 and 6.2-3 and presented in Tables 6.2-1 to 6.2-3. Figures 6.2-2 and 6.2-3 show the surface plume at 100 percent and 64 percent load, respectively. Table 6.2-1 presents associated surface areas enclosed by various ΔT isotherms. Table 6.2-2 presents

areas that the surface plume will sweep over a complete tidal cycle. Table 6.2-3 gives the distance from the point of discharge to the point of bottom detachment of the thermal plume. This table also gives the area of bottom contact of the thermal plume.

6.2.5 Intake Design Alternative - Fine-Mesh Screening

As a result of Environmental Protection Agency (EPA) concern regarding the number of organisms entrained at Big Bend Station - Units 1 through 3, the Applicant initiated a multiphase evaluation of alternative intake technologies to identify potential design alternatives for the Unit 4 intake structure.

The evaluation consisted of several tasks, including:

1. Reviewing available intake technologies that might be applied to Big Bend Station to minimize entrainment losses.

2. Selecting organism protection systems that show promise for biological effectiveness and engineering reliability, and conducting a more detailed site-specific evaluation of these systems.

3. Initiating preliminary studies to evaluate the feasibility of the selected system.

4. Conducting studies to prove the effectiveness and reliability of the alternative system.

Results of the first three tasks indicate that a fine-mesh screening system (specifically a modified, dual-flow traveling screen) could reduce the loss of entrained organisms at Big Bend Station (Appendix 3). Consequently, more detailed studies to evaluate the fine-mesh screen concept further were commenced in early 1980.

To ensure comparability of the data to be obtained from this detailed investigation, the test facility would incorporate a full-scale prototype traveling screen identical in every way, except for width, to a screen which could be incorporated into an actual fine-mesh screening installation for Unit 4. Design of the 1980 prototype studies and analysis of the Spring 1980 data are presented in Appendix 4.

The test results show that a fine-mesh screen system could reduce the entrainment losses at Big Bend by returning viable meroplankton organisms to the Bay system. As a basis for ecological and engineering evaluations of the potential effectiveness of a fine-mesh screen at Big Bend Station, a conceptual design for such a system was developed.

The preliminary conceptual design was developed on the basis of applying fine-mesh screens to existing Unit 3 and proposed Unit 4. Sheet piling would enclose the pump screenwell area, creating a forebay between the fine-mesh screens and the pumps. A layout of the new screening structure is shown on Figure 6.2-4.

Each of the six (three for each unit) dual-flow fine-mesh screens would be fitted in the sheetpile wall and the intake flow would pass through the screens and discharge into the forebay. The discharge opening would be sized to achieve a uniform flow distribution through the two parallel screen faces. To ensure proper hydraulic conditions at the four circulating water pumps and a relatively uniform flow through each of the six screens, the forebay would extend from the seawall about 60 feet (18.3 m) into the intake channel. The pumps would also be positioned to aid proper flow distribution so that each set of two circulating pumps would draw from three screens.

Stop gates would close the discharge opening in the event that a screen must be stopped or removed for maintenance. In case of emergency conditions roller gates would be installed in the sheetpile wall between screens and would be opened to supply water to the pumps if the pressure head differential across the screens exceeds 1.5 feet (0.46 m). To screen the flow and protect the pumps and condenser under this emergency operating mode, the existing coarse-mesh (3/8 inch (9.5mm)) screens would be maintained on Unit 3 and new similar coarse-mesh screens would be installed on Unit 4.

The dual-flow screen design with 3/8-inch (9.5mm) mesh has been used successfully at Big Bend Units 1 through 3 for many years and, based on testing to date, has the necessary features for protecting small organisms when using fine screens. The number and size of the screens have been preliminarily determined on the basis of achieving a screen face velocity (approach velocity) of 0.5 fps at water level El 0.0 mlw. This velocity criterion could be changed to a higher value (up to 1.0 fps), should ongoing studies show no significant difference between the velocities being evaluated. Such a change would result in substantial capital and operating cost savings. Based on the 0.5 fps velocity criterion, six 10-foot (3.05 m) wide screens would be required. Each screen would be submerged to El -21.5 feet. Each of the 53 screen baskets would be equipped with easily replaceable 0.5 mm mesh panels and fish collection buckets. The fine-mesh requires continuous screen operation to prevent clogging and to limit the time that organisms are impinged. Since continuous operation results in greater wear of the mechanical components than does intermittent operation, as on the existing screens, more reliability would be achieved through the use of heavy duty rollers, bushings, bearings, sleeves, chains, and motors. To reduce maintenance requirements further, 9.5-mm

mesh screen panels would be provided for periods of the year when entrainment of meroplankton is not of concern.

Each fine-mesh screen would be capable of operating continuously at speeds of up to 28 fpm. On automatic control, the screen would run continuously at 7 fpm, if ongoing studies continue to indicate that this speed is adequate to protect impinged organisms. As the head differential across the screen reaches 4 inches (10 cm), and then 6 inches (15 cm), the speed would automatically increase to 14 and 28 fpm, respectively. Should studies indicate the need for different speeds than these, the controls could be modified to achieve any speed between 0 and 28 fpm.

Each screen would be equipped with a low-pressure (approximately 5-10 psi) organism spray wash header on the ascending side and a high-pressure (40 to 60 psi) spray wash header for debris removal on the descending side of the screen. Separate pumps would supply water to each header and would take suction from the fine-screened water downstream of the circulating water pumps. These nozzles would have 1/2 inch (12.7 mm) diameter orifices and would be evenly spaced at 1-foot (0.3 m) intervals over the 10-foot (3.05 m) header length to ensure uniform spray pattern across the screen baskets.

Although the low- and high-pressure sprays would wash organisms and debris into separate troughs, all troughs would manifold into a common sluiceway that would carry organisms and debris to a release point north of the intake channel (Figure 6.2-4). This design will maximize the opportunity for survival of any organisms not removed by the low-pressure spray, but subsequently removed by the debris spray.

The organism return trough would be sized to achieve a transport velocity in the range of 2 to 3 fps at a water depth of from 6 to 12 inches (15 to 30 cm). The trough would run west along the south side of the intake channel to a footbridge from which it would be supported as it traverses the channel. From this point, the trough would take one of two possible routes. In one, the trough would travel west, north, and east to a channel where it would discharge. In the other, the trough would travel north and east, discharging in the same channel. While the first route would be longer, it would avoid road crossings, which require buried pipe sections, and thus may be more suitable from a biological and engineering standpoint. Total length of the return flume would approximately range from 1,500 to 4,700 feet (457 to 1,433 m), depending on the exact routing and location of discharge in the channel.

To alleviate fouling problems in the trough, it would be divided with each half being 18-inches (0.46 m) wide by 18-inches (0.46 m) deep. With this arrangement, the flow could be

frequently diverted from one side to the other and the unused side would be drained and dried. The trough would be covered with solid removable plates to eliminate sunlight, and it could be insulated, if necessary, to minimize temperature rise as the water travels from the screen to the discharge point.

The proposed design involves expanding the Unit 3 operating deck from which the dual-flow fine-mesh screens would hang. The design is similar to the existing screen structure installed at Big Bend, except for the overall dimensions and number of screens.

As with the existing structure, the expanded operating deck would be supported on piles at El +9 feet. The channel bottom would be maintained in the screen structure area at the existing depth of El -24.5 feet.

Initially, a chain link fence similar to that currently used at Units 1 through 3 to exclude large floating debris would be incorporated into the new screen structure and would extend to El -5 feet. If, in the future, the fence is found to be inadequate to protect the fine-mesh screening medium, provisions would be incorporated to allow for installation of stationary bar racks to replace the fence. Such racks would be located approximately 14 feet (4.27 m) upstream of the fine-mesh screens. The rack structure would be inclined at a 5:1 slope and would have bar spacings of 1.5 inches (3.8 cm). A common, moveable rake would raise all debris collected on the bar racks to the operating deck and into a rail-mounted hopper. In the event that trash racks are added, provisions will be made for lateral fish passageways at the end of the structure.

Construction would be performed "in the wet" and would consist of excavation, driving necessary piles and sheeting and fabricating the operating deck. The traveling screen assembly troughs and pumps would then be installed. It may be necessary to shut down Unit 3 during pile driving or equipment installation.

As a part of the conceptual design evaluation, cost estimates were developed for installing fine-mesh screens at Big Bend Units 3 and 4. In addition, costs were developed for a duplicate system which could be installed on Units 1 and 2 if further reduction in entrainment were required. These costs are compared to the differential cost (above the costs of a conventional once-through system) for a closed-cycle cooling system. Table 6.2-4 provides a summary of this cost analysis.

The closed-cycle cooling system which will be used for comparison is a mechanical draft cooling tower. An engineering study on closed-cycle heat rejection systems for Big Bend Unit 4 was performed. The study results indicate that a mechanical draft tower would be the preferred closed-cycle system. This tower

would be of concrete construction and would utilize saltwater as the cooling medium. Tower costs are based upon a design which will achieve a maximum drift rate of 0.002 percent of the circulating water flow. Site and foundation preparations costs are included as separate items. Energy requirements and derating penalties were calculated and are included in the estimated costs. The tower requires 4.5 MW of auxiliary power year round and creates a generation loss due to increased turbine pressure of 2.2 MW on both a summer peak and annual average basis.

Table 6.2-4 presents cost differentials above the cost of a conventional once-through cooling system. The additional cost required to add a fine-mesh screen system to Units 3 and 4 is $10,215,000. The costs to retrofit a fine-mesh screen system to Units 1 and 2 would be approximately $7,985,000. The cost of the two systems is approximately the same; however, the cost of the shared return system is included in the Units 3 and 4 estimate. The additional cost of providing a mechanical draft tower is $51,802,000.

TABLE 6.2-1

SURFACE AREA ENCLOSED BY ΔT ISOTHERMS
4 UNITS WITHOUT DILUTION PUMPS

ΔT (°C)	Area (Hectares)	
	100% Load	64% Load
1	1,449	1,166
2	720	559
3	457	324
4	291	154
5	150	77
6	77	43
7	43	24
8	25	15
9	15	10
10	9	-

TABLE 6.2-2

SURFACE AREA SWEPT OVER TIDAL CYCLE BY ΔT ISOTHERMS
4 UNITS WITHOUT DILUTION PUMPS

ΔT (°C)	Area (Hectares)	
	100% Load	64% Load
1	2,015	1,610
2	983	882
3	607	526
4	389	283
5	231	134
6	130	69
7	71	37
8	43	34
9	20	10
10	10	-

TABLE 6.2-3

BOTTOM CONTACT DATA FOR THERMAL PLUME
4 UNITS WITHOUT DILUTION PUMPS

Station Load (Percent)	ΔT (°C)	Distance to Isotherm (m)	Area Enclosed by Isotherm (Hectares)
100	10.1 (Bottom Detachment)	392	8
64	9.7 (Bottom Detachment)	331	6

TABLE 6.2-4

COST COMPARISON(*) FOR FINE-MESH SCREENS
VERSUS CLOSED-CYCLE COOLING SYSTEM
(MECHANICAL DRAFT TOWER)

Description	Units 3 & 4	Units 1 & 2	Cooling Tower
Structural			
Cooling Tower & Basin	-	-	6,042
Other Structural	-	-	6,481
Total Structural	2,080	1,670	12,523
Electrical	100	100	1,150
Mechanical	2,550	1,760	753
Instrumentation	Incl. in Mech.	Incl. in Mech.	208
Building Services	Incl. in Mech.	Incl. in Mech.	14
Environmental	Incl. in Mech.	Incl. in Mech.	32
Total Direct Cost	4,730	3,530	14,680
Distributables	420	300	2,165
Indirects	410	310	600
AFI (10%)	560	410	1,755
Total Present Day	6,120	4,550	19,200
Escalation	1,263	939	8,000
TECO Local Charges	333	247	1,224
Administrative & General Expense	70	52	257
IDC	904	672	2,692
Total Capital Cost	8,690	6,460	31,373

TABLE 6.2-4 (Cont)

Description	Units 3 & 4	Units 1 & 2	Cooling Tower
OPERATING COST PENALTIES			
Circulating Water Pump - Additional Head Required	106	106	-
Auxiliary Power for System	414	414	12,932
Generating Loss Due to Turbine Back Pressure Annual Average	-	-	6,324
Totals	520	520	19,256
OPERATION AND MAINTENANCE COSTS			
Screens	30	30	-
Screenwash Pumps	7.5	7.5	-
Organism Return	24	24	-
Total	61.5	61.5	-
Escalation	105.5	105.5	-
Total Cost	167	167	195
Total Evaluated Cost (Total Cost) (Fixed Chg Rate)	1,005	1,005	1,173
TOTAL COSTS			
Capital	8,690	6,460	31,373
Revenue Requirements			
Operating Cost Penalties	520	520	19,256
Operation and Maintenance	1,005	1,005	1,173
Total Evaluated Cost	10,215	7,985	51,802

NOTE:

* Figures are in thousands of dollars.

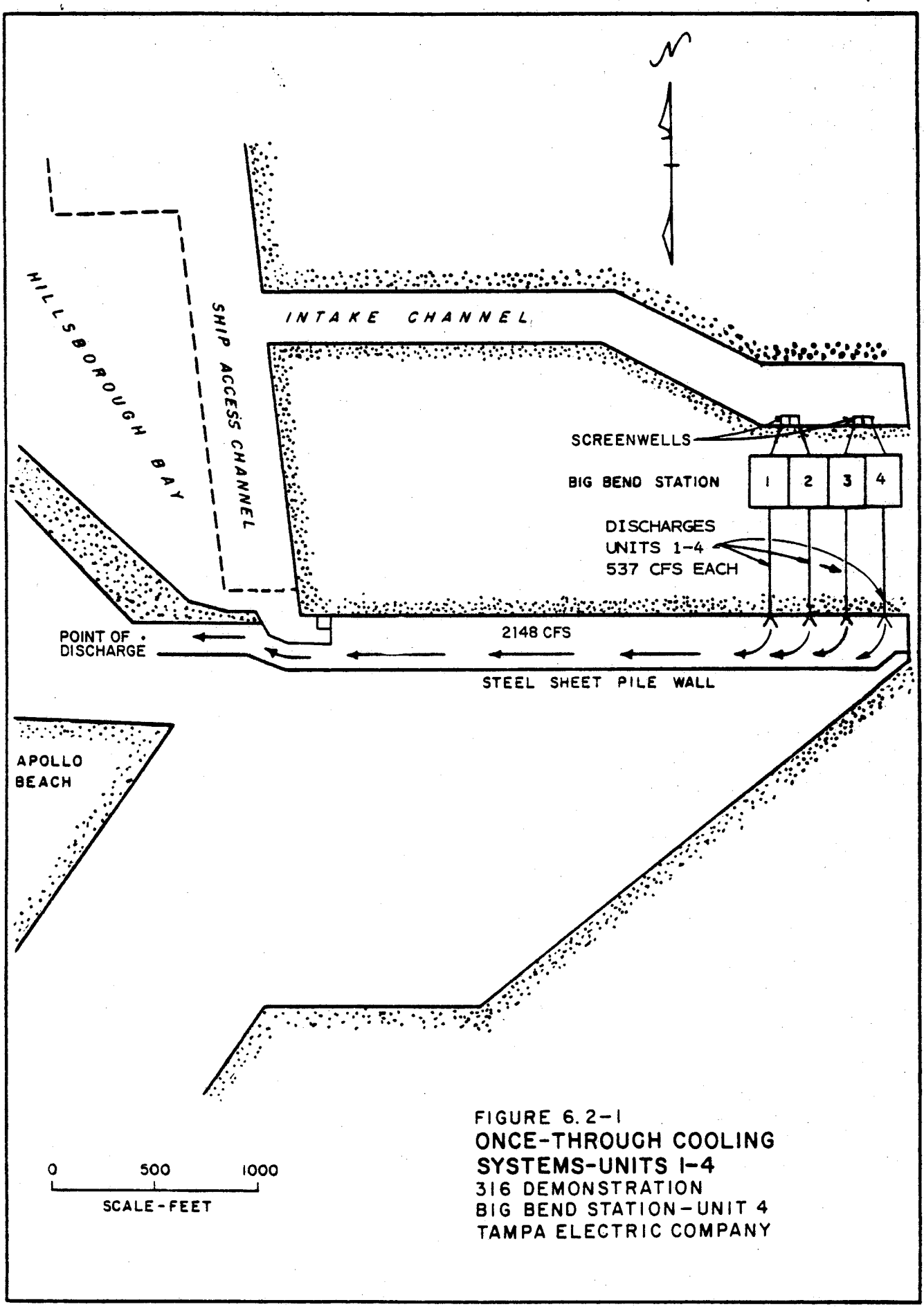


FIGURE 6.2-1
ONCE-THROUGH COOLING
SYSTEMS-UNITS 1-4
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

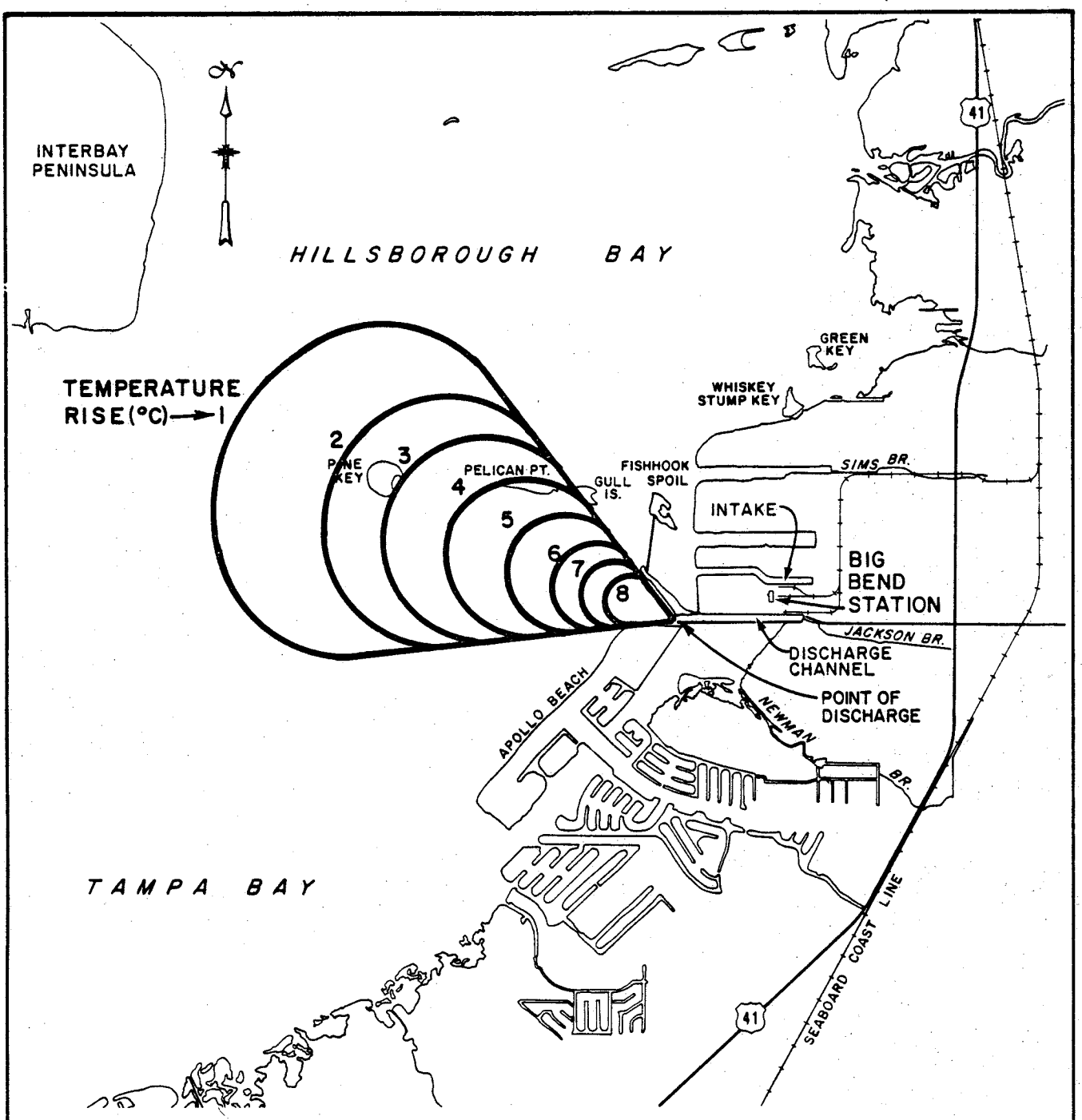


FIGURE 6.2-2
ISOTHERMAL CONTOUR MAP
4 UNITS, 100% LOAD, NO DILUTION PUMPS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

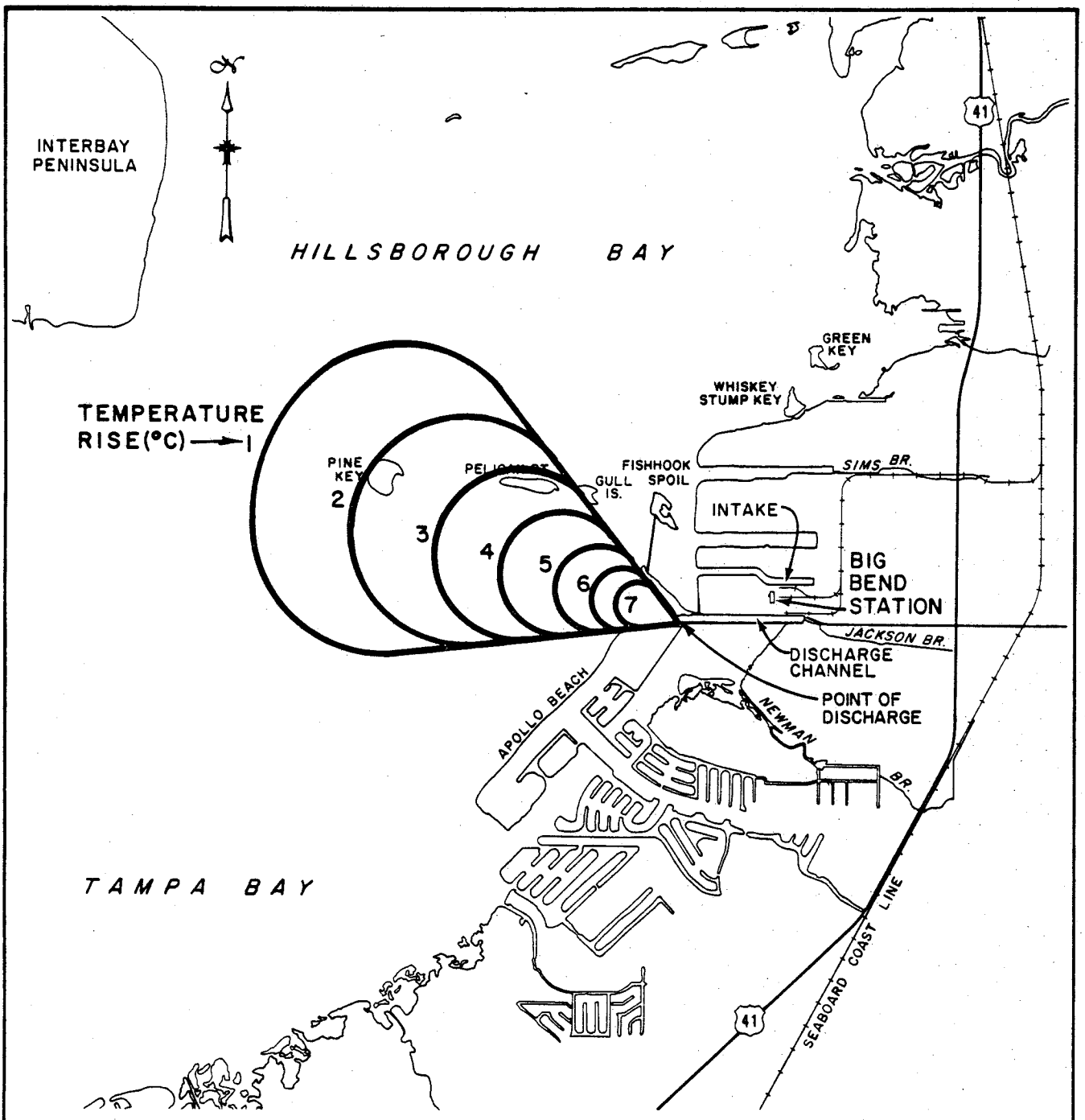
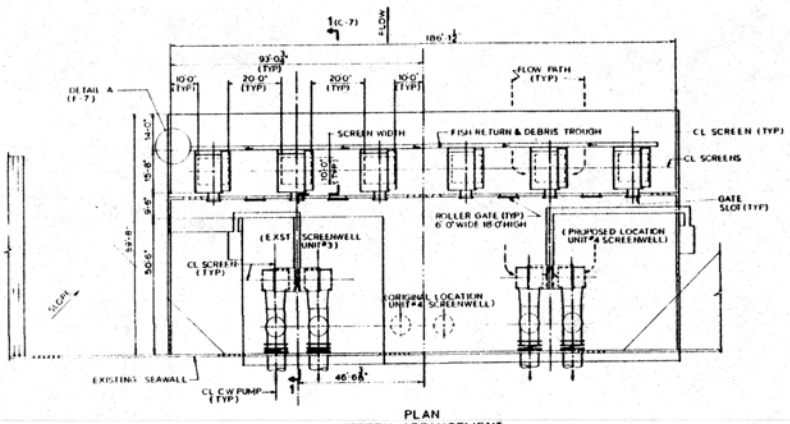
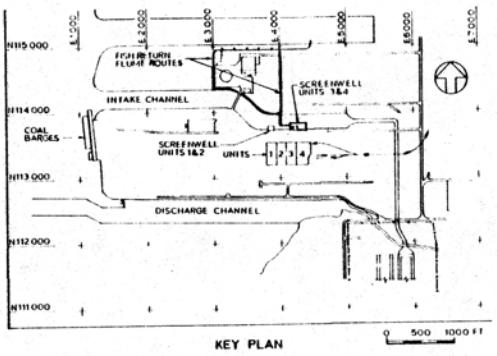


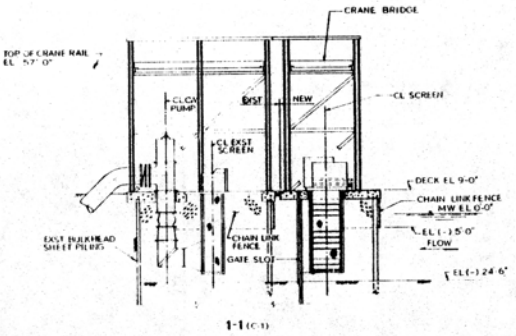
FIGURE 6.2-3
ISOTHERMAL CONTOUR MAP
4 UNITS, 64% LOAD, NO DILUTION PUMPS
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY



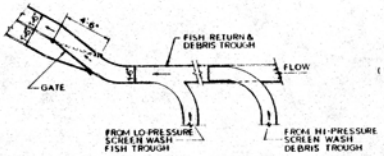
PLAN
SCREEN ARRANGEMENT



KEY PLAN

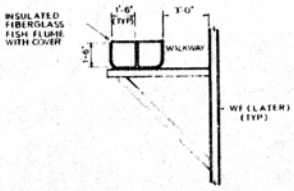


1-1 (C-1)



DETAIL A (B-2)
SCALE $\frac{3}{4}$"=1'-0"

NOTES
1 SCALE $\frac{1}{8}$" = 1'-0" UNLESS NOTED OTHERWISE
2 THIS IS CONCEPTUAL ENGINEERING DWG



TYPICAL FISH RETURN FLUME SECTION
(WITH SUPPORT STRUCTURE WHERE APPLICABLE)
SCALE $\frac{3}{8}$"=1'-0"

FIGURE 6.2-4
DUAL FLOW FINE-MESH SCREENS, UNITS 3 & 4
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

SECTION 7

IMPACT ASSESSMENT

7.1 PROCEDURES FOR ASSESSMENT OF POWER STATION EFFECT ON REPRESENTATIVE IMPORTANT SPECIES

The following sections describe the procedures that were applied to the affected life stages of each of the Representative Important Species (RIS) to assess the effects of the thermal discharge (Section 7.1.1), entrainment of planktonic stages (Section 7.1.2), and impingement of larger individuals (Section 7.1.3). In addition, these effects were considered in a cumulative fashion (Section 7.1.4) for the species population, even though each effect may be limited to distinct life stages.

The RIS analysis emphasizes the species population, since this level of biological organization constitutes the biological resource. The population has permanence in time and, as such, is the lowest level of biological organization that can be managed over the projected life of the plant.

Procedures are discussed in a general manner, as their application to each RIS is dictated by the degree and nature of the data available on the species population dynamics. This limitation is not unique but represents the state of knowledge of population dynamics.

7.1.1 Thermal Discharge

Data from several studies are synthesized to assess thermal impact for each of the RIS. The results of the hydrographic analysis (Section 6.2.4) define the area of the thermal plume with 4 unit operation at 100 percent capacity, as well as the areas bounded by the 10°C to 1°C isotherms. Combined with the ambient temperature data (Section 3.2), this information is used to estimate temperatures within the area of influence.

Results of the 1979 Aquatic Ecology Study (Appendix 1) provide the spatial and temporal abundance distribution of the RIS in the vicinity of Big Bend Station (Sections 4.4, 4.5, and 4.6). This information, combined with life history data (Section 5.2) and thermal tolerance data (Appendix 6), gives an estimate of the sensitivity of a given species to conditions in the thermal plume as well as an indication of the species ability to avoid intolerable conditions.

The combination of biological and hydrographic data is then used to predict the area of the plume that a species could not tolerate.

7.1.2 Estimation of the Number of Organisms Entrained

Meroplankton were sampled as a part of the 1979 Aquatic Ecology Study (Appendix 1) once every 2 weeks from February 1979 to February 1980. The analysis of the spatial and temporal distribution of these organisms indicates that the spatial pattern is time-, species-, and life stage-dependent (Table 4.5-5). In calculating entrainment, density data from the intake canal sampling station (Station A) were used because it most realistically represented the density of organisms in the water taken in by the plant.

The discharge canal (Station B) was also sampled for meroplankton; however, water volumes of these samples were somewhat lower than those from samples collected at other stations due to the low velocity of the discharge, thereby diminishing sample precision. Observations of the net during sampling at the discharge suggest that the low velocity and turbulent flow could affect the sample validity. Analysis of spatial patterns revealed that the mean organism densities at Stations A and B were seldom the same. There were no consistent trends in the differences in mean density at these stations (Table 4.5-8). Therefore, the intake samples were judged as the most representative and were used for entrainment estimates.

7.1.2.1 Calculation of Number of Organisms Entrained

Densities obtained from the field sampling were combined with the flow of the power station to estimate the number of organisms entrained. The calculation assumes four units are operating at 100 percent flow capacity, which represents the maximum situation.

7.1.2.2 Equivalent Adult Model

Once the number of organisms entrained is estimated, the number of adults that could have potentially developed from these entrained individuals is calculated under the conservative assumptions of the equivalent adult model. This model, first formulated by Horst (1975 and 1978), has been widely reviewed and used in the assessment of entrainment effects (Dahlberg 1978; Saunders 1978; Taylor 1978). Goodyear (1978) has produced a U.S. Fish and Wildlife Service guide on the use of the equivalent adult model for assessing the effects of entrainment.

The actual formulation of the model is very simple: in equilibrium, the fecundity produced by a breeding pair will be reduced in one generation to two breeding adults; i.e.,

$$2 = S_e \times F \qquad (7.1\text{-}1)$$

where

S_e is the survival from egg to adult,

F is the fecundity of a female during her life,

or

$$S_e = 2/F \qquad (7.1\text{-}2)$$

The survivorship from egg to adult is equal to the product of the suvivorship from egg to larvae (E) and the survivorship from larvae to adult (S_1):

$$S_e = E \times S_1 \qquad (7.1\text{-}3)$$

Therefore, if the entrained life stage is larvae, then F in Equation 7.1-2 must be multiplied by the survival from egg to larvae to give the survivorship from larvae to adult.

$$S_1 = 2/E \times F \qquad (7.1\text{-}4)$$

The number of entrained larvae (N_1) is multiplied by S_1, and the number of entrained eggs (N_e) is multiplied by S_e. The products are added together to give the number of adults (N_a) that would have resulted, assuming no density dependence.

$$N_a = S_1 \times N_1 + S_e \times N_e \qquad (7.1\text{-}5)$$

The model formulation relies on the following assumptions:

1. The population is in equilibrium, such that the number of fish in the population at any time and the proportion of fish at any age are constant, with stable age distribution. If the historical information on the fish population shows an increasing or decreasing trend in population size, the numerator of Equation 7.1-2 can be appropriately modified.

2. The lifetime of a fish in the population is the most probable age to which a fish will live or the mean generation time of the population.

3. The reference to a breeding pair applies to a situation where the number of males equals the number of females. If a skewed sex ratio exists in the population, Equation 7.1-2 can be altered accordingly.

4. The exploitation of eggs and larvae occurs at the times eggs are laid and larvae hatch.

5. The number of equivalent adults represents the annual loss in an equilibrium density-independent population with a stable age distribution. This loss is distributed in proportion to the stable age distribution.

Therefore, the minimal information required for the equivalent adult model is age of sexual maturity, longevity, and average fecundity. Fecundity is a relatively easy parameter to estimate and is generally available for most species.

7.1.2.3 Additional Perspectives on Entrainment

Two methodologies beyond that described in the previous section were employed to assess the effects of entrainment of planktonic organisms at Big Bend Station. These approaches provide a basis for judging the acceptability of the entrainment effect.

The first methodology utilizes hydrodynamic modeling to define the extent of entrainment influence. This methodology simply gives an indication of the area within which the concentration of planktonic organisms could change to some degree by power station operation.

The second methodology quantifies the loss of entrained organisms in terms of an area of the water body that would be required to produce the same number of organisms as are entrained. This area can be equated to an area of production lost due to entrainment.

7.1.2.3.1 Area of Entrainment Influence

The spatial extent of the influence of entrainment was analyzed using the finite element hydrodynamic models (Appendix 5), and the concentration of meroplanktonic organisms determined from the analysis of the 1979 meroplankton field study (Section 4.5.2).

The mathematical models first simulated the change in the pattern, observed in the field study, resulting from the operation of four units at Big Bend Station. This aspect of the analysis is conservative in two regards. First, since the field study was conducted while three units were operating, the actual change from the pattern observed would be attributable only to Unit 4. The analysis, however, assumes that the field study was

conducted with no units operating, and the change represents the addition of all four units.

Second, the dispersion coefficient (30 sq m/sec) is larger than observed in the hydrodynamic field study (refer to Appendix-5 for a more detailed discussion). The effect of the higher dispersion coefficient is to increase the area that will be affected in terms of the concentration. With a higher dispersion coefficient, the entrained intake water is replenished more rapidly with previously unentrained water, resulting in higher numbers of organisms being entrained.

These two aspects of the analysis result in an area of influence larger than expected. The extent of this area was defined by a 5 percent change in concentration after 12 tidal cycles with the plant in operation. At this time, the spatial pattern had stablized to a sufficient degree. Below 5 percent, the predicted change may be due to the numerical procedure, as well as the entrainment. Therefore, 5 percent was selected as the endpoint of the calculation.

Several spatial distribution pattern were examined to see what effect the distribution of the organisms would have on the area of influence. Based on the results of the analysis of the meroplankton field data, three distributions were selected (Section 4.5.2).

The base case was a uniform distribution throughout the water body. Figure 7.1-1, which presents the results of this analysis for four unit operation, suggests that the area of reduced concentration is small when compared to the area of the water body. This area of influence is simply one within which some change in concentration will occur without reference to the degree of change. The degree of change is addressed in a separate analysis (Section 7.1.2.3.2).

The other two distribution patterns used in the simulations were those exhibited by bay anchovy eggs and the egg and prolarvae of the scaled sardine. These were selected as representative of the range of spatial patterns of the species analyzed (Table 4.5-8).

The bay anchovy pattern was characterized by higher concentrations in Hillsborough Bay and near Big Bend than in Tampa Bay. The area of influence resulting from this distribution is shown on Figure 7.1-2.

The scaled sardine had higher concentrations in Tampa Bay than at other locations. The egg and prolarval life stages were chosen because of the different concentration gradients. Figure 7.1-3 snows the area of influence for the egg, which had a 70 to 1 gradient. Figure 7.1-4 represents the area of influence for the prolarvae, which had a 11 to 1 gradient.

The above analyses indicate that the area of entrainment influence is small when compared to the area in the water body. The area of influence is affected by the spatial pattern of concentration with steeper gradients having smaller areas of influence. As indicated previously, this analysis only depicts the area within which the density may be affected by entrainment and does not reflect the degree of change in the density.

7.1.2.3.2 Area of Equivalent Production

This methodolgy relates the number of entrained organisms to an area in Tampa Bay in which an equivalent number of organisms could have been produced. The analysis is conducted by species life stage and the area of production is measured in hectares (1 hectare = 2.471 acres).

The area of equivalent production is calculated for an area around sampling Station A. Station A was used as the basis for the estimate of production area since it is the sampling location closest to the intake. Consequently, this station integrates all sources of production and mortality which affect the density of entrained organisms. For some species life stages, the density at Station A was greater than at any other station. This implies that in these cases greater production was probably occurring near Station A.

This equivalent production area analysis complements the estimate of area of influence discussed in Section 7.1.2.3.1. The equivalent production area is smaller than the area of influence since this is an area of total loss. The area of influence is the entire affected area which experiences varying degrees of reduction. However, the following conservatism inflates the estimate of equivalent production area: since the maximum duration of the life stage is used rather than the shorter average length of the life stage. Average length of the life stage depends upon the maximum life stage length and the survivorship within the life stage and is not available from the literature.

This method assumes the following: a mean water depth near Station A is 7.3 meters and a specified duration of each life stage of each species as presented in Table 7.1-1.

The mean depth was computed using the water quality data collected during the 1979 meroplankton study. Additional information needed to apply this method is the mean density of each species life stage at Station A during its period of occurrence. For the analysis of the 1979 meroplankton field data (Section 4.5.2), the period of sufficient abundance for analysis has been defined as those sampling dates when 50 percent, or more, of the samples contained the organism of interest. This time period accounts for at least 90 percent of the entrainment

for each species life stage for which an equivalent production estimate is made. In addition, the statistical analysis of spatial and temporal distribution (Section 4.5) used only these data. The mean density is presented in Table 4.5-8.

The equivalent production area is determined for each species life stage as:

$$\text{Area} = \frac{\text{Number Entrained}}{\text{Density x Depth}} \times \frac{\text{Duration of Life Stage}}{\text{Number of Days in Abundance}}$$

where

Density = Density (in number per cu m) of the organism at Station A,

Depth = Water depth at Station A,

Area = The area around Station A where the number of organisms produced is equivalent to that entrained annually through Big Bend.

Because most species life stages did not occur in 50 percent or more of the samples on any of the sampling dates, this method was used on bay anchovy eggs, and prolarvae; scaled sardine larvae; silver perch and unidentified sciaenids eggs and larvae; and stone crab zoea Stages 1, 2, and 3. Because duration of the post-larval stage of bay anchovy is not well defined, this species life stage was not included. Results are presented in Section 7.2.

7.1.3 Impingement

Numbers of RIS impinged annually were estimated using trapezoidal integration of impingement data collected at Big Bend from March 14, 1979, to February 12, 1980. The trapezoidal integration in this case is a sum of products of average impingement in a sampling interval and length of the interval. Impingement samples were collected from one of the operating units approximately every 2 weeks. The procedure used to collect samples is detailed in Appendix 1. For each RIS, the mean of the number collected on every two sampling dates is used as the mean number impinged per day for the periods between sampling. For the late February and early March period of the year, when impingement samples were not collected, the number impinged per day was estimated from the mean of the March 14, 1979, and February 12, 1980, samplings. Impingement was calculated for four units operating at 100 percent load.

7.1.4 Cumulative Impact

Effects of entrainment and impingement were combined by assuming that all impinged organisms were adults and by combining this number impinged with the number of equivalent adults removed from the population by entrainment. The number of adults of each species removed from the population by impingement and entrainment was then related to commercial or sport catches in the area.

The component of impact associated with the thermal discharge cannot be directly added to entrainment and impingement impacts. This effect was evaluated by presenting the proportion of Tampa Bay from which the species would be excluded. The conservatism of this method is directly related to the production throughout Tampa Bay relative to the production that occurs in the areas of exclusion at the intake area. When the areas of exclusion are less productive than other areas of Tampa Bay, then the proportion of the Bay from which a species is excluded conservatively measures the reduction in the bay commercial or sport catch due to this component of impact. When the areas of exclusion are more productive than the average productivity in the rest of Tampa Bay, the method is not conservative.

Relating the effects of the thermal plume, entrainment, and impingement to potential reductions in the commercial or sport fishing harvest provides a scale for contrasting and totaling all sources of impact to a species. Therefore, this method for assessing cumulative impact can be followed for all RIS for which commercial or sport fishing data are available.

TABLE 7.1-1

DURATION OF LIFE STAGE OF VARIOUS
REPRESENTATIVE IMPORTANT SPECIES (IN DAYS)

Species	Egg	Larvae	Post-Larvae
Bay anchovy	1(1)	0.625-0.75(2)	No Information
Silver perch	0.75(3)	2(4)	No Information
Scaled sardine	1(5)	2(6)	No Information
	Z1	Z2	Z3
Stone crab	3-6(7)	3-6(7)	3-6(7)

SOURCES:

1. Kuntz 1914. p 3.
2. Kuntz 1914. p 16.
3. Kuntz 1914. p 3.
4. Kuntz 1914. p 11.
5. Houde 1977a. p 619.
6. Houde et al 1974. p 1,108.
7. Porter 1960. p 169.

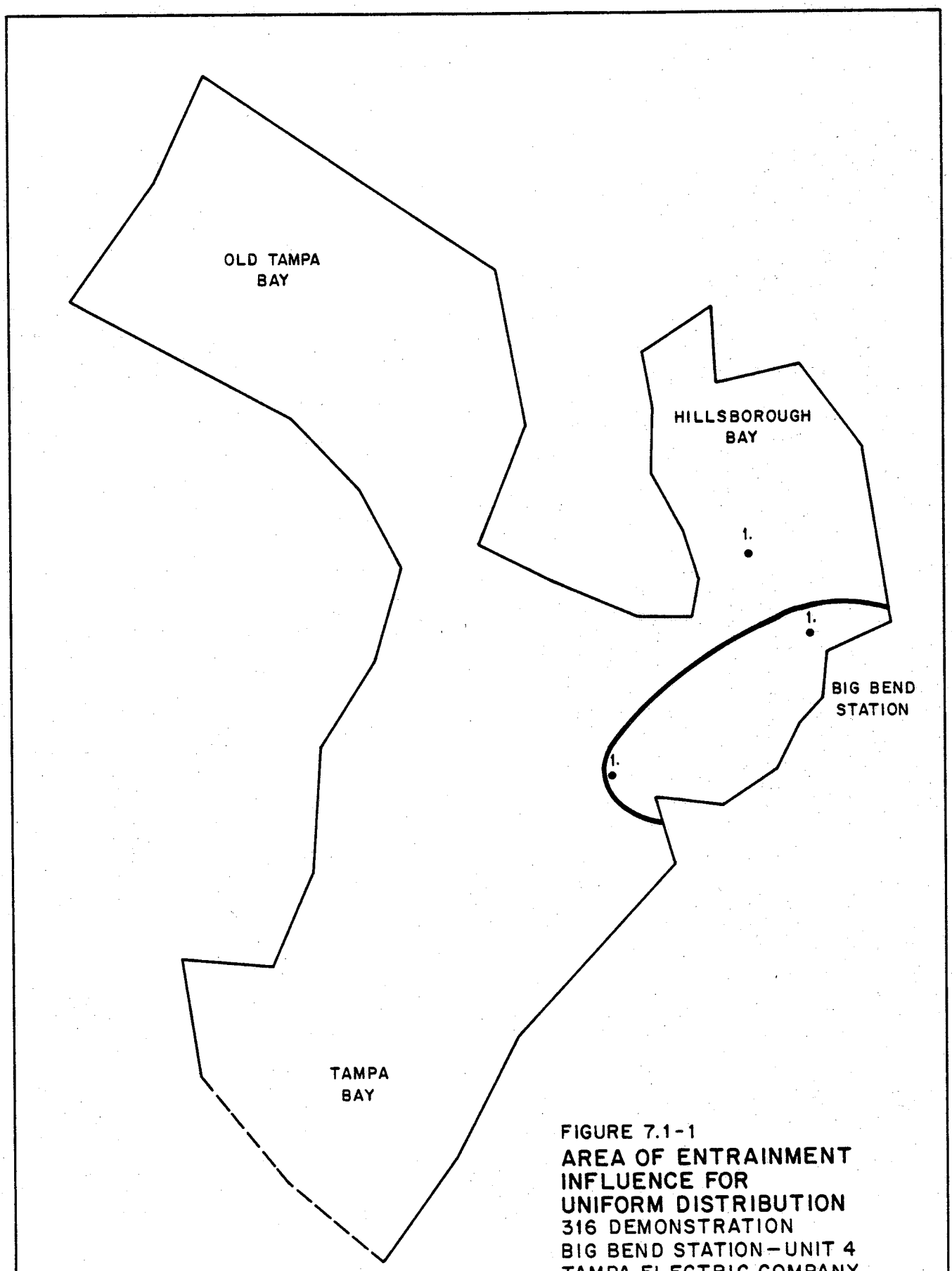


FIGURE 7.1-1
AREA OF ENTRAINMENT
INFLUENCE FOR
UNIFORM DISTRIBUTION
316 DEMONSTRATION
BIG BEND STATION – UNIT 4
TAMPA ELECTRIC COMPANY

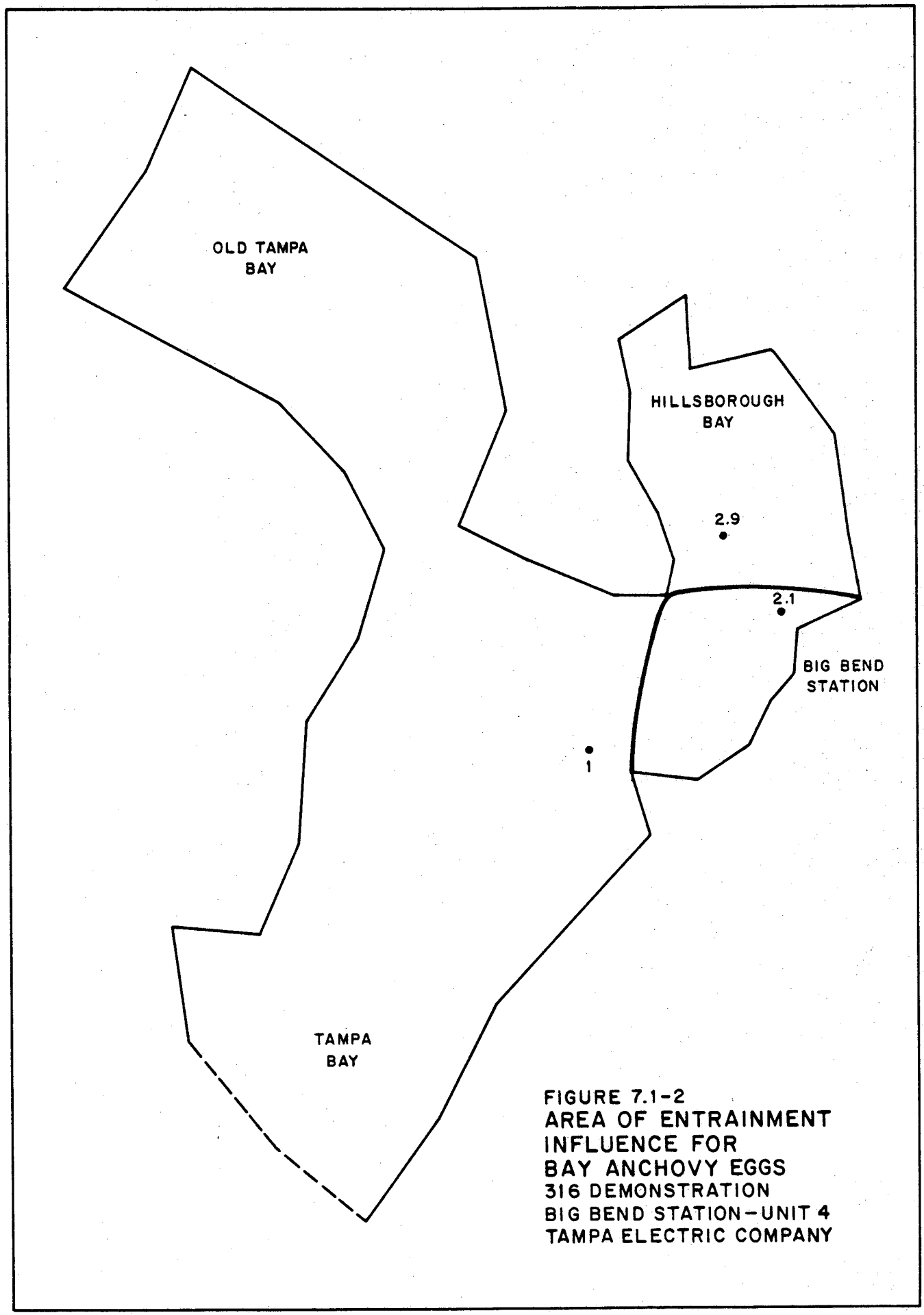


FIGURE 7.1-2
AREA OF ENTRAINMENT
INFLUENCE FOR
BAY ANCHOVY EGGS
316 DEMONSTRATION
BIG BEND STATION – UNIT 4
TAMPA ELECTRIC COMPANY

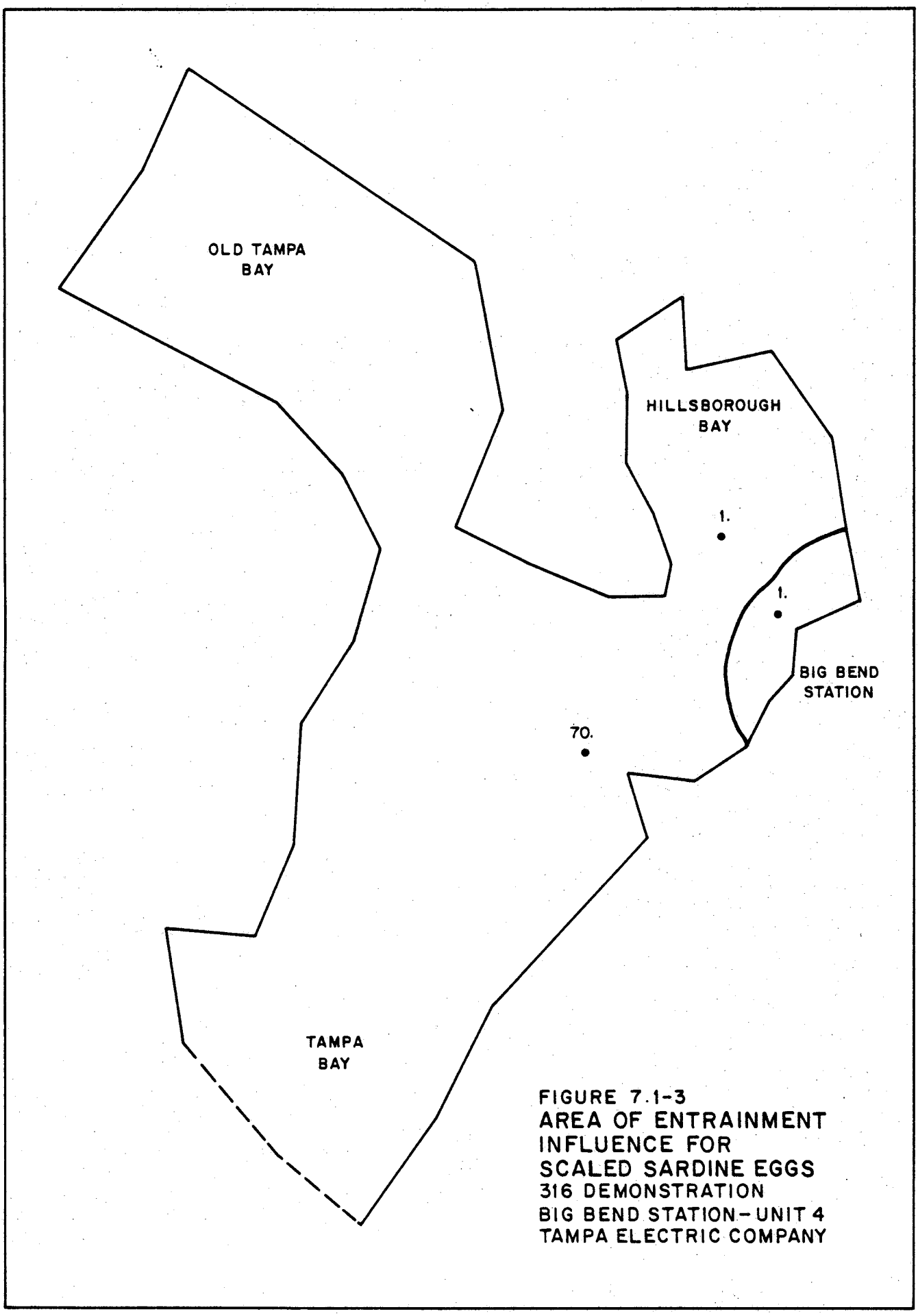


FIGURE 7.1-3
AREA OF ENTRAINMENT
INFLUENCE FOR
SCALED SARDINE EGGS
316 DEMONSTRATION
BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

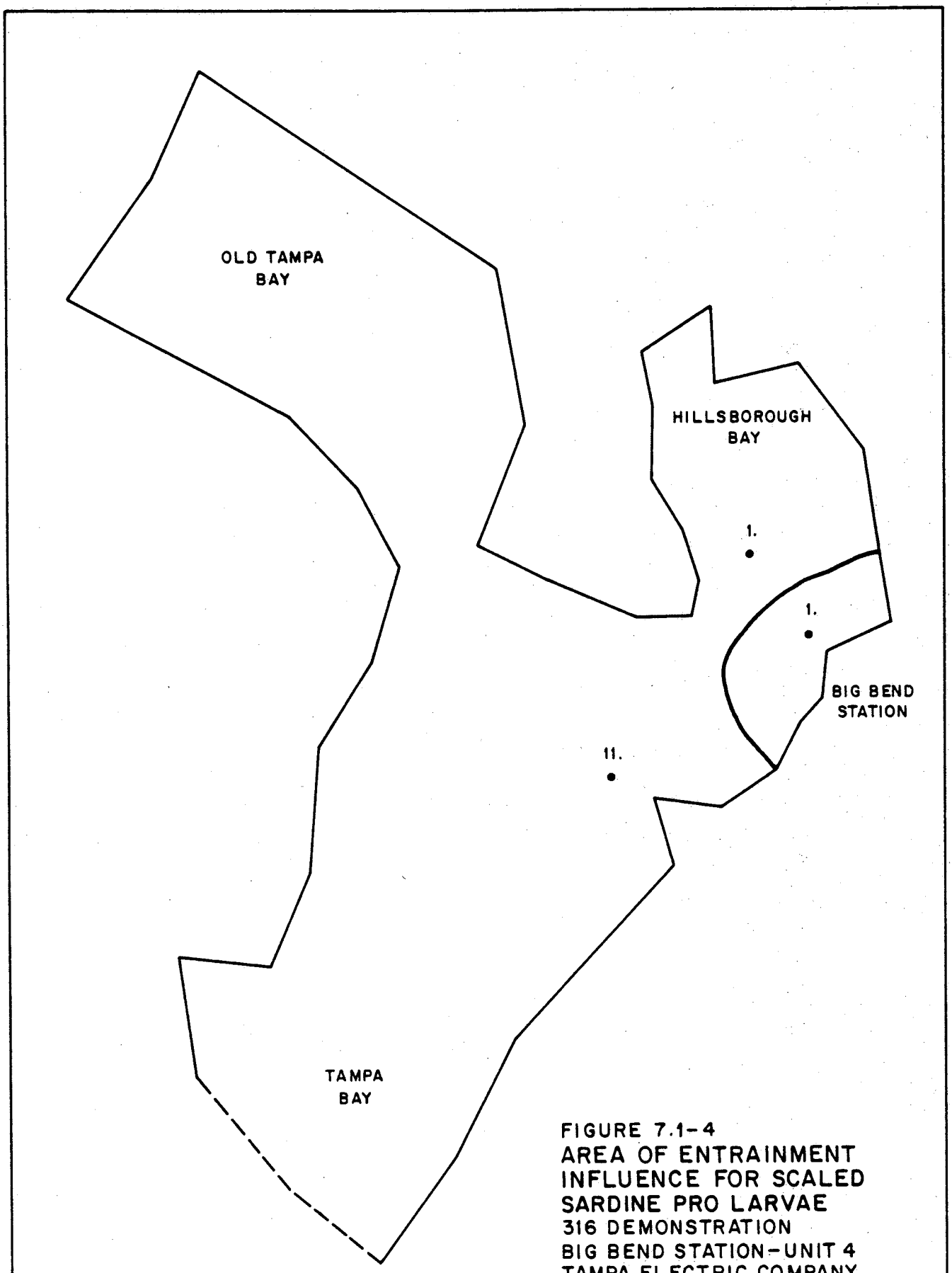


FIGURE 7.1-4
AREA OF ENTRAINMENT
INFLUENCE FOR SCALED
SARDINE PRO LARVAE
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

7.2 REPRESENTATIVE IMPORTANT SPECIES IMPACT

7.2.1 American Oyster (Crassostrea virginica)

7.2.1.1 Thermal Plume

American oysters are not abundant in Tampa Bay, probably due to lack of suitable substrate (Dawson 1953:5) and an increase in agricultural and domestic pollution (Harding 1980a). This species has been observed on submerged man-made structures and on mangrove roots.

Oysters have been observed on all man-made structures such as the sheetpiling in the discharge and intake canals. However, mortality appears to be very high during summer as a result of the high temperatures in the canal.

Results of the 1979 Oyster Spat Study (Appendix 1) show that spatfall takes place in the area around the plant, but it is lighter than reported in previous studies of Tampa Bay. Greatest spatfall took place in the discharge and the intake canals in early summer. By July, all settling had ceased in the discharge canal, and very few sets were observed there during August. Settling continued at other sample stations during July and August (Appendix 1). Other studies on the west coast of Florida have reported greatest spatfall from May through August. Therefore spatfall in the discharge canal appears to be limited by temperature. The adult oysters in the discharge canal appear to be the result of spat that settled out during the fall (Blanchet 1980).

The range of occurrence of American oyster has been reported as 1 to 36°C (Galtsoff 1964:407). However, feeding activity decreases at temperatures over 32°C (Loosanoff 1958:61; Galtsoff 1964:407) and ceases at temperatures above 38°C (Fingerman 1959, cited in Liden and Burton 1978:31-33; Galtsoff 1964:407). The decrease in feeding activity indicates that the organism is stressed at these temperatures, and if maintained at these temperatures for long periods, would not survive. This is supported by evidence that spawning is also inhibited at 35°C (Galtsoff 1964:308-309).

Davis and Calabrese (1964:655) report that settling and optimal growth of larvae occur between 30.0 and 32.5°C. Diaz (1973:993) reports that exposure of larvae to temperatures above 35°C decreases survival, while a 5-second exposure to 40°C significantly decreased the percent set. This would indicate that temperatures above 35°C are stressful to the larvae.

The thermal plume would affect a bottom area of 8.4 hectares outside the discharge canal with a ΔT of 10.1°C. Because the average ambient Tampa Bay temperature during spring and summer would be 27 and 30°C respectively (Section 3.2), American oyster

adults would be stressed and spawning and settling of larvae would be inhibited within this 8.4-hectare bottom area during spring and summer.

As temperatures over 35°C are expected to be stressful to pelagic larvae and adults attached to submerged objects above the bottom, the area of exclusion for American oyster would be defined by the 5°C ΔT isotherm during summer and the 8°C ΔT isotherm during spring under average conditions. Therefore, temperatures greater than 35°C would suppress all feeding and settling of this species within 231 hectares of the area swept by the thermal plume during summer and 43 hectares during spring. This area would be unsuitable for adult oysters which are sessile and unable to avoid high temperatures.

The area near Big Bend Station does not have the characteristics of prime American oyster habitat, and there are presently no existing, or planned, harvestable oyster beds within the area affected by the plume. The oysters attached to submerged power station structures will not be subjected to major changes in thermal regime as a result of the addition of Unit 4 and are not expected to be noticeably altered. Therefore, the thermal effluent of Big Bend Unit 4 should not significantly affect on the American oyster population of Tampa Bay.

7.2.1.2 Entrainment

The small size of planktonic stages of the American oyster precluded their capture in the meroplankton sampling gear used in the 1979 Aquatic Ecology Study (Appendix 1). American oyster larvae, however, are susceptible to entrainment at the Station. The American oyster is not of commercial importance in Tampa Bay at present. Of the 17 oyster beds leased in Tampa Bay, none are actively used, none are located in Hillsborough County, and only 2 are located in the southern portion of Pinellas County. As a result, the influence of entrainment (Figures 7.1-1 through 7.1-4) should be minimal on the Bay's oyster beds. While a small portion of the larvae in the Bay will be killed by entrainment, this loss is unlikely to adversely affect the Tampa Bay oyster population.

7.2.1.3 Cumulative Impact

The American oyster in Tampa Bay is restricted to a few locations where commercial harvesting may be feasible. The oyster is also found attached to artifical structures and mangrove roots within the Bay. While restrictions in habitat availability inhibit expansion of the oyster population, the commercial harvest of the oyster is restricted as a result of past and continuing pollution of the Bay from wastewater sewage treatment plants and chemical pollution (Harding 1980a).

The principal effect of the Big Bend Station on oysters will be due to the thermal plume. Oysters would not be precluded from colonizing any suitable natural substrate since there is none in the area. Oysters are presently encountered on the discharge canal sheetpile and associated structures, and the addition of Unit 4 would appear to have minimal if any effect on the existing population of oysters in the vicinity of Big Bend. Operation of Unit 4 should not preclude any future development of oyster populations or commercial oyster harvests within Tampa Bay.

7.2.2 Pink Shrimp (Penaeus duorarum)

7.2.2.1 Thermal Plume

The range of occurrence for adult and juvenile pink shrimp in Tampa Bay is 15.8 to 35.5°C (Eldred et al 1961:87; Dragovich & Kelly 1964:79). Marble and Mowell (1971) reported 37.2°C as lethal for prolonged periods. Trawl and impingement data collected at Big Bend Station (Appendix 1) show that this species is present all year, being most abundant from late summer through early winter.

This information, along with that presented in Appendix 6, indicates that adult and juvenile pink shrimp can not tolerate temperatures above 37°C. Based on average seasonal temperatures reported for Tampa Bay (Section 3.2) and the results of the hydrological analysis (Table 6.2-1), this temperature would be reached at the 7°C ΔT isotherm in summer and the 10°C ΔT isotherm in spring. Areas bounded by these isotherms would comprise 43 hectares and 9 hectares, respectively.

Pink shrimp post-larvae were collected in the Anclote area at temperatures from 24 to 31°C (FPC 1977a: V.173), with peak abundance occurring at 31°C. Thorhaug et al (1972: IX.1) reports 36 to 37°C as the upper tolerance limit for most larval life stages. Although Tampa Bay is utilized as a nursery by this species, few pink shrimp post-larvae were collected during the entrainment studies or in the meroplankton samples (Appendix 1); the greatest numbers were collected in the September samples.

Because post-larval pink shrimp cannot tolerate temperatures above 36°C, they would be excluded from an area of 77 hectares bounded by the 6°C ΔT isotherm during summer.

This area, as well as the exclusion areas calculated for adult and juvenile pink shrimp, comprises less than 1 percent of the area of Tampa Bay. And since relatively low densities of post-larvae were observed near Big Bend Station, the thermal effluent is not expected to significantly affect the pink shrimp population of Tampa Bay.

7.2.2.2 Entrainment

Based on the method of calculation described in Section 7.1.2.1 and the data presented in Chapter 2 of Appendix 1, approximately 1.9×10^7 pink shrimp post-larvae would be entrained at Big Bend Station per year. This is with the conservative assumption that all four units would be operating at 100 percent capacity all the time.

The equivalent adults model (Horst 1975) was used to estimate the number of adults lost to the population as a result of entrainment of early life stages. This model is based on the assumption that if the population of concern is in equilibrium and has a stable age distribution, a breeding pair will produce two breeding adults in their lifetime. The calculation, described in Section 7.1.2.2, utilizes life history data such as survival to each life stage and fecundity to estimate the number of equivalent adults represented by the entrained organisms.

Assuming the average pink shrimp has been harvested by the size of 19g (24 per pound, heads on) (Kutkuhn 1972:371), has produced at least 1.76×10^5 eggs at that size (calculated from Martosubroto 1974:614), and has an estimated survival from egg to post-larvae of 4 percent (Ewald 1965:445) (all conservative assumptions), approximately 5,275 adults would be lost to the population. If these adults were harvested at 24 per pound (heads on), this would represent about 403 lb, or less than 1.1×10^{-3} percent of the annual west coast Florida landings or 2.4×10^7 lb from 1973 to 1975 (NMFS 1976-1978). Therefore, it is unlikely that entrainment losses from Big Bend Station would significantly alter the west coast Florida shrimp population.

7.2.2.3 Impingement

Based on 1979-1980 data, pink shrimp were impinged in greater numbers than any other RIS. Pink shrimp were collected throughout the year, with the greatest number being impinged in July and August. The specimens collected during impingement sampling ranged from 33 to 152 mm in length and had a mean length of 64 mm. Weight of the sampled specimens ranged from 0.5 to 35.5 g and the mean weight was 2.85 g.

Based on impingement collections of 1,738 pink shrimp, some 98,000 pink shrimp are estimated to be impinged annually with four unit operation of Big Bend. Most of these shrimp are of a smaller size than is commonly harvested commercially. However, at 2.85 g per impinged shrimp, the 98,000 shrimp impinged annually would weigh about 618 lb. The only data available on commercial catch are for the fishery on the west coast of Florida. There are no data to suggest that the pink shrimp in Tampa Bay are not part of a single population on the west coast of Florida.

The 618 lb represents about 0.0026 percent of the 24 million lb of pink shrimp landed annually during 1973, 1974, and 1975 on the west coast of Florida (Section 5.2.2.1; NMFS 1976-1978).

7.2.2.4 Cumulative Impact

Even if it is conservatively assumed that all the pink shrimp harvested in the fishery on the west coast of Florida utilized Tampa Bay as a nursery area and were excluded from 0.094 percent of the Bay during summer, the cumulative annual loss to the pink shrimp fishery on the west coast of Florida due to entrainment, impingement, and exclusion by the thermal plume would amount to less than 0.1 percent of the annual landings. (Twenty-four million lb of pink shrimp were landed annually during 1973, 1974, and 1975 on the west coast of Florida.) Since pink shrimp utilize other inshore areas such as north Florida Bay (Section 5.2.2.2), the impact is expected to be considerably less than estimated above, and no adverse effect to the pink shrimp fishery is expected.

7.2.3 Blue Crab (Callinectes sapidus)

7.2.3.1 Thermal Plume

The range of occurrence of adult blue crab has been reported as 14.1 to 33.9°C in Tampa Bay (Dragovich & Kelly 1964:83). The upper tolerance limit for adults of the species is 40°C (Copeland & Bechtel 1974:173). Table A6-3 of Appendix 6 lists avoidance temperatures ranging from 34 to 37°C. However, blue crab have been observed entering waters of 40°C and greater for short periods to feed (Gallaway & Strawn 1975:199; Powers 1977:78).

Adult blue crabs were collected near Big Bend Station all year, although none were found in the trawl samples from July through September and few were found in the impingement samples from July through November.

No blue crab zoea were collected during the 1979 meroplankton studies (Appendix 1) or Dilution Pump Viability Study (S&W 1980a). This is to be expected, as this species spawns offshore. This lifestage is not expected to occur in the area affected by the thermal effluent.

Taking 34°C as the most conservative avoidance temperature, blue crab would be expected to avoid the area within the 4°C ΔT isotherm during summer and the 7°C ΔT isotherm during spring. Based on average seasonal conditions (Section 3.2), this represents areas of 291 hectares during summer, and 43 hectares during spring. As noted previously, blue crab are not abundant near Big Bend Station during summer, and they are known to go into waters above 40°C to feed.

Based on the ability of adult blue crab to avoid intolerable temperatures, the high thermal tolerance of the species, and the absence of the more sensitive lifestages near Big Bend Station, the blue crab population in Tampa Bay should not be adversely affected by the elevated temperatures in the discharge plume.

7.2.3.2 Entrainment

Blue crab adults spawn offshore, and the young are carried into the nursery areas as megalops (Costlow & Bookhout 1959:395). This life stage remains near the bottom and is not susceptible to entrainment. Results of studies dealing with planktonic life forms (Appendix 1) and the Dilution Pump Viability Study (S&W 1980a) support this conclusion.

7.2.3.3 Impingement

Based on the 1979-1980 impingement sampling data more juvenile and adult blue crab were impinged than all other RIS except pink shrimp and silver perch. Blue crab were impinged throughout the year, but they were collected in greater numbers in December, January, and February. Specimens collected during impingement sampling ranged from 12 to 176 mm in carapace width and had a mean carapace width of 48 mm. Weight of the sampled specimens ranged from 0.1 to 242.7 g while the mean weight was 17.6 g.

Based on an impingement collection of 246 blue crab, about 17,000 blue crab are estimated to be impinged annually with four unit operation of Big Bend. Most of these crabs are of a smaller size than is commonly harvested commercially. However, at 17.6 g per impinged blue crab, the 17,000 blue crab impinged annually would weigh 662 lb. The only data available on commercial catch are for the fishery on the west coast of Florida. There are no data to suggest that the blue crab in Tampa Bay are not part of a single population on the west coast of Florida. The 662 lb represents about 0.0052 percent of the 12.8 million lb of blue crab commercially landed on the west coast of Florida in 1975 (Section 5.2.3.1; NMFS 1976-1978).

7.2.3.4 Cumulative Impact

The thermal plume at its greatest extent would exclude blue crab from less than 0.06 percent of the Tampa Bay estuary. Even if all blue crab in the Florida west coast fishery were produced in Tampa Bay, the cumulative annual loss to the blue crab fishery on the west coast of Florida due to entrainment, impingement, and thermal exclusion would amount to less than 0.062 percent of the 1975 blue crab landings. Losses of this magnitude should not result in an adverse impact on the blue crab fishery.

7.2.4 Stone Crab (Menippe mercenaria)

7.2.4.1 Thermal Plume

The range of occurrence for adult stone crab in Tampa Bay is 15.4 to 29.7°C (Dragovich & Kelly 1964:83). Porter (1960:169) has reported 27 to 31°C as the range for successful spawning.

Adult stone crab are found primarily in deeper waters, and around shoals and pilings. Thus, as expected, none were collected by seine, only 1 was collected by trawl, and very few were collected on the intake screens at Big Bend Station (Appendix 1). Adult stone crab are bottom dwellers (Dragovich & Kelly 1964:83) and could be excluded from the area where the thermal plume is attached to the bottom, about 8.4 hectares. The ΔT within this area would be 10.1°C under average conditions (Section 6.2), potentially excluding the stone crab for most of the year. However, this area represents a very small part of Tampa Bay, and it is unlikely that adults and juveniles are abundant within this area because of the nature of the substrate.

Stone crab zoea have been observed at temperatures from 16 to 31°C, and the megalopa from 18 to 31°C (FPC 1977a: V.169-V.170). Survival of larvae increases with salinity and temperature from 23 to 30°C (Porter 1960:169).

The upper tolerance limit for stone crab eggs is 36.3 to 38.5°C, for zoea 33.1 to 36.0°C, and for megalopa 36.0 to 37.0°C (Thorhaug et al 1972: IX.2). However, molting larvae are intolerant of sudden fluctuations of temperature and salinity (Futch 1966:4). Data from the Dilution Pump Viability Study (S&W 1980a: Figure 3.5) indicate zoea of this species could tolerate a temperature rise from 30 to 36°C.

Although collected most of the year, peak abundance of stone crab zoea occurred in the meroplankton samples from mid-May through July (Appendix 1) when temperatures were rising but before they had reached their peak.

Based on this information, the pelagic stone crab larvae could tolerate temperatures from 33 to 37°C. To be conservative, 33°C is considered the limiting temperature, represented by the 3°C ΔT isotherm in summer, the 6°C ΔT isotherm in spring and the 10°C ΔT isotherm in fall. Based on Table 6.2-1, stone crab larvae could experience high mortality within 457 hectares in summer, 77 hectares in spring, and 9 hectares in fall.

Densities of stone crab larvae were consistently greater near Big Bend Station than at the offshore sample stations (Appendix 1). Therefore, there is a potential for impact to the stone crab population due to the effects of the thermal plume. Although the stone crab population could be reduced due to the effects of Big

Bend Station's thermal effluent, it is unlikely that the effect would be noticeable or permanent due to the conservative estimate of the size of the affected area, the high natural mortality of the early life stages, and the high fecundity of the species (Section 5.2.4.2).

7.2.4.2 Entrainment

The following numbers of stone crab zoea would be entrained each year by Big Bend Station:

2.2×10^9 (Stage 1),
1.2×10^8 (Stage 2),
3.2×10^7 (Stage 3),
4.4×10^6 (Stage 4),
4.3×10^6 (Stage 5).

This assumes that four units will be operating at full capacity 100 percent of the time.

Stone crab reach harvestable size approximately 30 months after hatching (Savage & Sullivan 1978:20). By this age, the average female stone crab has had the opportunity to spawn 6 to 7 egg masses of 0.5 to 1.0 $\times 10^6$ eggs each (calculated from Cheung 1969:330, 333; Binford 1912:18, cited in Savage & Sullivan 1978; Powell & Gunter 1968:289). Using the median survival for the range reported for each zoeal stage (Porter 1960:169), approximately 5,200 adults would be lost to the population as a result of entrainment of zoea by Big Bend Station.

Because the average harvested adult contributes approximately 0.19 lb (only one claw per adult is harvested) to the commercial catch (Savage et al 1975:4), entrainment of 5,200 equivalent adults represents 0.05 percent of the 1975 west coast Florida landings of 2.1×10^6 lb of claws (NMFS 1977-1978). Although most of the catch comes from areas south of Tampa Bay, this is the only set of catch data available for the area. Therefore, entrainment of early life stages of stone crab at Big Bend Station is not expected to significantly reduce the catch or the Florida west coast fishery.

Another way to view the effect of entrainment is by the area of entrainment influence.

The spatial distribution pattern for Stages 1,2, and 3 of the stone crab zoea (Table 4.5-8) resembles something in between the uniform and the scaled sardine larval density distribution (Figures 7.1-1 and 7.1-4). Therefore, the expected area of entrainment influence should be between the 2,680 and 3,150 hectare areas predicted for these distributions.

The number of entrained Stage 1, 2, and 3 stone crab zoea can be equated to an area around Station A over which this same number of organisms could have been produced. The 2.247×10^9 entrained Stage 1 zoea could have been produced over a 466 to 932 hectare area at Station A. A range is given since the data source for duration of life stage (Porter 1960: 169) provides a range (3 to 6 days) for length of lifestage. The 1.243×10^8 entrained Stage 2 stone crab zoea could have been produced over 312 to 623 hectares at Station A. The 3.218×10^7 entrained Stage 3 stone crab zoea could have been produced over 350 to 700 hectares at Station A.

7.2.4.3 Impingement

Stone crabs were collected infrequently during impingement sampling. The specimens collected during 1977-1980 impingement sampling ranged from 13 to 84 mm in carapace width and had a mean carapace width of 54 mm. Weight of the impinged specimens ranged from 0.6 to 159.7 g while mean weight was 82 g.

Based on impingement collections of 14 stone crab, about 800 stone crab are estimated to be impinged annually with four unit operation of Big Bend. Even though the mean weight of these stone crab is less than even the mean harvestable claw weight, at 82 g per impinged stone crab, the 800 stone crabs impinged annually would weigh 142 lb. The only data available on commercial catch are for the fishery on the west coast of Florida. There are no data to suggest that the stone crab in Tampa Bay are not part of a single population on the west coast of Florida. If the 142 lb is all harvestable (only one claw per adult is harvested in Florida), it would account for about 0.0068 percent of the stone crab commercial landings on the west coast of Florida (Section 5.2.4.1; NMFS 1977-1978).

7.2.4.4 Cumulative Impact

The thermal plume at its greatest extent could prevent stone crab from utilizing about 0.094 percent of the Tampa Bay estuary. Even if all the stone crab in the Florida west coast fishery were produced in Tampa Bay, the cumulative annual loss to that fishery due to entrainment, impingement, and thermal exclusion would amount to less than 0.16 percent of the 1975 Florida west coast landings. Losses of this magnitude are not expected to result in an adverse impact on the stone crab fishery.

7.2.5 Bay Anchovy (Anchoa mitchilli)

7.2.5.1 Thermal Plume

Adult bay anchovy have been collected in Florida waters ranging from 10.8 to 34.0°C (Appendix 6, Table A6-5). Adults avoid temperatures of 32°C (Meldrim et al 1974:41; Terpin et al

1977:37), and prefer temperatures from 24.7 to 30.0°C (Meldrim & Gift 1971:27; Terpin et al 1977:10, 26) when acclimated to 22°C. Bay anchovy are sensitive to abrupt temperature changes (Terpin et al 1977:14,15, 43,44).

Bay anchovy adults were observed all year near Big Bend Station (Appendix 1). They were most abundant in trawl and impingement samples from November through January and least abundant during the warmest months. Therefore, few adult bay anchovy are expected to be in the affected area during the summer months, and those remaining can avoid intolerable temperatures (Meldrim et al 1974:41; Terpin et al 1977:37).

Based on this information, bay anchovy would tend to avoid temperatures of 32°C or greater. This would be an area of 720 hectares within the 2°C Δ T isotherm during summer, 150 hectares within the 5°C Δ T isotherm during spring, and 17 hectares within the 9°C Δ T isotherm during fall. The fact that this species is most abundant during winter suggests its distribution is already limited by the ambient temperature regime, and the thermal plume should not affect the adult bay anchovy population.

Bay anchovy eggs have been collected from 9.7 to 30.0°C in northern waters (Table A6-5, Appendix 6). Larvae of this species have been collected from 11 to 31°C (Table A6-5, Appendix 6). Rebel (1973:22) reports 35.8°C as the maximum tolerance limit for larvae, with no significant difference in survival occurring between 18.6 and 32.5°C.

Eggs and larvae of this species were collected throughout most of the year. Peak abundance occurred in June and July 1979, when the water temperature was rising but had not yet reached the yearly maximum. Based on the above information, bay anchovy larvae have a low chance of survival at temperatures of 33°C or greater. Therefore, they would be excluded from a 457 hectare area defined by the 3°C ΔT isotherm in summer, 77 hectares defined by the 6°C ΔT isotherm during spring, and 9 hectares defined by the 10°C ΔT isotherm during fall. Since the largest of these areas comprises less than 1 percent of the surface area of Tampa Bay, and since bay anchovy is the most abundant fish species in Tampa Bay (Rounsefell 1975:356), the Big Bend Station thermal effluent is not expected to have a noticeable effect on the bay anchovy population of Tampa Bay.

7.2.5.2 Entrainment

Approximately 9.6×10^{10} bay anchovy eggs, 1.0×10^{9} prolarvae, and 1.0×10^{10} post-larvae would be entrained in 1 year at Big Bend Station (four units at maximum capacity).

Houde (1977b:333) reports 92.4 percent hatching success for bay anchovy, and greater than 40 percent survival from prolarvae to post-larvae. The 1979 Fecundity Study (Appendix 1) indicates that mean fecundity of this species near Big Bend Station is about 1,482 eggs per female. The maximum age for this population appeared to be I+, and there appeared to be no repeat spawners (Appendix 1). Based on this information, entrainment at Big Bend Station is expected to result in a loss of 1.5×10^{8} adults to the population in 1 year. Because bay anchovy is the most abundant fish species in Tampa Bay (Rounsefell 1975:356), the impact of this loss on the Tampa Bay population would probably be small. However, insufficient data on the size of the population are available to compare this loss to the adult population in Tampa Bay.

The area of entrainment influence for bay anchovy eggs and prolarvae is 4,160 hectares (see Figure 7.1-2). This represents the area where some reduction in density can occur. Additionally, the number of entrained bay anchovy eggs and prolarvae can be equated to an area around Station A over which this same number of organisms could have been produced. The 9.606×10^{10} entrained bay anchovy eggs could have been produced in a 429-hectare area around Station A. The 1.053×10^{9} entrained bay anchovy prolarvae could have been produced over a 115-hectare area at Station A. The large entrainment numbers and relatively small equivalent production areas are a reflection of the great abundance of anchovy eggs and larvae in Tampa and Hillsborough Bays. While a large number of eggs and larvae will be lost by entrainment, the areas of influence and equivalent production are small relative to the size of Tampa Bay. Therefore, it is expected that this loss represents only a small fraction of the total production of anchovies in the bay.

7.2.5.3 Impingement

Bay anchovy were impinged throughout the year but were collected in impingement samples in greater numbers in November, December, and January. The specimens collected during impingement sampling ranged from 32 to 68 mm in length and had a mean length of 50 mm. Weight of the sampled specimens ranged from 0.3 to 4.1 g and the mean weight was 1.5 g.

Based on impingement collections of 182 bay anchovy, some 11,000 bay anchovy are estimated to be impinged annually with four unit operation at Big Bend. This species is not commercially harvested (Rounsefell 1975:356). However, at 1.5 g per impinged bay anchovy, the 11,000 bay anchovy impinged annually would amount to a loss of 35 lb of potential forage for aquatic species of higher trophic levels. This loss rate can also be compared to the abundance of bay anchovy as measured with trawl data. On June 19, 1976, a single 5-minute trawl captured 244 bay anchovy

weighing 1.5 g apiece and a single seine haul on November 4, 1979, captured 2,364 smaller sized individuals.

7.2.5.4 Cumulative Impact

The thermal plume is expected to exclude bay anchovy from less than 0.2 percent of the Bay area. Entrainment is expected to harvest the equivalent number of bay anchovy that could be produced in 429 hectares of the Bay. Impingement impacts are expected to crop another 35 lb of this forage species annually. There are many sport and commercially-exploited fishes which could utilize bay anchovy. It is not known if the populations of these explcited species are limited by the abundance of bay anchovy; however, the percentages of production lost due to entrainment and thermal exclusion effects as well as the poundage lost due to impingement are probably small relative to the natural fluctuations in abundance of this species.

7.2.6 Scaled Sardine (Harengula jaguana)

7.2.6.1 Thermal Plume

Adult scaled sardine have been collected from Florida waters at temperatures of 14 to 34°C (Table A6-6, Appendix 6).

Although peak abundance of scaled sardine adults were observed in May near Big Bend Station, few were observed there during the warmest months since they move offshore to spawn. Therefore, few are expected to be present when the exclusion area covers the greatest area, and those that are present have the ability to avoid intolerable temperatures.

Assuming adults of this species would avoid temperatures of 34°C or greater, the exclusion area during summer would be 291 hectares defined by the 4°C ΔT isotherm, and in spring 43 hectares defined by the 7°C ΔT isotherm. These areas represent less than 0.4 percent of the surface area of Tampa Bay. As scaled sardine are also not abundant near Big Bend Station during warm periods, it is unlikely that the thermal effluent will affect adult scaled sardine.

Rebel (1973:17) reports hatching success of scaled sardine eggs from 14.9 to 36.5°C, while Saksena et al (1972:693) reports 35°C as the maximum tolerance limit for this life stage. Optimal growth of scaled sardine larvae is reported at 26 to 32°C (Saksena et al 1972:693) while the maximum tolerance limit is 35°C (Rebel 1973:17). Peak abundance of scaled sardine eggs and larvae was observed during summer 1979.

Mortality of scaled sardine eggs and larvae is expected to be 100 percent at temperatures of 35°C or greater. This would occur

within 150 hectares defined by the 5°C ΔT isotherm in summer and 25 hectares defined by the 8°C ΔT isotherm in spring.

Since these areas represent less than 0.2 percent of the surface area of Tampa Bay and since this species is one of the most common in Gulf of Mexico estuaries, including Tampa Bay (Springer & Woodburn 1960:18), the thermal effluent from Big Bend Station is not expected to noticeably affect the Tampa Bay scaled sardine population.

7.2.6.2 Entrainment

Approximately 5.9×10^7 scaled sardine eggs, 1.4×10^9 prolarvae and 3.4×10^8 post-larvae could be entrained by the four units at Big Bend Station.

All female scaled sardine are recruited to the spawning population by Age II (Martinez & Houde 1975:41), and by that time would have produced a total of 4.8×10^4 eggs (calculated from Martinez & Houde 1975:41,43). Assuming survival from hatching to prolarvae is 12 percent, and survival from prolarva to post-larva is 2 percent (Houde 1977a:626), it is estimated that 1.2×10^6 adults would be lost to the scaled sardine population in 1 year as a result of entrainment at these early life stages.

This number represents less than 0.05 percent of the estimated mean biomass of scaled sardine for 1971 through 1973 in the eastern Gulf of Mexico (Houde 1977a:613). Therefore, it is unlikely that entrainment of eggs and larvae at Big Bend Station will have a noticeable effect on the local scaled sardine population.

The spatial distribution pattern of scaled sardine eggs is similar to that of scaled sardine prolarvae. Therefore the area of entrainment influence for both eggs and prolarvae of this species is about 1,650 and 3,150 hectares, respectively.

The number of entrained scaled sardine prolarvae can be equated to an area around Station A. The 1.412×10^9 entrained scaled sardine prolarvae could have been produced over a 284-hectare area at Station A. Eggs and post-larvae were infrequently collected; thus, no area was estimated for their life stages.

7.2.6.3 Impingement

Scaled sardine were rarely collected during impingement sampling. The four specimens collected during impingement sampling ranged from 90 to 132 mm in length and had a mean length of 111 mm. Weight of the sampled specimens ranged from 13 to 54.6 g and the mean weight was about 30 g.

Based on impingement collections of 4 scaled sardines, some 220 scaled sardine are estimated to be impinged annually with four unit operation at Big Bend. At 30 g per impinged scaled sardine, 220 scaled sardine impinged annually would weigh about 15 lb. While there are no commercial harvest data to compare this annual loss rate with, there are trawl and seine data available with which to compare the impingement harvest rate. For instance, on May 10, 1979, when the mean weight of seine-captured scaled sardines was about 10 g, 388 scaled sardines were captured in a single seine haul off the northern shore of Apollo Beach. In addition, Houde (1977a:621) estimates the biomass of scaled sardines in eastern Gulf of Mexico to be 265,000 metric tons. In light of these comparative measures of abundance, it is apparent that 15 lb of scaled sardines represents a very small reduction in forage.

7.2.6.4 Cumulative Impact

The thermal plume is expected to exclude scaled sardine adults from less than 0.2 percent of the Bay. The area of entrainment influence for scaled sardine larvae is small relative to the size of Tampa Bay. Eggs and post-larvae of the species were infrequently collected, thus precluding calculation of an area of entrainment influence for these life stages. Entrainment of prolarvae is expected to harvest the equivalent number of scaled sardines that could be produced in 284 hectares of the Bay near Station A. An additional 15 lb of scaled sardine are lost due to impingement. As pointed out in the life history discussion (Section 5.2.6.1), the scaled sardine could be an important prey species for larger fish. It is not known if the populations of these larger fish are limited by the abundance of scaled sardine; however, the percent of production lost due to entrainment and thermal exclusion effects as well as the poundage lost due to impingement are expected to be small relative to the Gulf of Mexico biomass estimates of 265,000 metric tons for this species.

7.2.7 Tidewater Silversides (Menidia beryllina)

7.2.7.1 Thermal Plume

Adult and juvenile tidewater silverside have been collected at temperatures from 5.0 to 34.9°C in the Gulf of Mexico (Table A6-7, Appendix 6). Meldrim and Gift (1971:35) report an avoidance temperature of 32.8°C for individuals acclimated to 20°C.

Tidewater silverside was the most abundant and ubiquitous species collected during the 1979 Aquatic Ecology Study (Appendix 1). This species was most abundant in October and least abundant in June and July. Tidewater silverside are particularly abundant along beaches and in embayment areas.

Adult tidewater silversides would be expected to avoid areas with temperatures of 35°C or greater. These temperatures would occur within a 150 hectare area during summer, and a 25 hectare area during spring. These areas are defined by the 5 and the 8°C ΔT isotherms. As these areas represent a very small part of Tampa Bay and tidewater silversides are able to avoid intolerable temperatures (Meldrim & Gift 1971:35), the thermal effluent is not expected to affect the adult population of this species.

Tidewater silverside larvae have been collected at temperatures from 12 to 30°C in Chesapeake Bay (Dovel 1971:10). Eggs of this species hatch at temperatures from 21 to 29°C (Table A6-7, Appendix 6).

The adhesive, demersal eggs and demersal prolarvae are not susceptible to the sampling gear used in the meroplankton studies and did not occur in the samples (Appendix 1). As they stay near the bottom, they are expected to be stressed within 8.4 hectares of the bottom affected by the discharge plume. This is a relatively small area, and highest densities of these life stages are expected to occur during the early spring, thus minimizing potential impact.

Post-larvae of this species occurred in the 1979 meroplankton samples in December and from March through early June, with peak abundance occurring in March. At present there are no known thermal tolerance data for tidewater silverside post-larvae. However, this life stage is not expected to be present in great numbers within the affected area during summer, and the potential for thermal impact is small.

7.2.7.2 Entrainment

Approximately 1.6×10^6 tidewater silverside post-larvae would be entrained by the four units at Big Bend Station each year. Assuming survival from egg to post-larvae is 0.01 and the lifetime fecundity for an average female to be 3,927 eggs (calculated from Appendix 1), the number of adults lost to the population each year would be 8.1×10^4. As this is one of the most common and ubiquitous fish species in Tampa Bay (Appendix 1), this loss is not expected to have a noticeable effect on the tidewater silverside population there.

7.2.7.3 Impingement

Tidewater silverside were not collected by impingement sampling during 1979-1980. Section 5.2.7.2 of this report describes a life history for this species which indicates a potential for impingement. However, since no individuals of this species were collected in the 1979-1980 impingement study, it seems unlikely that impingement would be a major impact for this species.

7.2.7.4 Cumulative Impact

The thermal plume is expected to exclude tidewater silverside from less than 0.03 percent of the Bay. An additional 81,000 adults are expected to be lost annually due to entrainment effects. This species is also reported to be a forage species for other species including the spotted seatrout (Section 5.2.7.2). It is not known if the populations of the spotted seatrout or other species which forage on tidewater silverside are limited by the abundance of tidewater silverside; however, the percent of production area lost due to thermal exclusion as well as the 81,000 adults lost annually due to entrainment is expected to be small relative to the natural fluctuations in abundance for this species.

7.2.8 Silver Perch (Bairdiella chrysura)

7.2.8.1 Thermal Plume

Adult and juvenile silver perch have been collected in Florida waters from 9.9 to 34°C (Table A6-8, Appendix 6). The upper avoidance temperature for adults is reported as 29.7°C, and the critical thermal maximum is 34.4°C for individuals acclimated to 20°C (Gift & Westman 1971:47). The critical thermal maximum for juveniles is 35.5°C under the same conditions (Gift & Westman 1971:47). Silver perch are present in the vicinity of Big Bend Station all year. Their peak abundance is from May to mid-June (Appendix 1), before the water temperature reaches its maximum. Adult and juvenile silver perch would avoid temperatures of 34°C or greater, based on the above information. Therefore they would be excluded from 291 hectares defined by the 4°C ΔT isotherm during summer and 43 hectares defined by the 7°C ΔT isotherm during spring. As these fish are able to avoid areas of intolerable temperatures (Gift & Westman 1971:47), and these areas are relatively small portions of Tampa Bay (less than 0.4 percent), adult silver perch should not be noticeably affected by the thermal effluent from Big Bend Station.

Kuntz (1914:3) reports successful hatching of silver perch eggs at 27°C, however this observation was taken from a North Carolina population. Silver perch larvae have been collected at temperatures from 16.4 to 31.8°C (Jannke 1971:71). During the 1979 meroplankton sampling, eggs and larvae were collected from 16 to 32°C (Appendix 1).

Silver perch eggs were collected from January through September, with peak density occurring in mid-April (Appendix 1). The average ambient Tampa Bay temperatures in spring approach, and in summer exceed, that reported as the upper development range (27°C) (Kuntz 1914:3).

The larvae occurred in meroplankton samples from February through early July, and their peak abundance occurred from mid-March through late May (Appendix 1).

The lack of applicable thermal tolerance data for the early life stages of silver perch, particularly larvae, precludes a quantitative estimate of the area of potential impact of the thermal effluent on the silver perch population. However, egg and larval densities are highest when they are less likely to encounter intolerable temperatures. The present abundance of silver perch in the area suggests the species is able to tolerate temperatures greater than that reported. Therefore it is unlikely that the thermal effluent would have a noticeable effect on the early life stages of the silver perch population.

7.2.8.2 Entrainment

Approximately 8.8×10^9 silver perch eggs, 1.6×10^7 prolarvae, and 1.5×10^7 post-larvae are expected to be entrained per year by Big Bend Station Units 1 through 4.

Approximately 8.2×10^{10} eggs and 3.2×10^6 prolarvae identified only as sciaenids could be entrained each year at Big Bend Station Units 1 through 4. Occurring from January through October, these unidentified sciaenid eggs and prolarvae could represent 8 species of sciaenid in addition to the species discussed in this section. Of the RIS, the seasonal distribution of these eggs and prolarvae most closely parallels that of silver perch. Therefore, it is more likely that a significant portion of the unidentified organisms could be silver perch rather than spotted seatrout or black drum. Insufficient life history data are available to estimate the number of adults that would be lost to the population as a result of this entrainment.

Another way to view entrainment is by the area of entrainment influence. The spatial distribution pattern of silver perch and unidentified sciaenid eggs is something in between the uniform and the scaled sardine prolarvae density distributions (Table 4.5-8). Therefore the area of entrainment influence for silver perch and unidentified sciaenid eggs should be between 2,680 and 3,150 hectares.

The number of entrained silver perch and unidentified sciaenid eggs can be equated to an area around Station A over which this same number of organisms could have been produced. The 9×10^9 entrained silver perch eggs could have been produced over a 1,031-hectare area at Station A. The 8×10^{10} entrained unidentified sciaenid eggs, which are assumed to have the same lifestage duration as silver perch eggs, could have been produced over a 452 hectare area at Station A.

7.2.8.2 Impingement

Based on data collected in 1979-1980, the silver perch was impinged in greater numbers than any other RIS except pink shrimp. Silver perch were impinged throughout the year but the greatest numbers were impinged in May, June, and July. The specimens collected during impingement sampling ranged from 34 to 138 mm in length and had a mean length of 53 mm. Weight of the 408 sampled specimens ranged from 0.9 to 65.2 g and the mean weight was 3.4 g.

Based on impingement collections of 431 silver perch, some 29,000 silver perch are expected to be impinged annually with four unit operation of Big Bend. At 3.4 g per impinged silver perch, the 29,000 silver perch impinged annually would weigh 223 lb. While there are no commercial harvest data to compare this annual loss rate of silver perch, there are trawl and seine data available. For instance, on May 10, 1979, when the mean weight of trawl-captured silver perch was about 1.3 g, 958 silver perch were captured in two 5-minute trawls in the discharge canal. So the annual number impinged could be captured in about 30 such trawls, and the total weight of impinged silver perch could be captured in about 80 such trawls.

7.2.8.4 Cumulative Impact

The thermal plume is expected to impact silver perch in less than 1 percent of the Tampa Bay estuary. Entrainment of eggs of silver perch and unidentified sciaenids is expected to harvest the equivalent number of silver perch as could be produced in a 1,031 hectare area of the Bay in an area around meroplankton sampling Station A. Prolarvae and post-larvae were infrequently collected, thus precluding calculation of the influence for these life stages. The impingement loss is expected to total 223 lb per year. There are no commercial or sport fishing data with which to compare this impact.

7.2.9 Spotted Seatrout (Cynoscion nebulosus)

7.2.9.1 Thermal Plume

Adult spotted seatrout have been collected from Florida waters at temperatures ranging from 12.1 to 33°C (Table A6-9, Appendix 6). Along the Georgia coast, they have been observed migrating out of shallow water areas at temperatures greater than 25°C (Mahood 1974, cited in Johnson 1978:181).

Few adult spotted seatrout were collected during the 1979 (Appendix 1) and the 1977 studies (TECO 1977h). However, they were captured by fishermen during the earlier study, and a cursory study of local fishermen in 1979 and early 1980 indicated a decline in the spotted seatrout population (Appendix 1). This

decline has been attributed to the cyclic nature of species abundance or the loss of seagrass habitat (Appendix 1).

Those adult spotted seatrout that would be present in the area affected by the thermal discharge would be expected to avoid an area of 291 hectares within 4°C ΔT isotherm in summer and 43 hectares within the 7°C ΔT isotherm in spring. These areas represent less than 0.4 percent of the surface area of Tampa Bay. Spotted seatrout can avoid intolerable temperatures (Mahood 1974, cited in Johnson 1978:181), and are not abundant near Big Bend Station. Therefore it is unlikely that the thermal effluent would affect adult spotted seatrout.

No eggs definitively identified as spotted seatrout were collected during the 1979 studies; however, eggs and prolarvae that could only be identified as Cynoscion sp. were collected. Since Cynoscion arenarius, the sand seatrout, also occurs in the area, these eggs could be attributed to either species. To be conservative, those eggs and prolarvae identified as Cynoscion sp. were considered C. nebulosus. Spotted seatrout eggs are known to hatch at temperatures from 23 to 27°C (Fable et al 1978:67).

Eggs were collected in sample surveys from late February through late May 1979 and January 1980 at temperatures from 16 to 28°C (Appendix 1). Peak densities occurred in April 1979 when water temperatures ranged from 23 to 25°C and before temperatures reached thier annual peak. Conservatively assuming that 27°C is the maximum temperature for successful hatching, spotted seatrout eggs would incur high mortaility within a 1,449-hectare area during spring.

Larvae had been colleted from 16.4 to 31.8°C in Florida waters (Jannke 1971:71,72). Larvae were collected from February through late September 1979 and from mid-January through February 1980 at temperatures from 14 to 32°C. Peak densities occurred from the end of June through mid-July (Appendix 1). Conservatively assuming that 32°C is the maximum temperature tolerated by this life stage, spotted seatrout larvae would be eliminated within 720 hectares during summer, 150 hectares during spring, and 17 hectares during summer.

7.2.9.2 Entrainment

Eggs and prolarvae identified as Cynoscion sp. were included in the entrainment estimate; therefore, the numbers entrained are conservative estimates as C. arenarius is also present in the vicinity of Big Bend Station.

Approximately 2.9×10^7 eggs, 7.6×10^5 prolarvae, and 6.0×10^6 post-larvae could be entrained per year by Big Bend Station Units 1 through 4. It is assumed that survival from egg to

prolarvae is 0.1, and from prolarvae to post-larvae is 0.1 as there is no available literature for these life stages. All spotted seatrout are mature by Age III (Klima & Tabb 1959:20), and Ages III and IV make up most of the spawning population (Tabb 1961:13). The lifetime fecundity of the average female would be 1,805,450 eggs (calculated from Sundararaj & Suttkus 1962:85). The sex ratio during that period would be 0.4:1 (calculated from Tabb 1961:16). It is estimated that 490 adults would be lost to the population in 1 year due to entrainment of eggs and larvae.

Approximately 8.2×10^{10} eggs and 3.2×10^{6} prolarvae identified only as sciaenids could be entrained each year at Big Bend Station Units 1 through 4. Occurring from January through October, these eggs and prolarvae could represent 8 species of sciaenid in addition to the species discussed in this section. Of the RIS, the seasonal distribution of these eggs and prolarvae most closely parallels that of silver perch. Therefore, it is more likely that silver perch could be a significant portion of the unidentified organisms than spotted seatrout or black drum were not included in this estimate.

The average spotted seatrout is harvested at about 2 lb (Sundararaj & Suttkus 1962:85) and the annual average commercial landings for the west coast of Florida was 2.2×10^{6} lb from 1970 to 1975 (NMFS 1973-1978). Thus these adults would represent 0.04 percent of the annual commercial landings for the west coast of Florida. Therefore, it is unlikely that a loss of this magnitude would have a noticeable effect on the local spotted seatrout population.

7.2.9.3 Impingement

Spotted seatrout were rarely collected in impingement sampling in 1979-1980. The two specimens for which length and weight information were collected were 103 and 128 mm in length and weighed 16.4 and 33 g.

Based on impingement collections of four spotted seatrout, some 284 spotted seatrout are estimated to be impinged annually with four unit operation at Big Bend. At 24.7 g per impinged spotted seatrout, the 284 spotted seatrout impinged annually would weight 16 lb. The only data available on commercial catch are for the fishery on the west coast of Florida. There are no data to suggest that the spotted seatrout in Tampa Bay are not part of a single population on the west coast of Florida. This 16 lb equals 0.0007 percent of the average commercial landings on the west coast of Florida in the years 1970 to 1975 (Section 5.2.9.1; NMFS 1976, 1978).

7.2.9.4 Cumulative Impact

The thermal plume is expected to exclude adult spotted seatrout from less than 0.2 percent of Tampa Bay. Spotted seatrout eggs could be excluded from less than 2 percent, and larvae from less than 1 percent, of Tampa Bay. These predictions are based on reported ranges of geographic occurrence due to the scarcity of applicable thermal tolerance data for this species. This is a conservative assumption, as the upper tolerance limit for a species is usually higher than the temperatures in which the organisms are typically found (Appendix 6). Entrainment and impingement effects are expected to harvest the equivalent of 0.0407 percent of the annual commercial landings for the fishery of the west coast of Florida. Even if all the west coast harvest was derived from Tampa Bay production, the cumulative effect of entrainment, impingement, and the thermal plume would equate to less than 0.25 percent of the harvest of this species on the west coast of Florida.

7.2.10 Black Drum (Pogonias cromis)

7.2.10.1 Thermal Plume

Adult black drum were collected in the vicinity of Big Bend Station from May through January. Most of these fish were collected in the discharge channel (Appendix 1). Although no thermal tolerance data exist for this species, adults and juveniles are known to prefer high temperatures (Simmons & Breuer 1962:200; Meldrim & Gift 1971:29). Therefore, the thermal effluent is not expected to have an adverse effect on this species.

Black drum eggs were collected from late March through early June 1979, December 1979, and January 1980. Peak densities occurred in April. Larvae were collected from late February through mid-August, with peak densities occuring in late March and April before temperatures reach their annual peak.

There are no thermal tolerance data available for these life stages at present; thus, it is not possible to quantify the extent of potential impact to these organisms. However, their peak abundance occurs during the cooler months of the year, thus minimizing their susceptibility to adverse impacts from the thermal plume.

7.2.10.2 Entrainment

Approximately 4.2×10^7 black drum eggs, 6.7×10^6 prolarvae and 2.7×10^6 postlarvae could be entrained per year at Big Bend Station Units 1 through 4. Approximately 8.2×10^{10} eggs and 3.2×10^6 prolarvae identified only as sciaenids could be entrained each year. Occurring from January through October,

these eggs and prolarvae could represent 8 species of sciaenid in addition to the species discussed in this section. Of the RIS, the seasonal distribution of these eggs and prolarvae most closely parallels that of silver perch. Therefore, it is more likely that silver perch could be a significant portion of the unidentified organisms than spotted seatrout or black drum and was not included in this estimate.

Pearson (1929:171) reported 6 million eggs in a female black drum of 1,100 mm SL. However, this species becomes mature at 1.5 to 2.0 years at 320 to 350 mm SL (Pearson 1929:171); therefore, this fecundity estimate would not be applicable to predict population effects. There are insufficient life history data available to provide an estimate of the number of adults lost and the potential impact of this loss on the population.

However, this species may live up to 35 years (Richards 1973:589) and long-lived species are less affected by changes in survival at age 0 than short-lived species (Horst 1977:304). Therefore, the black drum population should be relatively resistant to population perturbations due to entrainment of early life stages.

None of the planktonic stages of black drum was collected in sufficient abundance for areas of entrainment influence to be calculated. However, based on the collection of a limited number of the planktonic life stages of this species, there is no reason to believe that the spatial density gradient for this species is more extreme than that observed for other RIS in Tampa Bay. In any case, the greatest area of entrainment influence occurs when the distribution is uniform; that is, when no density gradient exists. In this case, the area of entrainment influence encompasses a 2,680-hectare area. This area is small relative to the area of Tampa Bay.

7.2.10.3 Impingement

Only one black drum was collected during impingement sampling in 1979-1980. That individual was 65 mm in length and weighed 6.9 g.

Based on the impingement collection of that one black drum, some 56 black drum are estimated to be impinged annually with four unit operation of Big Bend. At 6.9 g per impinged black drum, the 56 black drum impinged annually would weigh less than 1 lb. The only data available on commercial catch are for the fishery on the west coast of Florida. There are no data to suggest that the black drum in Tampa Bay are not part of a single population on the west coast of Florida. This 1 lb of black drum would amount to 0.003 percent of the 1975 commercial landings on the west coast of Florida.

7.2.10.4 Cumulative Impact

Adults of this species are not expected to be adversely affected by the higher temperatures in the plume area. In addition, since peak abundance of eggs and larvae occurs during the cooler months of the year, the susceptibility of eggs and larvae to adverse effects of the thermal effluent is minimal. Since appropriate fecundity information is not available for this species, the number of equivalent adults cannot be calculated. However, the longevity of this species makes the population more resistant to the effects of entrainment than the more short-lived RIS. The area of influence of the intake for planktonic lifestages of this species should not exceed 2,680 hectares, which is a small portion of Tampa Bay. The annual harvest by impingement is expected to amount to only 0.003 percent of the 1975 commercial landings for the west coast of Florida.

7.2.11 West Indian Manatee (Trichechus manatus)

7.2.11.1 Thermal Plume

The 1979 manatee studies (Appendix 2) indicate the West Indian manatee regularly utilizes the discharge canal of Big Bend Station as a warm water refuge during the winter months. Aerial sightings of manatee increased as ambient water and air temperatures decreased. The manatees moved in and out of the discharge canal in response to cold fronts and warming trends. The aerial surveys also showed that the greatest numbers of manatees were sighted at the Gardinier Phosphate Plant discharge on the Alafia River.

The potential for cold shock due to plant shutdown should be reduced as the probability of all four units going down simultaneously is lower than that of three units shutting down simultaneously. No adverse effects are expected as a direct result of the thermal effluent at Big Bend Station. However, those manatees in the discharge canal could be exposed to injury from fish nets and careless boaters. In an attempt to minimize the potential of injury, information signs have been erected to alert canal users to the presence of manatee.

7.2.11.2 Intake System

Manatees would not be affected by operation of the intake system at Big Bend Station.

7.3 THERMAL PLUME EFFECTS ON THE BENTHIC COMMUNITY

Changes in the faunal community in the past, due to operation of Units 1 to 3 coupled with hydrothermal models comparing three- and four-unit operation, provide data to assess the impact of Unit 1 to 3 operation and the incremental impact of Unit 4 operation. Benthic data collected during operation of Units 1 to 3 enhances impact assessment for four-unit operation.

During the 1976-1977 and 1979 benthos studies conducted at Big Bend, areas inside and outside the expected bottom contact areas of the thermal discharge plume were sampled (see Figures 4.4-4 and 4.4-5). The effects of the plume on the benthic community and selected benthic species have been addressed in the 316 Demonstration for Units 1-3 (TECO 1977g), and in a recent technical report by Mote Marine Laboratory (1980b). Additional information on the effects of the thermal discharge has been developed with different techniques for selected species. This is presented in Section 7.3.2.

7.3.1 Community Impacts

The 316 Demonstration for Units 1-3 (TECO 1977g) and the report by Mote Marine Laboratory (1980b) summarize the results of the 1976-1977 and 1979 benthos studies at Big Bend. Both studies characterize the communities by measures or indices such as faunal density, species richness, diversity, and faunal similarity.

Faunal density in the thermal (BC) transect in 1976-1977 (TECO 1977g: Table 4.13) was generally higher than at non-thermal (E) transect stations. The corresponding stations sampled in 1979 did not show this or any other discernible pattern. In the 1976-1977 study, the faunal density in the discharge canal (Stations I-1 and I-16) was relatively low. Again this was not observed in the 1979 data; in fact, the discharge (Stations 1 and 2) occasionally exhibited the greatest faunal density. In both studies, temporal variation in faunal density was very great.

Species richness (the number of species) in 1979 (see Figures 11 to 16 of MML 1980b) was generally about one-half the level observed in the 1976-1977 study (TECO 1977g:Table 4.15). In 1976-1977, the non-thermal transect contained more species than the thermal transect. In the 1979 study, Stations 4, 5, and 6 had generally the same species richness as Stations 10, 11, and 12. For both the 1976-1977 and 1979 studies, species richness at the discharge canal stations (I-1 and I-16 or 1 and 2) was generally lower than at other sampling stations. The lower species richness indicates that some species of the benthic community are being excluded from the discharge canal.

Diversity values for the stations sampled in 1976-1977 (TECO 1977g: Table 4.17) were lower at the thermal transect (BC) stations than at the non-thermal transect (E) stations. Diversity values for the discharge canal stations were comparable to those in the non-thermal transect. In 1979 diversity (MML 1980b:Figures 11 to 16) was again generally higher at the non-thermal stations (10, 11, and 12) than at corresponding thermal transect stations (4, 5, and 6). Unlike the 1976-1977 data, the discharge canal stations (1 and 2) in 1979 tended to have lower diversity values than the thermal transect stations. So generally, diversity was inversely related to proximity to the discharge.

The lower relative diversity at the thermal transect may have resulted from the reduced species richness and/or a greater abundance of one or two of the remaining species. In either case, the lower diversity indicates that some effect of the thermal effluent on the benthic community occurs in the discharge canal.

Another measure of community characteristics is faunal similarity. Morisita's index (Morisita 1959) measures faunal similarity by comparing the presence and proportions of species in two samples. Faunal similarity analysis of the 1976-1977 data (TECO 1977g:Appendix 4E) showed that similarity was less related to the thermal plume and more related to sediment type. Analysis of the 1979 data (MML 1980b:Figures 17 to 37) indicate that somewhat greater similarity exists among stations in and just outside of the discharge canal than among other stations. Spatial trends in faunal similarity with one exception were weak and no statement can be based on similarity to delineate the extent or magnitude of impact of the thermal plume. The one exception occurred in December 1979, when there was a high degree of faunal homogeneity amoung nearly all stations due to the widespread abundance of Mulinia lateralis.

In summary, community impact analysis indicates that there are two areas that are affected by the thermal plume, each with a different degree of impact. Reduced species richness in the discharge canal indicates that a direct adverse effect of exclusion of some indigenous species is occurring in the discharge canal. The faunal similarity between the discharge canal and the thermal transect stations and the reduced faunal diversity at the thermal transect relative to the non-thermal transect indicate some indirect effects of the thermal plume are exerted in the benthic community in the thermal transect stations outside the discharge canal.

The benthic community in the Big Bend area is not unlike that in other altered environments that make up most of Tampa Bay. The areas of direct and indirect impact are small relative to the 90,000 hectare area and the 334 km of shoreline in Tampa Bay.

Therefore, the operation of Units 1 to 3 impacts only a localized area within and immediately outside the discharge canal and does not have an impact on the bay-wide benthic community.

In Section 6 it has been shown (Tables 6.1-3 and 6.2-3) that operation of an additional unit will increase the area of bottom contact of the plume outside the discharge canal about 17 percent. Since this expanded area of influence of the plume is still small, the operation of four units is expected to only marginally increase the area of local impact just outside the discharge canal and is not expected to alter the bay-wide benthic community.

7.3.2 Species Impacts

The purpose of this analysis was to determine areas around the discharge where particular species of the benthic infauna respond to changes in thermal additions from the discharge of Big Bend Units 1, 2 and 3. This was done for the 22 stations sampled in 1976-1977 and the 14 stations sampled in 1979. The results were used to project the impact for Unit 4. The particular species chosen for analysis were among the more abundant species collected during each of the two sample surveys. The method of analysis used was analysis of covariance.

The dependent variable used in the analysis was a transformation of the abundance of a species. Since the estimate of abundance used was a count of organisms collected in a grab sample, a square root transformation of the measurement variable (counts per grab) was used for the analysis (i.e., $(x + 1)^{1/2}$). This type of variance stabilizing transformation is suggested by Snedecor and Cochran (1967:325) for count data. The pattern of residuals also confirmed that the square root transformation was preferable to the untransformed data.

A variable was created to estimate the thermal addition of Units 1-3 to Tampa Bay for the time period prior to each sampling trip. This variable was the sum of the daily thermal additions for the 21 days preceding sampling, where the daily thermal addition is defined as the product of pump-days and average temperature rise across the condensers for that day.

Sediment and water depth characteristics are important factors in benthic invertebrate abundance (Wells 1957:127; Sykes & Hall 1970:302). Therefore, mean grain size, sorting coefficient, and water depth which had been measured at all stations on every sampling trip in 1979 and once every 12 weeks in the 1976-1977 study were used as covariates in the linear model. Covariates serve as controls for variables which may affect the observed value of the dependent variable but which cannot be selected for before the sample is drawn. When the sediment and water depth variables are used as covariates, the result is to adjust the

observed values of the dependent variable to the value that most likely would have been observed had the sediments and water depth characteristics at all the sampling stations been the same.

A separate analysis was conducted for each species, since each species would not be expected to select for the same substrate characteristics. The abundance of a given species is expected to increase or decrease with various levels of thermal discharge, depending on its temperature preferences, the temperature preferences of competitors, or other indirect effects of the discharge (e.g., preference of predators or food organisms). If all stations are not affected equally by the thermal discharge, the response of a species to the thermal variable will be station dependent. If these responses are real (not spurious correlation) the analysis will reveal a spatially patterned response with the greatest response located at stations near the discharge.

The linear model used is:

$$Y = \mu + A + B + C + D + E + \text{Thermal} + \text{Station} + \text{Thermal} * \text{Station} + \text{Residual}$$

where

A = Linear effect of sediment grain size,

B = Quadratic effect of sediment grain size,

C = Sorting coefficient (a measure of uniformity in size of grains of the sediment),

D = The percent silt or clay in the sediment,

E = Water depth,

Thermal = 21 day thermal addition variable,

Station = Station effect,

Thermal * Station = the interaction between thermal effect at each station (called the thermal by station variable or interaction in the text). This variable tests the homogeneity of the response among stations to the thermal discharge.

A pattern of non-homogeneity among stations in response to thermal additions (Thermal by Station variable) indicates a zone of response of the Big Bend discharge.

7.3.2.1 1976-1977 Benthic Study Data

Organism counts from the grab samples taken every 6 weeks from February 1976 to March 1977 were used as estimates of abundance. For purposes of this analysis, only the more abundant species were considered. A more subjective evaluation of the spatial distribution pattern of the thermal tolerant Capitella capitata, Nereis succinea (TECO 1977g:4-89) and the pioneer species Streblospio benedicti (TECO 1977g:4-92) was also conducted. The data of the nine most abundant species (TECO 1977g:4-64 to 4-65) were examined for occurrence and equality of variance among the trips and stations. The great abundance for three of the species was due to extremely high abundance at only a few stations or in occasional individual grab samples. These species could not be included in the covariance analysis without violating the equality of variance assumption. Some of the remaining species were only rarely collected at a few stations. For these species the analysis was conducted by dropping these low abundance stations from the analysis. The six species found in sufficient abundance at most of the 22 stations (Figure 4.4-4) to be analyzed with this approach included Mysella planulata, Ampelisca abdita, Parasterope pollex, Mulinia lateralis, Ampelisca holmesi, and Cyclaspis varians. However, Parasterope pollex was not collected in proportion to its true abundance, since most individuals of this species are smaller than the mesh of the sieve used to separate the macrobenthos from the sediment.

Since sediment characteristics were measured every 12 weeks, only data collected on this schedule were used. If the analysis showed that sediment characteristics were not important for a particular species, the sediment variables were dropped from the model and the resulting model was tested using all the data (samples every 6 weeks).

Results of the analysis of the data for the six species mentioned above are presented below.

7.3.2.1.1 Mysella planulata

The full model was not required to explain the variability in abundance of Mysella planulata, the most abundant species. The variables for sorting coefficient, percent silt clay, and water depth did not significantly improve the model fit (Table 7.3-1). The model was evaluated without these variables, and the coefficients of the remaining variables were relatively unchanged as was the residual mean squares. The ratio of Thermal by Station interaction mean square to residual mean square was significantly larger than 1 ($p<0.0001$). The magnitude of the response to the thermal effect for each station is presented in Table 7.3-2. The pattern of response at the stations indicates that the greatest response (a negative one) to thermal discharge occurred at Stations BC8 and BC7. Station BC78, a station

located spatially between BC8 and BC7, also had a negative response that was not as great in magnitude. Two other Stations, F2 and F3 (located in the finger canals), had large coefficients of response to thermal addition contributing to the high significance level of the Thermal by Station interaction. However, the direction of response for these two stations were opposite in sign. Because of this and because Stations F2 and F3 are located much farther (along a water route) from the thermal discharge than most of the other stations, it seems likely that these were spurious correlations.

The response at Stations I1 and I16 was much less than at Stations BC8 and BC7 even though I1 and I16 were in the discharge canal. The slope for Station I16 was particularly influenced by a collection taken in February 1976 when some relatively coarse substrate was encountered. In general, the abundance at Stations I1 and I16 was less than at other stations. Station BC8 had the greatest abundance despite the negative response to the thermal effect at that station.

Because Stations BC4 and BC6 had positive (but small) coefficients of response to the thermal effect, it appears that the zone of response for Mysella planulata to the thermal discharge is limited to the discharge canal and the few stations (BC7, BC78, BC8) immediately outside the discharge canal.

7.3.2.1.2 Mulinia lateralis

The full model for Mulinia lateralis was not required to explain the variability in abundance (Table 7.3-3). A reduced model, including only thermal effect, station effect, and Station by Thermal effect was found to be sufficient. In addition, since the sediment variables and depth were not important in the full model, the reduced model was evaluated with all the data, including collections made when sediment characteristics were not measured. The mean square error and the estimated coefficients of the variables common to the full model when evaluated with a portion of the data (samples every 12 weeks) and to the reduced model when evaluated with all the data (samples every 6 weeks) were similar. The magnitude of the response in abundance to changes in thermal addition for each station are presented in Table 7.3-4. The three stations with slopes most different from zero were BC8, BC78, and BC7. The abundance (as measured by the square root of count plus 1) was negatively affected by the thermal effect at these three stations.

The responses at Stations I1 and I16 were also negative but much less so than at the offshore stations (BC8, BC7, BC78). The data indicate a disproportionately large abundance for the May 1976 collection at Station I1 (average 156 Mulinia lateralis per grab). The magnitude of the response may have been influenced by the higher abundance of Mulinia lateralis at BC stations than at

the I stations. Mulinia lateralis were in very low abundance at Station I16 throughout the sampling period.

Because most of the significance of the Thermal by Station interaction was influenced by Stations BC8, BC78, and BC7 and since the responses at Stations BC6 and BC4 were small in magnitude, the zone of response for Mulinia lateralis to the thermal discharge was limited to the discharge canal and the few stations immediately outside the discharge (BC8, BC78, BC7).

7.3.2.1.3 Cyclaspis varians

The full model for Cyclaspis varians was not required to explain the variability in abundance (Table 7.3-5). After the percent silt and clay variable was further examined, a reduced model without the grain size, percent silt clay, and water depth variables was found to be sufficient. The residual mean square and the estimated coefficients of the variables common to the full and reduced models were not greatly altered.

The magnitude of the response to the thermal effect for each station is presented in Table 7.3-6. In general, the response in abundance to the thermal effects was not as great in magnitude as for the Mysella planulata or Mulinia lateralis analyses, which may be due to the relatively lower abundance and the more even spatial distribution of Cyclaspis varians.

The largest magnitude responses to thermal addition were for Stations BC4 and BC78. In fact, all the BC Stations had a larger negative response to the thermal effect than most of the other stations. The only other stations with relatively large response were Stations I17, F3, and SP3, but they showed no particular pattern in their response.

Although the response to the thermal effect was, in general, milder for this species than for Mysella planulata, the response was more widespread, since the zone of response encompasses an area that includes all the BC stations.

7.3.2.1.4 Ampelisca abdita

This species, as well as Ampelisca holmesi and Parasterope pollex was, in general, less abundant and less evenly distributed over all stations. This requires that some stations be dropped from the analysis. The species low abundance at these stations may be important in the overall assessment of impact but these stations cannot be directly included in this method of analysis without violating the assumptions used for the linear model. Ampelisca abdita was not found in great enough abundance at Stations I16 and I2 for these stations to be included in the analysis.

The full model for this species was not required to explain the variability in abundance (Table 7.3-7). After further examining the percent silt-clay variable, a reduced model, without grain size and percent silt-clay variables, was found to be sufficient. The magnitude of the response to the thermal effect for each station is presented in Table 7.3-8.

The pattern of the response indicated that Ampelisca abdita responded positively to the discharge at Stations BC78, BC8, and less so at Stations BC7, E6, and I1. There were also negative responses for Stations F2, I4, I15, and I17, but since these four stations were so distant from the discharge and since there was no pattern in this response, these may have been spurious results.

A positive response in a species abundance to increased thermal loads is not unexpected. As discussed in Section 7.3.2 thermal additions can directly affect a species abundance based on that species temperature preferences. However, indirect effects like temperature preferences of competitors, predators and food organisms can influence a species abundance to a similar degree. In addition, the complex interactions of these factors in the benthic community make changes in abundance in either direction reasonable.

The Station I1 response was obscured by a highly variable set of observations on this species made in May 1976 at this station. An additional difficulty exists in measuring the response at Station I1 in the analyses for all six species due to a negative correlation in this set of observations between the percent silt-clay at Station I1 and the thermal addition variable. Discharge volume is also directly associated with thermal addition. If the rates of deposition and resuspension of silt and clay, in the area of Station I1, are influenced by discharge volume, then this is a possible mechanism to explain the association between the silt-clay and thermal variables at Station I1.

The pattern of response of Ampelisca abdita to the thermal discharge is not as strong or obvious as that of Mysella planulata or Mulinia lateralis. However, it appears that the zone of influence (positive response in abundance for increasing thermal discharge) includes the discharge canal and areas sampled at Stations BC8, BC78, and possibly the areas around the Stations BC7 and E6.

7.3.2.1.5 Ampelisca holmesi

This species was not found in great enough abundance at Stations BC7, BC6, BC4, E4, E2, I1, I16, I15, and SP3 for these stations to be included in the analysis. The reason for dropping stations is more fully explained in the results section for Ampelisca abdita (Section 7.3.2.1.4).

The full linear model for Ampelisca holmesi was not required to explain the variability in abundance (Table 7.3-9). After further examining the percent silt-clay variable, a reduced model without the grain size and percent silt-clay variables was found to be sufficient. The size of the response to the thermal effect for each station is presented in Table 7.3-10.

The stations with the largest magnitude response to thermal addition were Stations I18 and SP1, located on the intake side of the plant. The response (in abundance) is negatively related to thermal discharge. No pattern or zone of response is evident for this species. However the two discharge stations and three of the five thermal transect stations had to be dropped from the analysis. This may indicate that the thermal plume is responsible for the low abundance at these stations.

7.3.2.1.6 Parasterope pollex

The sampling gear used was expected to collect only the larger individuals of this species. Therefore, the population considered in this analysis is only the larger adults of this species. This species was not found in great enough abundance at Stations I16, I4, I15, and F3 for these stations to be included in the analysis. The reason for dropping stations is explained more fully in the results section for Ampelisca abdita (Section 7.3.2.1.4).

The full linear model for Parasterope pollex was not required to explain the variability in abundance (Table 7.3-11). After additional examination of the silt-clay variable, a reduced model without the grain size, percent silt-clay, and depth variables was found to be sufficient. The lack of importance of the thermal and Thermal by Station interaction variables to the model indicate a lack of response at all stations to thermal additions (Table 7.3-12). Because of the poor fit of the model and because of the unclear pattern of the response to thermal addition by station, there is no pattern or zone of response to the thermal discharge for Parasterope pollex based on the abundance data.

7.3.2.1.7 Summary of Covariance Analysis Results Using 1976-1977 Data

A linear model was developed for each of six of the more abundant and evenly distributed species. The dependent variable was a measure of abundance (i.e., (count per grab + 1)$^{1/2}$). Sediment (mean grain size, sorting coefficient, and percent silt-clay) and water depth variables were used as covariates. A created variable (thermal) was included in the model to characterize the effect of thermal additions to Tampa Bay by Big Bend Units 1-3 for the 3-week period preceding each sampling date. The effect of thermal addition is evaluated for each station using the Thermal by Station interaction. From the pattern of response, a

zone of responsiveness to thermal additions was delineated for four of the six species.

The discharge canal was part of the zone of response for all four of these species. The abundance of both Mysella planulata and Mulinia lateralis was also negatively associated with increased thermal addition at the three stations immediately outside the discharge channel (BC7, BC78, BC8). The abundance of Cyclaspis varians was also negatively associated with increased thermal additions over all five of the BC sampling stations. Finally, abundance of Ampelisca abdita was positively associated with increased thermal additions at two sampling stations (BC8, BC78) and possibly at two additional stations (BC7, and E6) near the discharge. No pattern of response was revealed for the other two species.

Since the species used in this analysis dominated the macrobenthos community, the effect of the thermal discharge on these species gives an indication of the extent of influence of the thermal discharge on the macrobenthos community. For the most part, the influence of the thermal discharge did not extend beyond the three stations immediately outside the discharge canal (BC8, BC78, and BC7).

The estimates of the area of impact obtained with this method of analysis correspond closely to those obtained with the community analysis. There is no information available to indicate that the bay-wide populations of any of these species are confined to the Big Bend area. The zones of response for these species are small relative to the 90,000 hectare area of the bay; thus, the operation of Units 1 to 3 impacts only a localized area within and just outside the discharge canal and does not have an impact to the bay-wide population of these species. Since these species indicate the extent of influence of the thermal discharge on the community, the analysis confirms the results obtained in the community analysis.

7.3.2.1.8 Additional Species Collected in 1976-1977

Three benthic species, Capitella capitata, Nereis succinea, and Streblospio benedicti, which have been termed as indicators of thermal pollution or of pioneer conditions (TECO 1977g:4-89, 4-92), were not collected in sufficient abundance and/or at enough stations to be included in the covariance analysis. A more subjective analysis that examined presence-absence and median abundance over time revealed some interesting spatial patterns.

Capitella capitata was most abundant at Station I1 (a discharge canal station) and Station F3 (in the fingerfill canals). Capitella capitata occurred 85 percent of the time at inshore stations (F2, F3, I1, I15, I16, I17, I18, I2, I4), but only

30 percent of the time at the remaining offshore stations. The occurrence of Capitella capitata at the offshore station closest to the discharge was more frequent than at the other offshore stations.

Nereis succinea occurred at least 40 percent of the time at every station. The stations with the greatest median abundance are in order of decreasing abundance: I1 (the discharge station), I16 (the dilution pump station), and BC8 (the offshore station closest to the discharge).

Over 92 percent of the Streblospio benedicti were captured in five sampling trips to Station I15. This species occurred relatively frequently at most of the inshore stations (F2, F3, I1, I15, I16, I17, I18, I2, and I4). Among the offshore stations, Streblospio benedicti occurred most consistently at Stations BC78 and BC8. This species was never captured at Stations SP1, SP2, SP3, BC4, E2, E4, E5 and E56.

The distribution of Capitella capitata appears to be more related to the proximity of the sample station to shore than to the location of the sample station relative to the discharge. The distribution of Nereis succinea seems to be greatly influenced by the thermal discharge and the effect of the discharge on its abundance is limited to the area within and just outside the discharge canal. The distribution of Streblospio benedicti appears to be more related to proximity of the sample station to shore but may be somewhat greater in abundance just outside the discharge canal due to the thermal plume.

7.3.2.2 1979 Benthic Study Data

Organism counts from grab samples taken on May 11, June 21, August 2, August 24, September 19, November 1, and December 13 were used as estimates of abundance. The abundance of the most abundant species was examined for occurrence and equality of variance among the trips and stations. Only seven species were found to be sufficiently and consistantly abundant at most of the 14 sampling stations (Figure 4.4-5) to be analyzed with this approach. Of these seven species, five (Glycinde solitaria, Mediomastus californiensis, Nereis succinea, Paraprionospio pinnata, and Streblospio benedicti) were polychaetes; one was a bivalve (Mulinia lateralis), and one was a gastropod (Odostomia c.f. conoidea). Some of these species were only rarely collected at a few stations. For these species, the analysis was able to be conducted only by dropping these low abundance stations from the analysis.

The 1979 data set differed from the 1976-1977 data set in that there was a positive correlation between ambient water temperature and the thermal variable because Big Bend units were in operation more in the months with warmer water temperatures

than in the months with cooler ambient water temperatures. Also unlike the 1976-1977 data there were temporal abundance patterns in that density of most species was lowest in the months of warmest water temperatures. These combined factors completely confounded temporal changes in abundance with the thermal effect. The result was that spatial patterns of response were obscured by temporal abundance patterns. Therefore, results for the abundant species in 1979 are presented in a less detail than has been done with the 1976-1977 data.

7.3.2.2.1 Results

Four of the seven species showed no zone of response to the thermal discharge. There was also no pattern in overall abundance revealed from the stations that were dropped from the analysis to indicate an effect of the thermal discharge for these species. The names of the species and the tables depicting the full model analysis of variance and the magnitudes of response at each station are: Glycinde solitaria (Tables 7.3-13 and 7.3-14); Nereis succinea (Tables 7.3-15 and 7.3-16); Paraprionospio pinnata (Tables 7.3-17 and 7.3-18); and Mulinia lateralis (Tables 7.3-19 and 7.3-20).

Two other species, Mediomastus californiensis and Odostomia c.f. conoidea, also did not show patterns of response to the thermal discharge. The analysis of variance and magnitude of response tables for these species are in Tables 7.3-21, 7.3-22, 7.3-23, and 7.3-24. For both these species, Stations 1, 2, and 3 were dropped from the analysis due to very low abundance at these stations. The low densities at the stations in and just outside the discharge canal indicate that the reduced density may be due to the thermal discharge.

The remaining species, Streblospio benedicti, did show a spatially patterned response. This species was not found in great enough abundance at Stations 3 and 12 for these stations to be included in the analysis.

The full linear model for Streblospio benedicti was not required to explain the variability in abundance (Table 7.3-25). A reduced model without the grain size, sorting coefficient, and percent silt-clay variables was found to be sufficient. The size of the response to the thermal effect for each station is presented in Table 7.3-26. The significance of the Thermal by Station variable is entirely attributable to the large negative response at Station 1. This species was much more abundant at Station 1 than at all other stations.

Since Station 1 is different from all other stations in terms of abundance of Streblospio benedicti and response to thermal addition, the zone of response for Streblospio benedicti was limited to the area near Station 1.

7.3.2.2.2 Summary of Covariance Analysis Results Using 1979 Data

A linear model was developed for each of seven of the species collected in 1979. Sediment (mean grain size, sorting coefficient, and percent silt-clay) and water depth variables were used as covariates. A variable (thermal) was created and included in the model to characterize the effect of thermal additions to Tampa Bay by Big Bend Units 1-3 for the 3-week period preceding each sampling date. From the pattern of response, a zone of responsiveness to thermal additions was delineated for one of the seven species. From the pattern of stations that were dropped from the analysis due to low abundance, areas of effect for two other species were delineated.

There are a number of potential reasons why zones of response were not as apparent in the 1979 data as they were for the 1976-1977 data. From the 1976-1977 data, 10 sampling dates provided 10 observations of the thermal effect for many of the stations; the 1979 data provided 7 observations per station. The thermal variable was just as confounded with time as for 1976-1977. However, colinearity of the 1979 thermal values with ambient water temperature causes the effects due to thermal additions to be obscured by temporal changes in abundance due to warmer ambient water conditions.

The zone of response for Streblospio benedicti was confined to Station 1. Mediomastus californiensis and Odostomia c.f. conoidea have relatively low density in and just outside the discharge canal. While a smaller proportion of the species analyzed with the 1979 data showed effects due to the thermal discharge than those analyzed with the 1976-1977 data, the areas of effect are not unlike those depicted with the 1976-1977 data.

These zones of response are small relative to the 90,000 hectare area of Tampa Bay. The operation of Units 1 to 3 impacts a localized area within and just outside the discharge canal and does not have an impact on the bay-wide populations of these species.

7.3.3 Impact to Benthos by Addition of Unit 4

Although it is not reasonable to extrapolate quantitative predictions beyond the range of the data used as the basis of that prediction, a qualitative estimate of increase in the area of response can be made. Table 6.1-3 provides characteristics of the plume at points of bottom contact with three-unit operation. This table indicates that 7 hectares of bottom will be exposed to a 9.8°C ΔT at 100 percent load. Table 6.2-3 provides characteristics of the plume at points of bottom contact with four-unit operation. This table indicates that 8 hectares of bottom will be exposed to a 10.1°C ΔT at 100 percent load. Since the ΔT's are very similar, the benthic organisms would be exposed

to similar qualitative conditions as the area already subject to the plume with three unit operation. Therefore, the areas of response outside the discharge canal with four-unit operation are expected to increase by about the same proportion as the bottom contact area increases with four-unit operation; that is, about 17 percent (see Tables 6.1-3 and 6.2-3).

The community analysis (Section 7.3.1) and two covariance analyses (Sections 7.3.2.1.1 to 7.3.2.1.7 and 7.3.2.2) as well as the presence-absence, median abundance analysis of pollution and thermal indicator species (Section 7.3.2.1.8) all indicate that operation of Units 1 to 3 impacts the benthos in and just outside the discharge canal. Operation of Unit 4 is expected to increase that area of impact to the benthos by a small portion. This localized area is small relative to the size of Tampa Bay. Since there are no data to suggest that the benthic species present at Big Bend do not occur elsewhere in the Bay, the impact of operation of Units 1 to 4 to individual species populations and to the benthos communities in Tampa Bay is expected to be small.

TABLE 7.3-1

FULL MODEL ANALYSIS OF VARIANCE FOR MYSELLA PLANULATA
1976-1977 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	21	23,669.840	43.87	0.0001
Thermal	1	595.516	23.18	0.0001
Thermal * Station	21	3,838.051	7.11	0.0001
Grain Size-Linear	1	1,241.025	48.30	0.0001
Grain Size-Quadratic	1	99.620	3.88	0.0494
Sorting Coefficient	1	18.384	0.72	0.3979
Percent Silt-Clay	1	56.783	2.21	0.1376
Depth	1	41.883	1.63	0.2022
Residual	611	15,697.718		
Total	659	45,258.820		

TABLE 7.3-2

RESPONSE OF ABUNDANCE OF MYSELLA PLANULATA TO THERMAL ADDITION FOR EACH STATION 1976-1977 DATA

Station	Slope
BC8	-0.0206
BC78	-0.0068
BC7	-0.0203
BC6	0.0046
BC4	0.0038
E6	-0.0061
E56	-0.0090
E5	-0.0068
E4	-0.0019
E2	0.0012
I1	-0.0046
I16	0.0094
I2	0.0009
I4	0.0054
I15	0.0014
I17	-0.0011
I18	-0.0045
F2	0.0168
F3	-0.0135
SP1	-0.0001
SP2	-0.0015
SP3	0.0039

TABLE 7.3-3

FULL MODEL ANALYSIS OF VARIANCE FOR MULINIA LATERALIS
1976-1977 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	21	2,414.343	13.49	0.0001
Thermal	1	844.994	99.16	0.0001
Thermal * Station	21	2,293.504	12.82	0.0001
Grain Size-Linear	1	5.533	0.65	0.4207
Grain Size-Quadratic	1	13.292	1.56	0.2122
Sorting Coefficient	1	0.165	0.02	0.8893
Percent Silt-Clay	1	10.976	1.29	0.2569
Depth	1	19.593	2.30	0.1300
Residual	611	5,206.867		
Total	659	10,809.261		

TABLE 7.3-4

RESPONSE OF ABUNDANCE OF MULINIA LATERALIS TO THERMAL ADDITION FOR EACH STATION
1976-1977 DATA

Station	Slope
BC8	-0.0210
BC78	-0.0242
BC7	-0.0096
BC6	0.0002
BC4	-0.0004
E6	-0.0034
E56	-0.0047
E5	-0.0013
E4	-0.0003
E2	0.0002
I1	-0.0034
I16	-0.0005
I2	0.0001
I4	-0.0013
I15	-0.0016
I17	-0.0037
I18	-0.0004
F2	0.0053
F3	-0.0057
SP1	-0.0028
SP2	-0.0021
SP3	-0.0004

TABLE 7.3-5

FULL MODEL ANALYSIS OF VARIANCE FOR CYCLASPIS VARIANS
1976-1977 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	21	625.017	5.20	0.0001
Thermal	1	143.764	25.10	0.0001
Thermal * Station	21	324.068	2.69	0.0001
Grain Size-Linear	1	3.551	0.62	0.4313
Grain Size-Quadratic	1	3.596	0.63	0.4284
Sorting Coefficient	1	42.454	7.41	0.0067
Percent Silt-Clay	1	34.252	5.98	0.0147
Depth	1	0.085	0.01	0.9033
Residual	611	3,499.027		
Total	659	4,675.808		

TABLE 7.3-6

RESPONSE OF ABUNDANCE OF *CYCLASPIS VARIANS* TO THERMAL ADDITION FOR EACH STATION 1976-1977 DATA

Station	Slope
BC8	-0.0024
BC78	-0.0061
BC7	-0.0027
BC6	-0.0033
BC4	-0.0078
E6	-0.0018
E56	0.0004
E5	-0.0010
E4	0.0013
E2	-0.0012
I1	-0.0004
I16	0.0007
I2	-0.0011
I4	-0.0002
I15	0.0006
I17	-0.0028
I18	-0.0024
F2	0.0004
F3	-0.0036
SP1	0.0008
SP2	0.0021
SP3	-0.0033

TABLE 7.3-7

FULL MODEL ANALYSIS OF VARIANCE FOR AMPELISCA ABDITA
1976-1977 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	19	6,603.198	13.72	0.0001
Thermal	1	550.722	21.74	0.0001
Thermal * Station	19	6,726.784	13.98	0.0001
Grain Size-Linear	1	22.087	0.87	0.3508
Grain Size-Quadratic	1	2.302	0.09	0.7632
Sorting Coefficient	1	372.185	14.69	0.0001
Percent Silt-Clay	1	214.518	8.47	0.0038
Depth	1	145.803	5.76	0.0168
Residual	555	14,059.106		
Total	599	28,696.703		

TABLE 7.3-8

RESPONSE OF ABUNDANCE OF AMPELISCA ABDITA TO THERMAL ADDITION FOR EACH STATION 1976-1977 DATA

Station	Slope
BC8	0.0038
BC78	0.0082
BC7	0.0011
BC6	-0.0003
BC4	0.0016
E6	0.0021
E56	-0.0002
E5	0.0039
E4	-0.0014
E2	-0.0014
I1	0.0040
I4	-0.0246
I15	-0.0106
I17	-0.0051
I18	-0.0013
F2	-0.0405
F3	-0.0032
SP1	-0.0009
SP2	0.0002
SP3	-0.0002

TABLE 7.3-9

FULL MODEL ANALYSIS OF VARIANCE FOR AMPELISCA HOLMESI
1976-1977 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	12	2,376.023	37.86	0.0001
Thermal	1	1,158.369	221.49	0.0001
Thermal * Station	12	1,716.118	27.34	0.0001
Grain Size-Linear	1	0.187	0.04	0.8500
Grain Size-Quadratic	1	14.109	2.70	0.1014
Sorting Coefficient	1	68.281	13.06	0.0003
Percent Silt-Clay	1	60.426	11.55	0.0008
Depth	1	71.120	13.60	0.0003
Residual	359	1,877.569		
Total	389	7,342.199		

TABLE 7.3-10

RESPONSE OF ABUNDANCE OF AMPELISCA HOLMESI TO THERMAL ADDITION FOR EACH STATION 1976-1977 DATA

Station	Slope
BC8	-0.0146
BC78	-0.0081
E6	-0.0005
E56	-0.0045
E5	-0.0021
I2	-0.0036
I4	-0.0022
I17	-0.0127
I18	-0.0194
F2	0.0008
F3	0.0023
SP1	-0.0157
SP2	-0.0031

TABLE 7.3-11

FULL MODEL ANALYSIS OF VARIANCE FOR *PARASTEROPE POLLEX*
1976-1977 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	17	3,657.204	12.55	0.0001
Thermal	1	284.855	16.61	0.0001
Thermal * Station	17	210.525	0.72	0.7816
Grain Size-Linear	1	5.414	0.32	0.5744
Grain Size-Quadratic	1	3.116	0.18	0.6701
Sorting Coefficient	1	1,512.051	88.18	0.0001
Percent Silt-Clay	1	997.545	58.17	0.0001
Depth	1	8.498	0.50	0.4818
Residual	499	8,556.523		
Total	539	15,235.726		

TABLE 7.3-12

RESPONSE OF ABUNDANCE OF *PARASTEROPE POLLEX* TO THERMAL ADDITION FOR EACH STATION
1976-1977 DATA

Station	Slope
BC8	-0.0055
BC78	-0.0039
BC7	-0.0016
BC6	0.0011
BC4	-0.0061
E6	0.0004
E56	-0.0013
E5	-0.0003
E4	-0.0019
E2	-0.0013
I1	-0.0057
I2	-0.0080
I17	-0.0024
I18	-0.0062
F2	-0.0008
SP1	-0.0009
SP2	0.0003
SP3	0.0003

TABLE 7.3-13

FULL MODEL ANALYSIS OF VARIANCE FOR GLYCINDE SOLITARIA
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	13	109.0878	14.48	0.0001
Thermal	1	138.9570	239.74	0.0001
Thermal * Station	13	32.6403	4.33	0.0001
Grain Size-Linear	1	9.5921	16.55	0.0001
Grain Size-Quadratic	1	8.6434	14.91	0.0001
Sorting Coefficient	1	3.5956	6.20	0.0130
Percent Silt-Clay	1	2.0799	3.59	0.0587
Depth	1	2.4414	4.21	0.0406
Residual	555	321.6869		
Total	587	628.7249		

TABLE 7.3-14

RESPONSE OF ABUNDANCE OF GLYCINDE SOLITARIA TO THERMAL ADDITION FOR EACH STATION 1979 DATA

Station	Slope
1	-0.0007
2	-0.0011
3	-0.0019
4	-0.0026
5	-0.0030
6	-0.0002
7	0.0001
8	-0.0024
9	-0.0019
10	-0.0012
11	-0.0019
12	-0.0019
13	-0.0010
14	-0.0013

TABLE 7.3-15

FULL MODEL ANALYSIS OF VARIANCE FOR NEREIS SUCCINEA
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	10	617.0570	44.34	0.0001
Thermal	1	2.2432	1.61	0.2049
Thermal * Station	10	21.9853	1.58	0.1098
Grain Size-Linear	1	1.2696	0.91	0.3401
Grain Size-Quadratic	1	0.0193	0.01	0.9063
Sorting Coefficient	1	4.3548	3.13	0.0776
Percent Silt-Clay	1	3.6953	2.66	0.1039
Depth	1	57.8076	41.54	0.0001
Residual	435	605.4245		
Total	461	1,313.8569		

TABLE 7.3-16

RESPONSE OF ABUNDANCE OF *NEREIS SUCCINEA* TO THERMAL ADDITION FOR EACH STATION 1979 DATA

Station	Slope
1	-0.0009
2	-0.0010
3	0.0014
4	-0.0001
5	-0.0006
6	-0.0003
7	0.0018
8	-0.0018
12	0.0004
13	-0.0001
14	0.0010

TABLE 7.3-17

FULL MODEL ANALYSIS OF VARIANCE FOR PARAPRIONOSPIO PINNATA
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	13	249.3528	19.32	0.0001
Thermal	1	2.8318	2.85	0.0918
Thermal * Station	13	33.0596	2.56	0.0020
Grain Size-Linear	1	0.2921	0.29	0.5877
Grain Size-Quadratic	1	0.0080	0.01	0.9284
Sorting Coefficient	1	0.3582	0.36	0.5483
Percent Silt-Clay	1	11.0908	11.17	0.0009
Depth	1	6.5070	6.56	0.0107
Residual	555	550.8961		
Total	587	854.3965		

TABLE 7.3-18

RESPONSE OF ABUNDANCE OF PARAPRIONOSPIO PINNATA TO THERMAL ADDITION FOR EACH STATION
1979 DATA

Station	Slope
1	-0.0002
2	0.0019
3	0.0001
4	0.0008
5	-0.0014
6	-0.0006
7	-0.0008
8	0.0010
9	0.0010
10	0.0003
11	0.0005
12	-0.0006
13	-0.0001
14	0.0001

TABLE 7.3-19

FULL MODEL ANALYSIS OF VARIANCE FOR MULINIA LATERALIS
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	10	206.9142	2.63	0.0041
Thermal	1	28.3772	3.60	0.0584
Thermal * Station	10	59.2183	0.75	0.6759
Grain Size-Linear	1	92.0998	11.68	0.0007
Grain Size-Quadratic	1	16.9450	2.15	0.1433
Sorting Coefficient	1	134.2804	17.04	0.0001
Percent Silt-Clay	1	110.3359	14.00	0.0002
Depth	1	113.1018	14.35	0.0002
Residual	435	3,428.7513		
Total	461	4,190.0241		

TABLE 7.3-20

RESPONSE OF ABUNDANCE OF MULINIA LATERALIS TO THERMAL ADDITION FOR EACH STATION 1979 DATA

Station	Slope
1	0.0044
3	-0.0007
4	-0.0022
5	0.0005
6	0.0003
7	0.0018
8	-0.0040
9	0.0002
10	0.0006
13	0.0001
14	0.0001

TABLE 7.3-21

FULL MODEL ANALYSIS OF VARIANCE FOR MEDIOMASTUS CALIFORNIENSIS
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	10	655.4055	11.36	0.0001
Thermal	1	691.7653	119.86	0.0001
Thermal * Station	10	193.6950	3.36	0.0003
Grain Size-Linear	1	358.0767	62.04	0.0001
Grain Size-Quadratic	1	15.0543	2.61	0.1070
Sorting Coefficient	1	8.3640	1.45	0.2293
Percent Silt-Clay	1	362.5411	62.82	0.0001
Depth	1	8.0131	1.39	0.2393
Residual	435	2,510.5002		
Total	461	4,803.4152		

TABLE 7.3-22

RESPONSE OF ABUNDANCE OF MEDIOMASTUS CALIFORNIENSIS TO THERMAL ADDITION FOR EACH STATION
1979 DATA

Station	Slope
4	-0.0046
5	-0.0056
6	-0.0010
7	0.0031
8	-0.0054
9	-0.0065
10	-0.0042
11	-0.0072
12	-0.0015
13	-0.0006
14	-0.0033

TABLE 7.3-23

FULL MODEL ANALYSIS OF VARIANCE FOR ODOSTOMIA C.F. CONOIDEA
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	10	33.7649	5.69	0.0001
Thermal	1	0.7178	1.21	0.2722
Thermal * Station	10	4.8721	0.82	0.6090
Grain Size-Linear	1	5.8667	9.88	0.0018
Grain Size-Quadratic	1	6.6243	11.16	0.0009
Sorting Coefficient	1	5.9197	9.97	0.0017
Percent Silt-Clay	1	4.2802	7.21	0.0075
Depth	1	3.4438	5.80	0.0164
Residual	435	258.3044		
Total	461	323.7939		

TABLE 7.3-24

RESPONSE OF ABUNDANCE OF ODOSTOMIA C.F. CONOIDEA TO THERMAL ADDITION FOR EACH STATION
1979 DATA

Station	Slope
4	-0.0004
5	0.0005
6	0.0008
7	0.0008
8	-0.0011
9	0.0004
10	0.0005
11	-0.0004
12	-0.0008
13	0.0005
14	-0.0001

TABLE 7.3-25

FULL MODEL ANALYSIS OF VARIANCE FOR STREBLOSPIO BENEDICTI
1979 DATA

Source of Variation	D.F.	Sums of Squares	F-Ratio	Probability Level
Station	11	1,001.7686	12.09	0.0001
Thermal	1	55.3100	7.35	0.0070
Thermal * Station	11	596.5459	7.20	0.0001
Grain Size-Linear	1	1.3972	0.19	0.6668
Grain Size-Quadratic	1	43.5589	5.78	0.0165
Sorting Coefficient	1	3.4764	0.46	0.4972
Percent Silt-Clay	1	5.7494	0.76	0.3827
Depth	1	58.4460	7.76	0.0056
Residual	475	3,576.8311		
Total	503	5,343.0836		

TABLE 7.3-26

RESPONSE OF ABUNDANCE OF STREBLOSPIO BENEDICTI TO THERMAL ADDITION FOR EACH STATION
1979 DATA

Station	Slope
1	-0.0121
2	0.0014
4	-0.0005
5	0.0002
6	0.0001
7	0.0008
8	-0.0011
9	0.0000
10	0.0005
11	-0.0005
13	-0.0004
14	-0.0011

7.4 IMPACT IMPLICATION OF FINE-MESH SCREENING

The results of survival studies presented in the Fine-Mesn Screen Prototype Study - Spring 1980 report (Appendix 4) demonstrate that fine-mesh screening can be effectively used to remove viable organisms from the circulating water flow of Big Bend Station.

Determining the survival rate of organisms removed from to the fine-mesh screen has been a prime objective of the 1980 fine-mesh screen prototype study. The fine-mesh screen system allows the collection of virtually all organisms larger than 0.5 mm including invertebrate and fish eggs, larvae, juveniles, and adults which are impinged on the fine-mesh screen or which are collected in the fish baskets.

Results of the Spring 1980 tests for invertebrate larvae and fish eggs, larvae, and post-larvae indicate that initial survival and latent survival are highly species- and life stage-dependent (see Tables 4-2, 4-8, and 4-9, Appendix 4). These results do not presently incorporate control survivorship (Table 4-7, Appendix 4). Since control survivorship primarily reflects natural and holding mortalities, its consideration in the evaluation of overall screening survivorship will decrease the mortality attributed to screening effects. It should also allow a more realistic judgment of the effect of impingement on the fine-mesh screen.

Based on the preliminary results presented in Appendix 4, a fourth unit could be added to the existing three units at Big Bend without increasing entrainment beyond present levels if any two of the four units, for instance Units 3 and 4 (the design is presented in Section 6.2.5), utilized fine-mesh screen intakes. Further studies during the summer will refine these preliminary results. Additional RIS life stages will be studied during the summer; additional control data will be collected; filtration and spray wash efficiencies will be verified; and return flume survival rates will be estimated.

Although few fish and invertebrate juveniles and adults are impinged at the existing units at Big Bend Station, a fine-mesh screen intake system would reduce impingement mortality. Observations during 1979 and 1980 of the survival of the few juvenile and adult organisms collected by the fine-mesh screen suggest that they are not adversely affected by the impingement and removal process. These organisms can be returned to Tampa Bay with little effect from their exposure to the fine-mesh screen.

A fine-mesh screen intake system could reduce entrainment and impingement at Big Bend Station. However, since the Station's effect on aquatic populations is not adverse, the utilization of a fine-mesh screen intake system is not warranted.

SECTION 8

SUMMARY OF ENVIRONMENTAL IMPACTS AND CONCLUSIONS

8.1 INTRODUCTION

The impact to the Tampa Bay environment as a result of the operation of Big Bend Station, Units 1 through 4, has been investigated by studying 11 Representative Important Species (RIS) and the benthic community. The RIS were selected based on dominance, commercial and recreational importance, and sensitivity to and potential for incurring some effect from the power station. These organisms are distributed among several trophic levels.

The effects of entrainment and impingement at the intake were analyzed using several methodologies. First, the presence of three operating units at Big Bend provided the opportunity to monitor the number of organisms entrained and impinged. This information was used to extrapolate the number of organisms expected to be affected by four-unit operation using some conservative assumptions.

Second, entrainment effects were analyzed using data collected in a meroplankton study and considering hydrodynamic characteristics of Tampa Bay. This analysis utilized finite-element models of tidal circulation and dispersion to represent the hydrodynamics. The results of this analysis provided an estimate of the area of Tampa Bay within which organisms will be affected by entrainment.

Third, meroplankton density data collected near the intake in conjunction with information regarding the biological dynamics of the entrained organisms were utilized to estimate the equivalent area of production in Tampa Bay which would be lost due to entrainment.

Station A was used as the basis for the estimate of production area since it is the sampling location closest to the intake. Consequently, this station integrates all sources of production and mortality which affect the density of entrained organisms.

Since all three methodologies estimate the effect on a particular life stage, which is a transient part of the species life history, the results were used when possible to predict the number of equivalent adults lost from the population. This estimated number of equivalent adults was then compared with data from previous population exploitation activities such as commercial and recreational fishing.

The thermal effect of the discharge plume on the RIS was assessed by using temperature tolerance data, life history information on the distribution and abundance of organisms, and the thermal characteristics of the discharge plume. Where feasible, the effect of the plume was extrapolated to estimate the area of Tampa Bay where organisms would be excluded during a portion of the year.

The thermal plume analysis also considered impacts to the benthic community, since the thermal discharge acts as a regulating mechanism in the environment and thus could alter the benthic communities which develop within its influence. Selected benthic populations were evaluated, since response at the population level may be equally important in assessing the overall effect of the thermal plume. The effect on the benthos of adding Unit 4 was assessed by considering the incremental change in the thermal plume with the addition of Unit 4.

The prediction of power station effects is conservative based on the following assumed conditions.

1. The continuous maximum Station flow rates and heat additions were used to estimate the number of organisms potentially affected by four unit operation.

2. One hundred percent mortality was used in calculations of entrained organisms, even though mortality is likely to be less under normal operation during certain times of the year.

3. Conservative estimates of biological parameters such as fecundity and survivorship were made when the available information indicated a range of values.

4. The estimates of power station effect to the RIS populations did not consider biological compensation (density dependence) in the population growth.

8.2 SUMMARY OF THE INDIVIDUAL SPECIES IMPACT

The 11 RIS were selected as indicators which characterize the Tampa Bay ecosystem. The conservative nature of the analysis resulted in predicted effects even though effects of that magnitude may not have been observed at the existing operating units. The predicted effects are localized and should not limit the present state of the biological system in Tampa Bay. The individual effects are summarized below.

The area near Big Bend Station is sandy which is not suitable American oyster habitat. However, spatfall has been observed within the discharge canal and adult oysters are found attached to manmade structures. The predicted thermal effect is seasonally dependent and limited to 8.4 hectares. Although the small size of oyster larvae precluded their collection in entrainment samples, they should be minimally affected given the undesirable nature of the habitat and the small area of influence of the intake.

Juvenile and adult pink shrimp could be excluded from 43 hectares during the summer and 9 hectares during the fall, either of which represents less than 1 percent of the surface area of the Bay. The post-larvae could be excluded from a 77 hectare area by the thermal discharge during the summer; however, few post-larvae were collected during the monitoring program; therefore, they are expected to be minimally affected. The estimated entrainment and impingement losses were compared to commercial harvest and are equivalent to less than 0.1 percent of the annual west coast of Florida landings.

Only impingement is expected to affect the blue crab, since the adults can avoid adverse temperatures and the planktonic stages remain near the bottom thus avoiding entrainment. The area which the blue crab would avoid is not considered prime habitat and presently contains few blue crabs. The projected effect of impingement is estimated at 0.005 percent of the annual west coast of Florida blue crab landings.

The stone crab inhabits substrate with rubble and thus the adults should be affected only by that portion of the thermal plume which is attached to the bottom. The pelagic zoeal stages could incur mortality within 457 hectares in summer, 77 hectares in spring, and 9 hectares in fall. The peak abundance of this life stage occurs from mid-May through July. The effects of thermal discharge were combined with the estimated entrainment and impingement loss. The total loss would represent less than 1 percent of the fishery for stone crabs on the west coast of Florida.

The bay anchovy is one of the most abundant and ubiquitous species collected in the monitoring program. The thermal plume

will exclude adults from 720 hectares during the summer and 17 hectares during the fall. The anchovy is not abundant during the summer and thus should be minimally affected by the thermal discharge. The area of intake entrainment influence was estimated at less than 5 percent of Tampa Bay with less than a 10 percent reduction in density within this area. The effect of impingement was estimated at 35 lb/yr. In view of the abundant nature of this species and the level of effect anticipated, there will not be a noticeable effect on the population.

The thermal discharge will not affect the adult scaled sardine since it is not abundant near Big Bend during the summer months. The eggs and larvae could incur mortality within 150 hectares during the summer and 25 hectares during the spring. The entrainment effect is expected to be small as indicated by the area of equivalent production (280 hectares) and the small area of entrainment influence. The impingement loss is expected to be 15 lb/yr.

The effect of the power station on the tidewater silverside is expected to be acceptably small considering the ubiquitous nature of the species in Tampa Bay. The thermal discharge will affect only post-larvae, since the adult can avoid the thermal plume and the prolarvae are demersal. The species was not collected during impingement sampling at the existing intakes at Big Bend and, given the abundant nature of this species, the entrainment projections are comparatively small.

The thermal effect on silver perch is expected to be minimal since the adults will avoid the plume and the planktonic stages are not numerous during the warm summer months. The area of entrainment influence for the silver perch is estimated at less than 5 percent of Tampa Bay with the equivalent production loss of 1,031 hectares, or about 1 percent of the area of Tampa Bay. The impingement loss is estimated at 200 lb/yr. This loss is equivalent to the catch in a relatively small number of trawls conducted around Big Bend Station during the monitoring program.

The effect of Big Bend Station on the spotted seatrout is expected to be minimal. The adults will be excluded from 291 hectares during the summer and 43 hectares during the spring. There is no information on the thermal tolerance of the planktonic stages of the species; however, peak densities occur in the spring rather than the summer. The effect of entrainment was estimated at 0.04 percent of the commercial landings for the west coast of Florida. Impingement will not have an effect on the species as only four were collected in the monitoring study.

The thermal discharge will not affect adult black drum, as the species is attracted to warmer water. Although no thermal tolerance data exist for eggs and larvae, these life stages are least abundant during the warmest months. The effects of

entrainment are expected to be minimal as relatively few black drum eggs and larvae were collected in the meroplankton samples. Impingement will be minimal as only one adult black drum was collected in the impingement samples.

The only potential effect to the manatee is from the thermal discharge. With four units in operation, the chance of cold shock to manatees in the discharge canal will be minimal and will be less than exists with only three units operating at the site.

8.3 SUMMARY OF IMPACTS TO THE BENTHOS

The community analysis and covariance analyses as well as the presence-absence, median abundance analysis of pollution and thermal indicator species all indicate that operation of Units 1 to 3 impacts the benthos in and just outside the discharge canal. Operation of Unit 4 is expected to increase the area of impact to the benthos by about 17 percent. This localized area is very small relative to the size of Tampa Bay. Since there are no data to suggest that the benthic species present at Big Bend do not occur elsewhere in the Bay, the impact of operation of Units 1 to 4 to individual species populations and to the benthos communities in Tampa Bay is expected to be small.

8.4 CONCLUSION

The effect on the marine ecosystem of Tampa Bay from the operation of Big Bend Station has been addressed by predicting impact to selected species populations and communities and by considering the general characteristics of the ecosystem. The RIS affected by power station operation represent a small fraction of each population. These losses should be less than the observed year-to-year variation in total standing crop for those species. The effect of the thermal discharge on the benthic community will be small.

The general nature of the ecosystem in Tampa Bay has been assessed from studies conducted at the site. The trophic structure is diverse at all levels with many interactions among species. There appears to be redundancy in functional groups. These characteristics suggest the ecosystem should withstand the predicted effects of Big Bend Station with a minimal change in structure and function. Thus, the chance of irreversible damage to the ecosystem should be minimal.

This Demonstration has shown, therefore, that the proposed once-through cooling system for Big Bend Units 1-4 will not adversely affect and, therefore, will assure protection of the "balanced indigenous population of fish, shellfish, and wildlife" in Tampa Bay.

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AMENDMENT 1

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November 8, 1979

Mr. Tommie A. Gibbs, Chief
Air Facilities Branch
United States Environmental
Protection Agency
Region IV
345 Courtland Street
Atlanta, Georgia 30308

RECEIVED
NOV 14 1979
H.C.E.P.C.

Dear Mr. Gibbs:

We are pleased to respond to your letter of October 16, 1979 requesting additional data in three areas.

The first area deals with an analysis of NO_x and CO emission in relation to NAAQS. The first is straightforward; maximum NO_x emissions will be 0.6 lbs/MMBTU which is exactly one-half of the 1.2 lbs/MMBTU rate used as a maximum for SO_2 modeling. Thus ambient impacts from SO_2 and NO_x can be directly compared, by dividing SO_2 impacts by a factor of 2. The only averaging time for which there is a NAAQS for NO_x is the annual average. As concluded for SO_2 and included in Table 5.3 of Volume I of the Application, the maximum annual SO_2 impact from Big Bend 4 will be 1.0 microgram per cubic meter. It can be concluded then that NO_x maximum annual impact will be 0.5 microgram per cubic meter from Big Bend 4.

The CO impact is more difficult to define because of the paucity of available data, however, the boiler manufacturer suggests that the normal emission rate from the boiler will be less than 50 ppm (1.19 lbs CO per ton of coal) with a maximum of 300 ppm (7.14 lbs CO per ton of coal). This normal emission rate corresponds roughly to the emission rate calculated in accordance with AP-42. The higher emission rate is an estimate for unstable operation, e.g. start-up, rapid load change, etc. The ambient impact will again be examined by scaling down from the SO_2 modeling effort. The emission rate stated above, 1.19 lbs CO per ton of coal, is equivalent to 0.57 lbs per million BTU, a factor of 21 less than that of 1.2 lbs per million BTU of SO_2. Unfortunately the averaging times for the pollutants are not identical, but the 3-hour averaging time for SO_2 will be used for this exercise. The maximum 3-hour ambient SO_2 impact is 163 micrograms per cubic meter. Dividing this by (21) results in an impact of 7.76 micrograms per cubic meter over the 3-hour period. This can be compared to NAAQS for CO of 40,000 micrograms per cubic meter (1-hour) and 10,000 micrograms per cubic meter (8-hour).

21

The second item in your letter requests a best available control technology analysis for fugitive TSP emissions. Measures taken to minimize fugitive coal pile emissions fall into three categories: proper maintenance of the coal pile, enclosure of all transfer points and conveyors, and water spraying. Proper maintenance of the coal pile includes shaping and sizing for easy access and consolidation. Included in shaping and sizing is compaction, to minimize the possibility of spontaneous combustion. This compaction serves to form a crust which also minimizes erosion and the subsequent dust problem. Enclosure is a simple and effective way to minimize wind contact with the coal on conveyors and at transfer points. All points are enclosed that are practical. The exceptions are the yard belt and stacker reclaimer (due to the large physical size and mobility), the tail-end conveyor feeding the tripper (due to emergency measures to ensure alternate ways to get coal to the tripper if the stacker reclaimer is out of service), and the belt coming off the barge equipment to the first transfer point (the coal from the barge is nearly always quite wet; hence little dust). Water spraying is provided for at all drop points and is utilized in high winds or during dry periods. Also several times per year during dry periods a water tank truck is utilized to spray the entire pile for a week or more. We feel that these measures, in addition to the high moisture content of the barge coal and the high annual rainfall described in the application, will effectively reduce fugitive TSP emissions to an insignificant level. Measures taken to minimize fugitive TSP emissions from limestone handling and storage are still in the conceptual stage due to the schedule of selecting the proposed FGD system. Proposed BACT measures for limestone handling and storage will be included in later submittals with details of the FGD system.

The third and last area addressed in your letter concerns hydrocarbon (HC) emissions from the boiler and any other HC sources. Emissions from the boiler are calculated to be 0.001 tons per hour (2.065 lbs/hr) or 4.755 tons per year (based on a fuel rate of 951,000 tons coal per year). These emissions are calculated using an emission rate of 0.01 lbs HC per ton coal, as recommended in a memorandum sent from the office of Air Quality Planning and Standards to EPA, Region VIII on January 23, 1978 (copy attached). The boiler is the only source of hydrocarbon emissions from the addition of Big Bend Unit 4.

We hope this information fulfills your requirement for additional data and look forward to your notification of a complete application soon.

Very truly yours,

William J. Johnson

W.J. Johnson, Ph.D.
Manager
Environmental Planning

WJJ:mo
attachment

cc: J.D. Hicks
A. Kaiser
D.E. Pless
PSD Application Recipients

JAN 23 1978 Office of Air Quality Planning and Standards
Research Triangle Park, North Carolina 27711

Reactive VOC From Coal-Fired Power Plants

Robert E. Heligan, Director
Monitoring and Data Analysis Division (MD-14)

David Hagoner, Director
Air and Hazardous Materials Division, Region VIII

The purpose of this memorandum is to respond to your request for further guidance on the nature and amount of volatile organic compounds (VOC) from coal-fired power plants. Because we had received similar requests from several other areas of the country, we recently evaluated the available data base on VOC emissions from power plants. The results of that analysis were provided to the Regions in an October 13, 1977, memorandum.

Specifically, the analysis indicated that there are several reasons why the 0.3 lb/ton emission factor which currently appears in AP-42 is inappropriate for estimating VOC emissions from coal-fired power plants. First, EPA's July 8, 1977, VOC policy specifies that methane (and several other organic compounds) are photochemically nonreactive and should, therefore, be excluded when calculating emissions from sources. A large fraction of the current AP-42 emission factors for coal combustion is methane. Second, more recent data on newer plants suggest that VOC emissions may be lower than previously believed. Limited data resulting from several recent IERL-RTP and RAPS (St. Louis) studies indicate that VOC emissions in power plants exhaust streams are frequently undetectable (at a 1 ppm sensitivity level), and usually do not exceed several ppm. This corresponds to emission factors that would typically be less than 0.01 lb/ton. Such low VOC levels lead us to the conclusion that no new coal-fired power plants in the size range now being considered would likely produce more than 100 tons/year of reactive VOC.

Because of the limited data, I hesitated in my earlier memo to recommend a new VOC emission factor for power plants. However, the available data suggest that an average of approximately 0.01 lb/ton of coal burned will be emitted from a typical power plant.

IERL-RTP is now conducting several source assessment studies on coal-fired power plants and plans to test numerous boilers (including some firing sub-bituminous coal) in the next half-year. Because of this

pending data base as a result of these studies, we do not feel it appropriate to revise AP-42 at this time to reflect the limited data currently available. IERL-RTP is cognizant of our needs for improved VOC emission factors and is coordinating its activities with us. They have indicated that detailed VOC data should be available for a number of power plant boilers within three to four months. We expect to revise AP-42 thereafter to incorporate these updated emission factor data.

Robert E. Neligan

Enclosure

cc: Director, Air & Hazardous Materials Division, Regions I, III-VII, IX, X
Director, Environmental Programs Division, Region II
E. Reich
E. Tuerk
W. Barber
D. Denny
N. Dunfee
K. Berry

bcc: M. Fast
E. Lillis
B. Steigerwald

AMTB/SAS/T.LAHRE/bc - Ext. 5474 (1-20-78)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET
ATLANTA, GEORGIA 30308

received on Oct 29, 1979

October 16, 1979

W. J. Johnson, Ph.D.
Manager, Environmental Planning
Tampa Electric Company
Post Office Box 111
Tampa, Florida 33601

Dear Dr. Johnson:

The subject of this letter is Tampa Electric Company's (TECO) application to construct generating unit number four at Big Bend, Florida. The application was received and subsequently reviewed for completeness under the provisions of Federal Prevention of Significant Deterioration (PSD) Regulations (40 CFR 52.21). We have found that the application (assigned the number PSD-FL-040) is incomplete.

Information on the following items must be included in the application to allow PSD review to continue.

1. An analysis to demonstrate that the National Ambient Air Quality Standards (NAAQS) for nitrogen dioxide (NO_X) and carbon monoxide (CO) will not be violated.

2. Best available control technology (BACT) analysis for fugitive TSP emissions. This analysis should detail specific measures to be implemented to control TSP emissions from unloading, storing and transfer of coal and limestone.

3. Potential and allowable emissions of hydrocarbons (HC) from the boiler and any other HC emission sources.

When these materials are received, EPA will continue to process your PSD application. Please address submittals to this office with a copy to Mr. J. L. Shumaker of TRW, Inc., Suite 200, 201 N. Roxboro Street, Durham, North Carolina 27701. TRW, Inc. is under contract to EPA and its personnel are acting as authorized representatives of the agency in providing aid to the Region IV PSD review program. If you have questions please feel free to contact me here or Mr. Shumaker at 919/682-9661.

Sincerely yours,

Tommie A. Gibbs

Tommie A. Gibbs, Chief
Air Facilities Branch

TAG:JLS:cg

AMENDMENT 2

TECO
TAMPA ELECTRIC COMPANY

POST OFFICE BOX 111 TAMPA, FLORIDA 33601 TELEPHONE (813) 879-4111

January 18, 1980

Mr. Tommie A. Gibbs, Chief
Air Facilities Branch
United States Environmental
Protection Agency
Region IV
345 Courtland Street
Atlanta, Georgia 30308

RECEIVED
JAN 23 1980
H.C.E.P.C.

RE: Amendment 2 of PSD Application
Big Bend Station - Unit 4
Tampa Electric Company

Dear Mr. Gibbs:

This is in response to your letter dated December 7, 1979 requesting two additional items of information in the area of fugitive TSP emissions. This submittal constitutes Amendment 2 to the application.

The first item concerns potential and allowable fugitive TSP emissions from transfer and storage of coal and limestone. Environmental Science and Engineering, Inc. was retained to perform this analysis. This report, with conclusions and summary, is included.

The second item concerns a best available control technology analysis for fugitive TSP emissions from limestone handling and storage. As stated in Amendment 1 to the application (submitted November 8, 1979) proposed BACT measures for limestone handling and storage can only be included in a later submittal as part of the details of the FGD system.

As before, we certainly hope that this information satisfies your request in order to finally obtain a completeness designation.

Sincerely,

William J. Johnson

William J. Johnson, Ph.D., P.E.
Manager, Environmental Planning

/mo
cc: J.D. Hicks
A. Kaiser
D.E. Pless
T.L. Jones
PSD Application Recipients

TAMPA ELECTRIC COMPANY
BIG BEND POWER PLANT

ESTIMATION OF COAL HANDLING EMISSIONS FOR
BIG BEND UNIT 4

PROCESS DESCRIPTION

Coal to fire the proposed Big Bend Unit 4 will be brought in by barge and routed through the existing barge unloading, transfer/conveying, and storage pile systems which service Units 1 through 3. Unit 4 will require approximately 951,000 tons per year of additional coal supplies.

Figure 1 is a schematic of the route the additional coal will take at Big Bend. Emission sources are identified by number, corresponding to the emission summary table (Table 1). The coal barge is first unloaded by means of a bucket unloader. The bucket unloading mechanism is lowered into the hold of the ship and is further lowered as needed to maintain contact with the coal stockpile. The coal is conveyed through a number of transfer points until is reaches Transfer Tower 1. The coal is then further conveyed through Transfer Tower 2 and to the stacker/reclaimer. One transfer point exists within the stacker/reclaimer.

The stacker/reclaimer, which is movable along the entire length of storage area, then loads the coal storage pile. The stacker/reclaimer is adjustable so that short drop distances and piles of any height can easily be loaded or unloaded. Heavy machinery is utilized along with the stacker/reclaimer to efficiently distribute the coal within the piles.

The storage piles are unloaded by means of the stacker/reclaimer. Coal is transfered through a surge hopper, an intermediate transfer point, and then to Transfer Tower 3. From this point the coal is loaded onto a surge pile. The surge pile is unloaded below the pile by gravity feed conveyors, and then conveyed to the coal bunkers in boiler building.

Maximum transfer rate of coal along any leg of the system is 4,000 TPH. Because the stacker/reclaimer both loads and unloads the coal storage pile, both operations cannot be conducted simultaneously.

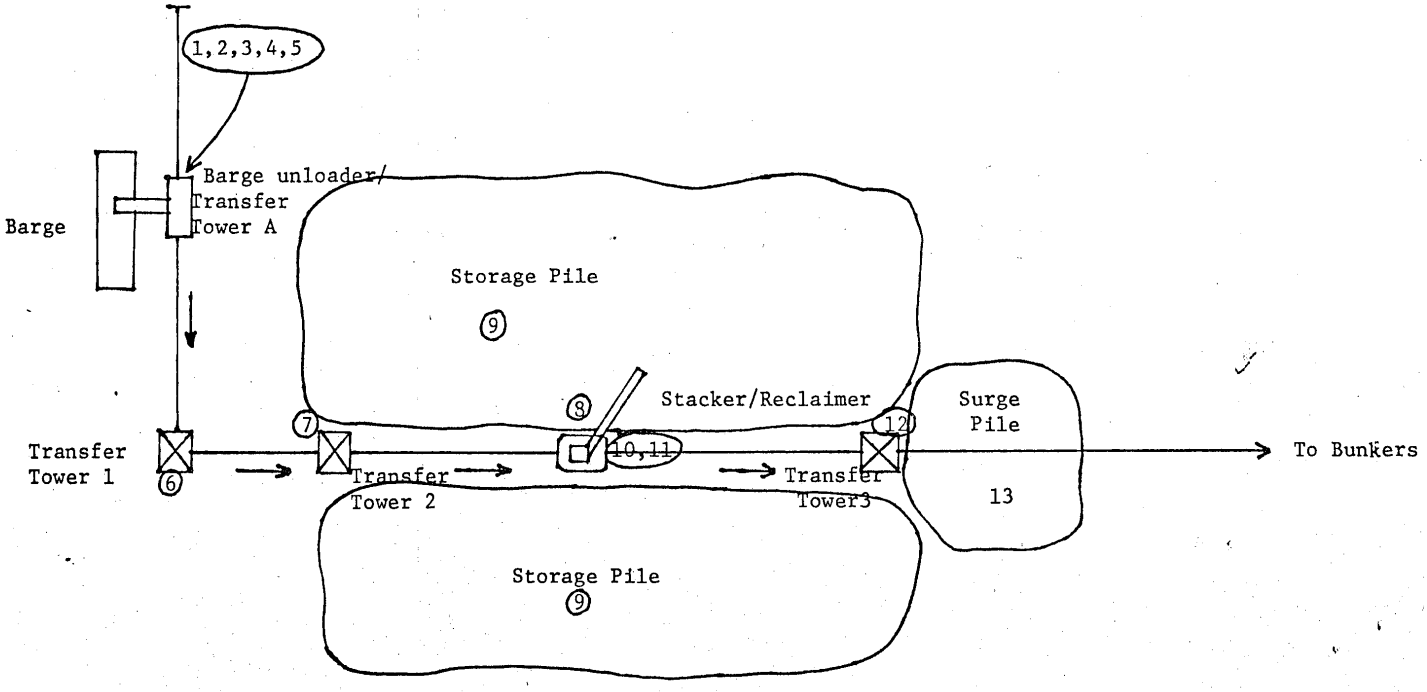

Figure 1. Schematic of TECO Big Bend Coal Handling Facilities.

POTENTIAL EMISSIONS

Potential (uncontrolled) emissions from the operation were estimated from the document entitled "Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions" (EPA-450/3-77-010, March 1977).

Section 2.1.2 of the technical guidance document presents an uncontrolled emission factor for barge loading of coal of 0.4 pound/ton, with a reliability factor of E. Since this factor is the only factor presented for coal, it was assumed that unloading emissions would be similar to loading emissions, and the 0.4 pound/ton factor was utilized.

Section 2.1.1 of the document presents transfer/conveying uncontrolled emission factors. For coal, a range from 0.04 to 0.96 pound/ton is given, with a reliability factor of E. The geometric mean or medium value from this range of 0.20 pound/ton was chosen as an average emission factor.

Section 2.1.4 of the document does not present a specific emission factor for coal. Therefore, Section 2.6 of the document, Materials Extraction and Beneficiation, was utilized since a specific factor for coal storage piles is presented therein. The factor presented is 0.054 pound/ton, but is noted that this factor does not include loading and unloading emissions. Based on Section 2.1.4, loading and unloading of storage piles constitute 27 percent of the total emissions. Therefore, the total coal storage pile uncontrolled emissions were estimated to be 0.074 pound/ton.

CONTROL EFFICIENCIES

Visual inspection of the coal handling facilities at Big Bend were conducted in order to develope control efficiencies. Coal brought in by barge is normally saturated with water and remains saturated in the hold of the barge. During the barge unloading operation, certain materials were seen to fall from the buckets--apparently overflow material from the buckets. However, this material fell directly and rapidly downwards

and back into the hold of the ship, giving the distinct impression that the material was water laden or of large particle size. Based on the saturated nature of the coal at unloading, and the visual inspection, a control efficiency of 90 percent was assumed.

All transfer points within the coal handling facility are enclosed. While some of the coveyors are covered, it is assumed that the majority of transfer/conveying emissions are generated at the transfer points and not from belt conveying. Section 2.6 of the technical guidance document, in Table 2-44, presents a control efficiency of 90 to 99 percent for enclosing conveyors and transfer points. For the Big Bend operation, an estimated control efficiency was based in part on visual observation. Because of the moisture content of the coal and with the use of enclosure, the control efficiency was estimated to be 95 percent

Section 2.1.4 of the document, dealing with storage piles, presented control efficiencies for both of the various operations encountered within storage piles. These include loading onto piles, vehicular movement within pile, wind erosion, and loadout. For the coal storage piles, the following controls and efficiencies are applicable (see Page 2-38, technical guidance document):

	% of Total Emissions	Control	Control Efficiency (%)	Overall Control (%)
Loading onto piles	12	Adjustable rate	75	9
Vehicular movement	40	Watering/traveling boom	50	20
Wind erosion	33	---	0	0
Loadout	15	Stacker/reclaimer	37	5.6
TOTAL				34.6

The stacker/reclaimer can be adjusted to any height to minimize fall distance of the coal onto the pile. Watering by truck is performed in the area of the pile whenever conditions warrant this action. The midpoint of the stacker/reclaimer efficiency, 25 to 50 percent, was utilized. The overall resulting control efficiency for the storage piles is 34.6 percent.

For the surge pile, only loadout emissions are controlled by means of gravity feed onto a conveyor (underground), resulting in an 80 percent reduction in loadout emissions. This reduction results in an overall control efficiency of 12 percent for the surge pile.

SUMMARY OF EMISSIONS

Fugitive dust emissions due to coal handling for TECO Big Bend Unit 4 are presented in Table 1. Each emission point is shown along with its potential emissions, control efficiency, and controlled emissions. Calculations are based upon 951,000 tons per year utilized in the proposed Unit 4. Estimated annual uncontrolled emissions are about 900 tons per year and controlled emissions are estimated at about 120 tons per year.

It should be kept in mind that the factors used to estimate coal dust emissions have a very low reliability factor. Because of the great uncertainties involved in deriving and applying emission factors and control efficiencies to fugitive dust generating processes, such estimates may be in error by an order of magnitude or greater.

Table 1. Summary of Fugitive Dust Emissions from Coal Handling Operations, TECO Big Bend Unit 4

Process	Emission Source	Source Number	Basic Emission Factor*	Annual Potential Emissions (TPY)	Control Efficiency (%)	Controlled Emissions (TPY)
Barge Unloading	Bucket Elevator	1	0.4 lb/ton	190.2	90	19.0
Transfer/Conveying to Storage Piles (Existing)	Transfer Tower A:					
	A belt to B belt	2	0.2 lb/ton	95.1	95	4.8
	B belt to surge hopper	3	0.2 lb/ton	95.1	95	4.8
	Surge hopper to C belt	4	0.2 lb/ton	95.1	95	4.8
	C belt to D belt	5	0.2 lb/ton	95.1	95	4.8
	Transfer Tower 1	6	0.2 lb/ton	95.1	95	4.8
	Transfer Tower 2	7	0.2 lb/ton	95.1	95	4.8
	Stacker/Reclaimer	8	0.2 lb/ton	95.1	95	4.8
Storage Piles (Existing)	Loadon, Loadout, Wind Erosion, Vehicular Traffic	9	0.074 lb/ton	35.2	34.6	23.0
Transfer/Conveying to Surge Pile	Surge Hopper to H belt	10	0.2 lb/ton	95.1	95	4.8
	H belt to F belt	11	0.2 lb/ton	95.1	95	4.8
	Transfer Tower 3	12	0.2 lb/ton	95.1	95	4.8
Surge Pile (Existing)	Loadon, Loadout, Wind Erosion, Vehicular Traffic	13	0.074 lb/ton	35.2	12	31.0

* Represents potential or uncontrolled emissions.

Source: Environmental Science and Engineering, 1980.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET
ATLANTA, GEORGIA 30308

DEC 7 1979

W. J. Johnson, Ph.D
Manager, Environmental Planning
Tampa Electric Company
Post Office Box 111
Tampa, Florida 33601

Dear, Dr. Johnson:

The subject of this letter is Tampa Electric Company's (TECO) application to construct generating unit number four at Big Bend, Florida. Your letter of November 8, 1979 was received and again reviewed for completeness under the provisions of Federal Prevention of Significant Deterioration (PSD) Regulations (40 CFR 52.21). We have found that the application (assigned the number PSD-FL-404) remains incomplete for the purpose of determining increment rights.

Your recent submittal partially addressed the requests of our October 16, 1979 letter. However, certain information has yet to be submitted. These are listed as follows:

1. The potential and allowable fugitive TSP emissions from transfer and storage of coal and limestone.

2. Best available control technology (BACT) analysis for fugitive TSP emissions from limestone handling and storage (note: your letter states that this information is in preparation).

When these materials are received, EPA will continue to process your PSD application. Please address submittals to this office with a copy to Mr. A. J. Kaufman of TRW, Inc., P. O. Box 13000, Research Triangle Park, N.C. 27709. TRW, Inc. is under contract to EPA and its personnel are acting as authorized representatives of the agency in providing aid to the Region IV PSD review program. If you have questions please feel free to contact William Rhea of my staff or Mr. Kaufman at (919) 541-9100.

You are encouraged to submit these materials as soon as possible. As you know, increment rights are determined by the date on which EPA receives a complete application. Please also be aware that certain sections of the PSD regulations are under revision as a result of a recent court decision ("Alabama Power vs. Douglas M. Costle"). These revisions are expected to make PSD regulations more restrictive in certain respects and less restric-

tive in others. Because the court has temporarily stayed its order and the final outcome is somewhat uncertain at this time, EPA Region IV is continuing to review applications under the PSD regulations as promulgated June 19, 1978. However, this does not necessarily preclude sources currently under review from the requirements of the revised regulations.

Sincerely yours,

Tommie A. Gibbs

Tommie A. Gibbs, Chief
Air Facilities Branch

TAG:AJK:jg

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

REGION IV

345 COURTLAND STREET
ATLANTA, GEORGIA 30308

DEC 7 1979

W. J. Johnson, Ph.D
Manager, Environmental Planning
Tampa Electric Company
Post Office Box 111
Tampa, Florida 33601

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Sincerely yours,

Tommie A. Gibbs

Tommie A. Gibbs, Chief
Air Facilities Branch

TAG:AJK:jg

PREVENTION OF SIGNIFICANT
DETERIORATION (PSD) APPLICATION
TAMPA ELECTRIC COMPANY

D.E.R.
OCT 2 1979
SOUTHWEST DISTRICT
TAMPA

RECEIVED
SEP 25 1979
H.C.E.P.C

Volume 1 - Prevention of Significant Deterioration Analysis

Section 1 Introduction
Section 2 Source Description
Section 3 Methodology
Section 4 Baseline Air Quality
Section 5 Air Quality Analysis
Section 6 Additional Impacts

Volume 2 - Best Available Control Technology Demonstration

Section 1 Introduction
Section 2 Project Description
Section 3 Regulatory Requirements
Section 4 Proposed Air Pollution Controls
Section 5 Alternate Air Pollution Controls
Section 6 Evaluation of Alternative SO_2 Control System
Section 7 Summary & Conclusion

Appendix A: Description of Atmospheric Dispersion models

Appendix B: AQDM Model Output

Appendix C: CRSTER Model Output

Appendix D: PTMTPW Model Output

Appendix E: Maximum Composite Tables: Baseline, Projected, and PSD Increments

Appendix F: Baseline SO_2 Emissions for Big Bend Site

Appendix G: List of Identified New and Modified Sources Commencing Construction After January 1, 1975

Appendix H: Meteorological Data: Worst Days and Periods

AMENDMENT 3

RECEIVED
MAR 17 1980
DIV. ENVIRONMENTAL PERMITTING

RECEIVED
MAR 6 1980
H.C.E.P.C.

Amendment 3

Contents

Estimation of Limestone Handling Fugitive Emissions

Air Quality Impact Analysis of Limestone and Fly Ash Handling Emissions

Calculations for Background Annual and 24-Hour TSP and Explanation of Increment-consuming Sources List

Growth Impacts

Revised Table 4-2

Tampa Electric Company

Big Bend Power Plant

Estimation of Limestone Handling Fugitive Emissions For

Big Bend Unit 4

Preliminary Process Design

The proposed SO_2 removal systems will necessitate the onsite handling, transfer, and storage of limestone. These operations potentially release particulate matter for which state-of-the-art control techniques will be employed to minimize the emissions.

The primary method for receiving the limestone will be bottom hopper rail cars and/or dump trucks. A car dumper facility will be provided at the unloading point.

In the car dump facility, the limestone will flow by gravity from the car to hoppers to underground belt feeders. A totally enclosed tubular conveyor will transport the limestone from this point to the limestone storage pile, and discharge through a telecoping chute.

At the car dump facility, an exhaust system will be provided whose inlet is connected at several places on the limestone receiving hoppers. The exhaust system will be sized to create a negative pressure at both the hopper inlet and the discharge at the conveyor belt. Dust will be removed from the exhaust air before discharging the air to atmostphere by a bag filter or a wet scrubber.

The reclaiming of limestone from the pile will be by underground hoppers. Since reclaiming occurs continuously, a depression will occur over the reclaim hoppers. The limestone delivery will be so arranged that the quantity of limestone delivered will fill the depression in the limestone storage pile by an adjustable telescopic chute. This process will minimize free fall and reduce particulate emissions. It is expected that bulldozer activity will be minimal, further reducing emissions.

From the reclaim hoppers the limestone will emerge above ground in a totally enclosed tubular covered conveyor which ravels to the limestone day silos. A local exhaust system similar to the one used at the car dumper facility will be provided at the reclaim hopper and any transfer house that may be required.

Each of the day silos will be provided with an exhaust system to create a negative pressure and prevent dust-laden air from infiltrating from the silos. Dust will be removed from the exhaust air by a bag filter and returned to the silo.

Fugitive Emissions

Based on the preliminary design given above, the only fugitive emission point will be the limestone storage pile. All other fugitive emission generating processes will either be totally enclosed and/or vented to dust collection equipment.

Potential (uncontrolled) and controlled fugitive emissions from the limestone storage pile were from the document entitled "Technical Guidance for Control of Industrial Process Fugitive Particulate Emissions" (EPA-450/3-77-010, March 1977). Section 2.1.4. of this document presents estimates for uncontrolled emissions from storage piles and control efficiencies for various control techniques.

For the typical storage pile, the uncontrolled emission factor is 10.4 lb/acre of storage/day, on an area basis. This factor includes contributions from the following operations:

Loading onto piles	12%
Equipment and vehicular movement in storage area	40%
Wind erosion	33%
Loadout from piles	15%

Control efficiencies for loading piles by use of an adjustable chute is given as 75%. Loadout emissions control, by use of gravity feed onto a conveyor, is given as 80%. The limestone storage pile will be of about 1 acre in size.

Potential emissions

$$10.4 \text{ lb/acre-day} \times 1 \text{ acre} \times 365 \text{ day/year} \div 2000 \text{ lb/ton} = 1.9 \text{ tons/year}$$

Controlled emissions

Operation	Percent of Total Emissions	Control Efficiency	Resulting Control
Load onto piles	12%	75%	9%
Vehicular movement	40%	--	--
Wind erosion	33%	--	--
Loadout	15%	80%	12%
		Overall control -------	21%

$$1.9 \text{ tons/year} \times (1-0.21) = 1.5 \text{ tons/year}$$

TECO Big Bend Unit 4

Air Quality Impact Analysis of Limestone and Fly Ash Handling Emissions

Introduction

At the request of Tampa Electric Company, Environmental Science and Engineering, Inc. has conducted an air quality impact evaluation of estimated emissions from the proposed Big Bend Unit 4 limestone and fly ash handling systems. Emissions and stack parameters utilized in the analysis were supplied by TECO. The proposed emission sources consist of a limestone receiving facility, limestone storage silos and fly ash silos, all vented to fabric filter dust collectors.

Methodology

All emission sources were simulated in the analysis as operating 24 hours per day, 365 days per year, and at maximum operating levels. The emission inventory utilized in the analysis is presented in Table 1. The U.S. EPA CRSTER Single Source model was utilized to predict maximum annual and highest, second-highest 24-hour particulate matter (TSP) impacts due to the proposed sources. A five-year meteorological data base (1970-1974) from Tampa, Florida was utilized in the evaluation. Ring distances in the CRSTER were set at 0.1, 0.3, 0.5, 0.7 and 0.9 km. Stack exit temperatures were set equal to 10° F above the maximum ambient temperature for the two limestone handling sources, and 20° F above ambient for the fly ash handling sources.

Maximum annual TSP impacts were obtained directly from the CRSTER output. The CRSTER output was also utilized to identify worst-case 24-hour meteorological conditions producing highest, second-highest 24-hour impacts. These worst-case meteorological conditions were then input into the U.S. EPA PTMTPW model to refine the maximum predicted concentrations. The PTMTPW model refines the predicted concentrations by using a 10 x 10 receptor grid with a 0.1 kilometer spacing. Concentrations were not adjusted for the two limestone handling sources,(i.e. a calibration factor of 1.0 was employed in the modeling). Stack exit temperatures were adjusted to 10° F above the average ambient temperature for the worst-case 24-hour meteorological conditions. The fly-ash handling sources were adjusted to 20° F above the same average ambient temperature.

The following computer models were executed for this analysis:

1) CRSTER - Tampa Meteorology 1970-74
   Ring distances - 0.1, 0.3, 0.5, 0.7, 0.9

2) PTMTPW - Day 173, 1972 - Direction = 90°
   Distance = 0.3 km

Results

The results of the modeling are presented in Table 2. The maximum predicted 24-hour concentration was 4.11 ug/m^3. The maximum predicted annual concentration was 0.33 ug/m^3. Copies of the appropriate computer model outputs are attached.

The results of the computer modeling show the maximum predicted concentrations for both annual and 24-hour time periods are less than the significance levels as defined in the Federal Register, Vol. 43, No. 118, June 19, 1978.

Table 1. Emission rates and stack parameters for the TECO Big Bend Unit 4 Limestone and Fly Ash Handling Systems.

Source	Emission rate (g/s)	Stack Height (m)	Stack Temp. (°K)	Velocity (m/s)	Diameter (m)
Baghouse	0.08	13.05	10° above ambient	51.2	0.29
Day Silos	0.006	22.90	10° above ambient	5.3	0.25
Fly Ash Silos	0.024	36.00	20° above ambient	1.2	0.76

Table 2. Results of Air Quality Impact Analysis for the TECO Big Bend Unit 4 Limestone and Fly Ash Handling Systems.

	Particulate	
	Annual	24-hour
Maximum Predicted Concentration (ug/m^3)	0.33	4.11
Significance Levels (ug/m^3)	1	5

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3
TAMPA MET 1970-1970 - RURAL

	MET FILE STN NO.	YR	REQUESTED STN NO.	YR
SURFACE	12842	70	12842	70
UPPER AIR	12842	70	12842	70

PLANT LOCATION: RURAL
NO TAPE OUTPUT
MET DATA WILL NOT BE PRINTED

DAY-- 1 1 1

RING DISTANCES(KM)= 0.10 0.30 0.50 0.70 0.90

STACK # 1--BAGHOUSE
STACK # 2--DAY SILOS
STACK # 3--FLY ASH SILOS

STACK	MONTH	EMISSION RATE (GMS/SEC)	HEIGHT (METERS)	DIAMETER (METERS)	EXIT VELOCITY (M/SEC)	TEMP (DEG.K)	VOLUMETRIC FLOW (M**3/SEC)
1	ALL	0.0800	13.05	0.20	51.20	320.00	3.38
2	ALL	0.0000	22.90	0.25	5.30	320.00	0.26
3	ALL	0.0240	36.00	0.76	1.20	325.00	0.54

RECEIVED
MAR 12 1980
DIV. ENVIRONMENTAL
PERMITTING

PLANT NAME: TECH BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

MAXIMUM MEAN CONC= 2.7538E-07 DIRECTION= 27 DISTANCE= 0.3 KM

YEAR= 70

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	8.45629E-08	1.29503E-07	8.10497E-08	5.03908E-08	4.28124E-08
2	9.78573E-08	1.49401E-07	9.19555E-08	6.10874E-08	4.46109E-08
3	9.56535E-08	1.40314E-07	8.62477E-08	5.78705E-08	4.20705E-08
4	8.18110E-08	1.09185E-07	6.79431E-08	4.72572E-08	3.59547E-08
5	8.05172E-08	1.13507E-07	7.03685E-08	4.82462E-08	3.63417E-08
6	1.04822E-07	1.17777E-07	6.89204E-08	4.60248E-08	3.40381E-08
7	1.23209E-07	1.25169E-07	6.97354E-08	4.47735E-08	3.21243E-08
8	1.57953E-07	1.68235E-07	9.23453E-08	5.75715E-08	3.97447E-08
9	1.84056E-07	2.00422E-07	1.56654E-07	1.04505E-07	7.06316E-08
10	1.22076E-07	1.07725E-07	9.98795E-08	6.58267E-08	4.75832E-08
11	5.97863E-08	1.03980E-07	6.68544E-08	4.74437E-08	3.68546E-08
12	4.20512E-08	1.04506E-07	7.16484E-08	5.20468E-08	4.05170E-08
13	3.94476E-08	1.16174E-07	8.15462E-08	6.13301E-08	4.95095E-08
14	3.79906E-08	1.17298E-07	8.28428E-08	6.20706E-08	4.98990E-08
15	3.88806E-08	1.04238E-07	7.26916E-08	5.45027E-08	4.38320E-08
16	3.06657E-08	9.27860E-08	6.41069E-08	4.78441E-08	3.83661E-08
17	3.39576E-08	7.84905E-08	5.42819E-08	4.04093E-08	3.23190E-08
18	3.31140E-08	8.94063E-08	6.47905E-08	5.08628E-08	4.28306E-08
19	3.05735E-08	6.03806E-08	4.57635E-08	3.36321E-08	2.65871E-08
20	3.41119E-08	7.68524E-08	5.35728E-08	4.00471E-08	3.21166E-08
21	4.22995E-08	1.03628E-07	7.29604E-08	5.46985E-08	4.41079E-08
22	4.51028E-08	1.11158E-07	7.81875E-08	5.80865E-08	4.66090E-08
23	5.20104E-08	1.38871E-07	9.73817E-08	7.48775E-08	6.24805E-08
24	6.37914E-08	1.71685E-07	1.25976E-07	1.00874E-07	8.61399E-08
25	6.83725E-08	1.80312E-07	1.18705E-07	9.24991E-08	7.97527E-08
26	7.97562E-08	1.87548E-07	1.31572E-07	1.03035E-07	8.79974E-08
27	9.00120E-08	2.75377E-07	2.01743E-07	1.58709E-07	1.32143E-07
28	9.40120E-08	2.36415E-07	1.67315E-07	1.29249E-07	1.06474E-07
29	9.93009E-08	1.93926E-07	1.32140E-07	9.94319E-08	7.99665E-08
30	1.12786E-07	2.10059E-07	1.50573E-07	1.16704E-07	9.70496E-08
31	1.06653E-07	1.70436E-07	1.12420E-07	8.21292E-08	6.42608E-08
32	9.63107E-08	1.59289E-07	1.03199E-07	7.47767E-08	5.88625E-08
33	8.96382E-08	1.65011E-07	1.09315E-07	7.93821E-08	6.23952E-08
34	7.72971E-08	1.45554E-07	8.22115E-08	5.97806E-08	4.71751E-08
35	6.48073E-08	8.02606E-08	5.24583E-08	3.84418E-08	2.81386E-08
36	7.43540E-08	1.14435E-07	7.32303E-08	5.20949E-08	4.03406E-08

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 24-HOUR CONC= 2.2951E-06 DIRECTION= 5 DISTANCE= 0.3 KM DAY=222

YEAR= 7V

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	9.0952E-07 (231)	1.3943E-06 (80)	9.3172E-07 (80)	6.3542E-07 (88)	5.0519E-07 (88)
2	1.3272E-06 (91)	1.5101E-06 (63)	1.1394E-06 (63)	7.9113E-07 (80)	5.5604E-07 (101)
3	1.2106E-06 (238)	1.9956E-06 (221)	1.3913E-06 (221)	9.4145E-07 (221)	6.6948E-07 (221)
4	8.6729E-07 (192)	1.9906E-06 (222)	1.4059E-06 (222)	9.5578E-07 (222)	6.8135E-07 (222)
5	9.0328E-07 (180)	2.2951E-06 (222)	1.5009E-06 (222)	9.8696E-07 (222)	6.8963E-07 (222)
6	1.1009E-06 (161)	1.2709E-06 (359)	7.7419E-07 (186)	4.9674E-07 (223)	3.6412E-07 (146)
7	1.4799E-06 (161)	1.0063E-06 (177)	6.6209E-07 (358)	4.6029E-07 (358)	3.3173E-07 (358)
8	1.0965E-06 (196)	1.5618E-06 (198)	7.7409E-07 (198)	4.6577E-07 (187)	3.4878E-07 (187)
9	1.8934E-06 (198)	1.7788E-06 (198)	1.0199E-06 (179)	7.2748E-07 (179)	5.5887E-07 (325)
10	1.1894E-06 (190)	1.4093E-06 (42)	8.7918E-07 (42)	5.6998E-07 (42)	4.0294E-07 (162)
11	7.5313E-07 (184)	1.1028E-06 (48)	7.4024E-07 (48)	5.4529E-07 (43)	4.3844E-07 (183)
12	8.5502E-07 (184)	1.3895E-06 (96)	9.2741E-07 (19)	7.0062E-07 (19)	6.1955E-07 (73)
13	9.4861E-07 (150)	1.4852E-06 (81)	1.3612E-06 (81)	9.4866E-07 (81)	6.9046E-07 (81)
14	7.5542E-07 (180)	1.3248E-06 (49)	1.1038E-06 (7)	8.3032E-07 (49)	6.0981E-07 (49)
15	8.1024E-07 (254)	1.4649E-06 (7)	1.0809E-06 (217)	7.2268E-07 (217)	5.1127E-07 (217)
16	8.9534E-07 (254)	1.2406E-06 (171)	8.4912E-07 (104)	6.3647E-07 (104)	4.7361E-07 (104)
17	5.8749E-07 (254)	1.0557E-06 (1)	7.0758E-07 (1)	5.2253E-07 (1)	3.8821E-07 (49)
18	6.4252E-07 (120)	1.3048E-06 (3)	9.4255E-07 (1)	6.7359E-07 (21)	5.2385E-07 (21)
19	5.3487E-07 (304)	1.1694E-06 (320)	8.5272E-07 (320)	5.8054E-07 (320)	4.2514E-07 (27)
20	7.0055E-07 (164)	1.1701E-06 (320)	9.0544E-07 (320)	6.3288E-07 (320)	4.5615E-07 (320)
21	7.0058E-07 (58)	1.3918E-06 (3)	1.1182E-06 (3)	7.7136E-07 (37)	5.4683E-07 (37)
22	7.8029E-07 (244)	1.2010E-06 (38)	8.7969E-07 (13)	6.6730E-07 (125)	5.5187E-07 (125)
23	7.5237E-07 (182)	1.9152E-06 (272)	1.3098E-06 (272)	8.7941E-07 (272)	6.2263E-07 (272)
24	1.0384E-06 (274)	2.0193E-06 (273)	1.4595E-06 (273)	9.9498E-07 (272)	7.9730E-07 (273)
25	8.8021E-07 (277)	1.4426E-06 (181)	9.8585E-07 (181)	8.2928E-07 (139)	7.0596E-07 (139)
26	1.0466E-06 (100)	1.4284E-06 (269)	1.0881E-06 (16)	7.2307E-07 (14)	5.6785E-07 (269)
27	9.0134E-07 (269)	2.1162E-06 (138)	1.3558E-06 (138)	8.9870E-07 (138)	7.9701E-07 (345)
28	1.2119E-06 (120)	1.9582E-06 (143)	1.4406E-06 (152)	1.0902E-06 (152)	8.4175E-07 (152)
29	1.2779E-06 (227)	1.8658E-06 (149)	1.3307E-06 (150)	9.8317E-07 (66)	7.6119E-07 (152)
30	1.1922E-06 (205)	1.6943E-06 (205)	1.2745E-06 (153)	8.8374E-07 (130)	7.2767E-07 (130)
31	1.2079E-06 (195)	1.1299E-06 (293)	6.9099E-07 (32)	4.7835E-07 (338)	4.3904E-07 (135)
32	1.0132E-06 (107)	1.0973E-06 (203)	7.4093E-07 (318)	5.3202E-07 (318)	3.9799E-07 (347)
33	1.1392E-06 (107)	1.5505E-06 (87)	1.2075E-06 (87)	8.4750E-07 (203)	6.1537E-07 (203)
34	1.1047E-06 (195)	1.6159E-06 (85)	1.1429E-06 (347)	8.5143E-07 (85)	6.1202E-07 (85)
35	8.1227E-07 (215)	1.1639E-06 (89)	8.1759E-07 (89)	5.5458E-07 (89)	3.9395E-07 (89)
36	1.1331E-06 (127)	1.1218E-06 (88)	8.2570E-07 (80)	5.9284E-07 (88)	5.0313E-07 (165)

PLANT NAME: TECH BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

MAXIMUM MEAN CONC= 3.2733E-07 DIRECTION= 9 DISTANCE= 0.3 KM

YEAR= 71

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	7.53630E-08	1.44144E-07	9.37898E-08	6.51823E-08	4.87005E-08
2	8.63693E-08	1.53805E-07	9.70658E-08	6.56117E-08	4.78300E-08
3	9.62053E-08	1.32008E-07	8.15916E-08	5.49865E-08	3.99404E-08
4	1.00508E-07	1.01232E-07	5.75528E-08	3.76162E-08	2.70343E-08
5	1.10002E-07	1.10885E-07	6.59597E-08	4.01448E-08	3.58586E-08
6	1.18817E-07	1.30945E-07	8.05600E-08	5.60646E-08	4.27475E-08
7	1.23603E-07	1.29397E-07	7.15408E-08	4.54469E-08	3.19920E-08
8	1.82006E-07	1.87786E-07	1.02538E-07	6.42560E-08	4.46161E-08
9	2.28615E-07	3.27328E-07	1.96238E-07	1.29010E-07	9.21503E-08
10	1.73500E-07	2.28390E-07	1.31573E-07	8.45253E-08	5.95586E-08
11	9.28292E-08	1.31761E-07	7.95026E-08	5.30181E-08	3.87658E-08
12	5.40596E-08	1.20143E-07	8.10264E-08	5.73174E-08	4.33200E-08
13	4.03395E-08	9.54055E-08	6.64803E-08	5.07600E-08	4.16000E-08
14	3.69304E-08	9.77251E-08	6.77578E-08	5.21825E-08	4.34970E-08
15	3.55602E-08	1.09931E-07	7.65928E-08	5.75712E-08	4.62437E-08
16	3.92049E-08	1.01501E-07	7.06025E-08	5.33881E-08	4.35238E-08
17	3.82481E-08	8.11990E-08	5.35509E-08	3.90092E-08	3.08867E-08
18	3.50383E-08	8.99166E-08	6.57157E-08	5.35421E-08	4.67795E-08
19	2.69933E-08	6.14170E-08	4.34661E-08	3.34404E-08	2.73639E-08
20	2.67159E-08	6.43192E-08	4.42660E-08	3.24419E-08	2.54656E-08
21	3.77723E-08	1.00919E-07	7.19293E-08	5.60773E-08	4.70561E-08
22	4.54217E-08	1.08405E-07	7.51218E-08	5.66181E-08	4.46587E-08
23	5.59602E-08	1.51075E-07	1.11241E-07	8.66992E-08	7.15680E-08
24	5.89400E-08	1.56215E-07	1.12139E-07	8.88579E-08	7.52261E-08
25	5.30476E-08	1.38150E-07	9.86678E-08	7.84113E-08	6.71054E-08
26	6.59902E-08	1.60546E-07	1.14127E-07	9.06785E-08	7.78720E-08
27	8.36432E-08	2.00101E-07	1.45055E-07	1.17301E-07	1.01738E-07
28	8.28626E-08	1.67334E-07	1.17586E-07	9.16797E-08	7.65381E-08
29	8.22259E-08	1.58004E-07	1.13035E-07	8.78965E-08	7.23375E-08
30	9.10418E-08	1.93382E-07	1.42537E-07	1.15749E-07	9.90037E-08
31	7.99756E-08	1.50177E-07	1.08866E-07	7.52515E-08	6.06827E-08
32	7.84596E-08	1.47196E-07	9.92438E-08	7.37942E-08	5.92406E-08
33	8.06559E-08	1.85638E-07	1.27645E-07	9.74413E-08	7.95197E-08
34	7.47716E-08	1.35640E-07	9.12352E-08	6.76325E-08	5.30016E-08
35	5.58698E-08	8.97795E-08	6.07889E-08	4.63641E-08	3.81259E-08
36	5.97927E-08	1.30202E-07	9.03569E-08	6.72716E-08	5.35153E-08

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 24-HOUR CONC= 2.3889E-06 DIRECTION= 9 DISTANCE= 0.3 KM DAY=167

YEAR= 71

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	9.8182E-07 (260)	1.4308E-06 (31)	9.8443E-07 (72)	6.4705E-07 (31)	4.8023E-07 (31)
2	1.0314E-06 (331)	1.6819E-06 (228)	1.0526E-06 (228)	7.3259E-07 (61)	5.1753E-07 (61)
3	1.0835E-06 (201)	1.1495E-06 (331)	7.7307E-07 (75)	6.0590E-07 (75)	4.7688E-07 (361)
4	1.1436E-06 (234)	1.0214E-06 (205)	5.0146E-07 (180)	3.7712E-07 (180)	2.6723E-07 (180)
5	1.0054E-06 (289)	1.0356E-06 (205)	7.2422E-07 (251)	5.7961E-07 (112)	4.8963E-07 (216)
6	1.0141E-06 (159)	1.4653E-06 (118)	1.0825E-06 (118)	8.5133E-07 (175)	6.8739E-07 (175)
7	9.7004E-07 (207)	1.0944E-06 (114)	7.2872E-07 (114)	4.9248E-07 (118)	3.9952E-07 (117)
8	1.2885E-06 (128)	1.1265E-06 (174)	7.4676E-07 (256)	5.2443E-07 (174)	3.8248E-07 (174)
9	1.9394E-06 (128)	2.3889E-06 (167)	1.5358E-06 (167)	1.0659E-06 (167)	7.8556E-07 (167)
10	1.3075E-06 (238)	1.5155E-06 (165)	1.0241E-06 (254)	7.5128E-07 (195)	6.3175E-07 (195)
11	1.0068E-06 (197)	1.2640E-06 (183)	7.2301E-07 (183)	5.8345E-07 (96)	4.7749E-07 (226)
12	8.6507E-07 (136)	1.3485E-06 (44)	9.3928E-07 (44)	6.5991E-07 (54)	5.3385E-07 (54)
13	7.4997E-07 (136)	8.7511E-07 (44)	6.7657E-07 (215)	5.4789E-07 (79)	3.9839E-07 (161)
14	6.1699E-07 (104)	8.9163E-07 (63)	6.1953E-07 (63)	4.4733E-07 (136)	3.5620E-07 (136)
15	8.8208E-07 (221)	1.3201E-06 (121)	8.0905E-07 (121)	6.3112E-07 (299)	5.4501E-07 (299)
16	8.1157E-07 (221)	1.1301E-06 (89)	8.7304E-07 (121)	5.5812E-07 (121)	4.0906E-07 (89)
17	5.3787E-07 (99)	8.7961E-07 (19)	6.4608E-07 (19)	4.4494E-07 (19)	3.3271E-07 (331)
18	7.0210E-07 (99)	1.0233E-06 (71)	7.6198E-07 (10)	6.4341E-07 (10)	5.0628E-07 (10)
19	6.3911E-07 (99)	9.0926E-07 (315)	6.5124E-07 (315)	4.7811E-07 (315)	3.6728E-07 (315)
20	4.6770E-07 (99)	8.1909E-07 (308)	6.7319E-07 (338)	4.6331E-07 (338)	3.3128E-07 (338)
21	6.9639E-07 (18)	1.6422E-06 (308)	1.1749E-06 (329)	8.3892E-07 (7)	6.0737E-07 (7)
22	7.6001E-07 (263)	1.2705E-06 (272)	9.9745E-07 (272)	7.6004E-07 (358)	6.1065E-07 (358)
23	9.1964E-07 (142)	1.6616E-06 (270)	1.2933E-06 (270)	9.7737E-07 (163)	7.5749E-07 (163)
24	9.9575E-07 (90)	1.4942E-06 (359)	1.0696E-06 (293)	9.4330E-07 (319)	8.3622E-07 (319)
25	8.5023E-07 (90)	1.2789E-06 (267)	8.7671E-07 (284)	7.3995E-07 (335)	5.8479E-07 (360)
26	9.9852E-07 (190)	1.6535E-06 (33)	1.2939E-06 (304)	9.2824E-07 (304)	6.8082E-07 (304)
27	1.2882E-06 (101)	1.5479E-06 (94)	1.1384E-06 (49)	9.7918E-07 (13)	8.4651E-07 (265)
28	1.0843E-06 (101)	1.2997E-06 (247)	8.8014E-07 (247)	7.0618E-07 (306)	6.2642E-07 (306)
29	1.3595E-06 (191)	1.3081E-06 (143)	1.1541E-06 (281)	7.7632E-07 (281)	5.5970E-07 (305)
30	1.1983E-06 (191)	1.7675E-06 (249)	1.2882E-06 (353)	1.1597E-06 (11)	1.0245E-06 (343)
31	1.0552E-06 (230)	1.1976E-06 (193)	7.9489E-07 (257)	6.1585E-07 (257)	4.6856E-07 (257)
32	8.0801E-07 (218)	1.0206E-06 (230)	6.4655E-07 (251)	5.3404E-07 (332)	3.7670E-07 (332)
33	9.1146E-07 (218)	1.5622E-06 (185)	1.0280E-06 (185)	8.0624E-07 (36)	6.4090E-07 (36)
34	9.9948E-07 (259)	1.2469E-06 (216)	9.5164E-07 (5)	8.1486E-07 (5)	6.5742E-07 (5)
35	9.6664E-07 (229)	8.2272E-07 (60)	7.0782E-07 (59)	6.0435E-07 (176)	5.3350E-07 (176)
36	1.1884E-06 (229)	1.3979E-06 (227)	1.0222E-06 (227)	6.9939E-07 (227)	5.7235E-07 (8)

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

MAXIMUM MEAN CONC= 3.0322E-07 DIRECTION= 9 DISTANCE= 0.5 KM

YEAR= 77

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	0.44963E-08	1.17986E-07	7.42471E-08	5.02965E-08	3.67415E-08
2	8.23463E-08	1.50710E-07	9.50764E-08	6.85273E-08	4.73597E-08
3	8.63994E-08	1.30308E-07	8.10418E-08	5.47526E-08	4.00725E-08
4	8.99481E-08	1.02000E-07	6.13624E-08	4.18276E-08	3.14057E-08
5	1.08341E-07	1.12027E-07	6.85165E-08	4.66622E-08	3.54445E-08
6	1.25378E-07	1.30510E-07	7.65272E-08	5.07537E-08	3.69585E-08
7	1.36705E-07	1.41121E-07	8.14781E-08	5.35620E-08	3.87945E-08
8	1.70673E-07	1.93559E-07	1.10555E-07	7.10536E-08	5.01408E-08
9	2.00903E-07	3.03223E-07	1.83140E-07	1.20880E-07	8.67469E-08
10	1.47298E-07	2.14471E-07	1.28408E-07	8.48169E-08	6.10897E-08
11	7.55166E-08	1.34477E-07	8.70103E-08	6.05976E-08	4.53013E-08
12	4.05785E-08	9.00853E-08	6.49471E-08	4.80790E-08	3.80818E-08
13	3.96327E-08	1.00092E-07	6.98862E-08	5.28197E-08	4.24595E-08
14	3.22804E-08	9.89455E-08	6.98850E-08	5.47978E-08	4.66013E-08
15	2.87011E-08	1.02551E-07	7.24036E-08	5.43578E-08	4.34907E-08
16	3.09721E-08	8.64740E-08	5.92503E-08	4.37420E-08	3.48817E-08
17	3.05916E-08	8.27220E-08	5.50600E-08	3.98547E-08	3.11910E-08
18	3.99180E-08	9.36961E-08	6.48587E-08	4.85568E-08	3.69523E-08
19	3.64204E-08	7.53078E-08	5.02026E-08	3.72911E-08	2.99626E-08
20	3.73097E-08	7.19152E-08	4.95474E-08	3.67194E-08	2.91304E-08
21	4.88092E-08	1.05977E-07	7.34589E-08	5.55780E-08	4.60144E-08
22	6.09202E-08	1.39540E-07	9.51636E-08	6.86513E-08	5.31104E-08
23	6.87115E-08	1.86531E-07	1.33402E-07	1.02042E-07	8.48047E-08
24	7.49520E-08	2.03065E-07	1.46283E-07	1.13569E-07	9.39481E-08
25	8.10080E-08	1.97702E-07	1.42016E-07	1.14867E-07	9.93185E-08
26	8.98731E-08	2.17222E-07	1.56770E-07	1.24072E-07	1.04920E-07
27	1.01074E-07	2.74867E-07	2.00552E-07	1.60254E-07	1.35791E-07
28	9.21193E-08	2.20833E-07	1.52872E-07	1.16247E-07	9.52376E-08
29	8.98496E-08	1.67392E-07	1.14279E-07	8.74081E-08	7.23933E-08
30	7.68047E-08	1.52208E-07	1.03393E-07	7.98056E-08	6.71105E-08
31	6.95026E-08	1.38955E-07	9.52243E-08	7.08091E-08	5.95132E-08
32	6.62993E-08	1.28609E-07	8.88547E-08	6.85874E-08	5.41167E-08
33	6.62986E-08	1.34346E-07	9.16217E-08	6.70495E-08	5.27918E-08
34	5.37927E-08	1.11665E-07	7.59367E-08	5.12892E-08	3.68233E-08
35	4.11436E-08	8.51311E-08	5.49001E-08	3.93274E-08	3.03310E-08
36	5.04741E-08	1.97779E-07	7.11394E-08	5.05336E-08	3.86502E-08

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

EARLY SECOND MAXIMUM 24-HOUR CONC= 3.4631E-06 DIRECTION= 9 DISTANCE= 0.3 KM DAY=173

EAR= 72

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE IR	0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	7.5998E-07 (107)	1.1597E-06 (330)	7.9316E-07 (330)	5.3424E-07 (330)	4.0309E-07 (357)
2	9.7067E-07 (355)	1.4613E-06 (237)	1.0702E-06 (89)	7.9501E-07 (89)	6.1011E-07 (89)
3	9.1066E-07 (110)	1.0675E-06 (89)	1.2962E-06 (89)	8.8639E-07 (76)	6.3062E-07 (76)
4	9.5314E-07 (269)	8.1172E-07 (104)	5.9077E-07 (104)	4.2141E-07 (104)	3.2431E-07 (98)
5	1.3707E-06 (211)	9.8997E-07 (98)	7.1387E-07 (98)	4.9903E-07 (188)	3.8137E-07 (312)
6	1.2679E-06 (211)	9.9861E-07 (177)	7.0072E-07 (177)	5.2415E-07 (239)	4.1338E-07 (210)
7	1.2484E-06 (194)	1.0796E-06 (172)	6.9906E-07 (172)	5.0302E-07 (220)	4.2484E-07 (180)
8	1.3062E-06 (220)	1.6735E-06 (180)	1.0645E-06 (180)	7.8428E-07 (180)	6.2768E-07 (180)
9	1.7807E-06 (242)	3.4631E-06 (173)	2.3005E-06 (173)	1.5485E-06 (175)	1.0988E-06 (174)
10	1.4731E-06 (242)	1.7656E-06 (178)	1.1187E-06 (182)	7.3928E-07 (182)	5.2718E-07 (182)
11	9.8765E-07 (195)	1.3131E-06 (44)	9.1045E-07 (44)	6.1889E-07 (44)	4.4272E-07 (44)
12	1.0952E-06 (245)	1.0052E-06 (143)	7.3082E-07 (331)	5.5027E-07 (331)	4.5776E-07 (142)
13	8.4340E-07 (245)	1.1734E-06 (358)	7.8939E-07 (91)	6.0436E-07 (91)	4.7445E-07 (91)
14	4.9890E-07 (249)	9.8269E-07 (280)	6.9569E-07 (358)	5.9709E-07 (358)	5.4338E-07 (325)
15	4.5349E-07 (263)	1.4938E-06 (6)	1.1613E-06 (6)	8.3349E-07 (6)	6.2306E-07 (6)
16	5.4067E-07 (189)	1.1317E-06 (148)	8.7267E-07 (148)	6.1630E-07 (148)	4.5166E-07 (148)
17	7.1921E-07 (245)	1.4899E-06 (6)	1.0390E-06 (6)	7.0079E-07 (6)	4.9661E-07 (6)
18	7.8191E-07 (263)	1.6859E-06 (328)	1.3396E-06 (328)	1.0153E-06 (328)	7.4198E-07 (326)
19	8.1979E-07 (189)	1.5892E-06 (236)	1.1775E-06 (236)	8.5606E-07 (236)	6.5078E-07 (236)
20	1.0383E-06 (252)	8.2980E-07 (40)	5.8393E-07 (40)	3.9413E-07 (40)	3.5273E-07 (300)
21	1.1999E-06 (252)	1.0863E-06 (92)	7.4602E-07 (92)	5.0232E-07 (92)	3.9174E-07 (193)
22	8.1718E-07 (208)	1.6296E-06 (69)	1.1051E-06 (69)	7.5347E-07 (278)	6.1847E-07 (278)
23	9.2186E-07 (189)	1.8095E-06 (117)	1.3383E-06 (277)	9.8170E-07 (353)	7.4603E-07 (353)
24	9.5339E-07 (158)	1.7219E-06 (271)	1.1139E-06 (271)	8.2470E-07 (353)	6.8360E-07 (311)
25	1.1733E-06 (156)	1.7243E-06 (42)	1.2088E-06 (18)	8.4312E-07 (18)	6.9769E-07 (295)
26	1.3547E-06 (265)	1.4794E-06 (277)	1.1313E-06 (277)	7.9104E-07 (27)	6.2845E-07 (277)
27	9.2358E-07 (265)	1.9151E-06 (164)	1.4221E-06 (132)	1.0853E-06 (167)	9.1063E-07 (167)
28	1.1971E-06 (247)	2.0119E-06 (121)	1.4782E-06 (121)	1.1037E-06 (121)	8.5189E-07 (121)
29	9.3962E-07 (185)	1.5334E-06 (101)	1.0514E-06 (119)	6.9402E-07 (119)	4.9210E-07 (101)
30	8.7593E-07 (196)	1.1655E-06 (185)	8.6319E-07 (324)	6.0264E-07 (324)	4.9330E-07 (102)
31	8.8014E-07 (185)	1.1063E-06 (332)	7.7353E-07 (21)	5.6931E-07 (21)	4.6745E-07 (308)
32	8.1707E-07 (229)	1.2690E-06 (301)	8.0945E-07 (134)	5.8440E-07 (1)	5.1475E-07 (1)
33	7.7827E-07 (1)	1.8033E-06 (301)	1.6179E-06 (335)	1.1980E-06 (12)	9.1822E-07 (12)
34	6.1391E-07 (262)	9.9781E-07 (237)	7.9148E-07 (237)	6.1497E-07 (236)	4.5120E-07 (236)
35	4.9534E-07 (262)	9.1677E-07 (307)	7.0810E-07 (316)	5.1992E-07 (309)	4.1462E-07 (324)
36	5.6150E-07 (315)	1.2483E-06 (90)	8.8027E-07 (357)	6.1100E-07 (357)	4.3796E-07 (357)

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/MA**3

MAXIMUM MEAN CONC= 2.1635E-07 DIRECTION= 27 DISTANCE= 0.3 KM

YEAR= 73

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	6.53050E-08	1.26265E-07	8.30800E-08	5.73506E-08	4.22669E-08
2	6.93061E-08	1.19391E-07	7.56578E-08	5.09024E-08	3.67704E-08
3	7.84843E-08	1.05989E-07	6.42229E-08	4.28717E-08	3.12517E-08
4	8.67678E-08	1.03948E-07	6.36919E-08	4.30118E-08	3.30892E-08
5	1.01573E-07	1.0142UE-07	5.80667E-08	3.91528E-08	2.94194E-08
6	1.27746E-07	1.31000E-07	7.51456E-08	5.03666E-08	3.76715E-08
7	1.46853E-07	1.55692E-07	9.19468E-08	6.20894E-08	4.63120E-08
8	1.54172E-07	1.60142E-07	9.01458E-08	5.72716E-08	4.01030E-08
9	1.56374E-07	2.13319E-07	1.29048E-07	8.53724E-08	6.13149E-08
10	1.15123E-07	1.82846E-07	1.13203E-07	7.60487E-08	5.53245E-08
11	7.17827E-08	1.37542E-07	8.83310E-08	6.15838E-08	4.63457E-08
12	4.63051E-08	1.09147E-07	7.74151E-08	6.02482E-08	4.97622E-08
13	3.31237E-08	1.04363E-07	7.86682E-08	6.25898E-08	5.21697E-08
14	3.03150E-08	1.04184E-07	7.51245E-08	5.82755E-08	4.81648E-08
15	2.89525E-08	9.10305E-08	6.34980E-08	4.88226E-08	3.74798E-08
16	3.05974E-08	7.46959E-08	5.51674E-08	4.26454E-08	3.46494E-08
17	3.58020E-08	7.86872E-08	5.58140E-08	4.18422E-08	3.37355E-08
18	3.91910E-08	7.81235E-08	5.51952E-08	4.26765E-08	3.49821E-08
19	4.05488E-08	8.52617E-08	5.86520E-08	4.35038E-08	3.47767E-08
20	4.86853E-08	1.08653E-07	7.77529E-08	5.79670E-08	4.56610E-08
21	5.75030E-08	1.33824E-07	9.60721E-08	7.40559E-08	6.10277E-08
22	5.67543E-08	1.29950E-07	8.98818E-08	6.88300E-08	5.72023E-08
23	6.03904E-08	1.46040E-07	1.01321E-07	7.61921E-08	6.17450E-08
24	8.01802E-08	1.92568E-07	1.36228E-07	1.06032E-07	8.87526E-08
25	9.73392E-08	2.15346E-07	1.50808E-07	1.19585E-07	1.01848E-07
26	8.75326E-08	1.93759E-07	1.35962E-07	1.04611E-07	8.71872E-08
27	8.02095E-08	2.16351E-07	1.57587E-07	1.24100E-07	1.03503E-07
28	7.67087E-08	1.93210E-07	1.34161E-07	9.99569E-08	7.95322E-08
29	7.72524E-08	1.82833E-07	1.25739E-07	9.44275E-08	7.59302E-08
30	8.51057E-08	2.04323E-07	1.43203E-07	1.09672E-07	8.96867E-08
31	9.04300E-08	1.89798E-07	1.28557E-07	9.61518E-08	7.79935E-08
32	9.89995E-08	1.87936E-07	1.23083E-07	8.83070E-08	6.83746E-08
33	9.78689E-08	1.68536E-07	1.07272E-07	7.51035E-08	5.71460E-08
34	8.48210E-08	1.39345E-07	9.00681E-08	6.41535E-08	4.95353E-08
35	6.77063E-08	1.19533E-07	7.87750E-08	5.64135E-08	4.34410E-08
36	6.86674E-08	1.31668E-07	8.77110E-08	6.21229E-08	4.71370E-08

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 24-HOUR CONC= 1.9923E-06 DIRECTION= 20 DISTANCE= 0.3 KM DAY= 24

YEAR= 73

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	7.5318E-07 (149)	1.3520E-06 (146)	9.2485E-07 (148)	6.3332E-07 (148)	5.0823E-07 (45)
2	7.3076E-07 (164)	1.4432E-06 (146)	1.0670E-06 (146)	7.1580E-07 (148)	5.0706E-07 (148)
3	9.7255E-07 (269)	1.0331E-06 (115)	7.0597E-07 (349)	4.8994E-07 (145)	3.7857E-07 (349)
4	8.9319E-07 (313)	1.2149E-06 (145)	9.8455E-07 (178)	7.0980E-07 (145)	5.4563E-07 (145)
5	1.4403E-06 (250)	8.9222E-07 (172)	5.7080E-07 (348)	4.1338E-07 (301)	3.3647E-07 (129)
6	1.4419E-06 (182)	1.3282E-06 (209)	7.3758E-07 (209)	5.2120E-07 (209)	4.2819E-07 (209)
7	1.4567E-06 (181)	1.3995E-06 (140)	9.2584E-07 (349)	6.3015E-07 (144)	4.8139E-07 (175)
8	1.6168E-06 (187)	1.1371E-06 (253)	7.0796E-07 (134)	4.5780E-07 (301)	3.7797E-07 (27)
9	1.5736E-06 (152)	1.0454E-06 (180)	1.2630E-06 (27)	9.6430E-07 (27)	7.4072E-07 (27)
10	1.1338E-06 (180)	1.5033E-06 (141)	1.0647E-06 (169)	7.0440E-07 (168)	5.7140E-07 (258)
11	9.2922E-07 (208)	1.0433E-06 (169)	1.0327E-06 (169)	6.8325E-07 (169)	5.1021E-07 (222)
12	5.4255E-07 (206)	1.4954E-06 (76)	1.0631E-06 (76)	7.8066E-07 (76)	5.9946E-07 (76)
13	5.7095E-07 (255)	1.3509E-06 (41)	1.2544E-06 (29)	8.4705E-07 (29)	6.0206E-07 (29)
14	6.0159E-07 (175)	1.4906E-06 (58)	1.0389E-06 (58)	7.3250E-07 (86)	6.0158E-07 (289)
15	6.2408E-07 (182)	1.0183E-06 (350)	7.7540E-07 (350)	5.7640E-07 (58)	4.3550E-07 (47)
16	7.0342E-07 (119)	1.0794E-06 (5)	9.3379E-07 (5)	7.2008E-07 (305)	6.0449E-07 (305)
17	7.3201E-07 (190)	1.4817E-06 (12)	1.0758E-06 (12)	7.4147E-07 (5)	5.5785E-07 (5)
18	8.5738E-07 (221)	1.0390E-06 (305)	6.9418E-07 (208)	5.0641E-07 (298)	4.4377E-07 (298)
19	7.9380E-07 (305)	1.2145E-06 (341)	9.2399E-07 (136)	6.3138E-07 (136)	4.5472E-07 (136)
20	1.0529E-06 (183)	1.9923E-06 (24)	1.5880E-06 (24)	1.1300E-06 (24)	8.3379E-07 (24)
21	1.3546E-06 (221)	1.0804E-06 (9)	1.2932E-06 (10)	9.3237E-07 (10)	6.8402E-07 (10)
22	1.3991E-06 (221)	1.4157E-06 (291)	1.0544E-06 (9)	7.3020E-07 (9)	5.2274E-07 (9)
23	1.0327E-06 (233)	1.2512E-06 (315)	9.5902E-07 (315)	6.9067E-07 (315)	5.3329E-07 (315)
24	1.0394E-06 (221)	1.8389E-06 (158)	1.2809E-06 (158)	8.8418E-07 (321)	6.9197E-07 (276)
25	1.3979E-06 (200)	1.4463E-06 (290)	1.2180E-06 (49)	8.7920E-07 (49)	6.6593E-07 (321)
26	1.2003E-06 (240)	1.5540E-06 (158)	1.0583E-06 (49)	7.5014E-07 (49)	5.9044E-07 (308)
27	1.1748E-06 (154)	1.6343E-06 (308)	1.1376E-06 (106)	8.0472E-07 (106)	6.1244E-07 (308)
28	1.1086E-06 (239)	1.5225E-06 (105)	1.0458E-06 (105)	7.0091E-07 (105)	5.7888E-07 (105)
29	9.2207E-07 (229)	1.0073E-06 (109)	1.1585E-06 (109)	8.0246E-07 (109)	5.9893E-07 (251)
30	9.8731E-07 (171)	1.8140E-06 (32)	1.2607E-06 (32)	8.4857E-07 (32)	6.0039E-07 (32)
31	8.0494E-07 (224)	1.0919E-06 (359)	1.2105E-06 (359)	8.2373E-07 (359)	5.8312E-07 (88)
32	1.1042E-06 (217)	1.9714E-06 (90)	1.3481E-06 (90)	9.0620E-07 (90)	6.4221E-07 (90)
33	1.5028E-06 (202)	1.1903E-06 (89)	7.9736E-07 (89)	5.4551E-07 (213)	4.3750E-07 (328)
34	1.3209E-06 (202)	1.3425E-06 (213)	1.0032E-06 (213)	8.0187E-07 (150)	6.8328E-07 (150)
35	9.9383E-07 (201)	1.5999E-06 (93)	1.0981E-06 (93)	7.3987E-07 (93)	5.5044E-07 (349)
36	7.8232E-07 (186)	1.3510E-06 (79)	9.8757E-07 (79)	6.8299E-07 (79)	5.4728E-07 (349)

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/MA**3

MAXIMUM MEAN CONC= 2.0814E-07 DIRECTION= 9 DISTANCE= 0.3 KM

YEAR= 74

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	9.97885E-08	1.23750E-07	8.00502E-08	5.53871E-08	4.12050E-08
2	7.20093E-08	1.23381E-07	7.81932E-08	5.32195E-08	3.88798E-08
3	7.50108E-08	1.05384E-07	6.40807E-08	4.30740E-08	3.13708E-08
4	8.88283E-08	1.06106E-07	6.48436E-08	4.33567E-08	3.16875E-08
5	1.13056E-07	1.14913E-07	6.58117E-08	4.35967E-08	3.19023E-08
6	1.38588E-07	1.44402E-07	8.20276E-08	5.31386E-08	3.79599E-08
7	1.55471E-07	1.57037E-07	8.72203E-08	5.55912E-08	3.94725E-08
8	1.75155E-07	1.91071E-07	1.06001E-07	6.91549E-08	4.89713E-08
9	1.9477QE-07	2.08141E-07	1.60113E-07	1.06056E-07	7.08874E-08
10	1.47445E-07	2.10022E-07	1.30529E-07	8.63218E-08	6.20577E-08
11	9.56457E-08	1.41055E-07	8.75311E-08	5.90909E-08	4.34243E-08
12	8.97557E-08	9.78732E-08	6.52510E-08	4.67737E-08	3.58925E-08
13	3.11914E-08	8.07107E-08	5.72317E-08	4.43443E-08	3.65175E-08
14	2.70908E-08	9.89042E-08	7.13218E-08	5.42850E-08	4.41071E-08
15	3.01056E-08	9.25573E-08	6.09818E-08	4.99434E-08	4.13801E-08
16	3.55027E-08	9.12069E-08	6.32454E-08	4.71775E-08	3.80413E-08
17	3.31650E-08	8.60034E-08	6.21907E-08	4.74942E-08	3.82134E-08
18	3.49088E-08	9.30282E-08	6.87781E-08	5.34109E-08	4.37860E-08
19	3.07312E-08	7.70109E-08	5.24272E-08	3.80447E-08	2.97100E-08
20	5.14706E-08	1.13353E-07	7.81961E-08	5.75781E-08	4.55784E-08
21	7.08602E-08	1.56721E-07	1.09776E-07	8.21966E-08	6.61199E-08
22	7.50743E-08	1.64891E-07	1.15251E-07	8.74883E-08	7.11796E-08
23	7.87314E-08	1.59501E-07	1.08851E-07	8.25866E-08	6.79494E-08
24	9.31177E-08	1.91093E-07	1.34421E-07	1.05366E-07	8.91678E-08
25	9.93016E-08	2.03181E-07	1.48103E-07	1.20341E-07	1.03808E-07
26	9.66993E-08	1.55294E-07	1.07021E-07	8.59138E-08	7.35598E-08
27	1.08708E-07	2.04384E-07	1.40788E-07	1.18190E-07	1.01403E-07
28	1.03917E-07	2.02002E-07	1.44029E-07	1.13682E-07	9.51244E-08
29	8.68799E-08	1.54709E-07	1.07220E-07	8.25023E-08	6.79631E-08
30	9.24996E-08	1.53905E-07	1.06872E-07	8.37924E-08	7.05145E-08
31	1.06366E-07	1.97513E-07	1.10326E-07	8.13942E-08	6.49842E-08
32	1.13139E-07	1.73447E-07	1.14082E-07	8.27621E-08	6.44500E-08
33	1.05742E-07	1.70847E-07	1.13142E-07	8.15067E-08	6.31558E-08
34	8.49808E-08	1.45537E-07	9.80275E-08	7.27595E-08	5.74425E-08
35	7.13726E-08	1.09351E-07	7.50060E-08	5.32875E-08	4.17006E-08
36	6.98790E-08	1.18052E-07	7.86449E-08	5.69911E-08	4.31196E-08

PLANT NAME: TECO BIG BEND POLLUTANT: TSP AIR QUALITY UNITS: GM/M**3

YEARLY SECOND MAXIMUM 24-HOUR CONC= 2.0351E-06 DIRECTION= 22 DISTANCE= 0.3 KM DAY=274

YEAR= 74

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

RANGE DIR	0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	7.8979E-07 (310)	1.1834E-06 (90)	8.6516E-07 (360)	7.7965E-07 (360)	6.3489E-07 (360)
2	7.5371E-07 (310)	1.1259E-06 (83)	8.4177E-07 (31)	5.9072E-07 (31)	4.5555E-07 (38)
3	7.8484E-07 (186)	1.1591E-06 (209)	8.6099E-07 (80)	5.9865E-07 (83)	4.4303E-07 (83)
4	9.4314E-07 (229)	1.1312E-06 (218)	7.9787E-07 (31)	5.9090E-07 (31)	4.4057E-07 (31)
5	8.9293E-07 (186)	8.7686E-07 (88)	5.7471E-07 (31)	4.4823E-07 (88)	3.3611E-07 (88)
6	1.1711E-06 (151)	1.3338E-06 (270)	9.3635E-07 (88)	6.2673E-07 (88)	4.4301E-07 (88)
7	1.2259E-06 (173)	1.0698E-06 (173)	6.3972E-07 (34)	4.7242E-07 (34)	3.5967E-07 (34)
8	1.2313E-06 (196)	1.1188E-06 (25)	7.3331E-07 (25)	4.8537E-07 (25)	3.7582E-07 (147)
9	1.5418E-06 (231)	2.0118E-06 (71)	1.2771E-06 (230)	8.6007E-07 (71)	6.6294E-07 (230)
10	1.1843E-06 (211)	1.3955E-06 (211)	8.8522E-07 (148)	6.6268E-07 (192)	5.2147E-07 (230)
11	1.0004E-06 (211)	1.2950E-06 (213)	8.1453E-07 (213)	5.0935E-07 (213)	3.6808E-07 (359)
12	8.1885E-07 (211)	1.2826E-06 (335)	8.0613E-07 (335)	5.8389E-07 (335)	4.1738E-07 (335)
13	7.0407E-07 (211)	1.0964E-06 (335)	7.5498E-07 (39)	5.0749E-07 (39)	3.7622E-07 (72)
14	6.8427E-07 (226)	1.3174E-06 (336)	9.7397E-07 (336)	6.7317E-07 (336)	5.2551E-07 (107)
15	6.1824E-07 (197)	1.2006E-06 (96)	7.9011E-07 (96)	5.3009E-07 (96)	3.7718E-07 (96)
16	6.0933E-07 (234)	1.0550E-06 (133)	7.3459E-07 (133)	5.2480E-07 (316)	4.1634E-07 (151)
17	7.2480E-07 (282)	1.2983E-06 (280)	1.0258E-06 (17)	7.3655E-07 (17)	6.0974E-07 (6)
18	7.4783E-07 (257)	1.4571E-06 (347)	1.1449E-06 (347)	9.1116E-07 (280)	6.5146E-07 (280)
19	6.7588E-07 (243)	1.1504E-06 (57)	8.4671E-07 (331)	5.9965E-07 (331)	4.3043E-07 (57)
20	8.3105E-07 (243)	1.3740E-06 (57)	9.8704E-07 (57)	6.7617E-07 (57)	5.4446E-07 (311)
21	9.9204E-07 (264)	1.7214E-06 (279)	1.2068E-06 (107)	8.2536E-07 (107)	6.5954E-07 (347)
22	1.0619E-06 (171)	2.0351E-06 (274)	1.3715E-06 (274)	9.3021E-07 (274)	6.9453E-07 (313)
23	1.1036E-06 (298)	1.5518E-06 (295)	1.1234E-06 (295)	7.6044E-07 (267)	5.3998E-07 (267)
24	1.3470E-06 (284)	1.9402E-06 (348)	1.4068E-06 (268)	1.0684E-06 (348)	7.9151E-07 (348)
25	1.3360E-06 (305)	1.0690E-06 (8)	1.1860E-06 (285)	8.5828E-07 (285)	6.5633E-07 (285)
26	1.3895E-06 (305)	1.2485E-06 (233)	8.9696E-07 (348)	6.2803E-07 (348)	4.9936E-07 (263)
27	1.4042E-06 (110)	1.6439E-06 (233)	1.1158E-06 (194)	7.7929E-07 (194)	6.3838E-07 (333)
28	1.1285E-06 (172)	1.0881E-06 (67)	1.2385E-06 (67)	9.0235E-07 (140)	6.7579E-07 (2)
29	9.3921E-07 (221)	1.2778E-06 (74)	9.6945E-07 (357)	7.4017E-07 (140)	5.4985E-07 (310)
30	1.1230E-06 (216)	1.0054E-06 (217)	7.8873E-07 (178)	5.6399E-07 (178)	4.9302E-07 (334)
31	1.2079E-06 (219)	1.4786E-06 (219)	9.3032E-07 (134)	8.1232E-07 (4)	6.4162E-07 (136)
32	1.1051E-06 (216)	1.1690E-06 (9)	8.8267E-07 (9)	6.5746E-07 (9)	5.5952E-07 (123)
33	1.1179E-06 (97)	1.0976E-06 (177)	8.7249E-07 (213)	7.6126E-07 (4)	6.0518E-07 (177)
34	1.0756E-06 (242)	1.1166E-06 (131)	8.0354E-07 (213)	7.2065E-07 (213)	5.6358E-07 (84)
35	1.0581E-06 (159)	1.1056E-06 (208)	9.0561E-07 (175)	6.8653E-07 (208)	5.8037E-07 (355)
36	7.138[illegible]-07 (164)	1.5058E-06 (175)	1.0238E-06 (175)	6.8356E-07 (209)	5.4561E-07 (209)

COMPOSITE ANNUAL CONCENTRATION TABLE,UG/CU.M

ANNUAL MEAN CONCENTRATION AT EACH RECEPTOR

DIR	RANGE 0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	0.	0.	0.	0.	0.
2	0.	0.	0.	0.	0.
3	0.	0.	0.	0.	0.
4	0.	0.	0.	0.	0.
5	0.	0.	0.	0.	0.
6	0.	0.	0.	0.	0.
7	0.	0.	0.	0.	0.
8	0.	0.	0.	0.	0.
9	0.	0.	0.	0.	0.
10	0.	0.	0.	0.	0.
11	0.	0.	0.	0.	0.
12	0.	0.	0.	0.	0.
13	0.	0.	0.	0.	0.
14	0.	0.	0.	0.	0.
15	0.	0.	0.	0.	0.
16	0.	0.	0.	0.	0.
17	0.	0.	0.	0.	0.
18	0.	0.	0.	0.	0.
19	0.	0.	0.	0.	0.
20	0.	0.	0.	0.	0.
21	0.	0.	0.	0.	0.
22	0.	0.	0.	0.	0.
23	0.	0.	0.	0.	0.
24	0.	0.	0.	0.	0.
25	0.	0.	0.	0.	0.
26	0.	0.	0.	0.	0.
27	0.	0.	0.	0.	0.
28	0.	0.	0.	0.	0.
29	0.	0.	0.	0.	0.
30	0.	0.	0.	0.	0.
31	0.	0.	0.	0.	0.
32	0.	0.	0.	0.	0.
33	0.	0.	0.	0.	0.
34	0.	0.	0.	0.	0.
35	0.	0.	0.	0.	0.
36	0.	0.	0.	0.	0.

COMPOSITE HIGHEST,SECOND-HIGHEST 24-HOUR CONCENTRATION TABLE,UG/CU.M

SECOND HIGHEST 24-HOUR CONCENTRATION AT EACH RECEPTOR

DIR \ RANGE	0.1 KM	0.3 KM	0.5 KM	0.7 KM	0.9 KM
1	1.	1.	1.	1.	1.
2	1.	2.	1.	1.	1.
3	1.	2.	1.	1.	1.
4	1.	2.	1.	1.	1.
5	1.	2.	2.	1.	1.
6	1.	1.	1.	1.	1.
7	1.	1.	1.	1.	0.
8	2.	2.	1.	1.	1.
9	2.	3.	2.	2.	1.
10	1.	2.	1.	1.	1.
11	1.	2.	1.	1.	1.
12	1.	1.	1.	1.	1.
13	1.	2.	1.	1.	1.
14	1.	1.	1.	1.	1.
15	1.	1.	1.	1.	1.
16	1.	1.	1.	1.	1.
17	1.	1.	1.	1.	1.
18	1.	2.	1.	1.	1.
19	1.	2.	1.	1.	1.
20	1.	2.	2.	1.	1.
21	1.	2.	1.	1.	1.
22	1.	2.	1.	1.	1.
23	1.	2.	1.	1.	1.
24	1.	2.	1.	1.	1.
25	1.	2.	1.	1.	1.
26	1.	2.	1.	1.	1.
27	1.	2.	1.	1.	1.
28	1.	2.	1.	1.	1.
29	1.	2.	1.	1.	1.
30	1.	2.	1.	1.	1.
31	1.	2.	1.	1.	1.
32	1.	2.	1.	1.	1.
33	2.	2.	2.	1.	1.
34	1.	2.	1.	1.	1.
35	1.	2.	1.	1.	1.
36	1.	2.	1.	1.	1.

TLCO BB - 24 HR TSP - BAGHOUSE @ 13.05 M - DAY 173,1972 - DIR 90 - DIST 0.3 KM

1. 7.0

★ ★ ★ S O U R C E S ★ ★ ★

NO.	Q (G/SEC)	HP (M)	TS (DEG-K)	VS (M/SEC)	D(M)	R(KM)	S(KM)	
1.	0.08	13.1	306.0	51.2	0.29	0.0	0.0	BAGHOUSE
2.	0.01	22.9	306.0	5.3	0.25	0.0	0.0	DAY SILOS
3.	0.02	36.0	312.0	1.2	0.76	0.0	0.0	FLY ASH SILOS

★ ★ ★ R E C E P T O R S ★ ★ ★

NO.	RREC(KM)	SREC(KM)	Z (M)
1.	0.0	-0.500	0.0
2.	0.0	-0.400	0.0
3.	0.0	-0.300	0.0
4.	0.0	-0.200	0.0
5.	0.0	-0.100	0.0
6.	0.0	0.000	0.0
7.	0.0	0.100	0.0
8.	0.0	0.200	0.0
9.	0.0	0.300	0.0
10.	0.0	0.400	0.0
11.	0.100	-0.500	0.0
12.	0.100	-0.400	0.0
13.	0.100	-0.300	0.0
14.	0.100	-0.200	0.0
15.	0.100	-0.100	0.0
16.	0.100	0.000	0.0
17.	0.100	0.100	0.0
18.	0.100	0.200	0.0
19.	0.100	0.300	0.0
20.	0.100	0.400	0.0
21.	0.200	-0.500	0.0
22.	0.200	-0.400	0.0
23.	0.200	-0.300	0.0
24.	0.200	-0.200	0.0
25.	0.200	-0.100	0.0
26.	0.200	0.000	0.0
27.	0.200	0.100	0.0
28.	0.200	0.200	0.0
29.	0.200	0.300	0.0
30.	0.200	0.400	0.0
31.	0.300	-0.500	0.0
32.	0.300	-0.400	0.0

33.	0.300	-0.300	0.0
34.	0.300	-0.200	0.0
35.	0.300	-0.100	0.0
36.	0.300	0.000	0.0
37.	0.300	0.100	0.0
38.	0.300	0.200	0.0
39.	0.300	0.300	0.0
40.	0.300	0.400	0.0
41.	0.400	-0.500	0.0
42.	0.400	-0.400	0.0
43.	0.400	-0.300	0.0
44.	0.400	-0.200	0.0
45.	0.400	-0.100	0.0
46.	0.400	0.000	0.0
47.	0.400	0.100	0.0
48.	0.400	0.200	0.0
49.	0.400	0.300	0.0
50.	0.400	0.400	0.0
51.	0.500	-0.500	0.0
52.	0.500	-0.400	0.0
53.	0.500	-0.300	0.0
54.	0.500	-0.200	0.0
55.	0.500	-0.100	0.0
56.	0.500	0.000	0.0
57.	0.500	0.100	0.0
58.	0.500	0.200	0.0
59.	0.500	0.300	0.0
60.	0.500	0.400	0.0
61.	0.600	-0.500	0.0
62.	0.600	-0.400	0.0
63.	0.600	-0.300	0.0
64.	0.600	-0.200	0.0
65.	0.600	-0.100	0.0
66.	0.600	0.000	0.0
67.	0.600	0.100	0.0
68.	0.600	0.200	0.0
69.	0.600	0.300	0.0
70.	0.600	0.400	0.0
71.	0.700	-0.500	0.0
72.	0.700	-0.400	0.0
73.	0.700	-0.300	0.0
74.	0.700	-0.200	0.0
75.	0.700	-0.100	0.0
76.	0.700	0.000	0.0
77.	0.700	0.100	0.0
78.	0.700	0.200	0.0
79.	0.700	0.300	0.0

80.	0.700	0.400	0.0
81.	0.800	-0.500	0.0
82.	0.800	-0.400	0.0
83.	0.800	-0.300	0.0
84.	0.800	-0.200	0.0
85.	0.800	-0.100	0.0
86.	0.800	0.000	0.0
87.	0.800	0.100	0.0
88.	0.800	0.200	0.0
89.	0.800	0.300	0.0
90.	0.800	0.400	0.0
91.	0.900	-0.500	0.0
92.	0.900	-0.400	0.0
93.	0.900	-0.300	0.0
94.	0.900	-0.200	0.0
95.	0.900	-0.100	0.0
96.	0.900	0.000	0.0
97.	0.900	0.100	0.0
98.	0.900	0.200	0.0
99.	0.900	0.300	0.0
100.	0.900	0.400	0.0

DAY= 173 YEAR= 72 HOURS= ALL WD SHIFT ANGLE= 0

1.	287.	5.1	5	980.	299.	0.
2.	282.	6.2	4	948.	299.	0.
3.	285.	6.2	4	916.	299.	0.
4.	251.	6.7	4	885.	299.	0.
5.	268.	7.2	4	853.	299.	0.
6.	268.	7.2	4	822.	299.	0.
7.	263.	6.7	4	790.	300.	0.
8.	274.	7.7	4	759.	300.	0.
9.	283.	8.2	4	727.	301.	0.
10.	259.	7.2	4	695.	301.	0.
11.	273.	8.7	4	664.	301.	0.
12.	279.	8.2	4	632.	302.	0.
13.	278.	8.2	4	601.	303.	0.
14.	271.	8.2	4	569.	303.	0.
15.	275.	7.7	4	569.	303.	0.
16.	270.	7.2	4	569.	303.	0.
17.	270.	7.2	4	569.	302.	0.
18.	267.	7.2	4	569.	301.	0.
19.	273.	5.1	4	569.	301.	0.
20.	267.	5.1	4	591.	300.	0.
21.	269.	5.1	4	630.	300.	0.
22.	272.	4.1	4	669.	300.	0.
23.	274.	5.1	4	707.	300.	0.

24. 268. 0.7 4 746. 300. 0.

AVERAGE CONCENTRATIONS FOR 24 HOURS.

* * * R E C E P T O R N U M B E R * * *

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TOTAL CONCENTRATION (UG/M**3)									
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

* * * R E C E P T O R N U M B E R * * *

	11.	12.	13.	14.	15.	16.	17.	18.	19.	20.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.0	0.0
2.	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.0	0.0
3.	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.0	0.0
	TOTAL CONCENTRATION (UG/M**3)									
	0.0	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.0	0.0

* * * R E C E P T O R N U M B E R * * *

	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.0	0.0	0.0	0.0	0.00	4.09	0.35	0.00	0.00	0.00
2.	0.0	0.0	0.0	0.0	0.00	0.03	0.00	0.00	0.00	0.00
3.	0.0	0.0	0.0	0.0	0.00	0.00	0.00	0.00	0.00	0.00
	TOTAL CONCENTRATION (UG/M**3)									
	0.0	0.0	0.0	0.0	0.00	4.11	0.35	0.00	0.00	0.00

*** RECEPTOR NUMBER ***

	31.	32.	33.	34.	35.	36.	37.	38.	39.	40.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.0	0.0	0.0	0.00	0.06	3.82	0.35	0.10	0.00	0.00
2.	0.0	0.0	0.0	0.00	0.00	0.08	0.01	0.00	0.00	0.00
3.	0.0	0.0	0.0	0.00	0.00	0.02	0.00	0.00	0.00	0.00
	TOTAL CONCENTRATION (UG/M**3)									
	0.0	0.0	0.0	0.00	0.01	3.92	0.36	0.10	0.00	0.00

*** RECEPTOR NUMBER ***

	41.	42.	43.	44.	45.	46.	47.	48.	49.	50.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.0	0.0	0.00	0.00	0.08	2.94	0.39	0.26	0.02	0.00
2.	0.0	0.0	0.00	0.00	0.00	0.09	0.01	0.01	0.00	0.00
3.	0.0	0.0	0.00	0.00	0.00	0.06	0.01	0.01	0.00	0.00
	TOTAL CONCENTRATION (UG/M**3)									
	0.0	0.0	0.00	0.00	0.08	3.09	0.42	0.28	0.02	0.00

*** RECEPTOR NUMBER ***

	51.	52.	53.	54.	55.	56.	57.	58.	59.	60.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.0	0.00	0.00	0.00	0.23	2.28	0.52	0.27	0.11	0.00
2.	0.0	0.00	0.00	0.00	0.01	0.09	0.02	0.01	0.00	0.00
3.	0.0	0.00	0.00	0.00	0.01	0.10	0.02	0.01	0.01	0.00
	TOTAL CONCENTRATION (UG/M**3)									
	0.0	0.00	0.00	0.00	0.25	2.43	0.56	0.28	0.12	0.00

*** RECEPTOR NUMBER ***

	61.	62.	63.	64.	65.	66.	67.	68.	69.	70.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.00	0.00	0.00	0.00	0.38	1.75	0.60	0.18	0.18	0.04
2.	0.00	0.00	0.00	0.00	0.02	0.08	0.03	0.01	0.01	0.00
3.	0.00	0.00	0.00	0.00	0.03	0.12	0.04	0.01	0.01	0.00
	TOTAL CONCENTRATION (UG/M**3)									
	0.00	0.00	0.00	0.00	0.42	1.94	0.66	0.20	0.20	0.04

* * * R E C E P T O R N U M B E R * * *

	71.	72.	73.	74.	75.	76.	77.	78.	79.	80.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.00	0.00	0.00	0.01	0.47	1.39	0.61	0.14	0.20	0.09
2.	0.00	0.00	0.00	0.00	0.02	0.07	0.03	0.01	0.01	0.00
3.	0.00	0.00	0.00	0.00	0.04	0.12	0.05	0.01	0.01	0.01
	TOTAL CONCENTRATION (UG/M**3)									
	0.00	0.00	0.00	0.01	0.53	1.58	0.70	0.16	0.23	0.10

* * * R E C E P T O R N U M B E R * * *

	81.	82.	83.	84.	85.	86.	87.	88.	89.	90.
SOURCE	PARTIAL CONCENTRATIONS (UG/M**3)									
1.	0.00	0.00	0.00	0.02	0.51	1.13	0.59	0.14	0.16	0.13
2.	0.00	0.00	0.00	0.00	0.03	0.06	0.03	0.01	0.01	0.01
3.	0.00	0.00	0.00	0.00	0.05	0.12	0.06	0.02	0.01	0.01
	TOTAL CONCENTRATION (UG/M**3)									
	0.00	0.00	0.00	0.02	0.59	1.31	0.69	0.16	0.18	0.14

* * * R E C E P T O R N U M B E R * * *

	91.	92.	93.	94.	95.	96.	97.	98.	99.	100.

SOURCE PARTIAL CONCENTRATIONS (UG/M**3)

1.	0.00	0.00	0.00	0.00	0.51	0.94	0.55	0.15	0.10	0.15
2.	0.00	0.00	0.00	0.00	0.03	0.05	0.03	0.01	0.01	0.01
3.	0.00	0.00	0.00	0.01	0.06	0.11	0.07	0.02	0.01	0.01

TOTAL CONCENTRATION (UG/M**3)

0.00	0.00	0.00	0.05	0.60	1.11	0.65	0.18	0.12	0.17

Calculations for Background Annual and 24-Hour TSP and Explanation of Increment-Consuming Sources List

1) The use of 35 ug/m^3 for an annual average TSP level is explained on pages 38 and 39, Volume 1, of the PSD application. The background concentration is intended to reflect existing TSP levels from sources not included specifically in the modeling (i.e. natural background TSP and fugitive TSP). Actual TSP sampling data from many stations in the vicinity of Big Bend were utilized to develope the background level. However, the sampling results included the effects of any point source emissions from the region. Since point sources are included specifically in the modeling, it is appropriate to subtract point source contributions from measured levels. Figure 5.9, page 68 of Volume I of the PSD application shows point sources of particulate matter contribute a minimum of 5 to 10 ug/m^3 to annual average TSP levels in the area, when operating at maximum allowable levels. It was therefore considered reasonable that these same sources would contribute at least 0.9 ug/m^3 when operating at actual emission rates. Therefore, the value of 35 ug/m^3 was considered justifiable for use as the annual average TSP concentration.

2) Use of the highest or second-highest 24-hour measured TSP concentrations, based on monitoring data, as the short-term background level is considered highly innappropriate. Because TSP data is available from a number of monitoring stations in the area, it is possible to rely on the meausred data to determine a background TSP level. However, such measured levels include unquantifiable contributions from other point sources in the area (i.e. Agrico Big Bend, Gardinier, etc.). In addition, measured TSP data can contain outliers or extreme values caused by very localized phenomenom (i.e. brush fires). It is therefore justifiable to utilize a background value lower than the highest or second-highest measured value. The 84th percentile concentration based upon the log-normal distrubution is considered reasonable because it is highly unlikely that worst-case short-term meteorological conditions for TECO Big Bend stack emissions will occur in conjunction with worst-case background concentrations, since the two are not related. The probability of the simultaneous occurrence of such conditions is extremely low. With use of the 84th percentile concentration, the probability is still about once in 3 years

$$\frac{(0.16 \times 365)}{(365)} \times \frac{2}{365} = 0.00088$$

$$\frac{1}{0.00088} \times 365 = 3.1 \text{ years}$$

Use of the highest or second-highest measured TSP value is not consistant with prior (1979 and before) EPA policy and approval of PSD permit applications. In addition, because TECO's Big Bend's predicted 24-hour TSP impact is less than the significance level of 5 ug/m^3, such a refined impact analysis is not specifically required (Federal Register, Vol., 43, No. 118, pg. 26398, June 1978).

3) Appendix G of the PSD application provides a list of all sources, major and minor and new or modified, which were issued a construction permit after January 6, 1975. This information was developed from information contained in FDER permit files. However, some of these sources are not emitters of sulfur dioxide or particulate matter, and therefore were not included in the EPA list of increment consuming sources. This accounts for the difference in the Appendix G and Appendix B listings of increment consuming sources. The EPA baseline listing includes those sources which were modified, but at their pre-modification emissions and stack parameters.

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PERMITTING

It is anticipated that an average of 510 construction workers (craft and nonmanual) will be required per year during the 3-year Unit No. 4 construction period. A peak of approximately 1,100 personnel is expected during a four month period in 1984, the third year of construction. Based on TECO observations and labor availability surveys from construction of the previous three Big Bend units, approximately 90 percent of the construction work force will be hired from labor organizations with jurisdiction over the Tampa Area.

It is, therefore, reasonable to assume that no special provisions for housing, education, or community facilities will be necessary. Construction Labor utilizing community services, e.g., roads, schools, and health services, will be primarily county taxpayers. In addition, taxes on Big Bend Unit No. 4 will compensate Hillsborough County for minimal stress which might occur on county services. The total annual property tax payments to Hillsborough County will be approximately $3,700,000.

TABLE 4-2

ESP SPECIFICATION

Performance Requirements

Flue gas temperature & economizer outlet (100% MCR*)	753 F
Estimated flue gas temperature ranges @ ecomonizer outlet	633°F @ 50% load 753 F @ 100% load
Flue gas temperature & air heater outlet (100% MCR*) without leakage	280°F± 55 F
Flue gas temperature & air heater outlet (100% MCR*) with leakage	267°F± 55 F
Precipitator design temperature	340°F
Flue gas design flow @ 340°F	2,200,000 acfm
Precipitator inlet loading	1.33-2.67 grs/acf**
Maximum flue gas velocity & design flow rate	4.5 fps

Guarantees

Outlet flue gas particulate loading	0.007 grs/acf** (1.03 lb/MMBtu, 132 lb/hr 20% opacity)
Draft loss, ESP inlet to outlet, excluding nozzle	0.5 in WG+
Draft loss, air heater outlet to ID fan inlet	2.5 in WG+

Equipment

(1) Two separate precipitators; two modules per precipitator.

(2) The number of separate electrical sections for each precipitator: five fields deep and four sections wide.

(3) Techniques to ensure uniform flow: air distribution model tests, outlet balancing dampers, inlet distribution baffles and plates, uniform spacing on collector plates, and antisneak baffles in hoppers.

(4) System to remove collected ash: vacuum system to convey ash from collection hoppers via pipelines to storage silo.

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*Maximum continuous rating.
**Grains per actual cubic foot.
+Inches of water

revised 3/3/80
Amendment 3

TABLE 4-3

FLYASH AND BOTTOM ASH DISCHARGES
FROM BIG BEND STATION UNIT 4

Parameter	Hourly Rate (lb/hr)	Annual Rate (tons/year)*
Fuel rate**	413,000	951,000
Total ash	55,755	128,400
Bottom ash	11,151	25,680
Flyash @ ESP inlet+	44,604	102,700
Flyash collected in ESP	44,474	102,400
Flyash @ ESP outlet	130	300

*Capacity factor = 52.57%.

**Based on coal F-1A: HHV, 10,495 Btu/lb; ash content, 13.5%.

+Based on outlet particulate loading equivalent to 0.03 lb/MMBtu.

Amendment 4

Contents

Big Bend 4 Site Certification Application - Responses to FDER letter of January 10, 1980.

Revised Table 4-5 FGD System Specification.

Revised Table 5-3 Maximum Air Quality Impacts.

Big Bend Station - History of Allowable Emissions of Sulfur Dioxide.

Significant Sulfur Dioxide Sources Within Significant Impact Range of TECO Big Bend Unit 4.

Thirty-day Rolling Average Sulfur Dioxide Emission Limit Range.

BIG BEND 4 SITE CERTIFICATION APPLICATION

RESPONSES TO FDER LETTER OF JANUARY 10, 1980

QUESTION 1

The 1971-75 meteorological data base used to model short-term impacts of the proposed facility contains mixing height errors which were corrected by the National Climatic Center and incorporated into a revised data base for the period 1970-74. These latter data should be used in all short-term (3-hour and 24-hour) impact evaluations including evaluations of PSD and nonattainment area impacts.

RESPONSE

In order to assess the effects of the mixing height error on predicted SO_2 concentrations, the PTMTPW scenarios as found in Appendix D of the TECO PSD application were re-run using the revised mixing height data. For the days and periods in question (207/72 and 249/72/4), the corrected mixing heights were for each hour identical to or greater than those used previously. Only the first five hours of the 24-hour case were affected. All hours of the 3-hour case were affected.

For the 24-hour averaging time, no concentration differences greater than roundoff error were observed based upon the modeling results. For the 3-hour averaging period, the corrected concentrations were from 84 ug/m^3 to 115 ug/m^3 lower than those calculated with the erroneous mixing height data, depending upon receptor location.

RESULT OF MIXING HEIGHT CHANGE

No.	Receptor E (km)	Receptor N (km)	Concentrations (ug/m^3) Previous Met. Data 3-hour	Previous Met. Data 24-hour	Corrected Met. Data 3-hour	Corrected Met. Data 24-hour
1	362.9	3075.0	812.5	149.5	700.1	149.6
2	363.0	3075.0	863.0	149.6	748.2	149.6
3	363.1	3075.0	364.1	149.6	759.1	149.6
4	363.2	3075.0	837.7	149.5	744.7	149.5
5	363.3	3075.0	801.1	149.2	717.3	149.2

Note: Three-hour concentrations based upon Day 249, Period 4, 1972.
Twenty-four hour concentrations based upon Day 207, 1972.

Note: This comparison was made using stack parameters as found in Appendix D of the TECO PSD application. The emissions modeled do not correspond to 100 percent load and these output are not used in determining the maximum impacts as reported in Volume 1 of the application.

In the Big Bend 4 PSD appliction, it was determined that the worst case 24-hour and 3-hour SO_2 impacts occurred under conditions of Units 1-4 all operating at 100 percent load. Stack parameters from Table 2.1 of the PSD application were input to the CRSTER model along with the revised mixing height data to re-determine the worst 24-hour and 3-hour periods. These periods had previously been calculated as 207/72 and 249/72/4, respectively. The worst periods calculated with the revised mixing heights were 124/72 (24-hour) and 180/74/4 (3-hour).

The CRSTER output was refined by the PTMTPW model to predict concentrations at points 0.1 km apart in a 100-point (1.0 km x 1.0 km) square grid. When the worst day was not clear from CRSTER, more than one PTMTPW was run to ensure that the actual worst day and highest, second highest concentration was identified. The recalculated highest, second highest 24-hour and 3-hour ground level SO_2 concentrations were 187 ug/m^3 and 1075 ug/m^3, respectively. Compared to the previously calculated values these represent a decrease of 12 ug/m^3 for the 3-hour period, and an increase of 2 ug/m^3 for the 24-hour period. The location of the receptor receiving the maximum 3-hour impact was shifted to the opposite side of the plant due to a change in the controlling hour of meteorology. Results are summarized in the chart below.

This analysis demonstrates that the error in mixing heights caused no significant error in predicted concentrations, and that the conclusions of the Big Bend 4 PSD application are not affected.

MAXIMUM AIR QUALITY IMPACTS (SO_2)

Load Scenario	Averaging Time	Worst Day	Receptor Location E (km)	Receptor Location N (km)	Concentration (ug/m^3)
Units 1-4 at 100% (Determined with erroneous mixing height data)	24-hour	207/72	367.0	3075.0	185
	3-hour	249/72/4	363.1	3075.0	1087
Units 1-4 at 100% (Revised mixing height data)	24-hour	124/72	366.3	3074.8	187
	3-hour	180/74/4	360.2	3075.0	1075

QUESTION 2

More extensive documentation is needed on the selection of worst-case operating conditions for modeling purposes. Modeling results summarizing worst-case baseline, incremental, and projected operating conditions for both 3-hour and 24-hour impacts should be presented, and scenarios other than those listed should be examined. Of particular interest are scenarios involving Stack #2 only, such as Unit #4 at 100 percent load with Unit #3 at 100, 75, and 50 percent loads.

RESPONSE

When two stacks are situated close enough together to be modeled as a single point, the maximum ground level impact of each plume will occur at the same point when the effective stack heights are equal. In the case of TECO Big Bend, the physical stack heights are equal, thus points of maximum impacts will coincide when the plume rise for each stack is the same.

The Big Bend 4 PSD application had previously determined that when all Units were operating under the same load conditions the maximum impact occurred at 100 percent load. Reduced emissions from lower load conditions were not sufficiently compensated for by decreased plume rise to result in higher ground level concentrations. For this reason, the search for further worst-case operating conditions was limited to identifying the highest load conditions that would result in equal plume rise from the two Big Bend stacks.

According to Briggs[1], rise of a buoyant plume is a function of (1) the average wind speed at stack level, (2) a factor representing the magnitude of the restoring acceleration per unit vertical displacement for adiabatic motion in the atmosphere, and (3) a buoyancy flux parameter, F. For the two stacks of concern, the first two parameters are identical for identical meteorological conditions.

One functional form of the buoyancy flux parameter is:

$$F = g\, V_s\, r_s^{\,2}\, ((T_s - T_a)/T_s)$$

g = gravitational acceleration
V_s = stack exit velocity
r_s = stack diameter
T_s = absolute temperature of stack effluent
T_a = absolute temperature of ambient air

In this case, g, T_a, and r_s for each stack are identical. Thus, F for each stack will be dependent on T_s and V_s; and the plume rises will be equal when F for each stack is equal.

The exit velocity and temperature of each stack at the Big Bend facility will be a functionof the output of the two boilers sharing each stack (Units 1 and 2 through Stack 1; Units 3 and 4 through Stack 2). Conservation of mass and energy and the asumption of ideal gas behavior leads to the following functions for the combined velocity and temperature resulting from the mixture of the streams from the individual boilers.

---

1 Briggs, Gary. Plume Rise, Air Resources Atmospheric Turbulence and Diffusion Laboratory, Oak Ridge, Tennessee (1969).

$$T_c = \frac{T_1 T_1 (V_1 + V_2)}{V_1 T_2 + V_2 T_1}$$

$$v_c = \frac{V_1 + V_2}{A}$$

V = exit velocity
T = absolute temperature
A = area of stack cross section
V = volumetric flow rate
1, 2 = conditions of streams from individual boilers
c = conditions of combined stream

These equations were used to develop a computer code which identified equal plume rise conditions for 256 combinations of the load scenarios described in Table 2.1 of the PSD application (100%, 75%, 50%, and 0%). The combination of Units 1, 3, and 4 at 100 percent load with Unit 2 at 75 percent load was identified as producing both equal plume rise conditions and maximum SO_2 emissions, thus resulting in worst-case air quality impacts for the interaction case.

CRSTER and PTMTPW models were executed for these conditions to determine worst (highest, second-highest) 24-hour and 3-hour periods and corresponding ground level concentrations. Where the worst day was not clear, each suspected day was input to PTMTPW to ensure accurate determination of the highest, second highest concentration. Where more than one location was suspected of receiving the greatest impact, both were investigated with the PTMTPW model. The calculated 24-hour and 3-hour SO_2 concentrations were 181 ug/m^3 and 1006 ug/m^3, in both cases less than the maximum concentrations produced when Units 1-4 are all operating at 100 percent load, namely 187 ug/m^3, and 1075 ug/m^3. The condition of equal plume rise does not represent a worse case than the previously determined (Units 1-4 at 100 percent) worst case. Therefore, it is concluded that the emission scenario of all four units operating at 100 percent load is the worst-case situation for Big Bend.

MAXIMUM AIR QUALITY IMPACTS (SO_2)

Load Scenario	Averaging Time	Worst Day	Receptor Location E (km)	N (km)	Concentration (ug/m^3)
Units 1-4 at 100% (Determined with erroneous mixing height data)	24-hour	207/72	367.0	3075.0	185
	3-hour	249/72/4	363.1	3075.0	1087
Units 1-4 at 100% (Revised mixing height data)	24-hour	124/72	366.3	3074.8	187
	3-hour	180/74/4	360.2	3075.0	1075

QUESTION 3

Since the ratio of stack height to building height for the proposed unit is only 1.86, which is well below the generally accepted "Good Engineering Practice" ratio of 2.5, the potential for building-induced downwash should be examined. The consultant or applicant should also perform a Froude number evaluation to assess the potential for stack-tip downwash.

RESPONSE

After construction of the proposed Unit #4, the tallest structure at Big Bend with the potential for influencing stack emissions will be the boiler house for Unit #4. This building will have approximate dimensions of 130' x 218' and will be approximately 223' high. The formula defining Good Engineering Practice (GEP) stack height is (40 CFR 51):

$$H_{GEP} = H_s + 1.5\,L$$

H_s = Height of structure or nearby structure

L = lesser dimension of height or width of the structure or nearby structure

Therefore, GEP for Big Bend would be:

$$H_{GEP} = 223 + 1.5\ (218) = 550\ \text{ft.}$$

However, the majority of the structures at Big Bend influencing stack emissions are the three existing boiler areas for Units #1, #2, and #3, which are located adjacent to each other. These structures are all 183' high, with overall dimensions of 445' x 190. GEP for these structures is 458 ft. Viewing the Big Bend structure in its entirety with the addition of Unit 4, dimensions are approximately 660' x 190', with an average height of about 200'. Therefore, GEP would approximate 485 ft. The existing stacks at Big Bend are 490 feet tall.

Based on the above analysis, and considering the existing stack heights, downwash potential at Big Bend is considered slight. The GEP equation does not consider the buoyance of the effluent gases, which will greatly increase the effective stack height for the emissions. In addition, the new Unit #4 will have the potential to cause downwash only when winds are directed from the south, which occurs about 6 percent of the time in Tampa, and when wind speeds are sufficiently high to severely reduce plume rise.

Concerning the subject of Froude number evaluation to assess the potential for stack tip downwash, ESE has researched the issue and concludes that the Froude number is not a direct indicator of the potential for stack tip downwash. This conclusion is based on conversation with Mr. G. A. Briggs concerning his discussion of this topic in Plume Rise (1969). Briggs references wind tunnel studies that indicate stack tip downwash is slight as long as the stack efflux velocity is greater than 1.5 times the wind velocity at stack height. In a very buoyant plume ($Fr < 1.0$), buoyant forces may counteract some of the adverse pressure forces and permit relaxation of the above criterion. If this criterion is met, however, stack tip downwash should not occur regardless of the magnitude of the Froude number.

QUESTION 4

The estimated volume of flue gas to be discharged from Big Bend Unit #4 appears to be from 519,016 ACFM to 652,780 ACFM too large at 100% load. This error makes the velocity of the flue gas from 19.1 F/S to 24.1 F/S too high. A similar situation exists for the 50% and 75% load conditions. The end result is that the plume rises have been over-predicted and the ground level concentrations under-predicted. Therefore, the mathematical modeling must be redone.

RESPONSE

All dispersion modeling has been performed using the flue gas flow rates given on Table 2.1 of Volume 1 of the PSD application. This discussion will be limited to the 100 percent load case as an example. Design coal parameters and preliminary boiler data were used early last year to calculate the maximum flue gas flow rate given in this table of 1,778,000 acfm.

In response to this question, the maximum flue gas flow rate has now been recalculated using latest design data. The result is very close to the original value. The calculation is summarized below.

Fuel - Elkton (F-1A) Excess Air - 25% (15% in Table 2-2 of the PSD is in error).

	Products of Combustion	
	lbs/lb. fuel	ft 3/lb. fuel
CO_2	2.0862	17.932
H_2O	.6510	13.666
SO_2	.0584	.3447
O_2	.4499	5.3174
N_2	7.5036	101.3548
Weight Wet	10.749	138.6185
Weight Dry	10.098	

Heat Input Rate = 4692 MMBTU/hour

Fuel Rate = 447,070 lbs/hour

447,070 lbs fuel/hour X 138.6185 ft^3/lb fuel X $\frac{1}{60}$ X $\frac{280+460}{60+460}$ = 1,469,853 acfm @ 280° F

447,070 lbs fuel/hour X 10,749 $\frac{lbs}{lbs\ fuel}$ = 4,805,555 lbs/hour

4,805,555 lbs/hour + 7.77% leakage* = 5,178,947 lbs/hour

Volume = 1,469,853 acfm @ 280° F = 1,032,870 scfm

Air Leakage = 373,392 lbs/hour X $\frac{1\ ft^3}{.076\ lb}$ X $\frac{1}{60}$ = 81,884 scfm

Total = 1,032,870 + 81,884 = 1,114,754 scfm = 1,558,512 acfm @ 267° F

Gas to FGD	(acfm)	1,558,512 @ 267° F
	(scfm)	1,114,754
Saturated Gas	(acfm)	1,262,395 @ 125° F
	(scfm)	1,122,128
Reheat Air	(acfm)	524,691 @ 270° F
	(scfm)	373,753
Total Gas to Stack	(acfm)	1,772,043 @ 156° F
	(scfm)	1,495,881

* Air preheater leakage, air side to gas side

QUESTION 5

The performance of the proposed flue gas desulfurization device is questionable. Projections indicate a maximum removal efficiency of about 72% on the basis of the specitifcations. The pH of the scrubbing solution could be the key. It would appear that a pH higher than specified is necessary. It is our observation that this could be the result of a typographical error, since the pH of the scrubbing solution is lower at the inlet than the outlet.

RESPONSE

The Bureau of Air Quality Management staff has indicated their projection of 72% removal was based on calculations found in the McIlvaine Scrubber Manual. The equations used, page 128.7, subsection 4.72, are quoted as semi-theoretical, and it is noted that the particular data are not to be interpreted as evidence of long-term reliable operation.

However, these equations were utilized to examine removal efficiencies predicted by this method. These calculations are based on a double loop FGD system operating on Elkton (F-1A) coal producing calcium sulfate dihydrate as a product of forced oxidation. Results of these calculations (see below) indicated total predicted SO_2 removal of 95.6%.

First Loop: Normal Conditions

L/G = 20 Velocity = 9.1 ft./sec.

pH = 4.5 SO_{2i} = 2426 PPM

Fraction SO_2 removed =

$$1 - EXP\ (-.000098(20)^{.92}(9.1)^{.19} \times EXP\ (4.5 - (.00017 \times 2426))\ )$$

$$= 1 - EXP\ (-.000098(20)^{.92}(9.1)^{.19}\ (59.595))\ )$$

$$= 13\%$$

$$SO_{2o} = 2426\ (1-.13) = 2110\ PPM$$

Second Loop:

L/G = 60 Velocity = 9.1 ft./sec.

pH = 6.5 SO_{2i} = 2110

Fraction SO_2 removed =

$$1 - EXP\ (-.000098(60)^{.92}(9.1)^{.19} \times EXP\ (6.5 - (.00017 \times 2110))\ )$$

$$= 1 - EXP\ (-.000098(60)^{.92}(9.1)^{.19}\ (464.6))$$

$$= 95\%$$

$$SO_{2o} = 2110\ (1-.95) = 105.5\ PPM$$

$$\text{TOTAL REMOVED} = \frac{2426 - 105.5}{2426} = 95.6\%$$

QUESTION 6

The data provided for the electrostatic precipitator is insufficient to make a determination of its estimated performance.

RESPONSE

Table 4-2 (ESP Specification) of Volume 2 of the PSD Application has been revised with additional specific information concerning the electrostatic precipitator. This revised table has been included in Amendment 3 to the PSD application.

QUESTION 7

The applicant has failed to adequately address fugitive emissions of particulate matter from the coal, fly ash and limestone facilities. Emissions of particulate matter from all controllable points must be addressed and appropriately included in the PSD modeling. The control technology to be applied to controllable emission points for the coal, fly ash, and limestone handling facilities must be addressed as part of the BACT application.

RESPONSE

Fugitive emissions from coal, fly ash handling, and limestone operations are addressed in Amendments 2 and 3 to the PSD Application. Both PSD increment consumption and BACT controls are discussed in detail in these amendments.

QUESTION 8

The explanation of the use of boiler operation to control particulate and nitrogen oxide emission is somewhat difficult to understand and appears somewhat ambiguous.

RESPONSE

Specific features of the boiler design are intended to minimize the formation and ultimate discharge of combustibles and nitrogen oxides from the Tampa Electric Company's Big Bend Station Unit 4. Similarly, operational procedures have been developed and will be optimized to control the emission of these pollutants. These design features and operational techniques are discussed below, detailing their effectiveness in controlling specific pollutant emissions, and their impact on other pollutant discharges.

Combustibles

Combustibles consist of unburned carbon (UC) and carbon monoxide (CO). These constituents of the boiler flue gas are formed in an oxygen deficient atmosphere in either the primary or secondary combustion zones of the boiler. This oxygen deficiency results from substoichiometric air-to-fuel ratios and poor air-fuel mixing. To minimize the formation of UC and CO, the following boiler design and operational features are employed:

- o the turbulent atmosphere generated in Combustion Engineering's tangentially-fired boilers promotes proper air-fuel mixing, and
- o the high-excess-air operation (approximately 25% excess air) ensures sufficient oxygen in both the primary and secondary combustion zones.

These features ensure sufficient oxygen and proper mixing to essentially complete oxidation of combustibles to carbon dioxide. In addition, there is flexibility in boiler design, including variable-tilt burners and individual air registers, to allow for optimization of the combustion process during both steady-state and transient operating conditions. These design and operational features are the only recognized control techniques for UC and CO.

Nitrogen Oxides

Most of the nitrogen oxides (NO_x), consisting of nitrogen oxide (NO) and nitrogen dioxide (NO_2), in the boiler flue gas is formed by the high temperature reactions of molecular nitrogen and oxygen present in the combustion air via the following reactions;

$$O_2 \rightleftharpoons O + O$$
$$O + N_2 \rightleftharpoons NO + N$$
$$N + O_2 \rightleftharpoons NO + O$$

Additional NO_x results from the oxidation of organically bound nitrogen in the fuel. The formation of NO is favored at high temperature: equilibrium concentrations of NO at flame temperature are on the order of 300 ppm while that of NO_2 are negligible. The major factors affecting the formation of NO_x in the combustion process are combustion temperature, availability of oxygen, air-fuel mixtures, and heat release. The NO_x control technique included in boiler design and operational procedures is comprised of off-stoichiometric combustion, which may be accomplished by:

- o biased-firing, consisting of operating selected burners at fuel-rich mixtures and others at fuel-lean mixtures, or

- o two-stage combustion, consisting of fuel-rich combustion at the burners and introduction of remaining combustion air above the primary combustion zone via over-fire air ports.

These techniques reduce NO_x formation by initiating combustion in a reducing atmosphere followed by complete combustion after substantial heat loss. Combustion Engineering has indicated that NO_x emissions can be maintained in compliance with the NSPS by means of bias-firing alone but has incorporated over-fire air ports for supplementary control.

Although the off-stoichiometric combustion techniques promote the formation of combustibles, sufficient excess air is introduced via alternative burners or the over-fire air ports to ensure complete combustion. In other words, excess air to boiler is maintained at high levels (up to 25%) while only the distribution of total air is altered. The table below demonstrates the impact of NO_x control techniques on emissions of both NO_x and CO. Note that both bias-firing and two-stage combustion results in coincidental reductions emissions of the two pollutants. Therefore, the proposed control techniques for NO_x and combustibles have been demonstrated to be both effective and complementary.

EPA TEST PROGRAM FOR NO_x REDUCTION

Test Condition	Excess Air (%)	Emission (lb/MMBtu) NO_x	Emission (lb/MMBtu) CO
No modification	22.7	0.58	0.022
Biased-firing	24.2	0.33	0.019
Two-stage combustion	25.4	0.55	0.016
Two-stage combustion (with water-wall slagging)	25.9	0.50	0.016
Two-stage combustion (-5° burner tilt)	25.9	0.39	0.016
Two-stage combustion ($+19^{\circ}$ burner tilt)	25.1	0.43	0.023

Source: EPA 1975. Program for Reduction of NO_x from Tangential Coal-fired Boilers. EPA-650/2-73-005a.

QUESTION 9

The application fails to address hydrocarbon emissions from the proposed facility or the impact of these on the Hillsborough County nonattainment area.

RESPONSE

Hydrocarbon emissions are addressed in Amendment No. 1 to the PSD Application. These emissions are calculated based on an emission rate of 0.01 lbs hydrocarbon per ton of coal burned, as recommended in a memorandum from the Office ofAir Quality Planning and Standards to EPA Region VIII on January 23, 1978. The boiler is the only source of hydrocarbon emissions from the addition of Big Bend 4.

QUESTION 10

The quantities and sulfur content of #2 fuel oil to be consumed during start-up and normal operation (flame stabilization) were not included in the application or modeling.

RESPONSE

The normal sulfur content of #2 fuel oil to be consumed during start-up and flame stabilization is 0.3%. Worst case sulfur content is expected to be 0.5%.

Conservatively assuming 6 hours of oil firing per start-up and 15 cold starts each year, 336,000 gallons of #2 oil will be required for Unit 4 start-up on an annual basis.

According to Combustion Engineering, flame stabilization will be required when the unit is operated at or below 65 MW. This will require approximately 70 gallons of #2 oil per hour. Based on the following table, it can be seen that the percentage of time Big Bend Unit 4 can be expected to operate at or below 65 MW is quite low.

BIG BEND UNIT 4

Year of Life	% of Time At Or Below 170 MW
0 - 15	3
16 - 20	10
21 - 25	11
26 - 30	18

QUESTION 11

The use of additives for conditioning of the fuel, fly ash, or flue gas was not discussed. In addition, the impact of the additives on particulate and nitrogen oxide (in the case of ammonia based additives) emissions was neither presented nor utilized in the application.

RESPONSE

At the present time there are no plans for the use of fuel, fly ash, or flue gas conditioning additives in association with the operation of Unit 4.

QUESTION 12

If cooling towers are opted for then these will be subject to both BACT and PSD requirements. Ambient particulate concentrations and drift impacts must be included in the application.

QUESTION 17

The cooling tower impact should be included.

RESPONSE

Cooling tower drift and particulate impacts are currently under study. A report will be forwarded to the Department in the near future.

QUESTION 13

An almost confusing number of fuel analyses were used in the calculation of emissions and ambient impacts from the facility. It is significant to note that the specification for design coals F-2A and F-2B do not match those under consideration specifically with regard to sulfur content.

QUESTION 14

The calculations in the air quality portion of the application appear to contain some errors and should be reviewed by the applicant for correctness.

RESPONSE

From conferences with the Department it appears Questions 13 and 14 have been generated due to some confusion concerning the fuel analyses presented in the application. This confusion was most likely compounded in part by Table 3.7-3 of the Site Certification Application being in error. A revised Table 3.7-3 is provided as Attachment A and should be inserted as directed into the Site Certification Application.

Basically there are two sets of fuel analyses presented in the Application. Table 3.2-1 presents the analyses of actual fuels which are being considered for Unit 4. The revised Table 3.7-3 presents "design" analyses which were used in specifying pollution control equipment. These "design" coals were formulated based on parameters of the actual fuels which represented worst case conditions for pollution control device performance. Similarly, the fuel analysis noted in Table 3.7-2 was the design fuel for the boiler.

It is significant to note that the ambient impacts presented in the Application were based on Maximum Allowable New Source Performance Standards Emission Limitations and not fuel analyses. Therefore, the predicted ambient impacts are conservative with respect to emission rates.

QUESTION 15

The application does not adequately address emissions of pollutants subject to NESHAPS.

RESPONSE

Fossil-fired steam generators are not sources designated for applicability with NESHAPS. However, in respose to this question we have undertaken a limited investigation into potential impacts from the combustion of coal.

An EPA publication, EPA-600/2-79-019e June 1979, by Monsanto Research Corporation entitled "Source Assessment: Dry Bottom Industrial Boilders Firing Pulverized Bituminous Coal" includes a table entitled "Arithmetic Mean of Proximate and Ultimate Analyses and Elemental Composition for Appalachian Coal Region Samples." The coal utilized for Big Bend 4 will likely come from Bureau of Mines Region 9. Appalachian Coal is Bureau of Mines Region 1-8, 13 and border geographically on Region 9. The following table summarizes the elemental composition of thoses NESHAPS in elemental forms in coal.

Beryllium	2.1 PPM	-	.00021%
Mercury	0.14 PPM	-	.000014%
Arsenic	26.0 PPM	-	.0026%
Cadmium	0.68 PPM	-	.000068%

QUESTION 16

The quantity of fluoride in the coals and resultant emissions (if any) were not addressed. The impacts of any fluoride emissions on ambient air and monthly grass samples should be included if fluoride levels in the coal exceed 0.1% by weight.

RESPONSE

An EPA publication, EPA-600/2-79-019e June 1979, by Monsanto Research Corporation, entitled "Source Assessment: Dry Bottom Industrial Boilers Firing Pulverized Bituminous Coal," includes a table entitled "Arithmetic Mean of Proximate and Ultimate Analysis and Elemental Composition for Appalachian Coal Region Samples." The coal utilized for Big Bend 4 will likely come from Bureau of Mines Region 9, Appalachian Coal is Bureau of Mines Regions 1-8, 13 and borders geographically on Region 9.

The table referenced above indicates an elemental flourine composition in coal of 78 PPM, or about .0078% flourine. Since this is far below the 0.1% value indicated in this question, impacts of flourine emissions on ambient air have not been examined.

TECO
TAMPA ELECTRIC COMPANY

POST OFFICE BOX 111 TAMPA, FLORIDA 33601 TELEPHONE (813) 879-4111

January 27, 1981

Mr. Hamilton S. Oven, Jr., P.E.
Florida Department of
Environmental Regulation
Twin Towers Office Building
2600 Blair Stone Road
Tallahassee, Florida 32301

Received DER

JAN 28 1981

P P S

RE: Tampa Electric Company
Big Bend Unit 4
Site Certification Application

Dear Mr. Oven:

Enclosed please find 35 copies of Amendment 5 to the Big Bend 4 Site Certification Application. This Amendment consists of a response to your letter of November 3, 1980 concerning the water quality impacts of the proposed unit. Also enclosed is a revised plant water balance (Figure 3.3-1). We trust that this material adequately addresses the insufficiencies and uncertainties identified in your letter.

If you have any questions, please do not hesitate to contact us.

Sincerely,

Jerry L. Williams

Jerry L. Williams
Manager
Environmental Planning

Enclosure

cc: C.H. Kaplan
D. Del Santo
SCA Recipients

AMENDMENT 5

TAMPA ELECTRIC COMPANY
BIG BEND STATION UNIT 4
SITE CERTIFICATION APPLICATION

QUESTION 1

LC_{50} for toxic materials or heavy metals are needed for any contaminants for which a mixing zone is sought.

RESPONSE

The continuous waste streams that will be discharged to the bay will be released to the discharge canal via the circulating water system (CWS). Since the waste stream flow rates will be very small compared to the circulating water flow rate and since the turbulent flow of the CWS will provide complete mixing, the applicant assumes that the trace metals in the waste streams will not normally be detectable above background concentrations (see Table 3-1 in the response to Question 3). Therefore, no heavy metal chemical mixing zones are requested. A mixing zone for chlorine residual from the circulating water system is addressed in the response to Question 10.

QUESTION 2

Has TECO decided to change the proposed location of the bottom ash discharge? If so, where?

RESPONSE

The conceptual design for the bottom ash system had the blowdown discharging from the secondary settling pond to Jackson Branch. The discharge location was subsequently revised (Amendment 4) to the circulating water system (CWS) from the bottom ash sluice water return line before reuse. Discharge of the blowdown to the CWS will provide better effluent mixing and dispersion than would discharge to Jackson Branch.

QUESTION 3

A review should be made of all discharge streams to insure that all contaminants are listed and their concentrations estimated.

RESPONSE

Table 3-1 is a list of continuous discharge streams with their expected contaminants and estimated concentrations. The combined effluents are the bottom ash blowdown, boiler blowdown, FGD bleed stream, and circulating water discharge. Three of the parameters in the intake water presently exceed Florida Water Quality Standards (FWQS). The percent increase (or decrease) caused by the combined effluent discharge for each of these contaminants is as follows:

Contaminant	Combined Effluent Concentration	Maximum Background Concentration	% Increase	Water Quality Standards
Mercury	0.0002008	0.0002	+0.42	0.0001
Selenium	0.5646	0.565	-0.07	0.025
Arsenic	0.2929	0.293	-0.03	0.05

It should be noted that the combined effluent concentrations were estimated using the maximum intake water concentrations.

Since the maximum background concentrations exceed FWQS and since the percent increase (or decrease) is relatively insignificant for the most conservative estimates, the applicant feels that there will be no significant impact from these discharges.

The following is a description of each noncontinuous stream:

Roof and Yard Storm Drainage: These streams will be discharged to either the intake or discharge canal. Since the discharge is rainfall, no process-related pollutants should be present in the discharge.

Limestone Storage Pile Runoff: There will be none due to the storage pile being enclosed under a building.

Coal Pile Runoff: Originally the coal pile runoff system was to contain all rainfall runoff up to that volume generated by the 10 year - 24 hour storm. Runoff in excess of these design conditions was to be discharged. This concept has been changed. The storm water runoff control system for the coal pile will retain all surface runoff. Water will be pumped from the coal pile perimeter ditch to the wastewater treatment pond.

FGD Byproduct Storage/Handling Area Storm Water Runoff: The response to Question 1 of the completeness question (Amendment 4, SCA) stated that stormwater from the FGD Byproduct Storage/Handling area would be discharged to Jackson Branch. This has now been changed so that no direct discharge to any body of water will occur. Stormwater falling within the bermed area will be directed to temporary stormwater storage areas within the bermed area and allowed to percolate into the ground.

Construction Runoff: There will be no discharge from the construction activities connected with the Unit 4 building and immediately associated facilities. Surface runoff will be intercepted and pumped to the wastewater treatment pond.

TABLE 3-1
CONTINUOUS DISCHARGE STREAM WATER QUALITY[1]

Parameter	Intake Cooling Water[7] Concentration			City Water[2] Concentration	Boiler Blowdown	Bottom Ash[5] Blowdown	FGD System[4] Blowdown	Combined[6] Effluents	Florida Class III WQ Standards
	Average	Minimum	Maximum						
Flow (gpm)	241,000				30	80	70 max	241,180	
Alkalinity	154.2	102	300	168					
Total Solids	25,199	23,550	26,580	500	10	500 min	91,300		
Total Sus. Solids	24.2	16.3	44.3	20	4	30	30		
Nitrate Nitrogen	0.05	LT 0.05	0.05	LT 0.05		LT 0.05	LT 0.05		
Phosphorus	2.5	0.90	3.3	LT 0.1		LT 0.01	LT 0.10		
Sulfate	1,892	1,850	1,965	44		44	55,700	1,980	
Phosphate	0.768	0.667	0.922						
Organic Phosphorous	0.169	0.005	0.206						Elemental phosphorous 0.001
Ammonia	0.07	0.04	0.08		2		-		
Nitrite	0.005	0.005	0.006						
Nitrate	0.023	0.005	0.046						
Bromide	1.52	0.071	2.98	0.48		0.48	0.48	2.9781	Bromine 0.1 Bromates 100
Chlorine								0.2 FAC	0.01 TRC
Chloride	12,774	8,326	19,813	23		23	26,200	19,806	Maximum 10 percent above background
Fluoride	2.0	1.2	5.3	0.5		0.50	0.50	5.2964	10.0
Aluminum	0.22	LT 0.1	0.38						1.5
Antimony	0.50	LT 0.2	0.80			(3)			0.2
Arsenic	0.204	0.124	0.293		0.193	0.02	0.250	0.2929	0.05
Beryllium	0.012	LT 0.005	0.019		LT 0.005	(3)	LT 0.02	0.0190	
Cadmium	0.001	0.001	0.001		LT 0.005	(3)	0.01	0.0010	0.005
Calcium	276	116	330	70		70	0	330	
Chromium	0.022	0.006	0.045	LT 0.05	0.065	0.01	0.03	0.0450	1.0 (total) and 0.05 after reasonable mixing in receiving waters
Copper	0.008	0.004	0.013	LT 0.05	1(Max)[8]	0.003	0.06	0.0132	0.015
Iron	0.05	0.01	0.08	0.05	1(Max)	0.71	0.05	0.0806	0.3
pH	7.3-8.5	7.3	8.5	7.8	8.5-9.0	8.4	6.5-7.0	8.0	6-8.5
Lead	0.01	0.01	0.01		LT 0.1	.005	0.05	0.0100	0.05
Magnesium	407	122	905	28			2,300	911	
Manganese	0.02	0.01	0.04	0.05		0.24	0.06	0.0400	
Mercury	0.0001	0.0001	0.0002		0.007	(3)	LT 0.0002	2.01×10^{-4}	0.0001
Nickel	0.005	0.004	0.01	0.05	0.096	0.02	0.03	0.0101	0.1
Selenium	0.281	0.129	0.565		0.032	(3)	0.009	0.5646	0.025
Potassium	278	204	301	2.1			2.1		
Sodium	7,150	4,550	7,600	15			2,200	7,595	
Thallium	0.15	LT 0.1	0.2			(3)	0.15		
Zinc	0.008	0.007	0.011	2.0	0.05	0.05	0.240	0.0126	1.0
Oil and Grease	1.5	LT 1.0	1.9	LT 1	5	15	20	1.9093	5
Vanadium				LT 0.001			LT 0.001		
Silver						(3)			0.00005
Sulfite							4,800	1.17	

Notes on following page

TABLE 3-1
CONTINUOUS DISCHARGE STREAM WATER QUALITY

CONTINUED

NOTES

(1) All concentrations in mg/l except where indicated.

(2) Analytical results for city water taken at Sample Point No. 13, 24-hour composite, April 29, 1973.

(3) Less than Minimum Quantifiable Concentration from "Treatability of Ash Settling Pond Effluents," by Utility Water Act Group, March 1979.

(4) Values reflect estimated concentrations after treatment. Values estimated for "Combined Effluents" concentrations utilized before treatment concentrations for conservative estimates.

(5) Values reflect effluent concentrations from bottom ash pond at plant burning Southern Illinois coal. "Treatability of Ash Settling Pond Effluents," by Utility Water Act Group, March 1979.

(6) Combined effluents were calculated using maximum intake water concentrations.

(7) Data was obtained from these five references as noted in the U.S. EPA NPDES permit application:

a. Water Quality Data for period April 29, 1973, through May 5, 1973, Stone & Webster Engineering, Incorporated

b. Water Quality Data for period October 15, 1979, through December 3, 1979, TECO Central Testing Laboratory

c. Water Quality Data for June 26, 1979, Thorton Laboratories, Incorporated

d. Water Quality Data for period June 17, 1980, through June 20, 1980, TECO Central Testing Laboratory

e. 316 Demonstration - BB4, Fine Mesh Screen Study Report, Tampa Electric Company, November 1980.

(8) Boiler blowdown - values in Table reflect maximums.
Estimates are: - Copper 0.04 mg/l
Iron 0.001 mg/l

QUESTION 4

A figure showing a better identification of NPDES discharge points is needed.

RESPONSE

Figure 3.1-6 has been revised to identify the discharge points with EPA NPDES identification numbers.

QUESTION 5

The velocities in the discharge canal should be identified.

RESPONSE

The velocity of the circulating water for a unit, as it flows in the circulating water discharge pipe (9 ft in diameter), is approximately 8.4 ft per second. In the 350-ft wide, 25-ft deep discharge channel, the circulating water combines with the circulating water discharged from the other units and flows west (see Figure 3.4-2). Based upon the cumulative flows, the approximate velocities in the discharge channel are presented in the following table:

Discharge Channel	Unit 4	Unit 3	Unit 2	Unit 1
Unit flow, cfs	537	537	537	537
Cumulative flow, cfs	537	1,074	1,611	2,148
Velocity, fps	0.06	0.12	0.18	0.25

QUESTION 6

It was noted that the pH adjustment and clarification system for the FGD blowdown has not been adequately described.

RESPONSE

The FGD chloride bleed stream will be treated by a skid-mounted liquid waste treatment system. The flow will enter a primary sedimentation tank including a polymer feed system, where the majority of solids will settle. The type of polymer, which will be used as a coagulant aid, will be determined once the system is in operation. The system has been designed to handle flow rates up to 70 gpm. After the sedimentation tank, the waste stream pH will be checked and adjusted to a value between 6.5 and 7.0 by adding either sodium hydroxide or sulfuric acid. The waste stream will then enter a clarifier for final effluent polishing before discharge. Sludge from the sedimentation tank and clarifier will be disposed of in the FGD byproduct storage/handling area.

QUESTION 7

The discharge frequency of wastes listed in Table 3.5-1 and 2 is needed.

RESPONSE

The freshwater inplant waste streams indicated in Table 3.5-1 are captured by the inplant collection system. This system collects the wastewater and conveys it to the main transfer sump, which transfers the waste to the wastewater treatment ponds. These waters are ultimately recycled for equipment washing purposes or disposed of through spray irrigation. (See Section 3.5.2.2, Freshwater Wastes in SCA.) The frequency of these flows associated with Unit No. 4 are given in the Unit No. 4 water balance, Figure 3.3-1.

Table 3.5-2, Wastewater Recycle Design Flows, lists the existing plant operations which are expected to utilize the recycled wastewater and their respective water requirements. This water is collected by floor drains and returned to the wastewater pond for reuse or disposal by spray irrigation. (See Section 3.5.3, Recycle System in SCA.) Big Bend Unit No. 4 will not require slag tank washing or slag tank aspirator water. The frequency of these flows associated with Unit No. 4 are given in the Unit No. 4 water balance, Figure 3.3-1.

QUESTION 8

The method of controlling or discharging runoff from the fly ash and bottom ash systems needs to be described.

RESPONSE

Stormwater falling within the area contained by the bottom ash berms will percolate into the ground. Stormwater falling within the fly ash berms will be collected and pumped, as needed, into the fly ash disposal ponds.

QUESTION 9

The impact of bottom ash leachate on ground water quality has not been adequately addressed.

RESPONSE

Table 9-1 is a supplement to Table 5.2-7 of the Site Certification Application document and lists water-quality data obtained from effluents produced at four different bottom ash disposal areas. These effluents are being used as conservative estimates for the bottom ash leachate. Column D lists the bottom ash effluents produced from a southern Illinois coal, which is the coal most similar to the type proposed to be used at Unit 4. Columns B and C list the bottom ash effluents produced from an eastern Ohio coal and Column A lists the bottom ash effluents produced from western West Virginia coal. These data were obtained from a Utility Water Act Group (UWAG) study prepared by NUS Corporation for submittal to EPA.(1)

Comparison of Columns A, B, C, and D with the Federal EPA Drinking Water Standards and the Florida DER Groundwater Standards, as listed in the table, shows that the estimated water quality of the bottom ash leachates conforms to these federal and state standards.

The UWAG study also showed that filtration of the bottom ash effluents through clean, sieved sand produced an average reduction of 41 percent in the total As concentration, an average reduction of 67 percent in total Cu, an average reduction of 12 percent in total Ni, an average reduction of 33 percent in total Zn, and an average reduction in total Mn of 38 percent.(1)

These data are based on all the various fly ash and bottom ash effluents that were used in the study of which bottom ash effluents composed about 50 percent.

The data clearly show that bottom ash leachate can be renovated during movement through porous media, and a similar or greater amount of renovation is expected to occur at the site area where the confining layer above the Floridan aquifer is composed of abundant clay minerals which have a much greater ion-exchange capacity than the sieved sand used in the UWAG study.

It also should be noted that the native groundwater in the site area contains saline water characteristics, as evidenced by the water quality analyses from the surficial aquifer and the Floridan aquifer taken at the site area which show relatively high concentrations of Cl, Na, SO_4, and Ca.

For these reasons, the applicant concludes that leachate from the bottom ash disposal area will not cause an adverse impact on the water quality of the site area.

(1) "Treatability of Ash Settling Pond Effluent" Utility Water Act Group (UWAG) March 1979. NUS Corporation.

TABLE 9-1

ADDITIONAL WATER QUALITY DATA[1]
OF EFFLUENTS PRODUCED BY BOTTOM ASH DISPOSAL AREAS

	Effluents				AVG	EPA[2]	FDER[3]
	A	B	C	D	A+B+C+D	NIPDWS	Groundwater Water Quality Standards
Fe Total	0.90	0.91	0.98	0.71	0.88		
Fe Dissolved	0.03	0.06	0.05	0.03	0.043		
Ni	0.009	0.02	0.03	0.02	0.02		
Cu	*	0.008	0.03	0.004	0.014		
Cd	0.001	*	*	*	0.001	0.01	0.01
Cr	*	*	*	0.006	0.006	0.05	0.05
Pb	*	*	*	*		0.05	0.05
Hg	*	*	*	*		0.002	0.002
Se	*	*	*	*		0.01	0.01
Zn	0.007	0.13	0.03	0.01	0.044		
Mn	0.10	0.29	0.15	0.01	0.138		
As	*	*	*	0.01	0.01	0.05	0.05
Sb	*	*	*	*			
Be	*	*	*	*			
Ag	*	*	*	*		0.05	
Ti	*	*	*	*			
TDS							
TSS		4.6	7.7	55.6			
pH	7.8	6.8	7.8	8.4			

Notes on following page

TABLE 9-1
ADDITIONAL WATER QUALITY DATA
OF EFFLUENTS PRODUCED BY BOTTOM ASH DISPOSAL AREAS

CONTINUED

NOTES

(1) Values are in mg/l and were obtained from "Treatability of Ash Settling Pond Effluent," UWAG, March 1979, Table 7, p. 15. The following letters identify the coal type for each pond from which the samples were taken:

A. Western West Virginia coal
B. Eastern Ohio coal
C. Southern Ohio coal
D. Southern Illinois coal

These effluents are being used as conservative estimates of leachate quality.

(2) US EPA National Interim Primary Drinking Water Standards

(3) Florida Administrative Code, Chapter 17 - 3.101

(4) *Refers to values less than the Minimum Quantifiable Concentration from "Treatability of Ash Pond Effluents," UWAG, March 1979.

QUESTION 10

The size of the mixing zone required for chlorine discharge needs to be specified. Also, toxicity data for potentially affected species should be provided.

RESPONSE

The Florida Administrative Code, Chapter 17, Section 3.121, contains water quality standards for all Class III waters except within zones of mixing. The standard for total residual chlorine (TRC) states that the concentration shall not exceed 0.01 mg/1. The maximum concentration allowed to be discharged under Title 40CFR (423.15) is 0.5 mg/1 free available chlorine (FAC). The allowable 30 day average concentration is 0.2 mg/1 FAC. Operational monitoring data taken at Big Bend Unit Nos. 1-3 (see Unit No. 4 SCA, Tables 5.2-1 to 3) indicate that FAC is approximately equal to TRC in the discharge at Big Bend. This relationship can be used to calculate a mixing zone for Unit No. 4.

Assuming a constant release of 0.5 mg/1 and the dilution factors cited in Table 5.2-4 of the SCA, about 6.1 acres would have a chlorine concentration in excess of 0.01 mg/1. This area would be entirely contained within the discharge canal and would extend about 1081 ft from the Unit No. 4 discharge outfall. This estimated mixing zone is conservatively large, since; 1) based on operation of Unit Nos. 1-3, discharge concentrations rarely exceeded 0.2 mg/1 and frequently were less than 0.1 mg/1 (chlorination procedures identical to those used at Unit Nos. 1-3 are proposed for Unit No. 4), and 2) the average discharge concentration would take place for a maximum of 2 hours per day. Subsequent to cessation of chlorination, the chlorine in the discharge will dissipate.

A search of the literature on chlorine toxicity revealed 96 hour LC_{50} values for four species' lifestages which are indigenous to the Big Bend area (see attached table). These values are based on continuous dosage rather than intermittant and thus may represent values that are unrealistically low for direct comparison to the Big Bend situation; however, no more pertinent data are available.

For this reason, the applicant feels that the chlorine mixing zone should be defined by the water quality standard of 0.01 mg/1 as calculated in the worse case presented above.

TABLE 10-1

TOLERANCE OF SELECTED SPECIES TO CONTINUOUSLY CHLORINATED EFFLUENT

Species	Lifestyle	96 hour LC_{50} (mg/l)	Reference
Crassostrea Virginia (Ostreidae) American oyster	Juvenile	0.023	Roberts et al (1975)
	Juvenile	> 1.500	Bongers et al (1977)
Brevoortia Tyrannos (Clopeidae) Atlantic Menhaden	Juvenile	$0.09 < LC_{50} < 0.223$	Bongers et al (1977)
Leidostomus Xanthurus (Schiamidae) Spot	Juvenile	$0.09 < LC_{50} < 0.223$	Bongers et al (1977)
Menidia Menidia (Atherinidae) Atlantic silverside	Larvae/ Juvenile	0.037	Roberts et al 1975

Roberts, M. H. Jr., R. J. Diaz, M. E. Bender, and R. J. Huggett, 1975. Acute Toxicity of Chlorine to Selected Estuarine Species, J. Fish. Res. Bd. Can. 32(12): 2525-2528

Bongers, L. H., B. Bradley, D. T. Burton, A. F. Holland, and L. H. Liden, 1977. Biotoxicity of Bromine Chloride- and Chlorine-Treated Power Plant Condenser Cooling Water Effluent. Martin Marietta Corporation, Baltimore, MD.

QUESTION 11

Size of mixing zones needed for heavy metals, their point(s) of discharge and estimated discharge concentrations.

RESPONSE

As indicated in the answer to Question 1, heavy metal mixing zones are not being requested. Refer to the answer for Question 3 for concentrations and discharge points.

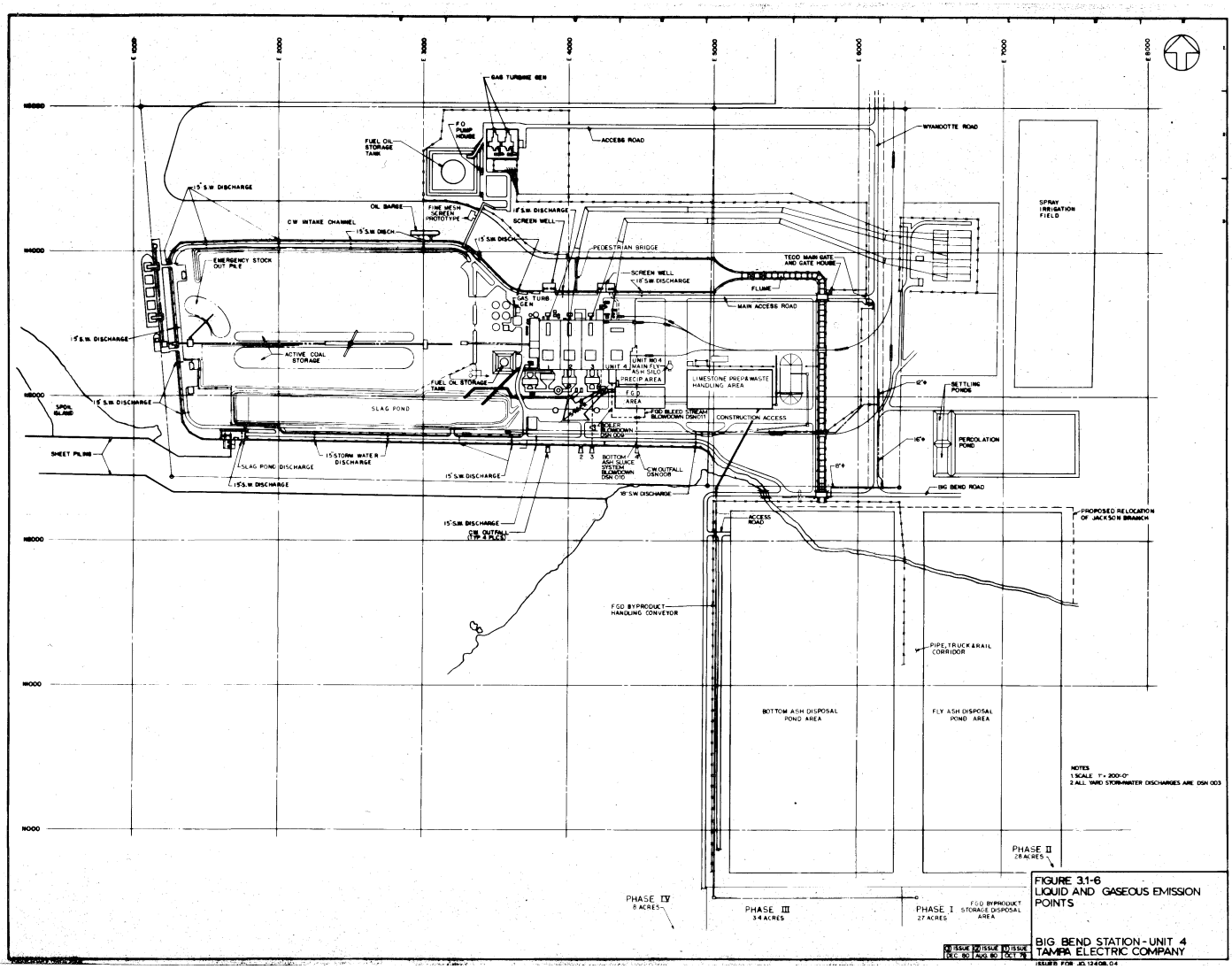

FIGURE 3.1-6
LIQUID AND GASEOUS EMISSION POINTS

BIG BEND STATION - UNIT 4
TAMPA ELECTRIC COMPANY

1) ISSUE DEC. 80 | 2) ISSUE AUG 80 | 3) ISSUE OCT 79

ISSUED FOR JES 124018.04

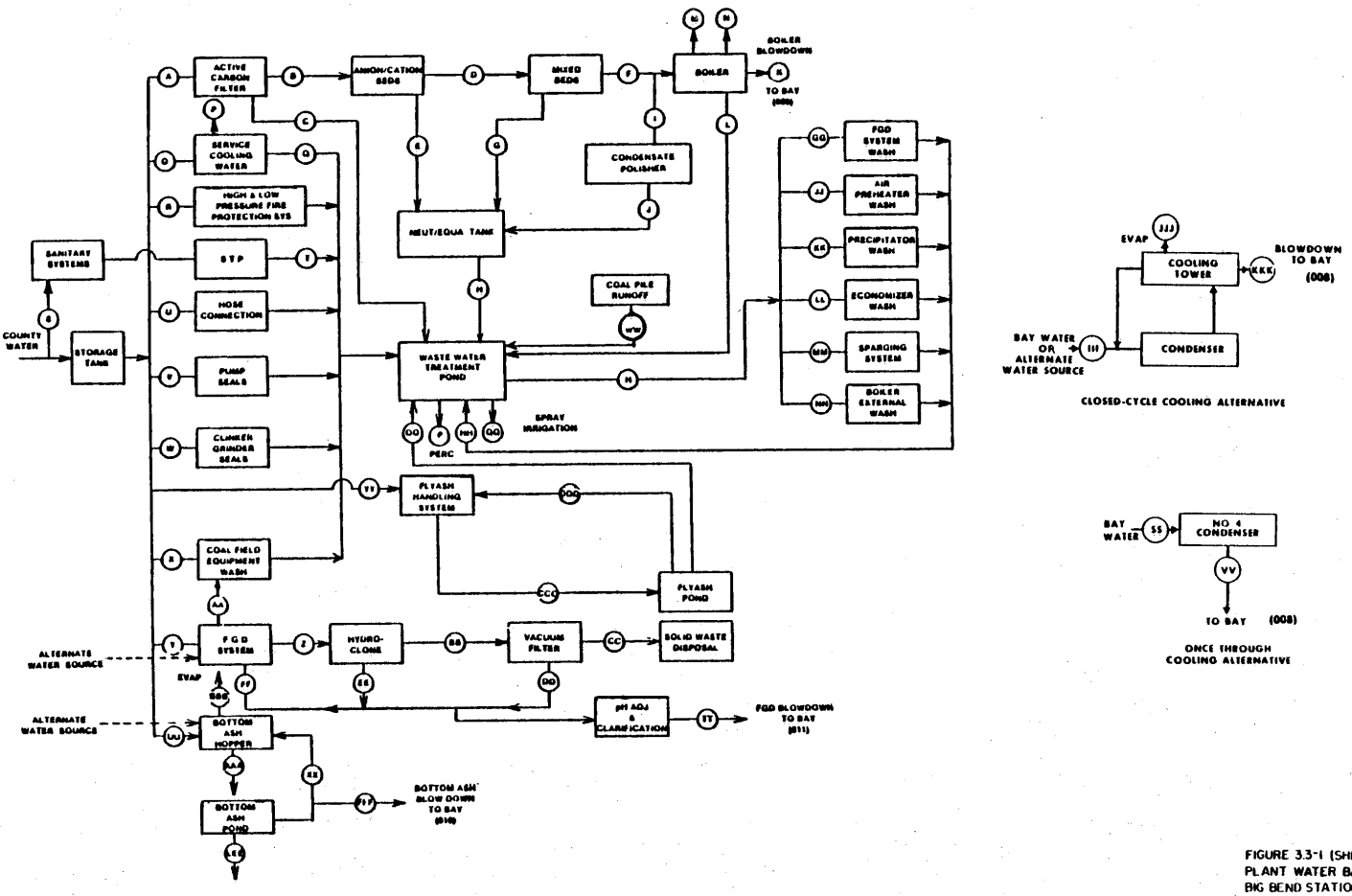

FIGURE 3.3-1 (SHEET 1 OF 3)
PLANT WATER BALANCE
BIG BEND STATION
TAMPA ELECTRIC COMPANY

FACILITY WATER USE
AVERAGE FLOW (10^3 gpd)

Line No.		Average	Maximum	Nature	Duration	Frequency
A.	Activated Carbon Bed Influent	145.2	145.2	C	-	-
B.	Activated Carbon Bed Effluent	144.9	144.9	C	-	-
C.	Activated Carbon Bed Backwash	0.3	0.3	I	-	1/wk
D.	Anion/Cation Bed Effluent	115.0	115.0	C	-	-
E.	Anion/Cation Bed Backwash	29.9	29.9	I	-	1/30 hrs.
F.	Mixed Resin Bed Effluent (Boiler Make-up)	114.2	114.2	C	-	-
G.	Mixed Bed Backwash	0.8	0.8	I	-	1/27 days
H.	Neutralization/Equalization Effluent Backwash	38.7	38.7	C	-	-
I.	Condensate Polisher Backwash Make-up	8.0	8.0	I	-	1/4 days
J.	Condensate Polisher Backwash	8.0	8.0	I	-	1/4 days
K.	Boiler Blowdown	43.2	43.2	C	-	-
L.	Boiler Chemical Cleaning Waste	0.9	0.9	I	2 hrs/stage	1/2 yrs.
M.	Vent Losses	15.0	15.0	C	-	-
N.	Soot Blowing Losses	47.1	47.1	I	-	-
O.	Service Cooling Tower Makeup	210.0	210.0	C	-	-
P.	Service Cooling Tower Evap. Losses	138.0	138.0	C	-	-
Q.	Service Cooling Tower Blowdown System	72.0	72.0	C	-	-
R.	High & Low Pressure Fire Protection	Nil	Nil	I	-	-
S.	Domestic Service Water	1.3	1.3	I	-	-
T.	Sewage Treatment Plant Effluent	1.3	1.3	I	-	-
U.	Hose Connection	0.1	2.9	I	4 hrs	1/4 wks
V.	Pump Seals	10.8	10.8	C	-	-
W.	Clinker Grinder Seals	1.3	5.4	I	2 hrs	3/day
X.	Coal Equipment Wash	2.1	2.1	I	16 hrs	4/yr
Y.	FGD System Makeup	1,123.2	1,123.2	C	-	-
Z.	FGD Slurry (85 % water)	1,741.0	1,741.0	C	-	-
AA.	FGD Evaporation Losses	989.3	989.3	C	-	-
BB.	Hydroclone Effluent to Filter	316.8	316.8	C	-	-
CC.	Vacuum Filter Sludge (20% water)	74.9	74.9	C	-	-
DD.	Vacuum Filter Recycle	241.9	241.9	C	-	-

FIGURE 3.3-1 (SHEET 2 OF 3)
PLANT WATER BALANCE
BIG BEND STATION
TAMPA ELECTRIC COMPANY

FACILITY WATER USE
AVERAGE FLOW (10^3 gpd)

Line No.	Average	Maximum	Nature	Duration	Frequency
EE. Hydroclone Recycle	1424.4	1424.4	C	-	-
FF. Recycle to FGD System	1607.1	1607.1	C	-	-
GG. FGD System Wash	66.6	133.3	I	-	-
HH. Service Water Effluent	21.2	21.2	I	-	-
II. Wastewater Treatment System Recycle	21.2	21.2	I	-	-
JJ. Air Preheater Wash	9.4	9.4	I	8 hrs	1/3 mos
KK. Precipitator Wash	5.3	5.3	I	80 hrs	3/yr
LL. Economizer Wash	0.3	0.3	I	4 hrs	3/yr
MM. Sparging System	4.6	4.6	I	24 hrs	3/yr
NN. External Boiler Wash	1.6	1.6	I	24 hrs	2/yr
OO. Flyash Pond Blowdown	72.0	72.0	I	-	-
PP. Waste Water Treatment System Percolation Losses	30.0	30.0	C	-	-
QQ. Spray Irrigation System	81.3	195.2	I	-	-
RR. Construction Runoff	0	0	I	-	-
SS. Condenser Cooling Water	347,072.0	347,072.0	C	-	-
TT. FGD System Blowdown	59.0	59.0	C	-	-
UU. Bottom Ash Pond Make-up	505.0	505.0	C	-	-
VV. Condenser Cooling Eff.	347,072.0	347,072.0	C	-	-
WW. Coal Storage Runoff	11.8	11.8	I	-	-
XX. Bottom Ash Recycle	1,825.0	1,825.0	C	-	-
YY. Flyash Sluice Water Make-up	72.0	72.0	I	-	-
AAA. Bottom Ash Sluice	2,300.0	2,300.0	I	-	-
BBB. Bottom Ash System Evaporation Losses	30.0	30.0	C	-	-
CCC. Flyash Sluice	1,440.0	1,440.0	I	-	-
DDD. Flyash Recycle	1,368.0	1,368.0	I	-	-
EEE. Bottom Ash Pond Percolation Losses	360.0	360.0	C	-	-
FFF. Bottom Ash Pond Blowdown	115.0	115.0	C	-	-
GGG. Construction Water Uses	NA	NA	I	-	-
HHH. Domestic Water Uses	NA	NA	I	-	-
III. Condenser Cooling Water Make-up	15,408.0	15,408.0	C	-	-
JJJ. Condenser Cooling Tower Evaporation Losses	5,184.0	5,184.0	C	-	-
KKK. Condenser Cooling Tower Blowdown	10,224.0	10,224.0	C	-	-

FIGURE 3.3-1 (SHEET 3 OF 3)
PLANT WATER BALANCE
BIG BEND STATION
TAMPA ELECTRIC COMPANY

316 DEMONSTRATION
BIG BEND STATION - UNIT 4

VOLUME II
APPENDICES

August 1980

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316 DEMONSTRATION
BIG BEND STATION - UNIT 4

VOLUME II
APPENDICES

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APPENDIX I

1979 AQUATIC ECOLOGY STUDY

1979 AQUATIC ECOLOGY PROGRAM BIG BEND POWER STATION, TAMPA, FLORIDA

FINAL REPORT

EDITED BY SELVAKUMARAN MAHADEVAN

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June 24, 1980

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Mr. Keith Taniguchi

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Mrs. Patricia Bird
Dr. Joseph Boatman
Dr. Perry Gilbert
Dr. William H. Taft
Dr. William Tavolga
Dr. William J. Tiffany III

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PREFACE

Studies described in this report are the results of dedicated efforts of a group of scientists from the La boratory and the funding by Tampa Electric Company (through Stone & Webster Engineering Corporation). The aquatic ecology program encompassed the study of meroplankton populations, adult fishes and invertebrates, oyster spat and age and fecundity of selected fish species in the Big Bend (Tampa Bay, Florida) area. Studies on the manatee populations and benthic communities of the area are presented as separate reports. Stringent Quality Assurance procedures were employed in the program to ensure the validity of the data collected. It is our hope that results presented in this report will provide a better understanding of the fauna indigenous to the study area and enhance the predictive value of the biological models (to be presented by Stone & Webster Engineering Corporation) to be used in assessing environmental impact.

William H. Taft, Ph.D.
President

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CHAPTER ONE

INTRODUCTION

BY

SELVAKUMARAN MAHADEVAN

CHAPTER ONE

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I. STUDY OBJECTIVES AND SCOPE

The 1979 Aquatic Ecology Program's primary objective was to provide field data necessary for assessment of entrainment impact on Big Bend populations of aquatic organisms. The program concentrated on the collection of data for a group of Representative Important Species (RIS):

1. American oyster (*Crassostrea virginica*)
2. Pink shrimp (*Penaeus duorarum*)
3. Blue crab (*Callinectes sapidus*)
4. Stone crab (*Menippe mercenaria*)
5. Bay anchovy (*Anchoa mitchilli*)
6. Scaled sardine (*Harengula jaguana*)
7. Tidewater silverside (*Menidia beryllina*)
8. Silver perch (*Bairdiella chrysura*)
9. Spotted seatrout (*Cynoscion nebulosus*)
10. Black drum (*Pogonias cromis*)

The RIS were chosen on the basis of abundance and/or commercial importance.

The program consisted of four major components:

1. Meroplankton studies
2. Adult fish and invertebrate studies
   (Trawls, seines and travelling intake screens)
3. Selected fish species' age and fecundity studies
4. Oyster spat studies

The study began in February, 1979 and was completed in February, 1980. Chapters that follow describe the specific objectives, methods used and results obtained for the above study components.

II. STUDY AREA

General location of the study area is shown in Figure 1.1. Specific sampling locations for the various study components are presented in the respective chapters.

A description of the Tampa Bay system and the study area was presented by Garrity (1977) in a previous report of ecological studies at Big Bend.

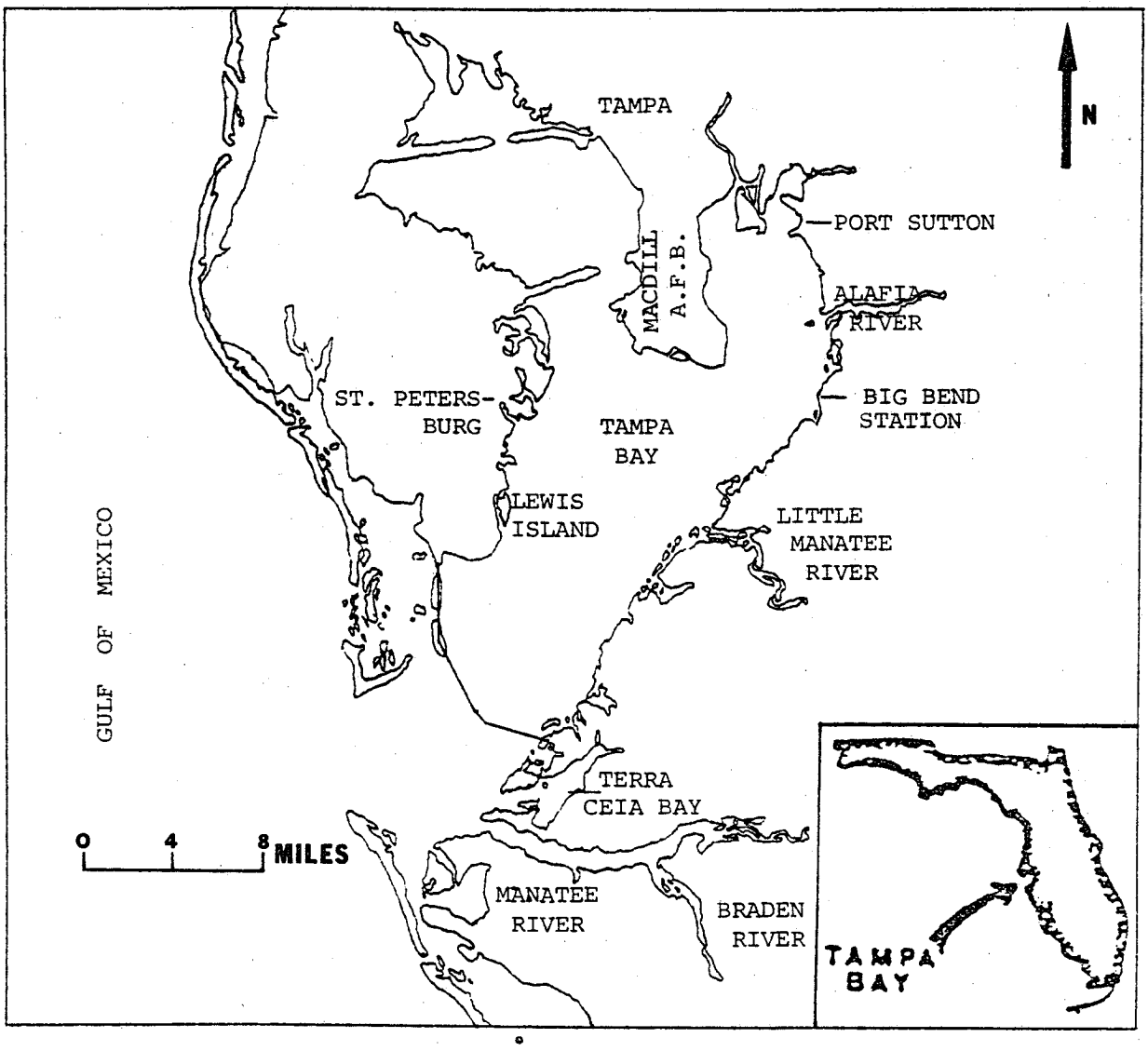

Figure 1.1. Study area.

III. QUALITY ASSURANCE

Stringent quality assurance (QA) procedures were employed throughout the program. A written QA manual outlining specific procedures was prepared at the initiation of the project. Highlights of the QA program were:

- A QA Committee independent of project management heirarchy to oversee field and laboratory data validation, traceability and documentation.
- Regular internal audits by the QA Committee.
- Back-up samples.
- Regular equipment calibration and maintenance procedures.
- Data documentation and checks at every critical stage of data incorporation/transfer.
- Data traceability from sample collection to final analysis/report. (Example Data flow is shown in Figure 1.2).
- At least 5% of samples resorted.
- At least 5% of final taxonomic identifications re-checked.
- Taxonomic confirmations obtained from specialists.

External QA audits were conducted by Stone and Webster Engineering Corporation and the Environmental Protection Agency (Region 4).

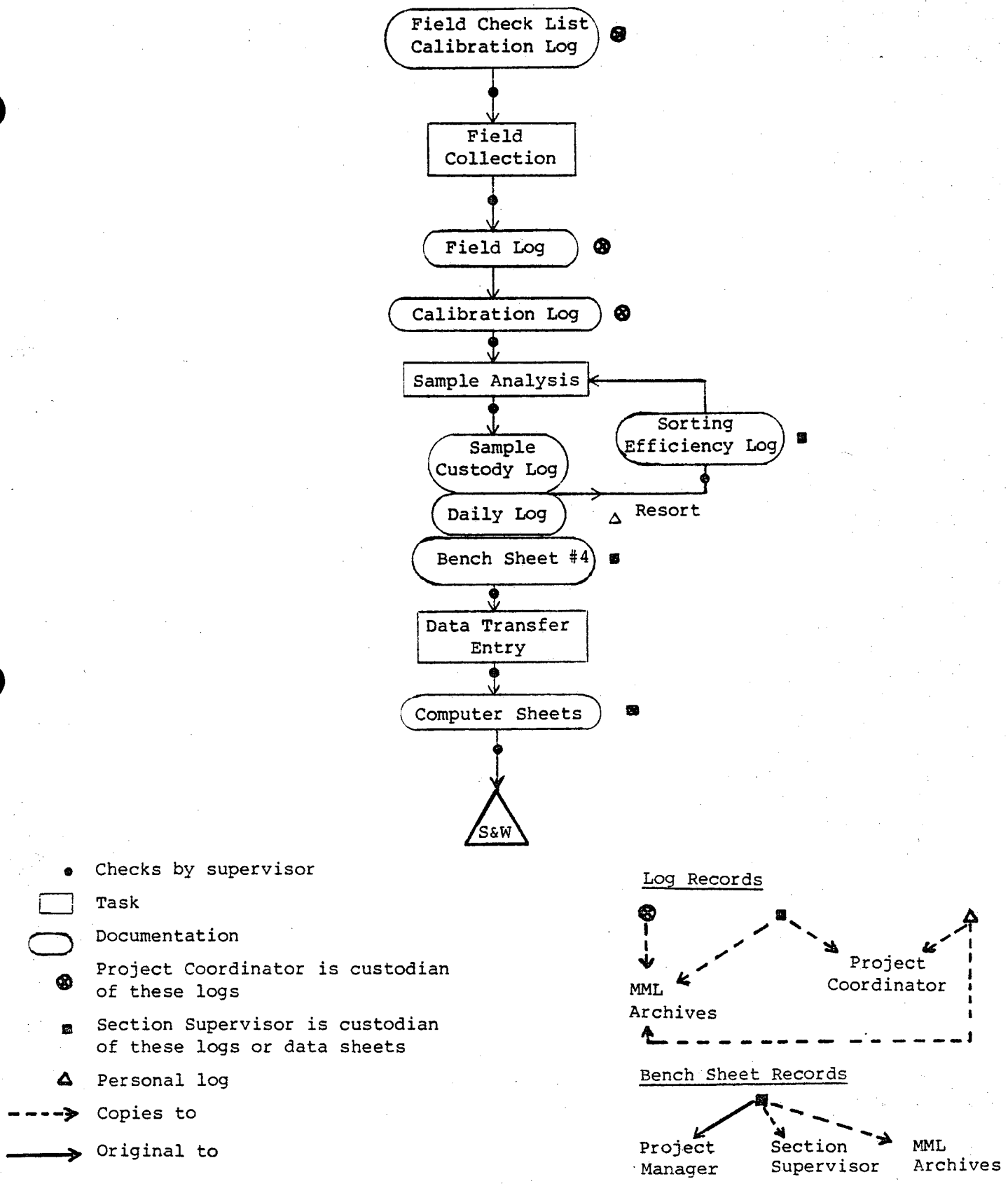

Figure 1.2. Example Data Flow.

IV. LITERATURE CITED

Garrity, R. D. 1977. Chapter 1, Introduction. In: Ecological Studies at Big Bend Steam Electric Station (Tampa Electric Company), A 316 Demonstration Biological Study. Conservation Consultants, Incorporated. 25 pages.

CHAPTER TWO

A STUDY OF SELECTED MEROPLANKTON SPECIES OF LOWER TAMPA BAY.

BY

T. DUANE PHILLIPS

AND

R. HARRY BLANCHET

CHAPTER TWO

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I. INTRODUCTION

The meroplankton portion of the 1979 Aquatic Ecology Program at Big Bend Station was conducted to provide field data on the local populations of fish and invertebrate larvae. These data are necessary for the assessment of entrainment impact (through biological models) on local populations and will supplement information from previous studies conducted at Big Bend.

The program concentrated on the collection of data for a group of Representative Important Species (RIS). These RIS include:

Crassostrea virginica (American oyster)*

Callinectes sapidus (Blue crab)

Penaeus duorarum (Pink shrimp)

Menippe mercenaria (Stone crab)

Anchoa mitchilli (Bay anchovy)

Harengula jaguana (Scaled sardine)

Bairdiella chrysura (Silver perch)

Cynoscion nebulosus (Spotted seatrout)

Pogonias cromis (Black drum)

Menidia beryllina (Tidewater silverside)

Specific objectives of the study were to:

1. Determine the relative abundance of the RIS in the Big Bend area.

2. Determine the seasonality of the RIS.

3. Provide information on the size of RIS fish larvae collected.

4. Determine the zoeal stage of all RIS crab larvae collected.

This report summarizes the data collected between February 1979 and February 1980.

---

* This species was not expected to be collected in this program due to the size of mesh used.

II. MATERIALS AND METHODS

Sampling locations are shown in Figure 2.1. Station A is located at the intake of the Big Bend Plant, and Station B is located at the discharge flume of Unit 1 of the Plant (unless Unit 1 was not operating in which case an operating unit was sampled). Stations C and D are located in Hillsborough Bay. Station E is located near the ship channel in southern Tampa Bay.

Stations A and B were easily located (while sampling) by land-based stationary structures. All open bay stations (C, D, and E) were located within 0.5 km of a navigation range marker or lighted channel marker. Exact station locations were marked by round crab trap buoys with reflective tape, visible for at least 200 meters on a calm night. These buoys were held in position by a cement-filled block. These anchors weighed at least 25 kg, and were not affected by wind or currents.

Samples were collected at two week intervals for twelve months beginning on February 27, 1979. Samples were taken during both day and night at different tides.

a) Physical parameters

Temperature, conductivity, dissolved oxygen content, and depth were measured at the surface, mid-depth, and bottom of each sampling station at the beginning of the replicate plankton tows with a Hydrolab Surveyor Model 6-D (automated in situ physico-chemical monitor). The Hydrolab was calibrated according to manufacturer's specifications the evening before each sampling trip and again just prior to the field sampling. Upon return to the lab, a post-calibration check was also performed.

In addition, time, wave height, and tidal stage were recorded at each station.

b) Biota

(i) Collection

Meroplankton samples were collected with two one meter mouth diameter 505 μm mesh conical plankton nets. The nets were towed in tandem from the ends of a 4.8 m beam mounted amidship on the sampling boat; so that the nets were not towed in the boat wake. A General Oceanics digital flowmeter, Model 2030, was mounted in each net mouth. In addition, a third flowmeter was suspended from the net ring of one net in a way as to be unaffected by boat or net-induced turbulence. A 1.4 kg weight was also suspended from the ring of each net.

Flowmeters were calibrated quarterly. Flowmeters were calibrated by towing three times over a measured course. Readings were taken at the beginning and end of each tow and the difference used to determine the number of counts per meter for each flowmeter. In the laboratory, the

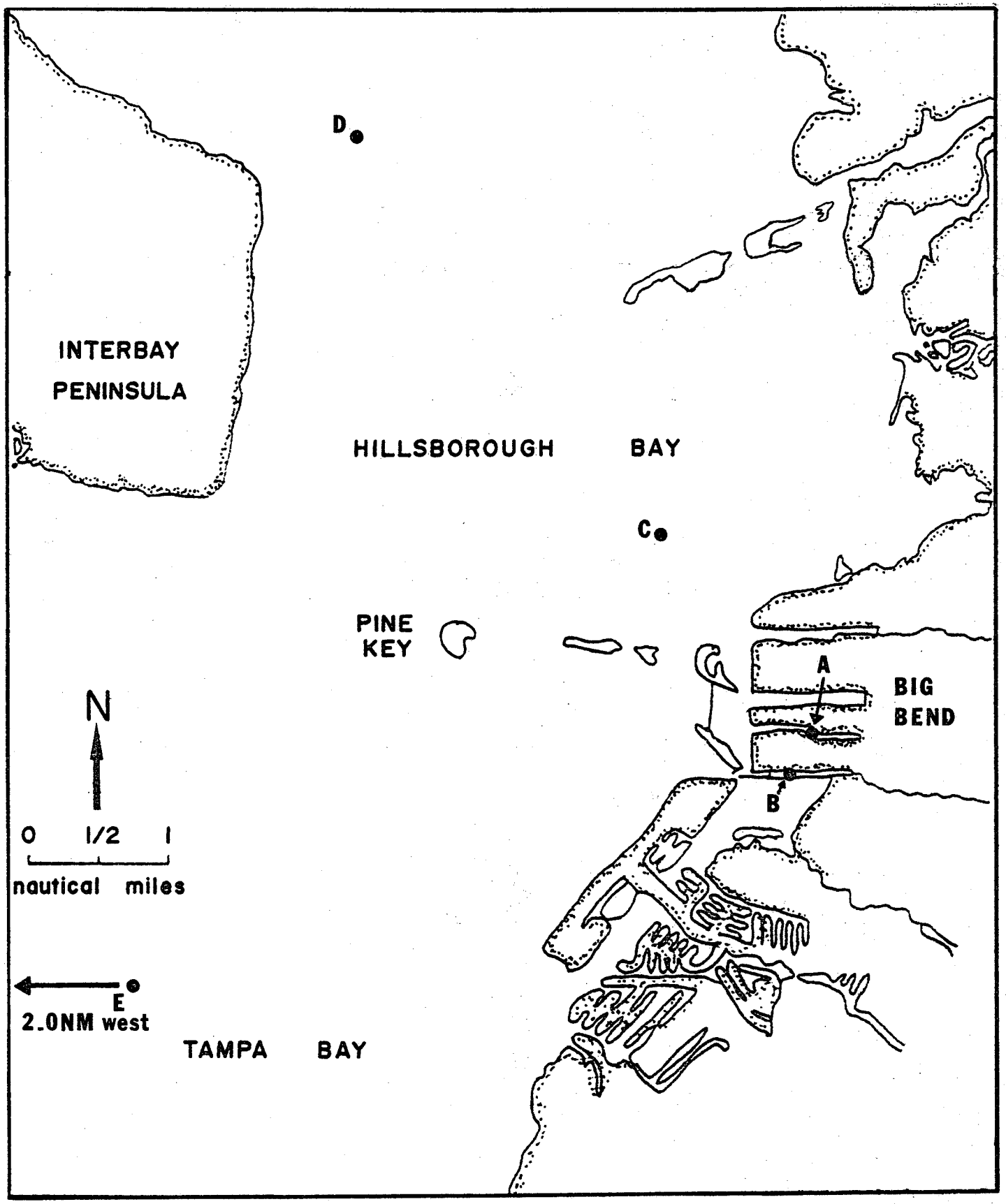

Figure 2.1. Location of meroplankton stations.

difference in the beginning and ending flowmeter readings was divided by the number of counts per meter which was predetermined for each flowmeter to give the distance travelled (in meters) by each net. This figure was then multiplied by the area of the net mouth to give the number of cubic meters filtered by each net. This procedure assumed that each flowmeter maintains its efficiency over all ranges of towing speed and over time.

Flowmeter readings were recorded at the start of each tow. The nets were launched simultaneously and allowed to sink, then towed at a speed of approximately one knot. This technique resulted in the nets fishing an oblique trajectory, starting near the bottom and ending at the surface. Plant discharge samples (Station B) were not taken by an oblique tow, but rather a surface tow. The bow of the sampling boat was tied to the discharge flume and the nets were launched from the stern of the boat, one on each side. The nets fished 'passively', the current from the discharge water being strong enough to cause them to trail behind the boat.

Filtering efficiencies were calculated by dividing the distance travelled by the flowmeter in each net by the distance travelled by the flowmeter mounted outside one of the nets and multiplying by 100 to give a percentage. This measure of net clogging is only accurate for the net on which the outside meter is mounted, because the other net may travel through a slightly different amount of water. Six relicates (three tows) were taken in this manner at each station. Four of the six replicates were sorted for meroplankton RIS, two were kept as back-up samples. Every effort was made to filter at least $100m^3$ of water with each tow; however, in certain circumstances, visual inspection of the nets indicated extreme net clogging and tow duration was reduced in order to maintain high filtration efficiency.

Plankton nets were thoroughly rinsed after each tow to minimize cumulative net clogging. Nets were checked for tears after each sampling trip. If necessary, minor repairs to the nets were performed in the field.

One liter plastic jars were used as cod-end containers. Samples were immediately preserved by adding a measured amount of formalin, buffered with marble chips, to give a final concentration of 5 percent. Samples were doubly labeled, i.e., both internal and external labels for sample containers. The labels identified the sample by date, station, gear, time of sampling and replicate number. Samples were taken to the laboratory at the completion of a sampling trip.

Stations were always sampled in the following order: E, D, C, A, and B. A schedule of sampling dates is included as Appendix 2 A.

(ii) Analysis

The samples were placed in a 1000 ml Erlenmeyer flask after the volume was adjusted to allow efficient sorting. The samples were then agitated thoroughly, and aliquots were withdrawn into a gridded petri dish. Subsampling was accomplished by use of a 10 ml capacity Tipet

dispenser (or 5 ml pipet for enumeration of very abundant eggs). Depending on the density of plankton, up to four 10 ml aliquots could be sorted at one time. Samples were completely sorted for any RIS for which less than 100 specimens had been sorted from the sample. The density (#/100m^3) of any species was then calculated by comparing the volume of sample examined (VE) to pick out any number of specimens (NS), to the total volume of the sample (TV) and the volume of water filtered (VF):

$$\left(\frac{TV \cdot NS}{VE} \right) \left(\frac{VF}{100} \right) = D$$

Identification of larval specimens was made through the use of standard literature sources for each RIS. As necessary, difficult to identify species were referred to appropriate external taxonomic consultants.

All sorted specimens were placed in numbered vials. Catalog numbers of sorted specimens were carried on the bench data sheets and in a bound notebook in which the specimens were logged as the samples were sorted.

RIS fish larvae were classified for larval development in accordance with Hubbs (1943), i.e., egg, prolarva, postlarva, juvenile. Standard length (SL) of RIS fish larvae were measured to the nearest 0.1 mm for up to 50 individuals of each species per sample. Measurements were made with ocular micrometers calibrated with an AO Stage Micrometer.

Larvae, if invertebrate RIS, were identified and classified according to developmental stage, i.e., zoea, megalops, postlarva. Zoea of the dominant RIS decapod larvae in the area, Menippe mercenaria, were sorted by zoeal molt stage (Stage I-V) to provide additional information on developmental stage.

All sorting was conducted by using dissecting microscopes. A compound scope was available for checking fine detail.

c) Study Limitations

Several factors affect the quantitative sampling of ichthyoplankton. Among these are the efficiency of sampling equipment, extrusion of eggs and larvae through the net mesh, and avoidance of the sampling gear. Phillips (1977) and Scotten, et al., (1973) provide overviews of these problems as they relate to ichthyoplankton sampling. More detailed discussions of some of these factors can be found in Clutter and Anraku (1968), Tranter and Smith (1968), and Vanucci (1968).

Plankton patchiness makes quantitative description of spatial and temporal distribution patterns difficult. For additional information on this subject, the reader is referred to Cushing (1962) and Wiebe (1971).

Clogging of the net mesh can also interfere with quantitative sampling. Smith and Richardson (1977) presented evidence that when clogging occurs, the sample taken becomes progressively less representative and the tendency is to undersample the surface layers. On some

occasions (approximately 5% of the total sampling effort or 15 times out of 260 sampling efforts), extreme net clogging was encountered. Hence, the density values of eggs and larvae obtained from these sampling times may have been under-estimated. Specific times that such net clogging occured were:

February 27, 1979	- Night, Stations A and B.
April 26, 1979	- Day, Station A
July 17 and 18, 1979	- Day, Stations A and B; Night, Stations A, B, and C.
July 31, 1979	- Day, Station A
August 1, 1979	- Night, Station A, B, C, and D.
October 9, 1979	- Night, Station E
November 20, 1979	- Day, Station E

A quantitative estimation of the effect of these specific instances of net clogging on the collection of eggs and larvae is not feasible. However, the sparse occurrence of net clogging during this program, we feel, precludes any major effect on the data obtained.

Identification of fish eggs and larvae are often difficult because of overlapping spawning seasons and because of similarity of appearance. Among the RIS, Anchoa spp. larvae smaller than 10-12 mm are very similar. Although we attempted to separate A. hepsetus and A. mitchilli in the smaller size ranges, we may have included some A. hepsetus in our counts of A. mitchilli. Since A. hepsetus is far less abundant in Tampa Bay, it is probable that only a small proportion of our larvae were misidentified. Sciaenid eggs also pose a taxonomic problem. Major distinguishing characteristics include egg diameter, number and size of oil globules, and pigmentation (or lack thereof) on the oil globule and embryo. Although there is some overlap in the size of the three sciaenid RIS, each possess unique characteristics which make separation possible. We did not attempt to identify Cynoscion spp. eggs to the species level because of the similarity of the eggs of the two species present within the study area, C. arenarius and C. nebulosus. Any egg which possessed the characteristics of the family but which did not have a developed embryo or was of questionable identity was lumped into the category "Unidentified Sciaenid".

The 505 µm mesh nets used during the present study may not adequately sample the smaller larvae. Although a 505 µm mesh net is often used for ichthyoplankton sampling, Smith, Counts and Clutter (1968) recommended using 333 µm mesh for sampling fish eggs and larvae. In a previous study at Big Bend (Phillips, 1977) 56 percent of the Anchoa mitchilli larvae were smaller than 4 mm NL. During the present study only 28 percent were smaller than 4 mm NL. This may indicate that the smaller larvae are extruded through the meshes of the 505 µm nets causing an under-estimation of their abundance or that the smaller mesh used earlier (through clogging) may have over-estimated their abundance. For the purposes of the present study, the 505 µm mesh appears to be an adequate net size.

III. RESULTS

a) Physical Characteristics

Surface temperatures at meroplankton stations are presented in Figure 2.2 and Appendix 2 B. Temperatures at the open bay stations (C, D, and E) were similar to each other throughout the study period. Temperatures at the plant intake (A) were also similar to those of the open bay stations, although they were usually about 0.5°C higher. Temperatures at the plant discharge (B) ranged from 3 to 9°C higher than those recorded at the plant intake station. The May 25 discharge temperature obviously represents a unit that was not in operation.

Surface temperatures at all stations, except the plant discharge, approached 20°C on March 27, 1979 and remained above the level until November 20. Highest surface temperature at these stations was recorded on July 3 (32°C, Station A) and on July 31 (32°C, Stations A and C). Lowest temperature at these stations occurred on February 12, 1980 (14°C, Station E). Surface temperatures at the plant discharge reached their highest level on July 31, 1979 (40°C).

Surface dissolved oxygen readings are presented in Appendix 2 C. Dissolved oxygen (DO) showed only slight seasonal variation. D. O. values were generally higher during the winter months than during the summer. Dissolved oxygen was usually highest at the surface and lowest at the bottom. On a number of occasions, from April to October 1979, bottom D. O. at open bay station D and at the plant intake (A) were below 2mg/l indicating near anoxic conditions. These low values can probably be attributed to the build-up of reducing muds at Station D and to the greater depth (7-8 m) and reduced mixing at the plant intake.

Surface salinities are presented in Appendix 2 D. Salinity values were generally lowest at the northern open bay station (D) and highest at the southern open bay station (E). Lowest values of the year occurred at Station D in late September and early October 1979 (8.5 - 9.5 °/oo) and are probably caused by unusually heavy rainfall in September and increased freshwater runoff.

b) Biotic Characteristics

The following is an account of the seasonality and relative density of the meroplankton RIS collected during the 1979 Aquatic Ecology Study. Seasonal densities of the RIS are presented in Appendices 2-E. through 2-N.

(i) *Crassostrea virginica* Gmelin (American oyster)

No larvae of this species were collected in the meroplankton program. They were in the water column at all stations since they settled on spat panels (see chapter 5). *C. virginica* larvae generally settle out of the plankton at a size between 275 mm and 393 mm (Loosanoff, Davis, and Chanley, 1966). The 505 µm mesh of the plankton net was obviously too large to retain *C. virginica* larvae.

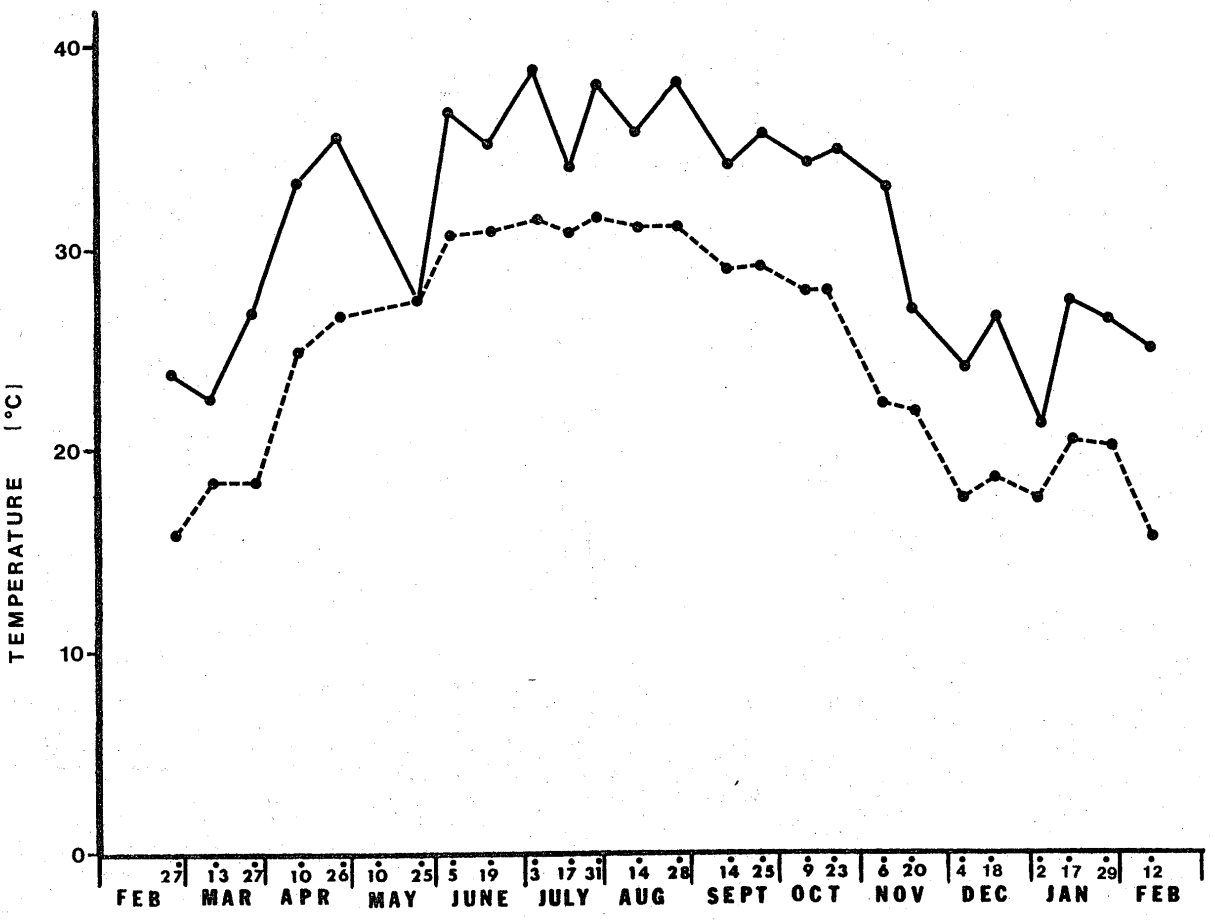

Figure 2.2. Surface temperatures at the plant intake (●---●) and discharge (●——●) during 1979.

(ii) Callinectes sapidus Rathbun (Blue crab)

No zoea of this species were collected during the present study. This species spawns offshore (probably beyond Egmont Key), and by the time the young return to the Big Bend area, they have already settled out of the plankton.

(iii) Menippe mercenaria Say (Stone crab)

M. mercenaria zoea are distinctive among the xanthids and were identified from descriptions of Porter (1960). Stone crab zoea were collected on most sampling dates after March 13, 1979. Relatively low numbers were collected through May 10, 1979, especially at open bay stations (C, D, and E). Peak densities occurred on May 25, 1979 and numbers remained high through early July (exception: June 19 samples contained very few zoea).

Zoea densities were always greater at the Plant Discharge (B) than at any other station. Throughout the study, stone crab zoea were always more numerous near the plant than at open bay stations. The northernmost open bay stations (C and D) usually had the lowest number of M. mercenaria zoea collected on each sampling date. Stage I zoea dominated the catch on all dates at the stations near the plant. Later stage zoea were usually most numerous at the southern open bay stations (E). Seasonal abundance of M. mercenaria zoea at Big Bend is shown in Figure 2.3.

(iv) Penaeus duorarum Burkenroad (Pink shrimp)

Pink shrimp spawn offshore and the young enter the bays and estuaries as postlarvae. All P. duorarum collected during the present study were postlarval stages. P. duorarum postlarvae were first taken at open bay stations (C and E) in late June and early July. The number of larvae collected increased gradually to a small peak on July 31 (most common at Station B), steadily declined, then suddenly peaked on September 25. Only a few larvae were collected after September 25.

Postlarvae were collected at all stations on September 25, but were most numerous at the plant intake (Station A, 39/100m^3) and at the plant discharge (Station B, 29/100m^3), respectively. Postlarvae were always more numerous at night than during the day.

(v) Menidia beryllina Cope (Tidewater silverside)

Eggs of this species (which are demersal) were never collected during the present study. Larvae were collected in low numbers (always $\leq$2/100m^3) on every date between March 27 and July 3, 1979 but were absent during the rest of the year. Larvae were most common at Station C and were never taken at Station E (open bay).

(vi) Harengula jaguana Poey (Scaled sardine)*

Eggs and larvae of the scaled sardine were collected between April

* H. jaguana Poey, 1965 (=pensacolae) See Whitehead (1973).

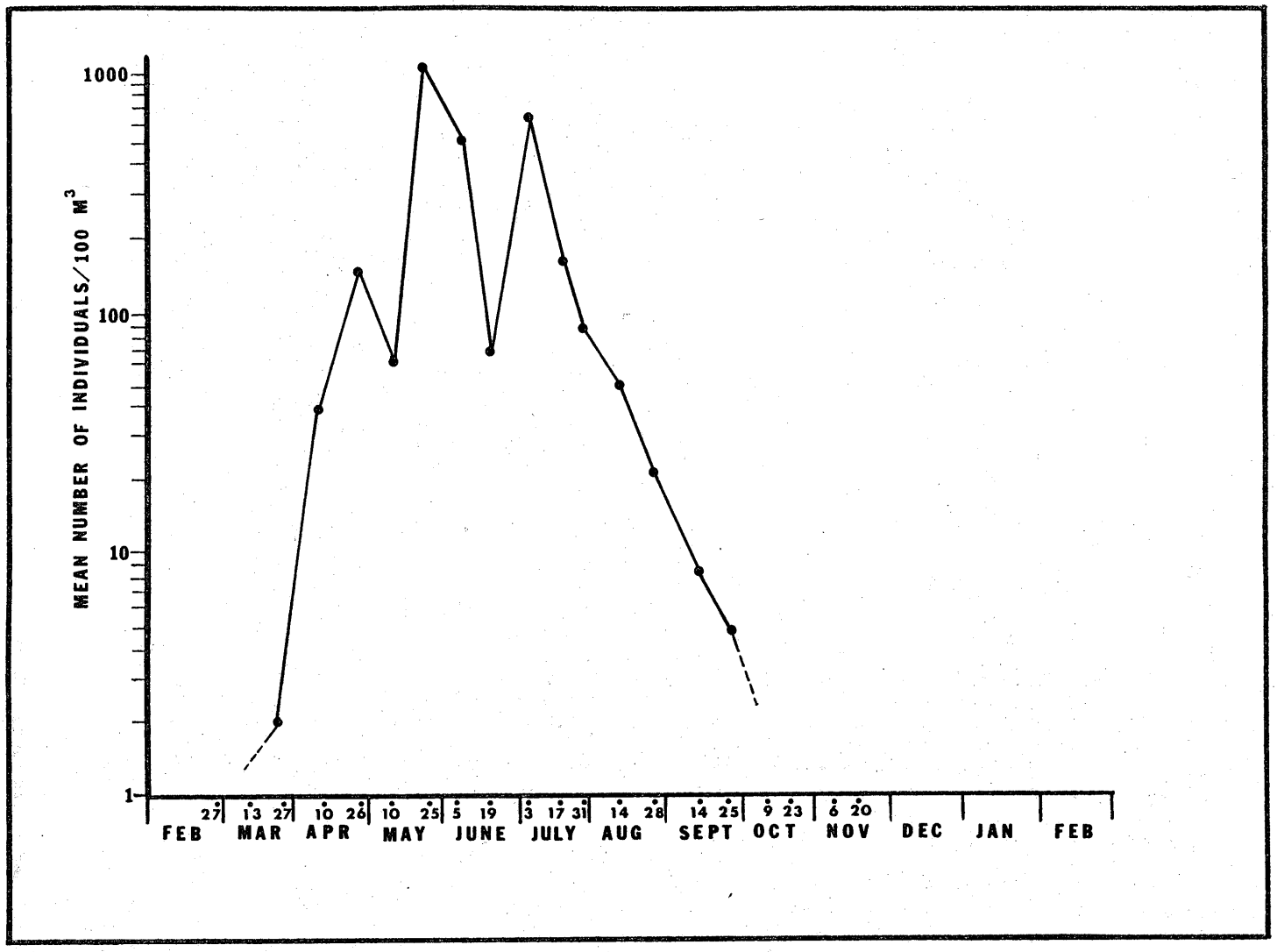

Figure 2.3. Mean densities (#/100 m^3) of Menippe mercenaria (zoea) during 1979.

26 and August 14, 1979. It is apparent that the majority of the spawning of this species occurred in the open bay (Station E). It appears that after hatching, the larvae are transported northward. Collections from the plant intake and discharge contained large numbers of larvae but only a few eggs. The area north of Big Bend was apparently not utilized as a spawning area by this species.

Seasonal abundances of H. jaguana eggs and larvae is presented graphically in Figure 2.4.

(vii) Sciaenidae (Drums)

As previously discussed in the limitations section, a large number of eggs which possessed characteristics common to the family Sciaenidae, but which could not be identified to species with certainty, were classified as unidentified Sciaenidae. Since at least nine species of Sciaenid are common in the Big Bend area, this group is certain to contain eggs of more than one species.

Sciaenid eggs were collected on all sampling dates except November 6, 1979. They were more common at the plant intake and discharge (Stations A and B) than at the open bay stations. Highest mean densities occurred between May 10 and July 3, 1979. Seasonal abundances are shown in Figure 2.5.

(viii) Cynoscion nebulosus (Cuvier) Spotted seatrout

Eggs of this species could not be identified with certainty because of the presence of C. arenarius in the Big Bend area. Hence, we identified eggs only to genus. Cynoscion spp. eggs were only collected between February 27 and June 5, 1979. Numbers were always very low. The highest density was at Station A on May 10 (32 eggs/100m^3).

C. nebulosus larvae were collected between March 13 and August 28, 1979. Densities were always low. Highest densities occurred at Station A on May 25 (10/100m^3) and at Station E on June 19 (11/100m^3). C. nebulosus larvae occurred more frequently at Station B (plant discharge) than at any other station.

(ix) Pogonias cromis (Linnaeus) Black drum

P. cromis eggs are larger than eggs of the other sciaenid species found in the Big Bend area, making them relatively easy to identify. Joseph, Massman, and Norcross (1964) described black drum eggs as having a mean diameter of 0.93 mm with an oil globule of 0.24 mm diameter. Discrete black dots on the oil globule and scattered pigmentation on the embryo are also diagnostic characteristics. We feel, therefore, that our identification of eggs of this species is reasonably accurate.

P. cromis eggs were collected from February 27 through June 19, 1979, although numbers were usually low. Peak densities occurred from April 10 through May 10, 1979. The largest number of eggs were collected at the open bay station (E). Black drum larvae were never common, but highest densities occurred at the plant intake (Station A).

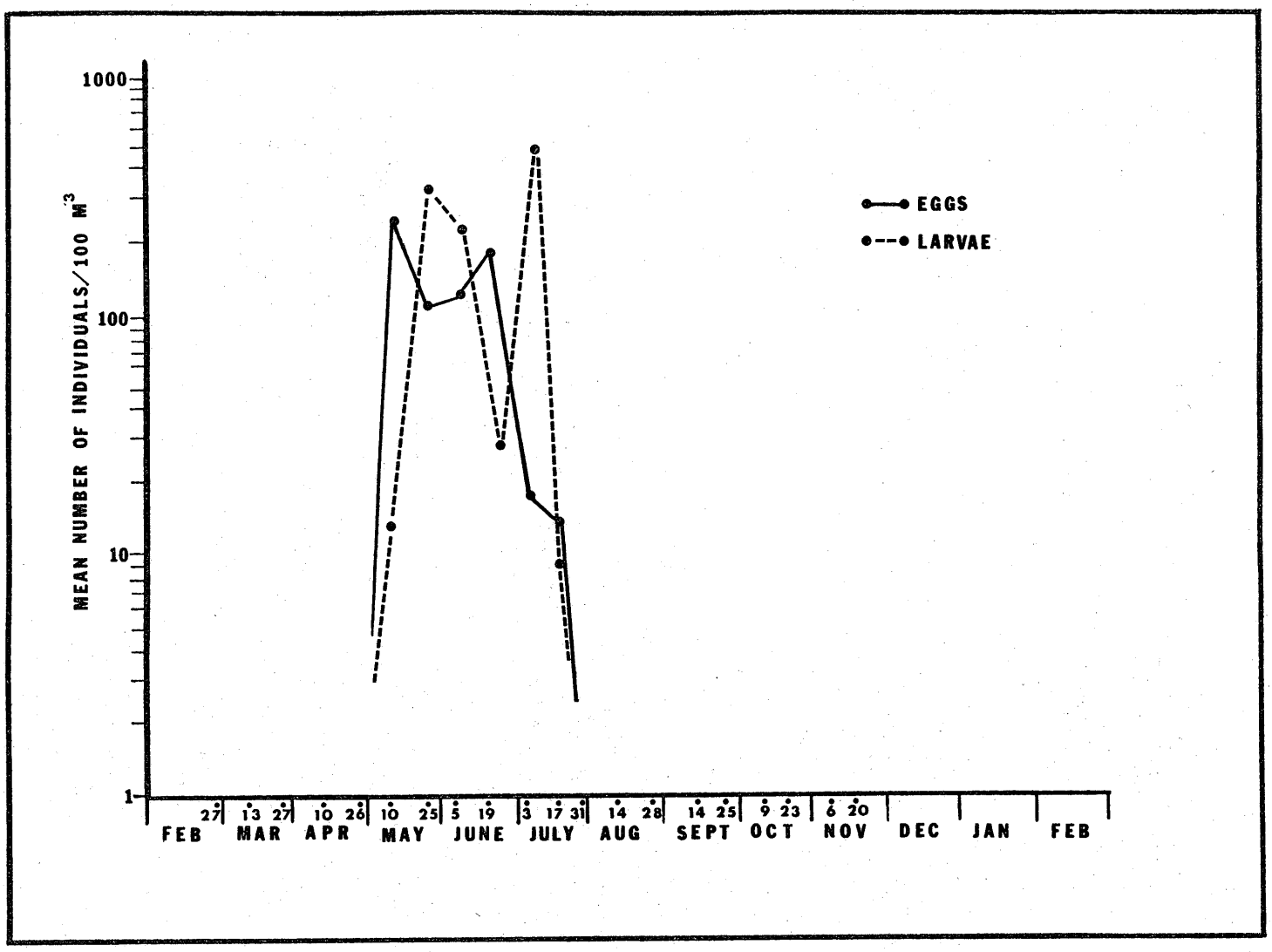

Figure 2.4. Mean densities of Harengula jaguana eggs and larvae during 1979.

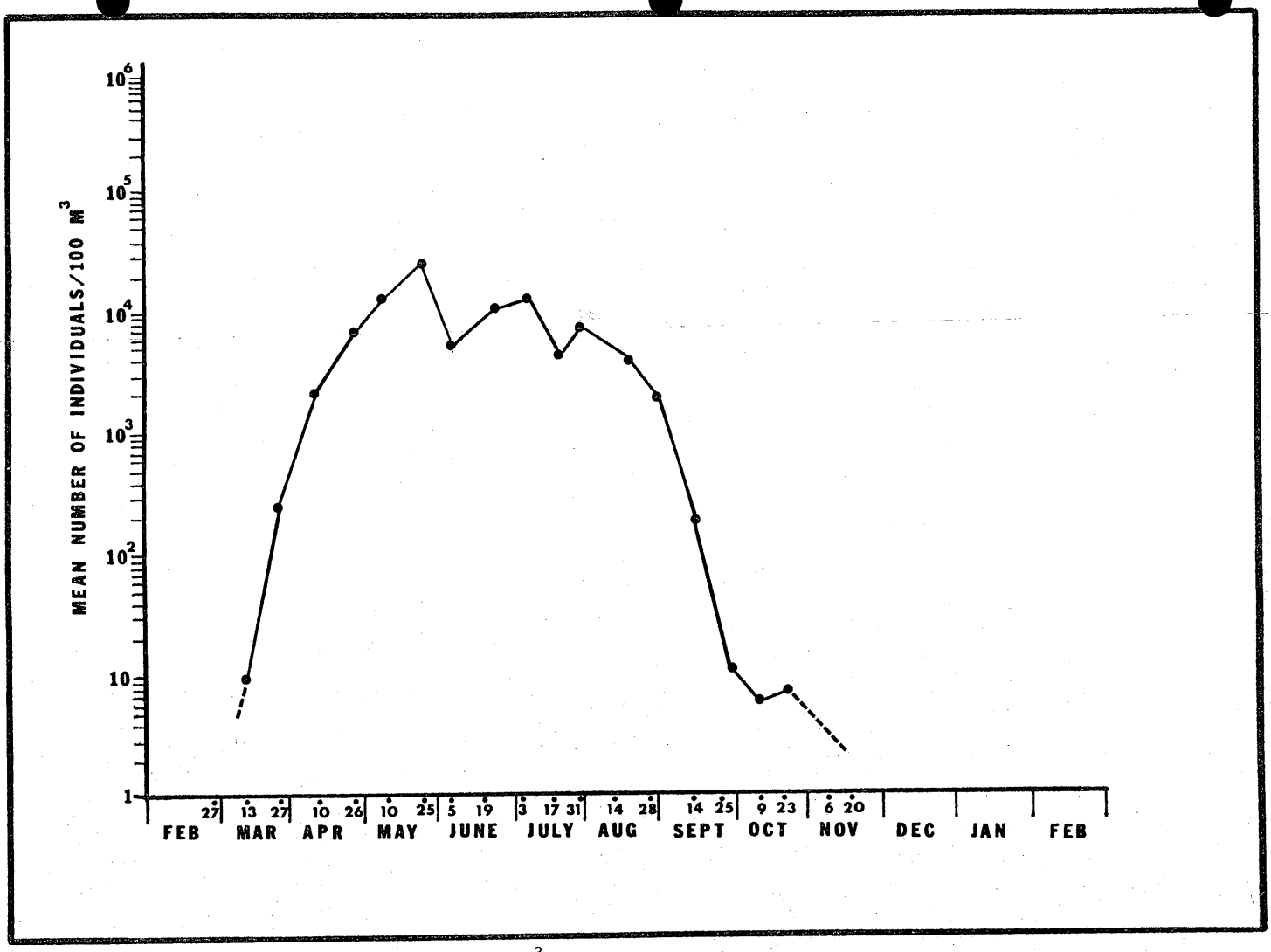

Figure 2.5. Mean densities (#/100 m^3) of sciaenid eggs at Big Bend during 1979.

(x) Bairdiella chrysura (Lacepede) (Silver perch)

B. chrysura eggs are typically sciaenid with a single pigmented oil globule ranging in size from 0.17 mm to 0.185 mm diameter. Total egg diameters range from 0.65 mm to 0.85 mm (Lippson and Moran, 1974).

B. chrysura eggs and larvae were collected on all dates between February 27 and July 31, 1979. Densities of both eggs and larvae were greatest on May 10, 1979. A spring peak of spawning was apparent but, a second peak in egg densities was noticed during the month of July. Eggs were always considerably more numerous than larvae. Seasonal abundances of B. chrysura eggs and larvae are shown in Figure 2.6.

(xi) Anchoa mitchilli (Valenciennes) (Bay anchovy)

Bay anchovy eggs and larvae were collected on all sampling dates between February 27 and November 6, 1979. Eggs were most numerous between March 13 and August 14, with peak densities occurring on June 5, 1979. Larval densities were highest between March 27 and August 28. Mean densities of A. mitchilli eggs and larvae are illustrated in Figure 2.7. Bay anchovy eggs and larvae were always more numerous than those of any other species.

Between March 13 and June 5, 1979, egg densities were highest at the two northermost stations (D and C). During late June and early July, densities were highest near the plant (Station A and B) and from July 17 through September 25, densities were greatest at the southern open bay station (E). It appears that the area of greatest spawning activity was in the northern parts of the study area early in the spring and gradually moved southward as time progressed. Although larval densities were always considerably less than egg densities, a similar spatial distribution was not evident. Larval densities throughout the study area were highly variable.

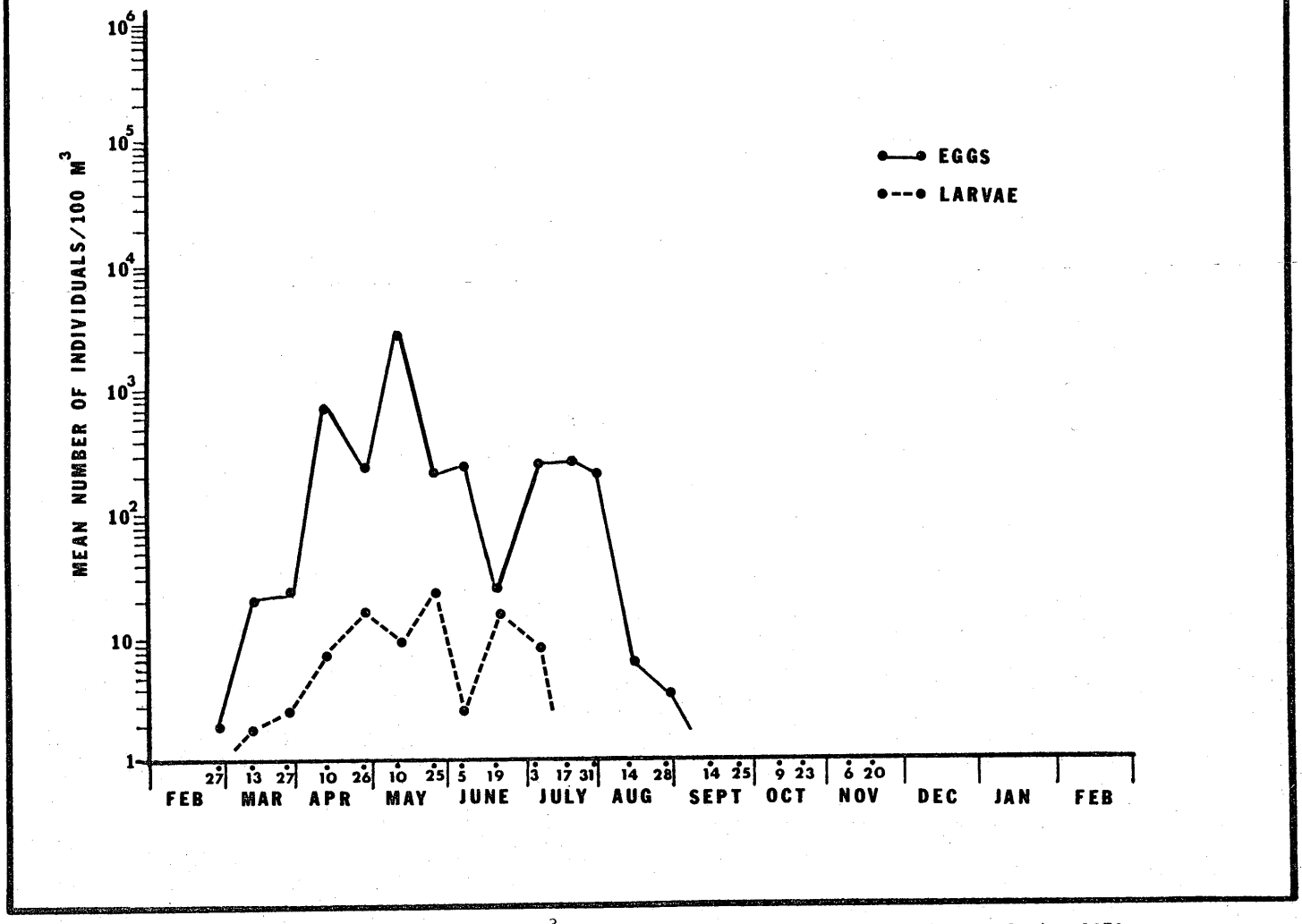

Figure 2.6. Mean densities (#/100 m^3) of Bairdiella chrysura eggs and larvae during 1979.

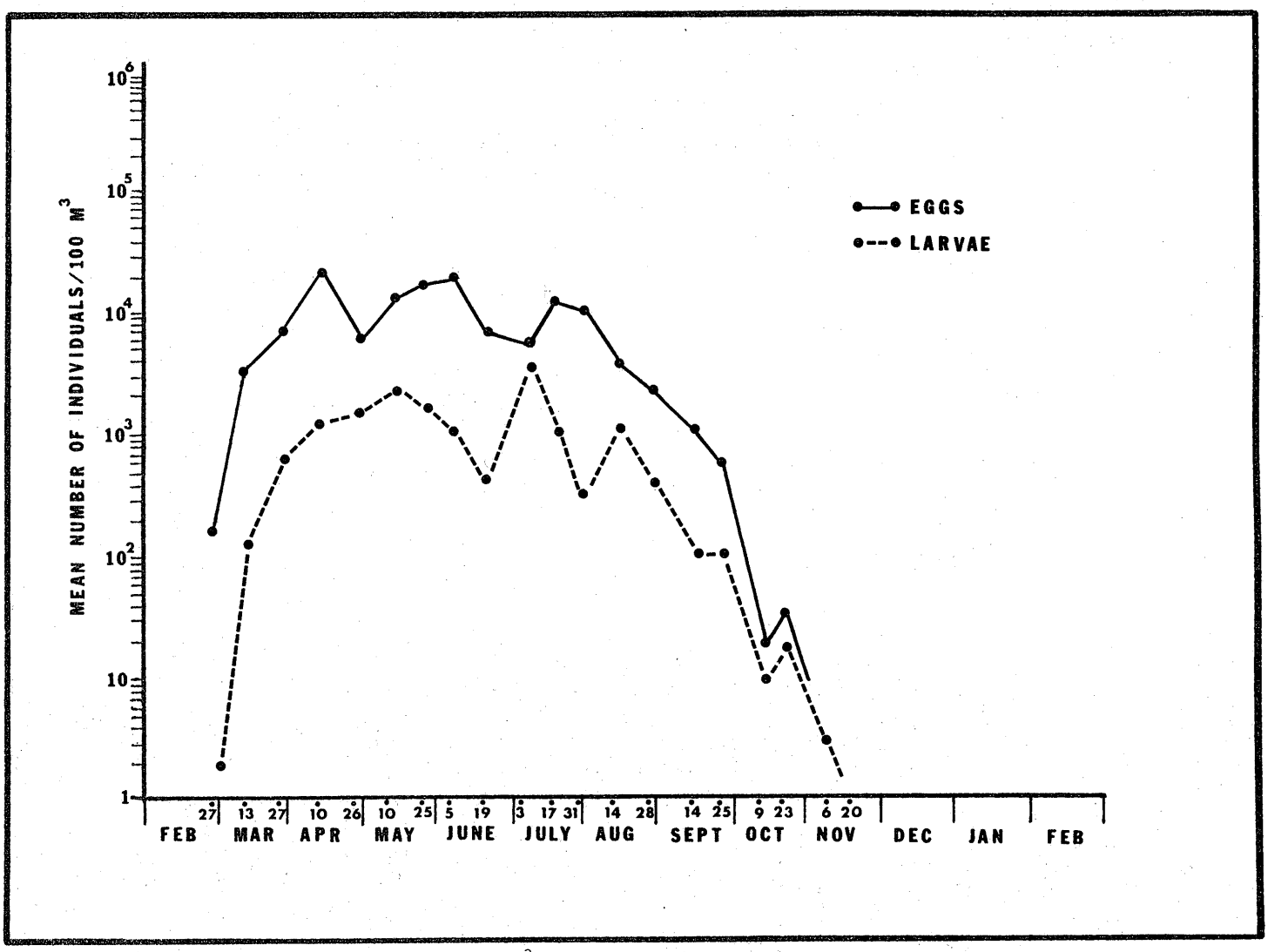

Figure 2.7. Mean densities (#/100 m^3) of Anchoa mitchilli eggs and larvae during 1979.

IV. DISCUSSION

The seasonal distribution and relative abundance of the eggs and early life stages of ten RIS were investigated in the vicinity of the Big Bend plant during 1979. Some life stages of several of the RIS were not taken during the study. Larvae of the American oyster, Crassostrea virginica were present in the water column but were not taken by the 505 µm mesh nets because they settle from the plankton at a smaller size. Callinectes sapidus (blue crab) zoea were not taken because they do not occur in the plankton in the Big Bend area. Early larvae of the pink shrimp (Penaeus duorarum) were not taken because this species enters the Big Bend area as postlarvae. Menidia beryllina (tidewater silverside) eggs were not taken because they are demersal rather than planktonic.

For the remaining RIS, seasonal data collected during 1979 and early 1980 was similar to a previous study (Phillips, 1977). The extended spawning period of many of the RIS (Menippe mercenaria, Anchoa mitchilli and the sciaenids) and the spring and early summer spawning peaks corresponded to earlier findings in the Big Bend area (Phillips, 1977).

Of the invertebrate RIS, stone crab larvae were by far the most abundant. The May through July peak in abundance was earlier than the September - October peak of a previous study (Blanchet, 1977) and the July through September peak reported for the St. Johns River during 1961 (Tagatz, 1968). Densities near the plant (Stations A and B), which were the highest of all stations sampled during the present study, were considerably higher than those found in the same area by Blanchet (1977). Densities reported in the present study and those reported by Blanchet (1977) were both much higher than those found by Tagatz (1968). This indicates that the area near the plant is probably an important one in terms of spawning of this commercially and recreationally exploited species. The plant intake canal probably harbors adults in the rock and rubble on its banks. Open bay stations are probably less densely inhabited by the adults and many of the zoeal stages collected at these stations were probably spawned elsewhere and carried to these stations by currents.

Among the fish studied, Menidia beryllina the tidewater silverside, appears important in the area because of its abundance (see chapter 3). It is probably one of the major forage species in the area but, because spawning occurs along the sand beaches rather than in the open bay, it is not an important constituent of the plankton in the area. Larvae of a related species, Membras martinica, the rough silverside, are probably more important as forage for the pelagic fish in the Big Bend area, since they are more abundant in areas away from the beaches (Phillips, 1977).

The scaled sardine, Harengula jaguana, spawn in the vicinity of the plant during the summer as shown by this and a previous study (TECO, 1977). Martinez and Houde (1975) described an April to May spawning period. While both studies at Big Bend indicate that spawning occurs between April and August near the plant, collections from the southern open bay station (E) indicate that a major portion of the spawning activity of this species may occur in the lower part of the bay, closer

to the Gulf. Some of the eggs and larvae of this species collected near the plant could have been carried into the area by water currents. Hillsborough Bay is apparently not a major spawning area for this species since only low numbers of larvae (and especially eggs) were collected north of the plant.

The sciaenid RIS were dominated by the early life stages of the silver perch, Bairdiella chrysura. The spring spawning peak was similar to that described by others (Hildebrand and Cable, 1930; Gunter, 1945; Jaanke, 1971; Phillips, 1976). Egg and larval densities were generally lower than those reported for Big Bend by Phillips (1976) but considerably higher than larval densities reported for Apalachicola Bay (Blanchet, 1979) or the Everglades (Jaanke, 1971). Finucane (unpublished data) found the greatest densities in the Tampa Bay area during 1971 - 73 occurred in southern Old Tampa Bay and in the ship channel just west of Big Bend. This would all tend to indicate that the lower Hillsborough Bay —upper Tampa Bay area is probably an important spawning ground for B. chrysura when compared to other parts of the west coast of Florida.

Other Sciaenid species such as the spotted seatrout, Cynoscion nebulosus, although collected during the present study, were only found in low numbers. The majority of spawning of this species probably occurs further south near the passes or over the grass beds along the southeastern shore of the bay. Eggs and larvae of the black drum, Pogonias cromis were collected in low numbers in the study area. The area near the plant is probably not a major spawning ground for this species.

The bay anchovy, as in an earlier study (TECO, 1977), was the predominant species spawning in the study area during 1979. Eggs and larvae of this species were always more abundant than those of any other fish species. The March through August peak in abundance coincides with the spring and summer spawning period attributed to this species by others (Gunter, 1945; Springer and Woodburn, 1960; Phillips, 1977; Blanchet, 1979). Present data suggests the possibility of a bimodal season with a peak in numbers of eggs in the spring, relatively low numbers during late June and early July followed by a second smaller peak in late July. A similar phenomenon has been noted by others (Phillips, 1976; Blanchet, 1979) but its significance is unknown.

The paucity of quantitative ichthyoplankton data from other parts of Florida makes it difficult to compare spawning of A. mitchilli in Tampa Bay with other areas. Collections in the St. Johns River (Seminole Electric Corp., 1978) contained virtually no A. mitchilli larvae during the daytime and averaged less than 65 larvae/100m^3 at night during March and April 1978. By comparison, our samples from the same months in 1979 averaged greater than 800 larvae/100m^3. Neither temperatures nor salinities at the St. John's sampling sites are given, making comparison difficult. Finucane (unpublished data) recorded A. mitchilli larvae only in the Hillsborough Bay area and southern Old Tampa Bay in a study of the greater Tampa Bay area. His highest densities occurred in the ship channel just west of Big Bend. The numbers/100m^3 of both eggs and larvae during the peak spawning period (April-June) in a previous study (Phillips, 1976) were generally three to four times greater than those collected in the present study. This may be due in part to the difference

in mesh sizes of the collecting gear or may be due to natural environmentally induced fluctuations. Spring and summer A. mitchilli egg and larval densities at Big Bend during 1979 are generally two to six times greater than those reported for Apalachicola Bay by Blanchet (1979) during the same time of year. It can be concluded that the lower Hillsborough Bay - upper Tampa Bay area is obviously an important one in terms of its use as a spawning ground for A. mitchilli.

It is interesting to note the apparent shift in the spatial abundance of A. mitchilli eggs from the northern portion of the study area early in the study, through the vicinity of the power plant during the summer to the more southern portion of the study area later in the summer and during the early fall. Earlier studies of the Big Bend system, because of their limited study area, did not show this trend. Blanchet (1979) found abundance of A. mitchilli eggs greatest between salinities of 20 and 25 °/oo in Apalachicola Bay. The trend of lowering salinities over the summer season seen in the study area (Appendix 2D) possibly result in a general southernly movement of the spawning area into more preferred salinities. The amount of food available to the adults, or other factors, might also be influencing this pattern.

It is well known that in natural fish communities large seasonal and year to year fluctuations occur. In addition, communities can be altered in their species composition over a period of years. Many factors can control such changes. In order to understand alterations in community structure, it is necessary to have a large data base collected over a period of years (Leggett, 1977). No long term quantitative studies of the fish populations, either larval or adult, exist for Tampa Bay. Direct comprisons with previous studies (Sykes and Finucane, 1966; Phillips, 1977) are not possible due to differences in stations sampled, sampling frequency and the variety of mesh sizes used. Data from the present study is adequate to delineate spatial and temporal distributions between February 1979 and February 1980, but any extrapolations should be undertaken with extreme caution.

V. SUMMARY AND CONCLUSIONS

1. The present study and other data from the Tampa Bay area indicate that the aquatic habitats near the TECO Big Bend Power Plant play an important role as spawning grounds for at least some species of invertebrates and vertebrates.

2. Menippe mercenaria, the stone crab; Anchoa mitchilli, the bay anchovy; Bairdiella chrysura, the silver perch; and Harengula jaguana, the scaled sardine utilize the area near the plant for spawning during the spring and summer. Some stages of all but H. jaguana reached densities greater than $1000/100m^3$ sometime during the spring or summer. H. jaguana reached densities around $500/100m^3$.

3. A. mitchilli eggs and larvae were the most common of the RIS investigated. Sciaenid eggs and B. chrysura larvae were also collected in large numbers. M. mercenaria was the most commonly collected invertebrate RIS.

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Appendix 2A. Meroplankton sampling schedule.

Day trip		Night trip	
1205 to 1830	2/27/79	2145 2/27 to 0240	2/28
1240 to 1636	3/13/79	2005 to 2323	3/13
1120 to 1448	3/27/79	2000 to 2322	3/27
1140 to 1522	4/10/79	1930 to 2350	4/10
1318 to 1634	4/26/79	1950 to 2330	4/26
1712 to 2000	5/10/79	0025 to 0530	5/11
1415 to 1756	5/25/79	2204 5/24 to 0059	5/25
1430 to 1757	6/5/79	2115 6/5 to 0150	6/6
1359 to 1830	6/19/79	2145 6/19 to 0110	6/20
1430 to 1822	7/3/79	2052 7/3 to 0140	7/4
1340 to 1925	7/17/79	2245 7/17 to 0220	7/18
1739 to 2125	7/31/79	2240 7/31 to 0328	8/1
1327 to 1730	8/14/79	2148 8/14 to 0052	8/15
1540 to 1845	8/28/79	2155 8/28 to 0317	8/29
1300 to 1700	9/14/79	2050 9/14 to 0020	9/15
1601 to 1841	9/25/79	2100 9/25 to 0225	9/26
1445 to 1900	10/9/79	2127 10/9 to 0030	10/10
1432 to 1745	10/23/79	1930 10/23 to 0025	10/24
1349 to 1722	11/6/79	1945 to 2305	11/6
1131 to 1634	11/20/79	2021 11/20 to 0100	11/21
1348 to 1735	12/4/79	1935 to 2303	12/4
1407 to 1720	12/18/79	1915 12/18 to 0040	12/19
1356 to 1804	1/2/80	1930 to 2314	1/2
1520 to 1830	1/17/80	2015 1/17 to 0030	1/18
1345 to 1800	1/29/80	2145 1/29 to 0127	1/30
0828 to 1143	2/12/80	1936 to 2354	2/12

Appendix 2B. Surface temperatures (°C) at meroplankton sampling stations.

Sampling Date	Station A		B		C		D		E	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
2/27/79	16.5	16.0	24.0	24.0	17.2	16.5	16.7	17.5	17.0	17.0
3/13/79	19.5	19.0	21.5	23.3	18.5	18.5	19.0	19.2	17.8	18.5
3/27/79	19.5	19.5	26.5	27.0	19.5	19.0	19.5	18.5	19.0	20.0
4/10/79	25.0	25.0	33.0	33.5	24.0	24.0	24.0	24.0	23.5	24.0
4/26/79	25.0	24.5	34.0	33.8	24.0	24.0	23.0	23.5	23.0	24.0
5/10/79	28.0	27.0	37.0	36.0	26.5	26.0	27.5	26.5	27.5	26.0
5/25/79	26.5	26.0	27.0	26.5	26.0	26.0	27.0	26.0	26.5	26.5
6/5/79	30.5	30.0	37.5	37.5	30.0	29.5	29.5	29.0	29.5	28.5
6/19/79	31.0	30.0	37.0	34.5	29.5	29.0	29.0	28.5	29.0	29.0
7/3/79	32.0	31.5	39.0	39.0	31.0	30.5	31.0	30.0	31.0	30.5
7/17/79	30.5	29.0	31.0	37.5	30.5	28.0	31.5	27.5	30.5	28.0
7/31/79	32.0	32.0	40.0	37.0	32.0	30.5	31.0	30.5	31.0	30.5
8/14/79	31.0	30.0	37.0	35.5	30.5	29.0	28.5	29.0	30.0	29.5
8/28/79	30.5	29.5	38.5	38.5	30.5	29.5	30.0	30.0	30.0	29.5
9/14/79	29.0	28.5	36.0	33.5	28.0	28.0	27.5	28.0	27.5	28.0
9/25/79	29.0	28.5	37.0	37.0	29.0	27.5	28.5	27.5	29.5	27.5
10/9/79	27.5	27.0	35.5	33.0	27.0	26.5	26.5	26.5	27.0	26.0
10/23/79	27.0	26.5	35.0	35.5	27.0	26.0	27.5	26.0	27.0	26.5
11/6/79	23.0	22.5	31.0	32.0	22.5	22.5	23.0	22.5	22.5	22.5
11/20/79	21.5	21.5	28.5	22.5	20.5	20.0	21.0	21.0	20.0	21.0
12/4/79	16.0	16.0	24.0	21.0	16.0	16.5	17.5	16.0	16.5	16.5
12/18/79	17.5	16.5	24.5	26.0	18.0	17.5	18.0	17.0	18.5	17.5
1/2/80	16.0	16.0	22.0	16.0	16.0	16.0	16.0	16.0	16.5	16.5
1/17/80	19.0	18.5	26.5	26.0	19.0	18.5	19.0	18.5	18.5	18.0
1/29/80	18.5	18.0	25.5	24.5	18.5	18.0	18.5	18.0	18.5	18.0
2/12/80	15.0	15.0	22.5	24.5	14.5	14.5	14.5	15.0	14.0	14.5

Appendix 2 C. Surface dissolved oxygen (ppm) at meroplankton sampling stations.

Sampling Date	Station									
	A		B		C		D		E	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
2-27-79	9.7	9.1	9.1	8.6	9.4	9.3	9.2	8.7	8.4	8.9
3-13-79	12.5	10.8	8.9	9.0	11.0	12.4	15.8	11.6	9.2	9.5
3-27-79	10.8	9.1	8.7	8.8	10.0	10.4	10.4	9.4	8.7	9.5
4-10-79	8.9	8.5	7.6	8.0	8.2	8.5	8.3	6.7	8.8	9.0
4-26-79	10.8	8.9	10.2	8.5	9.2	8.6	7.8	8.1	8.0	9.4
5-10-79	10.4	7.2	8.7	8.2	8.7	8.5	10.0	8.1	11.2	11.0
5-25-79	6.8	12.3	5.8	10.0	8.1	9.0	8.3	10.8	8.1	7.6
6-5-79	8.7	7.4	5.4	7.5	14.0	9.9	11.4	9.6	9.7	10.6
6-19-79	10.0	8.5	4.9	6.0	8.7	7.8	10.8	9.2	7.8	10.4
7-3-79	7.9	6.6	7.3	5.9	11.4	4.6	11.8	7.0	8.5	8.8
7-17-79	8.8	11.6	6.2	9.5	10.2	8.3	10.8	7.7	7.7	9.5
7-31-79	9.3	7.0	7.7	6.4	8.1	6.7	10.6	8.8	9.1	7.9
8-14-79	7.8	1.9	5.5	7.9	14.4	1.3	14.6	11.4	9.3	9.6
8-28-79	9.5	6.7	5.9	4.2	8.5	6.7	9.2	9.0	8.1	7.2
9-14-79	9.3	8.1	7.5	8.2	9.9	8.4	9.3	8.6	8.7	9.2
9-25-79	9.7	8.8	6.9	6.1	9.8	6.3	8.0	6.7	9.8	6.7
10-9-79	12.8	8.6	7.1	6.4	10.1	8.9	10.2	6.5	9.4	6.1
10-23-79	11.0	9.2	8.5	8.4	10.4	9.8	12.4	11.0	10.4	9.7
11-6-79	9.5	9.1	7.5	8.0	10.4	10.2	11.0	10.2	8.1	9.5
11-20-79	8.8	7.8	7.6	8.0	8.8	8.3	10.8	11.0	9.5	9.7
12-4-79	11.2	11.2	11.2	11.0	10.4	10.6	11.4	11.0	10.2	9.5
12-18-79	8.7	8.3	8.2	8.5	9.1	8.6	10.6	9.5	8.5	8.8
1-2-80	9.2	9.3	9.7	9.3	10.2	10.0	10.2	9.5	9.1	9.3
1-17-80	9.5	8.3	10.4	7.6	10.4	9.6	11.9	10.8	9.6	10.1
1-29-80	12.8	11.0	10.2	9.8	11.4	10.8	9.7	9.6	8.5	8.7
2-12-80	11.0	11.6	9.7	11.4	10.4	10.5	9.6	9.7	9.6	9.2

Appendix 2 D. Surface salinities ($^{o}/oo$) at meroplankton sampling stations.

Sampling Date	Stations A		B		C		D		E	
	Day	Night	Day	Night	Day	Night	Day	Night	Day	Night
2-27-79	22.5	22.5	22.5	23.5	24.0	24.0	23.5	24.0	26.0	25.5
3-13-79	21.0	21.5	23.0	22.5	22.0	21.0	20.0	19.5	25.0	24.0
3-27-79	22.5	22.5	23.5	23.0	23.0	23.0	21.0	21.0	25.0	25.0
4-10-79	25.0	25.0	25.0	25.5	24.5	24.0	23.0	22.5	26.0	25.0
4-26-79	25.5	25.5	26.0	26.0	25.5	25.0	24.0	23.5	25.5	26.0
5-10-79	25.5	25.5	26.0	25.5	23.5	24.0	21.0	21.0	26.0	25.5
5-25-79	22.5	22.5	22.5	22.0	22.0	22.0	19.0	20.0	25.5	22.5
6-5-79	21.0	21.0	22.5	21.5	21.0	22.0	21.0	21.0	25.0	24.0
6-19-79	23.5	23.5	25.0	24.0	22.5	24.0	23.5	23.5	23.5	25.5
7-3-79	25.5	25.5	25.5	26.0	24.0	25.0	23.5	24.0	25.5	27.0
7-17-79	21.0	23.5	24.5	25.5	23.5	22.5	23.5	23.0	26.0	26.0
7-31-79	24.0	24.5	25.0	25.0	25.0	24.0	22.5	23.0	25.5	26.0
8-14-79	24.0	24.0	25.0	24.0	21.0	21.0	20.5	20.0	23.5	26.0
8-28-79	24.0	24.0	25.0	25.0	23.5	23.0	17.0	17.0	23.5	25.5
9-14-79	21.0	21.0	22.5	21.0	19.5	20.0	18.0	18.5	22.0	22.0
9-25-79	16.0	16.5	19.0	18.5	13.0	12.0	9.0	8.5	18.0	18.5
10-9-79	12.0	12.5	14.0	14.0	12.5	12.0	9.5	10.0	13.0	16.0
10-23-79	20.0	19.0	20.5	21.0	20.5	19.0	18.0	17.0	20.0	20.0
11-6-79	18.5	20.5	21.0	21.0	20.0	21.0	20.0	20.0	22.0	22.5
11-20-79	23.5	24.0	24.0	24.0	23.5	24.0	22.5	22.5	25.0	24.5
12-4-79	23.0	22.5	24.5	23.5	21.0	23.5	22.5	22.5	25.0	25.0
12-18-79	22.5	23.5	24.0	24.0	24.0	24.0	23.5	23.5	26.0	26.0
1-2-80	24.0	23.5	23.5	24.0	24.0	24.0	23.5	23.5	25.5	26.0
1-17-80	22.5	25.5	25.0	26.0	25.0	23.5	22.5	22.5	25.0	25.0
1-29-80	23.5	24.0	24.0	25.0	22.5	24.0	22.5	22.5	24.0	25.5
2-12-80	22.5	23.5	25.0	22.5	22.0	24.0	19.5	23.5	23.5	25.0

Appendix 2 E. Density of Menippe mercenaria zoea at meroplankton sampling stations, 1979-80 (#/100m^3).

Sample Date	Station					Mean Density ($\bar{x}$/100 m^3)
	A	B	C	D	E	
3-13-79	2		1			0
3-27-79	1	7	2			2
4-10-79	89	69	5	2	7	34
4-26-79	469	207	6	3	48	147
5-10-79	141	126	22	8	12	61
5-25-79	917	4283	12	12	29	1051
6- 5-79	401	2298	27	22	38	556
6-19-79	94	218	6	4	42	73
7- 3-79	1006	2035	33	42	112	645
7-17-79	115	479	2	11	214	164
7-31-79	48	245	54	3	89	87
8-14-79	47	181	2	0	34	53
8-28-79	11	49	10	4	29	21
9-14-79	8	15	4	2	10	8
9-25-79	2	11	3	2	5	5
10-9-79		1			2	0
10-23-79					1	0
11-6-79	2	1	1	1	1	1
11-20-79		1			1	0

Appendix 2 F. Density of Penaeus duorarum postlarvae at meroplankton stations, 1979-80 (#/100m^3).

Sampling Date		Station				
		A	B	C	D	E
6-19-79	D					
	N					3
7-3-79	D					
	N			4		2
7-17-79	D					1
	N		7	3	7	29
7-31-79	D	1	37			
	N	11	25	10	5	
8-14-79	D					
	N		2		1	
8-28-79	D				1	
	N	1	2	1		
9-14-79	D					
	N		2	2	2	4
9-25-79	D		1			
	N	41	27	7	1	5
10-9-79	D					
	N					
10-23-79	D					
	N			1		
11-6-79	D		1			
	N					
11-20-79	D					
	N					1
12-4-79	D					
	N					
12-18-79	D					1
	N					1

Appendix 2 G. Density of *Menidia beryllina* larvae at meroplankton stations, 1979-80 (#/100m^3).

Sampling Date	Station				
	A	B	C	D	E
3-27-79	1	1	1	1	
4-10-79	1			1	
4-26-79			2		
5-10-79	1		1	1	
5-25-79	1				
6-5-79	1	1	2		
6-19-79		1			
7-3-79			1		

Appendix 2H. Density of Harengula jaguana eggs and larvae. (E = eggs; L = larvae).

Sampling Date		Station					Mean Density ($\bar{x}$/100 m^3)
		A	B	C	D	E	
4-26-79	E	0	0	0	0	0	0
	L	1	1	0	0	2	1
5-10-79	E	0	0	0	0	1275	255
	L	0	0	0	0	70	14
5-25-79	E	6	0	1	0	562	114
	L	520	664	19	4	426	327
6-5-79	E	74	12	0	8	596	138
	L	561	116	8	19	369	215
6-19-79	E	1	145	0	1	767	183
	L	81	14	6	2	45	30
7-3-79	E	1	8	0	0	82	18
	L	1275	1020	12	18	245	514
7-17-79	E	6	16			51	15
	L	24	4			16	10
7-31-79	E		5				1
	L				1		0
8-14-79	E						0
	L				1		0

Appendix 2 I. Density of Unidentified Sciaenid eggs and larvae. at meroplankton stations 1979-80 (#/100m^3).

Sample Date		Station A	B	C	D	E	Mean Density ($\bar{x}$/100 m^3)
2-27-79	E	1	2	1	1	7	2
	L	0	0	0	0	0	0
3-13-79	E	7	14	2	2	23	10
	L	0	0	0	0	0	0
3-27-79	E	7	11	33	126	1051	246
	L	1	0	0	0	0	0
4-10-79	E	1372	1983	1239	886	3914	1879
	L	0	0	0	1	1	0
4-26-79	E	11,037	6788	6590	374	5968	6151
	L	0	0	0	0	1	0
5-10-79	E	21,132	20,789	3923	482	3945	10,054
	L	1	1	2	1	0	1
5-25-79	E	29,158	91,017	6033	4969	716	26,379
	L	1	0	1	0	1	1
6-5-79	E	3655	5467	2842	4927	5712	4721
	L	2	0	0	1	2	1
6-19-79	E	14,265	25,277	4321	1316	7542	10,544
	L	1	0	0	0	0	0
7-3-79	E	24,088	26,945	3426	659	5483	12,120
	L	1	0	0	0	0	0
7-17-79	E	2301	12,208	165	1186	2310	3634
	L	0	0	0	0	0	0
7-31-79	E	6052	7835	52	27	25,344	7862
	L	0	0	0	0	0	0
8-14-79	E	570	568	676	681	13,653	3230
	L	1	0	0	0	0	0
8-28-79	E	53	39	133	1	783	202
	L	0	0	0	0	0	0
9-14-79	E	5	11	531	21	247	163
	L	0	0	0	0	0	0
9-25-79	E		1			57	12
	L		0			0	0
10-9-79	E					31	6
	L					0	0
10-23-79	E	3	8	4	18	5	8
	L					0	0
11-6-79	E						0
	L						0
11-20-79	E		2				0
	L						0

Appendix 2J. Density of Cynoscion spp. eggs during day and night at meroplankton stations 1979-80 (#/100m^3).

Sampling Date		Station A	B	C	D	E	Mean Density ($\bar{x}$/100 m^3)
2-27-79	D						
	N				1	1	0
3-13-79	D	1	2	1	2	6	2
	N		1				0
3-27-79	D	1		1		3	1
	N	1		1			0
4-10-79	D			1		4	1
	N				1	4	1
4-26-79	D	4		1	2	11	3
	N			9		1	2
5-10-79	D	32				2	7
	N					1	0
5-25-79	D	4		3	1		2
	N						0
6-5-79	D						0
	N		2				0

Appendix 2K. Density of Cynoscion nebulosus larvae at meroplankton stations 1979-80 (#/100m^3).

Sampling Date		Station					Mean Density ($\bar{x}$/100 m^3)
		A	B	C	D	E	
3-13-79	L		1	1	1		1
3-27-79	L	1		1	1	1	1
4-10-79	L		1				0
4-26-79	L	1				3	1
5-10-79	L			1		1	0
5-25-79	L	3	10	2			3
6-5-79	L	2	4				1
6-19-79	L		2			11	3
7-3-79	L	4	4	1	1	1	2
7-17-79	L		1			1	0
7-31-79	L			1		1	0
8-14-79	L						0
8-28-79	L		1				0

Appendix 2 L. Density of Pogonias cromis eggs and larvae at meroplankton stations 1979-80 (#/100m^3).

Sampling Date		Station					Mean Density ($\bar{x}$/100 m^3)
		A	B	C	D	E	
2-27-79	E		1			1	0
	L		1				0
3-13-79	E		1		1		0
	L	1	1	1	1		1
3-27-79	E		1	1	1		1
	L	2		2	2	1	1
4-10-79	E	1		2	10	101	23
	L	2		1	3	1	1
4-26-79	E	1		1	9		2
	L	4	1	3		5	3
5-10-79	E	53	3				11
	L	2		2	1	1	1
5-25-79	E	2				4	1
	L		4	1			1
6-5-79	E	1				2	1
	L	2					<1
6-19-79	E				6	2	1
	L		1				<1
7-3-79	E						0
	L	1					<1
7-17-79	E						
	L						

Appendix 2 M. Density of Bairdiella chrysura eggs and larvae at meroplankton stations 1979-80 (#/100m^3).

Sampling Date		Station A	B	C	D	E	Mean Density ($\bar{x}$/100 m^3)
2-27-79	E	1	1	2	1	3	2
	L	0	0	1	1	1	1
3-13-79	E	13	18	14	3	51	20
	L	4	2	2	2	1	2
3-27-79	E	8	12	14	2	76	22
	L	4	2	4	2	2	3
4-10-79	E	169	42	676	287	2404	716
	L	6	9	13	9	1	8
4-26-79	E	145	59	302	130	571	241
	L	4	54	14	2	11	17
5-10-79	E	10,306	1534	2753	1	35	2926
	L	4	12	13	7	14	10
5-25-79	E	145	100	26	162	719	230
	L	17	58	14	29	0	24
6-5-79	E	10	698	0	69	440	243
	L	4	4	0	4	5	3
6-19-79	E	2	38	0	1	82	25
	L	2	5	6	3	76	18
7-3-79	E	3	1294	0	0	22	264
	L	1	6	1	1	9	9
7-17-79	E	805	478	0	0	80	273
	L	0	0	0	0	2	0.4
7-31-79	E	396	793	1	0	1	238
	L	0	0	0	0	1	0.2
8-14-79	E	1	31	0	0	5	7
	L	0	0	0	0	0	0
8-28-79	E	2	0	0	0	0	0.4
	L	0	0	0	0	0	0
9-14-79	E	0	0	0	1	2	0.6
	L	0	0	0	0	0	0
9-25-79	E	0	0	0	0	0	0
	L	0	1	0	0	0	<1

Appendix 2N. Density of Anchoa mitchilli eggs and larvae at meroplankton stations 1979-80 (#/100m^3).

Sampling Date		Station					Mean Density ($\bar{x}$/100 m^3)
		A	B	C	D	E	
2-27-79	E	175	156	140	312	35	164
	L	1	5	2	3	0	2
3-13-79	E	2423	2817	3129	7081	562	3202
	L	168	74	101	332	5	136
3-27-79	E	2424	1910	14,599	9899	7603	7287
	L	602	777	1502	368	89	668
4-10-79	E	10,454	4459	32,197	36,422	17,470	20,200
	L	1353	946	980	1731	94	1021
4-26-79	E	1202	842	19,701	12,357	11	6823
	L	368	1191	4806	482	853	1540
5-10-79	E	6074	2225	39,478	26,950	39	14,953
	L	2033	5727	2886	1145	765	2511
5-25-79	E	18,478	24,022	33,585	13,870	2	17,991
	L	638	2770	2310	2515	57	1658
6-5-79	E	17,148	8075	74,136	8906	1	21,653
	L	1395	2702	730	454	14	1059
6-19-79	E	12,484	12,804	2859	7806	510	7293
	L	762	666	529	370	150	495
7-3-79	E	18,295	1780	2429	11,817	45	6866
	L	6615	6059	4190	4239	259	4272
7-17-79	E	13,358	3500	654	10,633	45,355	14,700
	L	454	724	289	2535	1238	1048
7-31-79	E	26,868	16,086	10	657	20,419	12,808
	L	94	175	109	79	1425	376
8-14-79	E	1297	1509	2739	3891	12,706	4428
	L	409	1510	656	650	2849	1215
8-28-79	E	1467	1576	3212	143	6117	2503
	L	64	616	978	288	225	434
9-14-79	E	175	95	2100	230	3358	1192
	L	186	53	219	55	73	117
9-25-79	E	397	740	35	24	2213	682
	L	106	158	180	15	123	116
10-9-79	E	0	2	27	1	76	21
	L	6	3	13	7	35	13
10-23-79	E	0	2	12	2	175	38
	L	1	18	12	15	53	20
11-6-79	E	0	0	1	0	1	4
	L	1	3	8	4	5	4
11-20-79	E	0	0	0	0	0	0
	L	0	2	0	1	2	1

CHAPTER THREE

A STUDY OF THE FISH AND INVERTEBRATE POPULATIONS OF LOWER TAMPA BAY

BY

GARY S. COMP

CHAPTER THREE

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I. INTRODUCTION

Fish and invertebrate communities are often studied in relation to environmental impact due to their diversity and ubiquity in many marine and estuarine systems. Long and short term changes in community structure often indicate stress. This stress can be manifested in a diversion from established trends in migration, seasonality, diversity and relative abundance.

This chapter deals with the portion of the 1979 Aquatic Biology Study at Big Bend that was designed to collect data on the relative abundance and seasonality of Adult Fish and Invertebrate Communities. Animals were sampled with trawls and seines and also collected on the traveling screens at the Big Bend Power Station. These data can be used in conjunction with the meroplankton (Chapter 2) and fecundity (Chapter 4) data for the purpose of obtaining an overview of the dynamics of the fish and invertebrate communities in the area. This information, along with the data collected in the Big Bend area in previous studies, can serve as a basis for predicting community changes that may occur in response to planned power plant expansion.

While data were collected on all captured adult fishes and macroinvertebrates, detailed information was collected on a group of Representative Important Species (RIS). This RIS included:

Pink shrimp (Penaeus duorarum)
Blue crab (Callinectes sapidus)
Stone crab (Menippe mercenaria)
Bay anchovy (Anchoa mitchilli)
Scaled sardine (Harengula jaguana)*
Tidewater silverside (Menidia beryllina)
Silver perch (Bairdiella chrysura)
Spotted seatrout (Cynoscion nebulosus)
Black drum (Pogonias cromis)

*The scaled sardine was formerly referred to as H. pensacolae. Whitehead (1973) has presented evidence which indicated that H. jaguana is the preferred name for this species.

II. MATERIALS AND METHODS

a) Field

(i) Seine

Locations of seine and trawl sampling stations are depicted in Figure 3.1.

Seining occurred every 4 weeks at high tide between March 14, 1979 and January 15, 1980 at the four designated stations. The seine was 150' X 6' and was constructed of 3/4" stretch mesh multifilament nylon. A 4' X 4' X 12' bag constructed of 1/2" stretch mesh multifilament nylon was added to the center of the seine. Two panels of 1/2" stretch mesh multifilament nylon were added on either side of the bag to facilitate the collection of small specimens.

The seine was deployed by boat at the three open water stations (W, X and Z). Since Station Y was inaccessible by boat, the seine was set by hand at this location. Due to unusually low water levels at high tide on January 15, 1980, the seine had to be set by hand at all stations except Station Z. All seine stations were located by using specific landmarks. One haul was collected at each station.

When the boat was used to set the seine, the set was made in the following manner: One end of the seine was anchored to the shore. The seine was payed out as the boat backed perpendicular to the shoreline. When approximately 3/4 of the seine was deployed, the boat changed course and began to form a semi-circular configuration with the net. The semi-circular formation was completed as the net was dragged toward shore by the boat. This configuration enclosed the area that was being sampled. The two ends of the seine were drawn together as the net was hauled onto the beach. The bag was the last part of the seine removed from the water.

The catches were emptied into doubly labeled (internal and external) one gallon plastic containers. The catches were preserved with 10% buffered formalin and seawater. Station location, time of day, and any unusual occurrences were recorded in a bound notebook. Any large specimens other than RIS were identified in the field and released alive. The number and identity of all released specimens were recorded in the field notebook.

(ii) Trawl

Trawl samples were collected every four weeks and coincided with the collection of meroplankton samples (See Chapter 2) in all but two instances. All trawl samples were collected at night. Stations were located by marker buoys and/or specific landmarks.

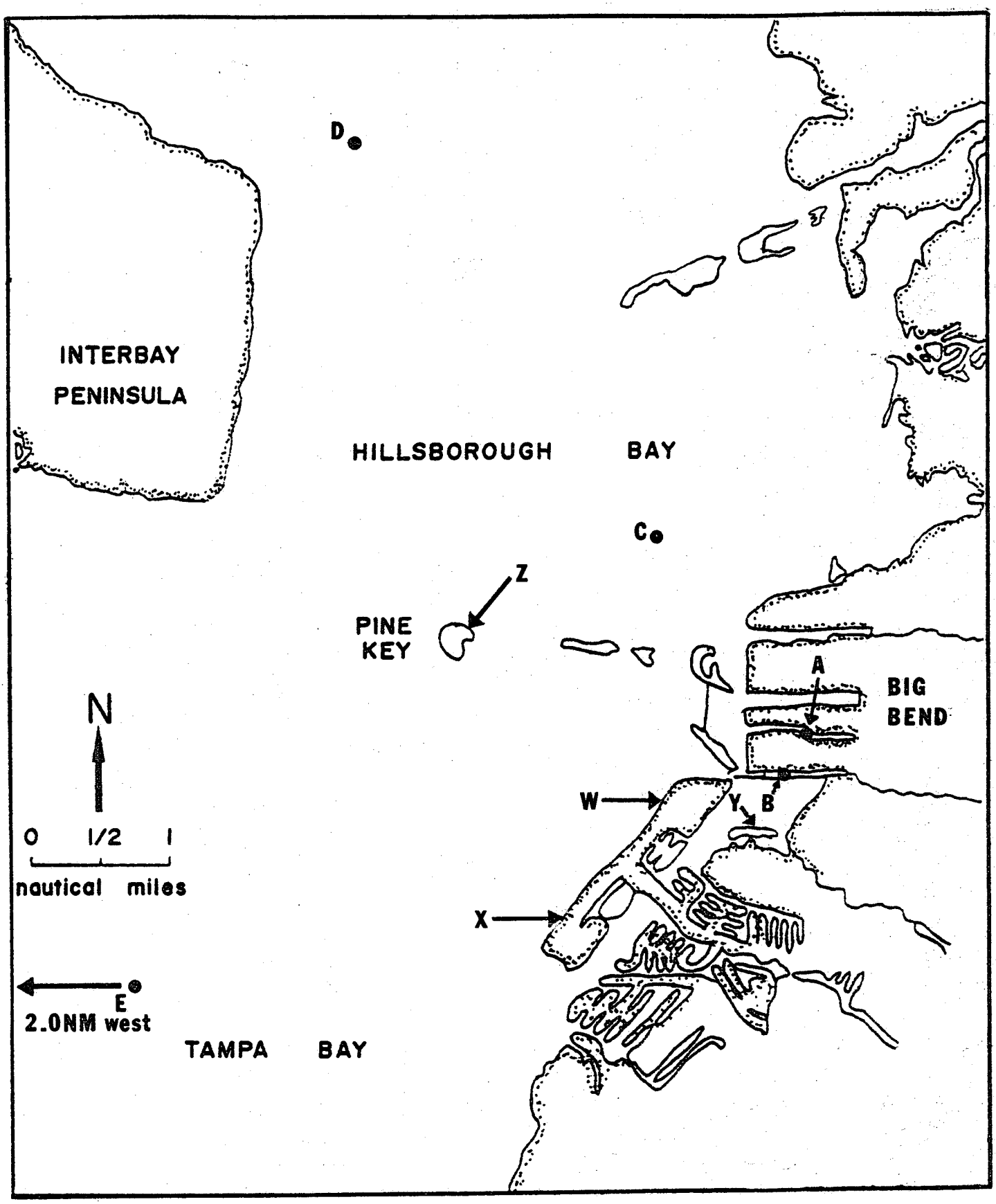

Figure 3.1. Location of trawl (A, B, C, D and E) and seine (W, X, Y and Z) stations.

The 10' Otter trawl was constructed of 1½" stretch mesh multi-filament nylon. A 4' bag constructed of ¼" ace nylon was added to the cod end.

At each station, the net was dropped from a moving boat and dragged along the bottom at 2-3 knots for 5 minutes. Two replicates (5 minute tows per replicate) were collected at each station. The contents of each haul were emptied into a 20 gallon plastic container. The fishes and macroinvertebrates were separated from the detritus and placed in doubly labeled (internal and external) one gallon plastic containers. The specimens were then preserved with 10% buffered formalin. Large specimens, other than RIS, were identified and counted and released alive in the field. The number and identity of all released specimens was recorded in a bound field notebook.

The stations were sampled in random order, except that Station B (discharge) was always sampled immediately after Station A (intake).

(iii) Impingement (traveling screens)

Impingement samples were collected once every two weeks between March 14, 1979 and February 13, 1980. Samples were collected from the traveling screens of one operating unit during each sampling period. Unit number one was sampled most often. In the event that Unit 1 was inoperable, Units 2 or 3 were sampled. The screens were washed at 0600 hrs on the day of sampling. Samples were then collected at 1200 hrs, 1800 hrs, 2400 hrs and 0600 hrs. The screens were rotated and washed twice at each sampling hour. The screen wash was collected in a wire mesh basket at the end of the sluicing trough. The contents of the basket(s) were emptied onto the deck surrounding the screens. The fishes and macroinvertebrates were separated from the detritus and placed in doubly labeled (internal and external) one gallon plastic containers. The animals were preserved with 10% buffered formalin. Large specimens, other than RIS, were identified, counted and released in the field if still alive. Large dead specimens were identified, counted and discarded. The number of specimens released and/or discarded was recorded in a bound field notebook.

b) Laboratory

All specimens in a sample were counted and identified. In addition to this, up to 100 individuals of each RIS per sample were weighed (wet weight, nearest 0.1 g), measured (standard length, nearest 1mm) and sexed (male, female, or immature). All information was logged on bench sheets.

c) Study limitations

The limitations to this study were imposed by (1) the gear selected for use, (2) the habitats that were sampled and (3) the mobility of the animals.

Otter trawls are designed to capture slow moving, bottom dwelling animals and certain pelagic species that occasionally inhabit the demersal zone. Fast moving species avoid capture in trawls by avoiding the trawl's path. To minimize net avoidance, all trawling was conducted at night during this program.

A large (150' X 6') seine was employed in this study. Several minutes are required to deploy a seine of this size and a number of animals undoubtedly avoided each enclosure simply by vacating the sample area.

The number of replicates required to "adequately" sample a given area is debatable and ranges from three or fewer (Gallaway and Strawn, 1974; Haedrich and Haedrich, 1974; McErlean, O'Connor, Mihursky and Gibson, 1973; Bechtel and Copeland, 1970; Dahlberg and Odum, 1970) up to ten (Livingston, 1975; Roessler and Tabb, 1974; Roessler, 1965). Since this study was designed to determine relative rather than absolute abundance, the number of replicates for seine samples (1) and trawl samples (2) appeared to be adequate.

The above-mentioned limitations are inherent in most fishery programs. However, with consistent sampling techniques between stations and sampling periods, these limitations should not adversely affect the collection of valid data for the specific objective of the study.

III. RESULTS AND DISCUSSION

a) Seasonality and Abundance of RIS

Lists of all RIS collected by seine, trawl and impingement are given in Appendices 3A, 3B, and 3C, respectively.

(i) Pink Shrimp (*Penaeus duorarum*)

1. Seine

Few pink shrimp (6) were captured by seine during this study. This was probably due in part to gear selectivity and type of habitat sampled. The burrowing habit of shrimp during daylight hours also enabled them to avoid capture (Wickham and Minkler, 1975).

2. Trawl

A total of 957 pink shrimp were collected by trawl during this study. Pink shrimp were collected each month and were most abundant in the late summer through early winter catches. Shrimp were collected at most stations throughout the year and were consistently abundant at stations A, B and C. The largest catch occurred in October when a combined station total of 220 individuals were collected.

3. Impingement

A total of 1738 pink shrimp were impinged during 552 sampling hours. Most of the shrimp (71%) were impinged between 1800 hrs and 0600 hrs. Most of the shrimp were impinged from mid-summer to early winter, which roughly corresponds to the period of peak abundance noted in the trawl collections.

Impingement rates varied seasonally and ranged from 2 shrimp per 24 hours in June, to 336 shrimp per 24 hours in early September. The average rate of impingement for pink shrimp was approximately 76 individuals per 24 hours, based on a total catch of 1738 shrimp during 552 sampling hours. This can be extrapolated to an estimated impingement rate of 27,740 pink shrimp per year on one unit or approximately 991 pounds (assuming an average ratio of 28 shrimp to the pound).

(ii) Blue Crab (*Callinectes sapidus*)

1. Seine

A total of 20 blue crabs were collected by seine during this study. Most individuals (10) were collected at Station W. Blue crabs were collected in all months except September and November 1979 and January 1980.

2. Trawl

Trawling accounted for 86 blue crabs, most of which (42) were collected in April 1979. Blue crabs disappeared in the trawl catches in July, August and September. They were present only in low numbers throughout the rest of the year. Of the total number of crabs collected by trawl, almost half (38) were collected in the intake and discharge canals.

3. Impingement

A total of 199 blue crabs were impinged during 552 sampling hours in 1979 and 1980. Most of the animals (170) were impinged in 96 sampling hours between January 2, 1980 and February 12, 1980 when the impingement rate was approximately 43 crabs per 24 hours for one unit. Lowest impingement for one unit occurred between late July and late November when the rate dropped to 1 crab impinged per 24 hours.

Impingement rates from the present study appear to indicate a precipitous decrease in the rates when compared to rates reported in a previous study (Peekstok et al., 1977). However, blue crabs appear to be most susceptable to impingement during the early part of the year, i.e. the cooler months. The previous study included two sampling periods during these months, (i.e. January to March 1976 and 1977); hence, the apparent reduced impingement rates for this species during the present study.

Blue crabs are reasonably strong swimmers and are probably able to avoid impingement under most circumstances. However, many blue crabs were impinged at night, indicating that they may have been drawn toward the screens at night due to the lighting on those structures. In addition to this explanation for impingement, blue crabs often feed by scavenging. Since there are often dead animals on the screens, the blue crabs are probably drawn to the screens in search of food.

(iii) Stone Crab (Menippe mercenaria)

1. Seine

No stone crabs were collected in seine hauls during this study. The stations that were sampled by seine did not include suitable habitats for this species.

2. Trawl

Only 1 stone crab was collected by the trawl. This individual was collected at station C in December 1979. Again, no suitable habitats for stone crabs were sampled using this gear.

3. Impingement

A total of 14 stone crabs were impinged during this study. Most of the animals (12) were impinged between September 1979 and early January 1980.

(iv) Bay Anchovy (Anchoa mitchilli)

1. Seine

A total of 25 bay anchovies were collected by seine. Anchovies were collected only during March through early June, 1979. They were most abundant (17) at station W. Most of these animals were adults and were collected during their peak spawning period.

A greater number of anchovies were collected during a previous study (Comp, 1977) than during this study. However, that change was probably the result of a change in the number of stations sampled, rather than a decline in the population. Two stations that commonly harbored thousands of anchovies were not sampled in the current study.

2. Trawl

Bay anchovies are pelagic in nature and trawling accounted for more individuals (480) than seining. Adult bay anchovies were collected during each sampling period and were most abundant between November 1979 and January 1980. Most of the specimens were collected in the intake canal (Station A) during this period.

3. Impingement

A total of 181 bay anchovies were impinged during 552 sampling hours. This represents a precipitous decline in the number of anchovies present three years ago when over 4000 individuals were collected during 744 sampling hours (Peekstok, et al. 1977). Fish population abundance generally fluctuates. This may explain the relative paucity of this species during this study when compared to catches made in the previous study. Based on ichthyoplankton data for the Big Bend area (See Chapter 2), there is probably no overall decline in the anchovy population of the area.

(v) Scaled Sardine (Harengula jaguana)

1. Seine

Scaled sardines were seasonally abundant in the Big Bend area. A total of 862 individuals were captured by seine during this study, most of which (526) were collected in May. The two Apollo Beach stations (stations W and X) accounted for 91% of the individuals. While generally considered a pelagic species, schools of scaled sardines often frequent shallow areas fronting open water beaches. These schools generally consist of immature specimens (since none of the individuals collected in May exhibited developed gonads). The adults generally spawn in this area in April and May (Springer and Woodburn, 1960; Phillips, 1977).

2. Trawl

Two scaled sardines were collected by trawl during this study. Even though the adults are pelagic in nature, they tend to inhabit the upper few meters of the water column. Hence, few were accessible by the trawl.

3. Impingement

Scaled sardines were rarely impinged during this study. Only 4 specimens were collected during the 23 sampling periods. Two individuals were collected in March and one individual was collected in September and one in October. Scaled sardines are strong swimmers and most healthy individuals would be able to avoid impingement.

(vi) Tidewater Silverside (Menidia beryllina)

1. Seine

M. beryllina was the most abundant (5661 individuals) and ubiquitous (collected at 2 to 4 stations each month) species collected by seine during this study. Tidewater silversides constituted 86% of the total RIS catch collected by seine. Silversides were least abundant during early June and July when a total of 50 individuals were collected during those two sampling periods. They were numerically dominant during the remaining months and catches ranged from 194 in April to 1365 in October. Although they were present often at all stations, most individuals (3319 or 59%) were collected at Station W.

Silversides are very common inhabitants of the Big Bend area (Comp, 1977) especially along the beaches and within the protected embayment areas. Over 20,000 tidewater silversides were collected in a similar study conducted three years ago (Comp, 1977). Additional stations and replicates were incorporated in that study, so a direct comparison is not feasible. However, both studies indicate the numerical dominance of this species in the Big Bend area.

2. Trawl

No specimens were collected by trawl. These animals exclusively inhabit the shoreline and protected areas and are therefore rarely captured by trawl.

3. Impingement

No silversides were impinged on the traveling screens during the study period.

(vii) Silver Perch (Bairdiella chrysura)

1. Seine

No silver perch were collected by seine. This demersal species generally inhabits deep water areas that are inaccessible with a seine.

2. Trawl

Silver perch were the most dominant RIS collected by trawl. A total of 1711 individuals were collected, most of which (95%) were collected at Station B. Peak abundance of this species was noted in June and July when 1640 specimens were collected and most of these were

juveniles that were spawned in late winter and early spring. Adults became more prevalent in the catches in the late fall-early winter months.

Silver perch frequent areas close to the bottom which makes them susceptible to capture by trawls.

3. Impingement

A total of 431 silver perch were impinged during 552 hours of sampling. Most impingement (68%) occurred in late May through early July. The presence of large numbers of silver perch during this period (especially during May and June) was confirmed by the trawl catches.

Most Bairdiella (77%) were impinged at night. Most of the impinged silver perch were juveniles that may have been attracted to the lights on the intake structure. Once near the structure, the juveniles may not have been strong enough to avoid the suction at the intake.

(viii) Spotted Seatrout (Cynoscion nebulosus)

1. Seine

Only 1 small spotted seatrout was collected with the seine. This specimen was captured at Station Y in October 1979.

2. Trawl

Trawling accounted for no spotted seatrout.

3. Impingement

A total of 4 spotted seatrout were impinged during this study: 2 were impinged in March 1979; 1 in September 1979; and 1 in December 1979.

(ix) Black Drum (Pogonias cromis)

1. Seine

A total of 46 black drum, all of which were juveniles, were collected by seine. All specimens were collected in June at Station Y. Black drum were never reported at this station in a previous study (Comp, 1977), however, the presence of young P. cromis in the embayment during this study emphasizes the importance of this area as a nursery. Juveniles of many species are known to utilize this area (Comp, 1977).

2. Trawl

Trawling accounted for 55 black drum. Most of the specimens (48) were collected at Station B. The other 7 were collected at Station A. Black drum are bottom dwelling species that often inhabit areas near fixed structures. They are seasonally abundant in both the intake and discharge canals and are often caught in large numbers in the canals by fishermen. Most of the black drum caught in trawls were collected in August through October 1979.

3. Impingement

One black drum was impinged on the traveling screens at 0600 hours on July 3, 1979. The specimen was 65 mm and weighed 6.9 g.

b) Seasonality and Abundance of Non-RIS

(i) Seine

1. Fishes

A total of 5416 non-RIS fishes (47 species) were collected by seine during this study. The five most abundant species (listed and discussed below) constituted 71.2% of the seine catch.

Species	Number Collected	% Total Non-RIS Catch
Fundulus similis Longnose killifish	1181	21.8
Leiostomus xanthurus Spot	1018	18.8
Lagodon rhomboides Pinfish	794	14.7
Cyprinodon variegatus Sheepshead minnow	477	8.8
Membras martinica Rough silverside	386	7.1

• Longnose killifish are common inhabitants of the Big Bend area (Comp, 1977) and are present in large numbers. Longnose killifish were collected each sampling period but were most abundant during the summer months. Catches ranged from a low of two individuals collected in December to a high of 662 individuals collected on July 3, 1979. Most of the longnose killifish (72.8%) were collected at Station Y.

• Spot are seasonal inhabitants of the Big Bend area. Young spot are generally found at inshore areas until they attain a length of about 80 mm (Kilby, 1955; Comp, 1977). As adults, they will migrate toward the Gulf where spawning will occur during the winter and early spring (Springer and Woodburn, 1960).

The transient nature of this species was evident during this study. Juvenile spot were present in the seine catches in high numbers between March and May 1979 when 98% of the total spot catch was collected. Larger specimens were collected sporadically through November. No specimens were collected in December 1979 or January 1980 indicating that the animals had moved to deeper water and were probably leaving the estuary and heading toward the Gulf or to areas of higher salinity to spawn.

• Pinfish are also seasonally abundant in the Big Bend area. Their patterns of distribution and abundance closely follow those of spot, e.g., the young were abundant at inshore areas during the spring and early summer, and the adults moved to offshore waters to spawn during the winter.

Pinfish were collected at all stations but were found to be most abundant (73.5%) at Station Y. Both juvenile pinfish and spot were abundant at this station which emphasizes its continued importance as a nursery area.

• Sheepshead minnows are common inhabitants of the Big Bend area, especially at Station Y where all of the specimens were collected. Its abundance at Station Y has been documented previously (Comp, 1977) and is a reflection of this species' habitat preference (Martin, 1972; Springer and Woodburn, 1960; Kilby, 1955).

Over 87% of the individuals collected during this study were obtained in June and early July. Summer peaks in abundance for this species have been reported previously (Comp, 1977).

• Rough silversides were collected every month during this study except December 1979 and January 1980. No distinct patterns of abundance were noted. Rough silversides are common inhabitants of the Big Bend area and frequent shoreline areas. They are often found schooling with tidewater silversides.

2. Invertebrates

Only 45 non-RIS invertebrates (9 species) were collected by seine during this study. The crown conch (Melongena corona) was the most abundant non-RIS invertebrate and constituted 51% of the total catch. Melongena were most prevalent at Station Y.

(ii) Trawl

1. Fishes

A total of 3106 non-RIS fishes (43 species) were collected by trawl during this study. Five species (listed below) constituted 73.3% of the total catch.

Species	Number Collected	% Total Non-RIS Catch
Cynoscion arenarius Sand seatrout	1040	33.5
Lagodon rhomboides Pinfish	380	12.2
Arius felis Sea catfish	301	9.7
Leiostomus xanthurus Spot	281	9.1
Orthopristis chrysoptera Pigfish	274	8.8

- Sand seatrout constituted 33.5% of the total trawl catch collected during this study. They first appeared in the trawl catches in May 1979 when 321 specimens were collected. They remained a prevalent member of the catches through October 1979. Most of the individuals were juveniles resulting from the spring and summer spawn. Most of the sand seatrout were collected in the discharge canal (47%) and the intake canal (24%).

- Pinfish, as indicated in the seine sampling, are seasonal inhabitants of the Big Bend area. They were relatively abundant in the trawl catches from March 1979 through July 3, 1979. They reappeared in large numbers at Station E in December 1979 and January 1980, when they were essentially absent from the trawl catches collected at the other 4 stations. As mentioned in the seine section and previous studies (Comp, 1977; Springer and Woodburn, 1960; Reid, 1954) pinfish tend to move toward the Gulf during the winter months. Their absence in the upper bay stations during the winter coinciding with their relative abundance at the lower bay station (E) at this time indicates an en masse movement toward the Gulf, or at least toward higher salinity areas, where spawning will occur.

- Sea catfish are year-round residents of the Big Bend and Tampa Bay areas in general. Sea catfish were most abundant (32%) in the discharge canal during this study, and were also abundant at Station C (25%) throughout much of the year.

- Spot were seasonally abundant in the trawl catches. Most of the specimens (98%) were collected between March and August 1979. Most of these individuals were the result of the spawning that occurred during the winter and spring of 1979. Their paucity in the trawl catches after August indicated a migration toward the Gulf where spawning occurs.

- Pigfish were the fifth most abundant non-RIS collected with the trawl. The inclusion of Station E in this program accounted for the increase in the number of pigfish collected in this study over previous studies in this area. While some specimens were collected at the upper bay stations (22% at Station B), Station E accounted for 71% of the total number of pigfish collected.

2. Invertebrates

A total of 983 non-RIS invertebrates (25 species) were collected by trawl during this study. The penaeid shrimp Trachypenaeus constrictus, constituted 63% of the total invertebrate (non-RIS) catch. T. constrictus were collected year-round but were most abundant in December 1979 and January 1980 when 451 individuals were collected.

(iii) Impingement

1. Fishes

A total of 2479 non-RIS fishes (47 species) were impinged on the traveling screens during 552 sampling hours. Most of the individuals (72%) were impinged between 1800 hrs and 0600 hrs. A list of the 5 most abundant species is given below.

Species	Number Collected	% Total Non-RIS Catch
Cynoscion arenarius Sand seatrout	1180	47.6
Chloroscombrus chrysurus Atlantic bumper	246	9.9
Orthopristis chrysoptera Pigfish	145	5.8
Lagodon rhomboides Pinfish	133	5.4
Opsanus beta Gulf toadfish	126	5.1

• Sand seatrout were by far the most commonly impinged fish during this study. The rate of impingement of this species during the 552 sampling hours was 2.14 per hour. This represents a considerable increase over the rate of impingement recorded three years ago (Peekstok et al., 1977) which was 343 sand seatrout impinged in 744 sampling hours or a rate of 0.46 animals impinged per hour.

Sand seatrout were also the most abundant non-RIS fish collected by trawl and they were found to be relatively abundant in the intake canal. It appeared that many of the sand seatrout were attracted by the lighting on the intake structure since 77% were collected between 1800 hrs and 0600 hrs. They may also have been attracted toward the screens in search of food.

Sand seatrout were impinged throughout most of the year but were most abundant between September 11 and November 20, 1979 when 97% of the individuals were captured. Most of these animals were young of the year and were the result of a spring-summer spawn.

• Atlantic bumpers constituted 9.9% of the impinged non-RIS fishes. They were an insignificant part of the impingement catch until October 9 and 23 when 211 of the 246 individuals were collected. Most of the specimens were young of the year.

• Pigfish were impinged in small numbers on April 4, 1979, peaked in abundance in June and July and disappeared from the screens after August 14, 1979.

• Pinfish were impinged sporadically, in low numbers throughout the year. They peaked in abundance on the screens between April 24 and May 25, 1979 when 64% of the specimens were collected. Fewer pinfish were collected during this study than during a similar study conducted three years ago when the impingement rate for pinfish averaged 15 per day. The rate during this study dropped to approximately 6 pinfish per day (24 hours).

• Gulf toadfish constituted 5.1% of the total number of non-RIS fish impinged. Opsanus beta were impinged in relatively low numbers throughout most of the study period. These animals prefer rocky, barnacle encrusted areas as habitats and probably move onto the submerged part of the screens for this reason. Most of the animals were alive when

collected and were probably caught as a result of their occupancy in their preferred habitat rather than as a result of actual impingement.

2. Invertebrates

A total of 2627 non-RIS invertebrates (17 species) were impinged during 552 sampling hours. Most of the individuals (54%) were impinged at night.

The horseshoe crab (Limulus polyphemus) was by far the most common impinged invertebrate (1,533 individuals) and it constituted 58% of the total non-RIS invertebrate catch. More horseshoe crabs were impinged during this study than were impinged over 744 sampling hours during a previous study when 1258 individuals were impinged (Peekstok et al., 1977).

Xanthid crabs (Hexapanopeus angustifrons, Hexapanopeus sp., Neopanope texana, Eurypanopeus depressus, Panopeus herbstii and unidentified xanthid species) constituted over 9% of the total catch. They, in addition to Portunus gibbesii which constituted over 17% of the catch, were probably attracted to the screens in search of food. Most of the crabs were alive when collected and were probably not actively impinged. Rather, they were collected as a result of their presence on the screens as they were probably scavenging impinged organisms.

c) General Discussion

The seasonality and relative abundance patterns of the fish and macroinvertebrate communities in the Big Bend area appear to be consistent with the patterns established in the literature and in a previous study conducted in the area (Comp, 1977). Some changes in the fauna were observed and they are summarized below.

- Spotted seatrout (Cynoscion nebulosus) were never common in the seine or trawl catches in this or a previous (Comp, 1977) study. They were however, commonly captured by fishermen in 1976 and 1977. A cursory survey of local fishermen revealed a decline in spotted seatrout catches in 1979-early 1980. The reason(s) for this decline is not immediately apparent. Two possibilities exist: 1) fish abundance fluctates from year to year. It is possible that 1979 represented a "low" level of abundance or 2) there may have been a loss of habitat in the area. Seatrout commonly inhabit seagrass beds, so loss of considerable amounts of seagrasses could result in a decline of the seatrout population.

- Impingement rates for both fishes and invertebrates were lower in this study than during a previous study. Peekstok et. al. (1977) determined that 9,946 fishes and 9,382 macroinvertebrates were impinged during 744 sampling hours between January 1976 and March 1977. That represents an average impingement rate of 13.4 fish impinged per hour and 12.6 macroinvertebrates impinged per hour. The present study determined that the average impingement rate for fishes was 5.5/hour and 5.2/hour for macroinvertebrates. The reasons for the decline may be attritubable to several factors: 1) The yearly fluctations of the populations tend to make absolute comparisons between years inaccurate. Rather, the natural oscillation of the population peaks and declines must first be

determined before valid one to one comparisons can be made. 2) The winter of 1977 was unseasonably cold. The precipitous and prolonged drop in water temperature during this period induced lethargy in hundreds of fishes. This undoubtedly led to increased impingement rates during that period. 3) The completion of a barrier due west of the intake canal (extending from the west end of the discharge canal to the northern-most spoil island (See Figure 3.1) may have influenced (over time) the movement of fishes and macroinvertebrates. This barrier may have prevented much of the fauna from moving into the canal. 4) It was noted during this study that little seagrass entered the canal and was impinged. During the previous study, the traveling screens were often coated with seagrasses (unidentified). If this change indicates a decline in the seagrasses in the area, it may also indicate a loss of habitat for several species. Hence, a decrease in impingement may occur.

- The mantis shrimp (Squilla empusa) was the sixth most abundant invertebrate impinged three years ago (Peekstok, et al. 1977). However, few mantis shrimp were collected during the current study by impingement and trawling in the intake canal. The reason for this decline is unknown.

- The number of Bairdiella chrysura impinged also declined during this study. During the period of April to September 1976, a total of 2595 siler perch were impinged (Peekstok, et al. 1977). Conversely, only 286 silver perch were impinged during a comparable period in 1979. Again, the natural oscillations of fish populations may have caused the decrease. Silver perch were abundant in the discharge canal during the present study. Hence, an area-wide decline in their population cannot be inferred in spite of their reduced densities in the intake canal.

- Station Y continued to function as a nursery area, but on a reduced scale. Fewer juvenile fishes were collected at this station than were collected here three years ago. One additional juvenile species was collected at this area. A total of 46 juvenile black drum (Pogonias cromis) were collected at this station in June. Before this time, black drum were not known to inhabit this area (Y).

IV. SUMMARY AND CONCLUSIONS

1) Adult fishes and invertebrates were sampled by trawl, seines and traveling screens near the Big Bend Steam Electric Station between March 1979 and February 1980.

2) All captured specimens were identified and enumerated and additional information was collected for a group of Representative Important Species (RIS): Pink shrimp (Penaeus duorarum), blue crab (Callinectes sapidus), stone crab (Menippe mercenaria), bay anchovy (Anchoa mitchilli), scaled sardine (Harengula jaguana), tidewater silverside (Menidia beryllina), silver perch (Bairdiella chrysura), spotted seatrout (Cynoscion nebulosus) and black drum (Pogonias cromis).

3) The seine, trawl and impingement data are summarized below:

	Seine	Trawl	Impingement
#RIS Fishes	6595	2246	621
Dominant Species	M. beryllina	B. chrysura	B. chrysura
#RIS Invertebrates	26	1044	1949
Dominant Species	C. sapidus	P. duorarum	P. duorarum
#Non-RIS Fishes	5416	3106	2479
Dominant Species	F. similis	C. arenarius	C. arenarius
#Non-RIS Invertebrates	45	983	2627
Dominant Species	M. corona	T. constrictus	L. polyphemus

4) The seasonal trends in relative abundance and species composition appear to be consistent with the patterns established in the literature and in a previous study conducted in the area.

5) Some differences in relative abundances of some species were noted when the results of this study were compared to a previous study. However, these differences could generally be attributed to the natural variations in abundance noted for many estuarine species and to differences in sampling locations.

6) A cursory survey of local fishermen indicated that a decline in the spotted seatrout population may have occurred in the Big Bend area. This is due possibly to 1) natural patterns of peaks and declines in the population or 2) loss of seagrass habitat in the area.

7) The embayment station (Y) continued to function as a nursery area for several species.

8) Impingement rates dropped from an average of 13.4 fishes per hour and 12.6 macroinvertebrates per hour in 1976 and early 1977 to 5.5 fishes per hour and 5.2 macroinvertebrates per hour in 1979 and early 1980.

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Appendix 3A. List of all RIS collected by seine between March 14, 1979 and January 15, 1980.

Date	3/14/79				4/10/79				5/10/79				6/5/79				7/3/79				7/31/79				8/28/79			
Station	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z
Penaeus duorarum	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	-	-
Callinectes sapidus	4	-	1	-	4	-	-	-	-	-	-	1	1	-	-	-	2	1	1	-	-	1	-	-	-	-	1	1
Menippe mercenaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harengula jaguana	-	-	-	-	-	-	-	-	388	138	-	-	-	-	-	-	-	-	-	-	2	-	-	-	38	22	-	-
Anchoa mitchilli	1	-	-	-	3	-	-	-	-	-	7	-	13	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-
Menidia beryllina	168	43	37	1	69	14	111	-	396	64	341	1	6	-	19	5	1	4	12	3	8	1	183	239	531	25	311	8
Bairdiella chrysura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cynoscion nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	173	43	38	1	76	14	112	-	784	202	348	2	20	-	65	6	3	5	13	3	10	2	186	239	569	47	312	9

Appendix 3A. List of all RIS collected by seine between March 14, 1979 and January 15, 1980.
- continued -

Date	9/25/79				10/23/79				11/20/79				12/18/79				01/15/80				Total
Station	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z	W	X	Y	Z	W	X	y	Z	
Penaeus duorarum	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	6
Callinectes sapidus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	1	-	-	20
Menippe mercenaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Harengula jaguana	32	32	-	23	80	13	4	3	40	3	-	44	-	-	-	-	-	-	-	-	862
Anchoa mitchilli	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25
Menidia beryllina	165	120	38	48	1020	2	337	6	250	2	4	102	555	48	-	123	150	68	21	1	5661
Bairdiella chrysura	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Cynoscion nebulosus	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	46
Total	197	152	38	71	1101	15	343	9	291	5	4	146	555	48	0	123	150	69	21	1	6621

Appendix 3B. List of all RIS collected by trawl between March 14, 1979 and January 15, 1980. Numbers are given as the combined total of 2 replicates.

Date	3/14/79					4/10/79					5/10/79					6/5/79					7/3/79				
Station	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Penaeus duorarum	2	-	8	6	18	29	13	17	10	6	5	6	2	4	3	-	11	-	-	2	5	-	18	4	10
Callinectes sapidus	2	-	3	1	2	18	4	-	13	7	1	4	1	-	-	-	-	3	3	-	-	-	-	-	2
Menippe mercenaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harengula jaguana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	6	-	10	8	3	-	-	3	2	3	3	4	6	-	2	1	19	8	-	-	1	-	-	1	5
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bairdiella chrysura	-	-	4	-	-	-	5	-	-	1	6	958	1	-	2	6	662	3	-	2	3	-	1	-	-
Cynoscion nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	-	3	-	-	-	1	3	-	-	-	2	1	-	-	-
Total	10	0	25	15	23	47	22	20	25	17	15	975	10	4	7	8	695	14	3	4	11	1	19	5	17

Appendix 3B, List of all RIS collected by trawl between March 14, 1979 and January 15, 1980. Numbers are given as the combined total of 2 replicates. - continued -

Date	7/31/79					8/28/79					9/25/79					10/23/79					11/20/79				
Station	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
Penaeus duorarum	11	3	31	-	10	56	3	45	-	5	16	9	28	3	16	2	106	61	25	26	34	63	27	11	7
Callinectes sapidus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1	-	-	-	3	-	-	-
Menippe mercenaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harengula jaguana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	2	5	6	5	2	4	-	4	-	2	8	-	3	6	8	18	3	3	3	1	131	8	1	2	6
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bairdiella chrysura	-	-	1	1	-	1	-	1	-	1	1	2	1	-	-	6	5	1	9	-	2	2	4	-	2
Cynoscion nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	8	-	-	-	1	9	-	-	-	2	10	-	-	-	-	6	-	-	-
Total	13	8	38	6	12	61	11	50	0	8	26	20	32	9	24	29	124	66	37	27	167	82	32	13	15

Appendix 3B. List of all RIS collected by trawl between March 14, 1979 and January 15, 1980. Numbers are given as the combined total of 2 replicates.

Date	12/18/79					1/15/80					Total
Station	A	B	C	D	E	A	B	C	D	E	
Penaeus duorarum	50	6	33	19	14	13	6	23	13	3	957
Callinectes sapidus	-	3	1	6	-	2	2	-	3	-	86
Menippe mercenaria	-	-	1	-	-	-	-	-	-	-	1
Harengula jaguana	-	-	-	-	1	-	-	-	-	1	2
Anchoa mitchilli	44	-	1	1	-	19	-	14	78	7	480
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	0
Bairdiella chrysura	10	1	1	-	-	1	1	-	-	3	1711
Cynoscion nebulosus	-	-	-	-	-	-	-	-	-	-	0
Pogomias cromis	1	5	-	-	-	-	3	-	-	-	55
Total	105	15	37	26	15	35	12	37	94	14	3292

Appendix 3C. List of all RIS impinged on the traveling screens on the sampling dates between March 14, 1979 and February 12, 1980.

Date	3/14/79				3/27/79				4/10/79				4/24/79				5/10/79				5/25/79			
Station	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6
Penaeus duorarum	2	-	1	2	5	3	9	8	-	-	7	10	-	1	18	12	4	-	2	6	1	-	-	2
Callinectes sapidus	2	3	3	6	2	1	3	1	-	-	2	2	1	-	-	1	-	1	1	2	-	-	-	1
Menippe mercenaria	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-
Harengula jaguana	-	-	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	-	1	1	2	1	1	10	5	-	1	-	-	-	-	-	-	-	2	1	-	-	-	-	-
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bairdiella chrysura	-	-	1	-	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	1	20	6	38	43
Cynoscion nebulosus	-	1	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	4	5	6	11	9	6	23	15	-	1	9	12	1	1	18	13	4	3	5	9	21	6	38	46

Appendix 3C. List of all RIS impinged on the traveling screens on the sampling dates between March 14, 1979 and February 12, 1980. - continued -

Date	6/19/79				7/3/79				7/17/79				7/31/79				8/14/79				8/28/79			
Station	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6
Penaeus duorarum	-	-	-	2	-	-	51	56	14	2	30	11	77	15	57	40	39	5	74	29	57	3	73	36
Callinectes sapidus	1	1	-	1	1	-	2	5	1	-	2	-	-	-	-	-	-	-	-	-	-	-	-	1
Menippe mercenaria	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Harengula jaguana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	2	3	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bairdiella chrysura	18	4	81	19	4	-	46	16	2	1	2	1	-	1	-	1	5	1	3	4	1	1	1	4
Cynoscion nebulosus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	21	8	83	22	5	1	99	78	17	3	34	12	77	16	57	41	44	7	77	33	58	4	74	41

Appendix 3C. List of all RIS impinged on the traveling screens on the sampling dates between March 14, 1979 and February 12, 1980. - continued -

Date	9/11/79				9/25/79				10/9/79				10/23/79				11/6/79				11/20/79			
Station	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6
Penaeus duorarum	34	4	242	64	19	5	62	41	86	11	67	45	12	-	13	21	4	8	-	30	15	9	44	40
Callinectes sapidus	-	-	1	2	-	-	1	-	-	-	-	-	-	-	-	1	-	-	-	-	2	-	1	-
Menippe mercenaria	-	-	1	-	-	-	1	-	-	-	-	-	-	-	-	2	1	-	1	-	1	-	-	-
Harengula jaguana	1	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Anchoa mitchilli	-	1	2	-	-	1	1	-	2	-	8	1	2	-	4	4	-	-	-	-	-	5	9	-
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bairdiella chrysura	3	5	5	8	-	-	3	4	5	-	-	4	1	-	1	2	-	-	1	-	1	-	3	2
Cynoscion nebulosus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	38	11	251	74	19	6	68	45	95	11	75	50	15	-	16	30	5	8	2	30	19	14	57	42

Appendix 3C. List of all RIS impinged on the traveling screens on the sampling dates between March 14, 1979 and February 12, 1980. - continued -

Date	12/6/79				12/18/79				1/2/80				1/15/80				1/29/80				2/12/80				Total
Station	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	12	18	24	6	
Penaeus duorarum	18	7	11	14	2	1	9	3	1	2	9	4	-	2	-	1	2	2	2	1	4	1	-	2	1738
Callinectes sapidus	4	1	3	8	1	-	2	2	2	3	6	23	-	-	7	6	9	1	7	19	27	8	28	24	199
Menippe mercenaria	-	-	-	-	2	-	2	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	14
Harengula jaguana	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Anchoa mitchilli	33	9	19	11	1	-	3	2	4	3	6	9	-	-	-	-	-	1	-	1	2	-	2	2	181
Menidia beryllina	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0
Bairdiella chrysura	8	4	15	8	-	2	12	1	-	2	2	-	-	-	1	-	-	-	-	-	1	-	-	-	431
Cynoscion nebulosus	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4
Pogonias cromis	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
Total	63	22	48	41	6	3	28	8	7	10	24	36	-	2	8	7	11	4	9	21	34	9	30	28	2570

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980.

INVERTEBRATES			
Aurelia aurita Moon jelly			I
Chrysaora quinquecirrha Sea nettle			I
Polinices duplicatus Moon snail		T	
Busycon contrarium Lightning whelk		T	
Melongena corona Crown conch	S	T	
Fasciolaria illium hunteria Banded tulip		T	
Oliva sayana Lettered olive		T	
Lollinguncula brevis Brief squid	S	T	I
Limulus polyphemus Horseshoe crab	S	T	I
Squilla empusa Mantis shrimp		T	I
Trachypenaeus constrictus Penaeid shrimp		T	I
Palemonetes pugio Grass shrimp	S	T	I
Pagurus longicarpus Hermit crab	S	T	
Pagurus pollicaris Hermit crab	S	T	
Pagurus sp. Hermit crab	S	T	
Hapatus pudibundus		T	

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980. - continued -

INVERTEBRATES			
Persephona aquilonaris Purse crab		T	
Portunus gibbesii Portunid crab	S	T	I
Hexanopeus angustifrons Xanthid crab			I
Hexanopeus sp. Xanthid crab			I
Neopanope texana Xanthid crab		T	I
Eurypanopeus depressus Xanthid crab	S	T	I
Panopeus herbstii Xanthid crab			I
Unidentified xanthid Xanthid crab		T	I
Sesarma cinerium Friendly crab			I
Sesarma sp.			I
Pinnixa chaetopterana Commensal crab		T	
Libinia dubia Spider crab		T	I
Luidia clathrata Sea star		T	
Molgula sp. Tunicate		T	I
FISHES			
Carcharhinus limbatus Blacktip shark			I
Dasyatis americana Southern stingray	S	T	
Dasyatis sayi Bluntnose stingray			I

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980. - continued -

FISHES			
Gymnura micrura Smooth butterfly ray		T	I
Rhinoptera bonasus Cownose ray		T	I
Myrophis punctatus Speckled worm eel			I
Ophichthus gomesi Shrimp eel			I
Brevoortia smithi Yellowfin menhaden	S	T	I
Dorosoma petenense Threadfin shad	S		I
Opisthonema oglinum Atlantic thread herring	S	T	I
Anchoa hepsetus Striped anchovy	S	T	I
Synodus foetens Inshore lizardfish	S		
Arius felis Sea catfish	S	T	I
Bagre marinus Gafftopsail catfish		T	I
Opsanus beta Gulf toadfish		T	I
Porichthys porosissimus Atlantic midshipman		T	
Gobiesox strumosus Skilletfish			I
Urophycis floridanus Southern hake		T	
Hyporhamphus unifasciatus Halfbeak	S		

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980. - continued -

FISHES			
Strongylura notata Redfin needlefish	S		
Strongylura timucu Timucu	S		
Cyprinodon variegatus Sheepshead minnow	S		
Floridichthys carpio Goldspotted killifish	S		
Fundulus grandis Gulf killifish	S		
Fundulus similis Longnose killifish	S		
Membras martinica Rough silverside	S		
Hippocampus erectus Lined seahorse		T	I
Hippocampus zosterae Dwarf seahorse	S		
Syngnathus louisianae Chain pipefish	S		I
Syngnathus scovelli Gulf pipefish		T	
Centropomus undecimalis Snook	S	T	I
Diplectrum formosum Sand perch		T	
Caranx hippos Crevalle jack			I
Chloroscombrus chrysurus Atlantic bumper	S	T	I
Hemicaranx amblyrhynchus Bluntnose jack			I

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980. - continued -

FISHES			
Oligoplites saurus Leatherjacket	S		
Selene vomer Lookdown			I
Trachinotus falcatus Permit	S		
Diapterus plumieri Striped mojarra	S	T	I
Eucinostomus argenteus Spotfin mojarra	S	T	I
Eucinostomus gula Silver jenny	S	T	I
Eucinostomus lefroyi Mottled mojarra	S	T	
Gerres cinereus Yellowfin mojarra	S		
Orthopristis chrysoptera Pigfish	S	T	I
Archosargus probatocephalus Sheepshead	S	T	
Lagodon rhomboides Pinfish	S	T	I
Cynoscion arenarius Sand seatrout		T	I
Leiostomus xanthurus Spot	S	T	I
Menticirrhus americanus Southern kingfish	S	T	I
Menticirrhus saxatilis Northern kingfish	S		I
Micropogon undulatus Atlantic croaker	S	T	

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980. - continued -

FISHES			
Sciaenops ocellata Red drum	S	T	I
Chaetodipterus faber Atlantic spadefish	S	T	I
Tilapia sp. Tilapia	S		
Mugil cephalus Striped mullet	S	T	I
Mugil trichodon Fantail mullet	S		
Astroscopus y-graecum Southern stargazer	S		I
Hypsoblennius hentzi Feather blenny		T	I
Microgobius gulosus Clown goby		T	
Prionotus scitulus Leopard searobin	S	T	I
Prionotus tribulus Bighead searobin	S	T	I
Ancylopsetta quadrocellata Ocellated flounder		T	
Etropus crossotus Fringed flounder		T	
Paralichthys albigutta Gulf flounder	S	T	I
Achirus lineatus Lined sole	S	T	I
Trinectes maculatus Hogchoker	S	T	I
Symphurus plagiusa Blackcheek tonguefish	S	T	I

Appendix 3D. List of all non-RIS invertebrates and fishes collected by seine (S), trawl (T) and impingement (I) between March 14, 1979 and February 12, 1980. - continued -

FISHES			
Aluterus schoepfi Orange filefish			I
Monacanthus hispidus Planehead filefish	S		I
Lactophrys quadricornis Scrawled cowfish	S	T	I
Sphoeroides nephelus Southern puffer		T	I
Chilomycterus schoepfi Striped burrfish		T	I

CHAPTER FOUR

AGE AND FECUNDITY STUDIES OF SELECTED FISH SPECIES

BY

BRANDT F. HENNINGSEN

CHAPTER FOUR

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I. INTRODUCTION

The purpose of this study was to gather data concerning age and fecundity of selected fish species in the vicinity of the Big Bend power plant. Such information can be paramount to a better understanding of the dynamics (potential recruitment, growth, spawning times, etc.) of faunal populations in the Big Bend area, especially when augmented with the concomitant studies of meroplankton, adult fishes and invertebrates. In addition, few to no fecundity studies have been conducted on four of the five selected fish species.

II. MATERIALS AND METHODS

Five species of fishes (Representative Important Species - RIS) spanning a range of estuarine habitats, trophic levels, densities, and/or commercial values were selected for age and fecundity measurements. In ascending trophic levels, these included: bay anchovy Anchoa mitchilli (Valenciennes), tidewater silverside Menidia beryllina (Cope), silver perch Bairdiella chrysura (Lacepede), black drum Pogonias cromis (Linnaeus) and spotted seatrout Cynscion nebulosus (Cuvier).

Specimens were selected from 1) monthly trawl and seine samples collected for the adult fishes and invertebrate studies and 2) supplementary monthly samples collected in an effort to procure sufficient numbers of RIS specimens (Figure 4.1, Table 4.1). Methodologies for supplementary sampling included hook and line fishing, cast netting (2.7 m, monofilament, 3.2 cm stretch mesh), gill netting (91 m; 7.6 cm stretch mesh), seining, and trawling (seine and trawl specifications are described in Chapter 3). Accessory sampling techniques also included interviews with, and purchases of fish from, local amateur and commercial fishermen, as well as employees of area bait camps. All accessory sampling was in the vicinity of the Big Bend power plant, with some sampling (15-16 October 1979) being conducted in the Alafia River. Field procedures followed those outlined in Chapter 3 of this report except that the seine was deployed and pulled by hand at all stations.

One hundred mature individuals of each RIS were to be examined over the duration of the 1979 Aquatic Ecology Program. Actual numbers of specimens examined varied depending upon the availability of individual species (See Table 4.2). Specimens were randomly selected from each 10 mm size class (standard length) for age and fecundity determinations.

Age Determinations

Standard length (mm ruler) and wet weight (nearest 0.1 g, triple beam balance) measurements were noted for each specimen. Ages were estimated using the scale annuli method in combination with established publications of length-frequency analyses (Rousefell and Everhart, 1953; Lagler, 1956; Tesch, 1968). All fish ages were recorded in "age groups" format.

At least three replicate scales were selected from the caudo-dorsal area of the left side of each fish. Also, at least two additional scales were retrieved from the mid-lateral area dorsal to the lateral line of the left side of each fish. Scales were dried flat between glass slides and annuli observations made through a dissecting microscope. Scale samples were individually labeled with the following information: species, date of capture, collection gear type, wet weight and standard length of the fish, number and sex of individual, and the initials of the principal investigator. Scales were stored in labelled slide boxes.

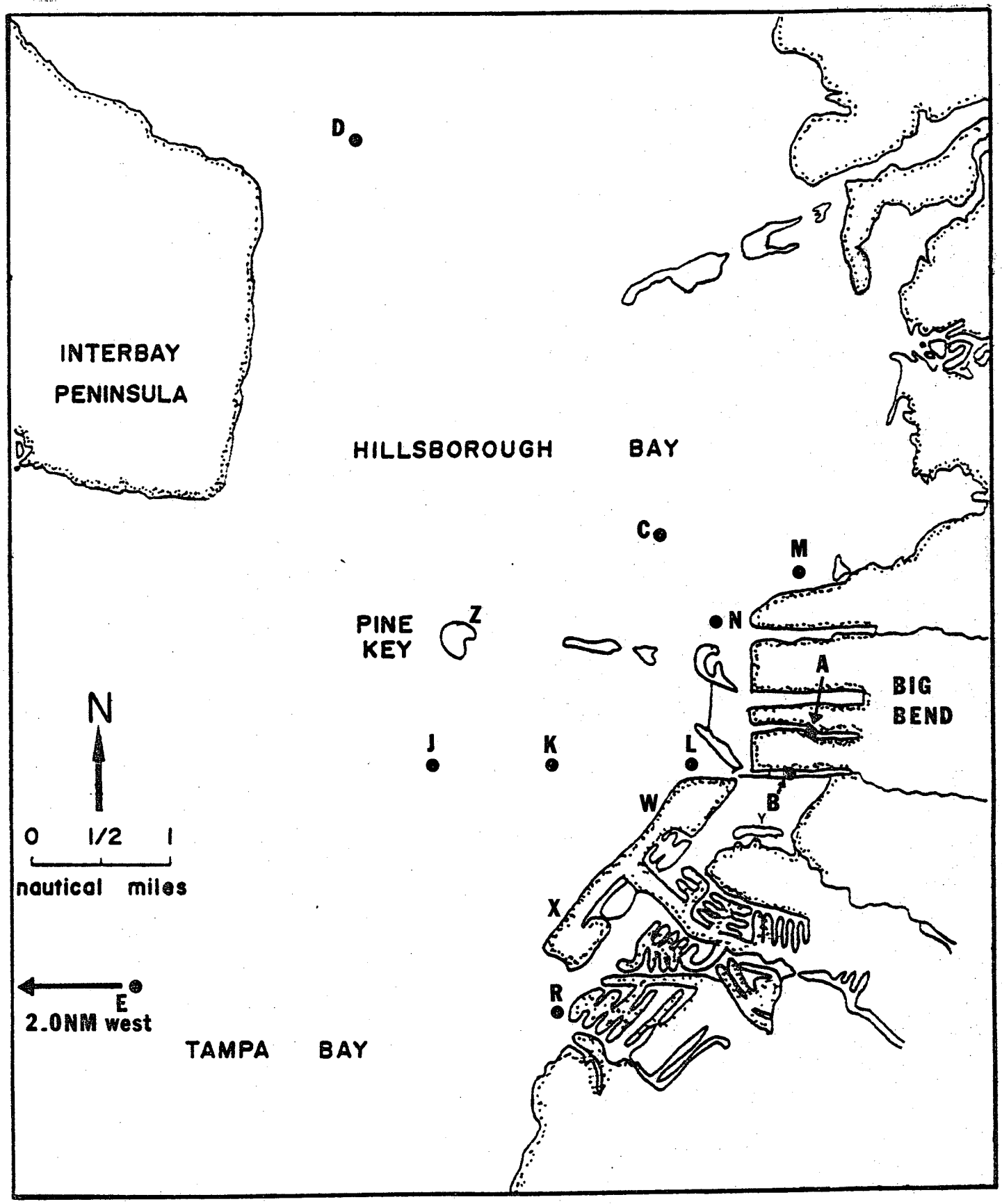


Figure 4.1. Fish age and fecundity - Sampling locations (includes supplementary sampling locations J through N and R).

Table 4.1. Supplemental sampling dates and methodologies used for the Fish Age and Fecundity Program.

Date	Methodologies
13 March 1979	cast net
24 April 1979	cast net
24 May 1979	cast net*
9 & 13 July 1979	trawl, seine
25 & 26 July 1979	trawl, hook-line, cast net, gill net
6 & 7 August 1979	trawl, seine
6 & 9 September 1979	trawl, seine
15 & 16 October 1979	trawl, hook-line
18 & 19 October 1979	trawl, seine
17 & 19 November 1979	trawl, seine
14 December 1979	trawl
3 January 1980	seine
26 & 27 January 1980	trawl, seine

* Capture of no RIS using cast net prompted the use of other methods.

Table 4.2. Number of specimens examined for the study.

No.	Species	Total	Male	Female	Unknown
1.	Anchoa mitchilli	188	81	103	4
2.	Menidia beryllina	149	38	111	-
3.	Bairdiella chrysura	136	56	73	7
4.	Pogonias cromis	87	21	31	35
5.	Cynoscion nebulosus	4	-	2	2
6.	Total	564	196	320	48

Because of the deciduous nature of scales of the bay anchovy, scales were collected wherever possible. In an effort to minimize scale loss of anchovies, specimens were isolated in the field from the remainder of the sample and preserved in ten percent buffered formalin.

Log - log (natural, ln) regressions of length-weight relationships were plotted using the least squares method (Rounsefell and Everhardt, 1953; Tesch, 1968).

Fecundity Studies

Fecundity estimates were made on all female specimens used in the age determination studies. Fecundity was defined as the total number of ova that would probably be spawned during one annual cycle; the gravimetric method was used to estimate fecundity (Bagenal and Braum, 1968).

Left and right ovaries removed from fish were placed in separate vials of five percent buffered formalin. Vials contained both internal and external labels with the same information as accompanied scale lables; in addition, each overy was labeled "left" (l) or "right" (r) according to its previous anatomical position in the fish. Fixed ovaries were then rinsed in deionized water, blotted with a paper towel, and weighed to the nearest 0.1 mg with a Sartorius electronic balance. Each ovary was then subsampled (3X) by cross section to determine the number of ova per unit weight. Depending on the size of the ovary, up to three subsamples were taken from each ovary and weighed. General condition and maturity of the ovary was also noted.

Ovary subsections were placed on etched glass slides. Several drops of deionized water were placed on each subsection to prevent dehydration. While observing subsections with a dissecting microscope, oocytes were teased apart with micro-forceps. A cover slip was then placed over the separated oocytes. The slides were then systemically scanned under a compound microscope (40X). All mature or maturing oocytes between grid lines were counted before going to an adjacent grid. For especially small ovaries (e.g. A. mitchilli, $\simeq$<7.5 mg), the whole ovary would be teased apart and maturing oocytes counted.

Maturing ovaries were found to contain oocytes at various stages of development as evidenced by various oocyte diameters. Ova diameters were measured using an ocular micrometer. To test whether a significant difference in ova size frequency distributions occurred along the length of ovaries, two fishes were selected of each species with maturing ova. Three subsections of each ovary were examined, i.e. sections from the anterior, middle, and posterior portions of the ovary. Numbers of ova per ground subsample were used for statistical analyses. If Friedman's test (Hollander and Wolfe, 1973) ($P = 0.5$) indicated no significant differences of oocyte distributions between differing areas of an ovary, subsequent subsections were taken from the middle portions of ovaries.

Ova size frequency distributions were plotted for maturing females collected over time. Ova size frequency distributions could reveal three characteristic states of oocyte development: undeveloped (primary mode), maturing (intermediate mode), and mature (most developed mode). Inter-

mediate oocytes were considered as all oocytes larger in diameter than those of the primary mode oocytes which are generally found in many species of female fishes throughout the year. Although most fecundity estimates are made using only the most advanced mode oocytes (Simpson, 1951; MacGreger, 1957; Nikolski, 1969), for fishes examined in this study, it was believed that oocytes in the intermediate mode were also spawned during an annual cycle due to the fact that spent females harbored only primary oocytes. For females of species examined, all ova in developing modes (maturing and mature oocytes) were counted for fecundity estimations. Similar reasoning and methodologies have been used by Martinez and Houde (1975) for fecundity estimates of the scaled sardine (Harengula jaguana Poey) on the southeast coast of Florida.

Fecundity was calculated as:

$$F = \frac{\text{(ovary weight)} \quad \text{(number of maturing ova in subsample)}}{\text{(subsample weight)}.}$$

Averages of fecundity estimates of the three subsamples for both right and left ovaries were summed for the total estimated fecundity of an individual. In addition, relative fecundity (F_r) was calculated as:

$$F_r = \frac{\text{total fecundity}}{\text{(total weight of fish - ovary weight)}}$$

An an additional indicator of maturation state, gonad indices (Martinez and House, 1975) were calculated as:

$$\text{gonad index (\%)} = \frac{\text{total ovary weight}}{\text{total fish weight}} \times 100$$

Fecundity was also examined in relation to length and weight. Untransformed and ln-ln transformed regressions of length and weight vs. fecundity were calculated using the least squares method (Bagenal and Braum, 1968). Regressions were performed using all data as well as for data relevant to only the months of most active spawning. Initial regressions using all available data were conducted with a programmable Texas Instruments TI-58 calculator and the University of South Florida's IBM 371-65. Additional regressions using data relevant to months of most active spawning were conducted by Stone and Webster Engineering Corporation. Calculations for fecundity and relative fecundity estimates were also performed by Stone and Webster Engineering Corporation.

Data Validity

To insure data validity, methodologies and data were discussed with biologists from various state universities: Dr. John C. Briggs (University of South Florida); Dr. Gertrude Hinsch (University of South Florida); Mr. Mark Godcharles (Florida Department of Natural Resources); Dr. William Richards (Southeast Fisheries Center, NMFS, Miami, Fl.); Dr. Ed Houde (Rosenstiel School of Marine and Atmospheric Science, University of Miami); Dr. Frank Truesdale (Louisiana State University); Mr. Nelson May (Center for Wetland Resources, Louisiana State University). No problems in the study design or methodology were noted by any of the above consultants.

Study Limitations

The major limitation of this study was a lack of mature specimens for three of the five RIS (B. chrysura, P. cromis, C. nebulosus). The problem of procurement of adequate numbers of mature RIS specimens represents a common phenomena often experienced by fisheries biologists attempting to collect certain stocks of various species, ages, etc. (Gulland, 1964; Brandt, 1972). In this study, various sampling methods were used in an attempt to solve this problem.

It is generally recommended that ova size frequency distributions be plotted monthly for a year in order to accurately delineate the various developing modes (if existent) that might be expressed during an annual cycle (Houde, personal communication). With the establishment of developing modes based on 12 months of data, one may be confident in subsequent fecundity estimates based on delineation of these modes (e.g. maturing and mature oocytes vs. undeveloped, immature oocytes).

Delineation of various developing modes (and subsequent fecundity estimates) based on 12 months of data was not feasible for this study. Therefore, for the two species in which maturing ova were found, (A. mitchilli, M. beryllina), ova size frequency distributions were plotted for individuals distributed over a four month period (14 March through 5 June 1979). Representative fish for both species displayed similar size frequency distributions for each of the four months (Figures 4.2, 4.3). These four months represented periods of peak spawning, and we believe that developing modes derived from these ova size frequency distributions are representative of the species. Therefore, based on developing modes indicated by these distributions, all ova greater than 150 µm (major axis for A. mitchilli) were counted as maturing oocytes for both species.

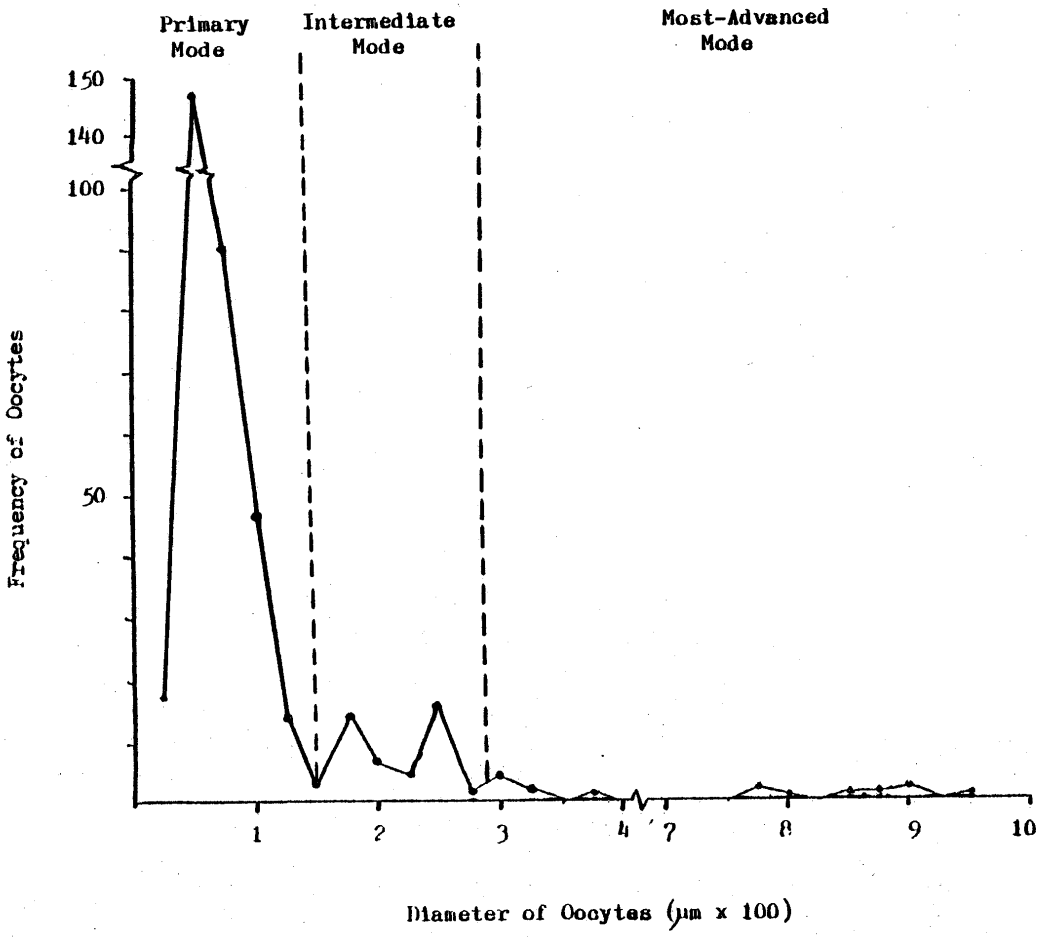


Figure 4.2. Representative ova size frequency distribution for Anchoa mitchilli, 40 mm SL, 0.8 g, left ovary weight = 8.5 mg; gonad index = 4.56; from sample collected at station B on 5 June 1979; female #11r.

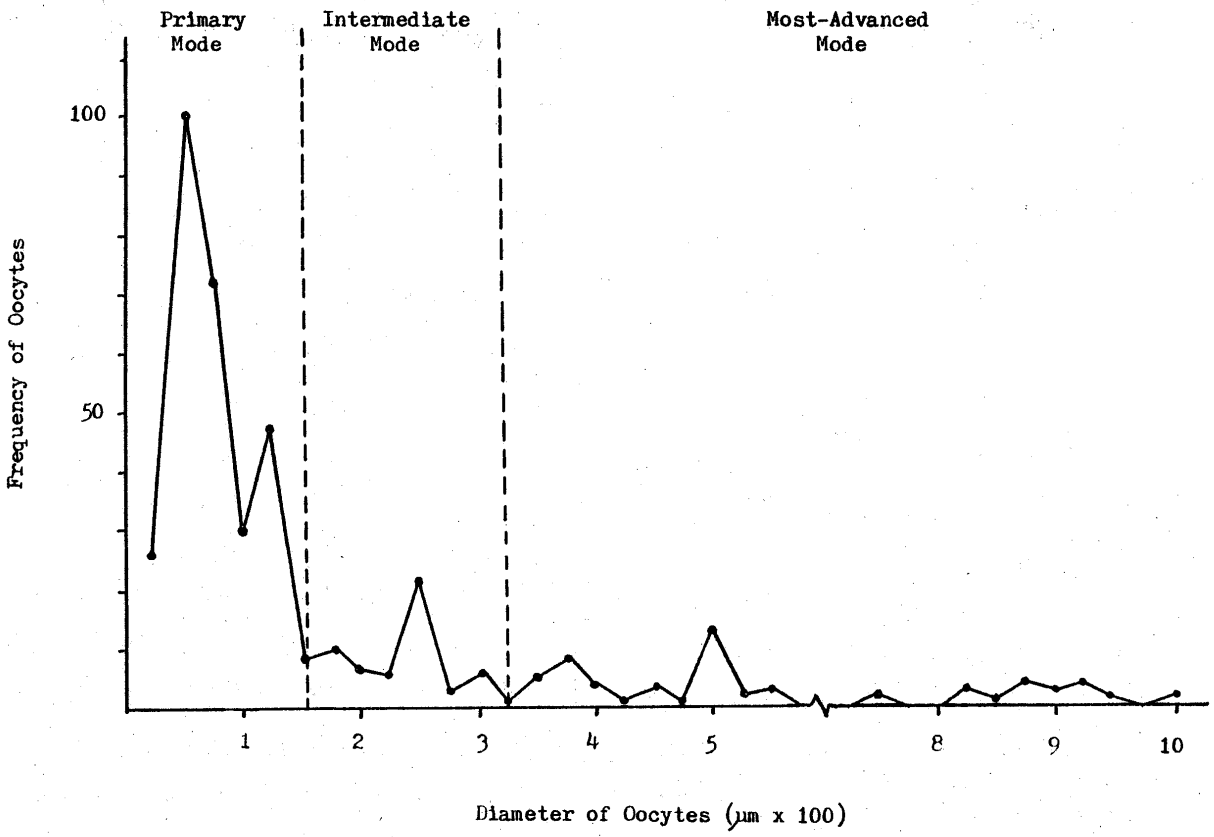


Figure 4.3. Representative ova size frequency distribution for Menidia beryllina, 66 mm SL, 4.6 g, right ovary weight = 113.8 mg; gonad index = 5.29; from sample collected at station Y on 10 May 1979; female #24r.

III. RESULTS

Anchoa mitchilli

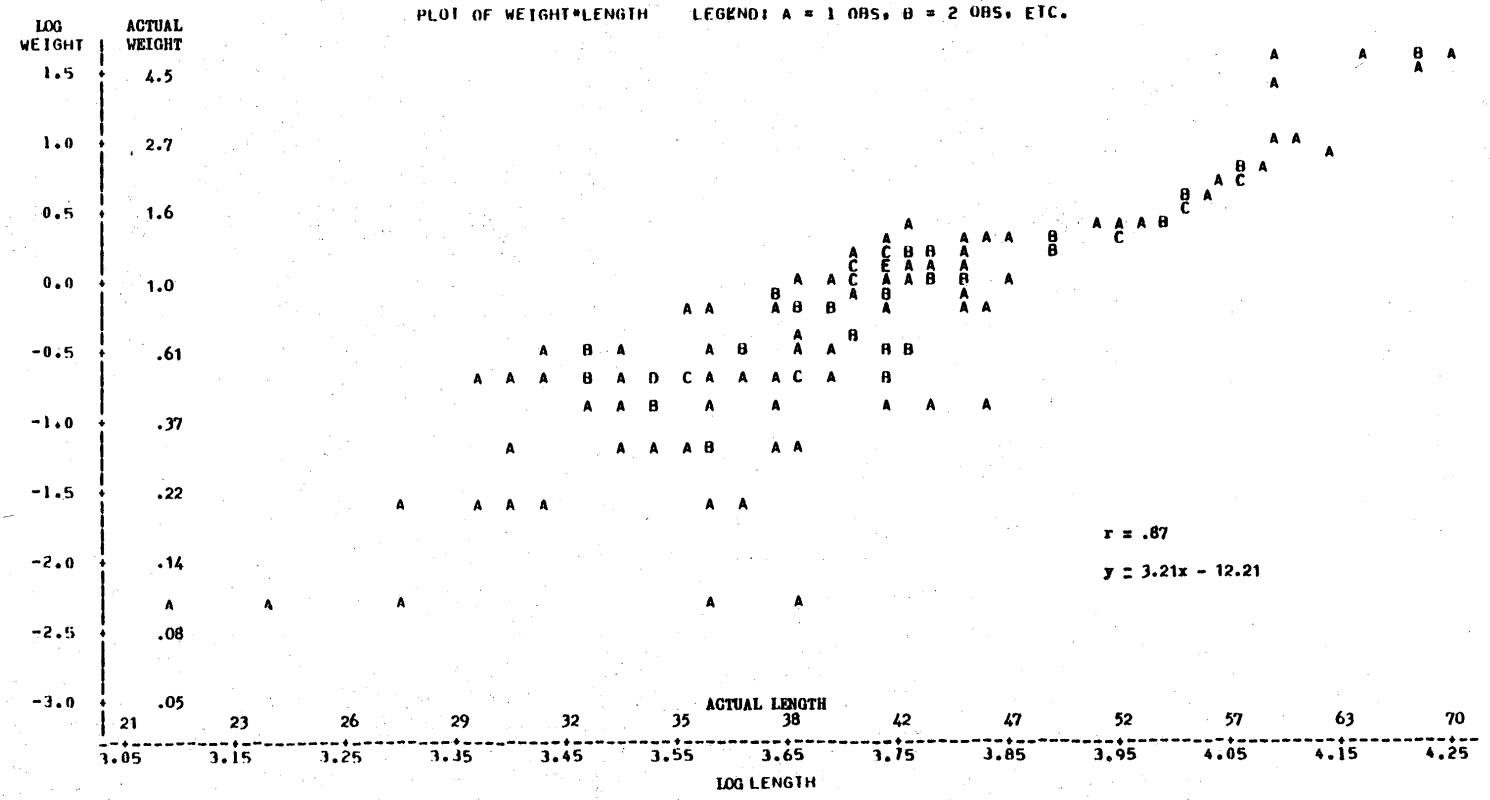
One hundred and eighty-eight individuals were collected during the study. One hundred and three were female, of which only sixty-six possessed maturing ova. Eighty-one individuals were male. Sex could not be determined for four undifferentiated specimens. Bay anchovies were collected all months but appeared to be most abundant during August and September. Sizes ranged from 29 - 70 mm SL ($\bar{x}$=42) and wet weights from 0.1 - 5.2 g ($\bar{x}$=0.8). Of the 103 females, sizes ranged from 29 - 68 mm SL ($\bar{x}$=46) and wet weights from 0.1 - 5.1 g ($\bar{x}$=1.3 g; Appendix 4A). All individuals appeared to represent age class 0, although it is possible that several individuals were approaching or may have attained age I, i.e. 65 - 70 mm SL. Ln-ln regressions of length vs. weight gave reasonably good fit (r = .87, Figure 4.4).

Paired, elongated ovaries are suspended from the dorsal wall of the abdominal cavity by the mesovarium. In 88% of the females examined, the left ovary was larger than the right. Preserved ovaries varied from extremely thin, transparent structures of immature individuals to comparatively thick, opaque, brownish structures of maturing females.

As determined by ova size frequency distributions (Figure 4.2), oocytes <150 µm represented immature, undeveloped ova. Bay anchovy oocytes were generally elongated, with major and minor axes. All measurements for ova size frequency distributions were made along major axes. Friedman's test (P=0.5) did not indicate any significant difference in distributions of oocytes between different regions of the ovary. Non-developed oocytes were transparent (little to no yolk) with a large nucleus that generally occupied ≤50% of the cell volume. Diameters of maturing oocytes (intermediate mode) ranged from ≥150 to approximately 275-300 µm. Developing oocytes were characterized by increasing yolk concentrations and a corresponding less obvious and proportionally smaller nucleus. Diameters of oocytes of the most advanced mode ranged from 300 - 1000 µm. Less developed ovaries and respective oocytes were generally tightly packed and cells firmly attached to one another. With maturity and increasing ova size diameters, ova became increasingly disjunct from neighboring cells.

Mean gonad indices per month ranged from 0.39% (November) to 8.18% (June) (Figure 4.5), although individual indices varied from 0.30 - 15.12%. Maturity of females could be appraised by the indices. The higher the index, the greater the percent of increasingly mature oocytes. Indices less than 1.0% generally represented ovaries where the majority of oocytes were ≤100µm; immature females fell in this category. Indices of about 1.0 - 4.0% represented females whose ovaries were composed primarily of oocytes of ≤500 µm. Females containing an abundance of rapidly maturing (500 µm) and full term oocytes (≈900 - 1000 µm) were characterized by indices ≥4.0%. Maturing and full term females possessed a spectrum of ova diameters distributed over the three modes.

Figure 4.4. LOG-LOG REGRESSION - LENGTH-WEIGHT - ANCHOA MITCHILLI



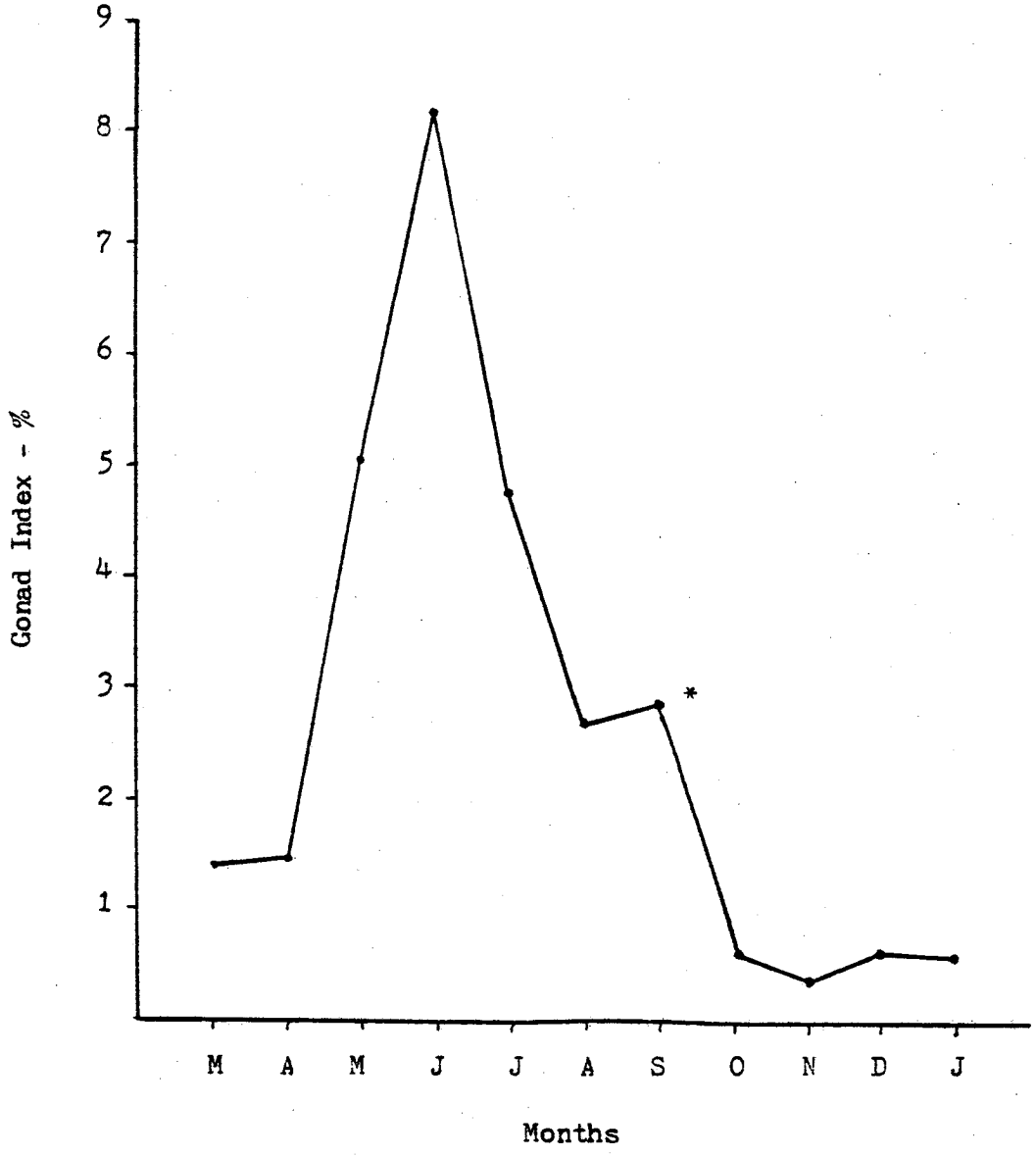


Figure 4.5. Mean gonad index per month for female Anchoa mitchilli.

* Exclusive of individual index value of 13.1; if included, mean gonad index = 3.7%; 13.1 considered spurious.

Fecundity estimates ranged from 64 ova (relatively immature specimens) to 3963 ova per female ($\bar{x}$=925 ova/female; Appendix 4A). Relative fecundities ranged from 41 - 4280 ova/g soma ($\bar{x}$=1587 ova/g soma). Using fecundity data relevant to only the months of potential active spawning (i.e. gonad indices generally $\geq$1%, March through September), fecundity estimates for all specimens collected (60) ranged from 94 - 3963 ova per female ($\bar{x}$=1563 ova/female; Appendix 4B); relative fecundities ranged from 190 - 4280 ova/g soma ($\bar{x}$=1689 ova/g soma). The six fish collected during March and April 1979 were all greater than 60 mm and appeared to have attained Age I although their scales did not have a discernable annulus. These Age I individuals had very low relative fecundity ($\bar{x}$=435 ova/g soma) and may have spawned previously either in early March 1979 or late Fall 1978. Therefore, these fish are considered partially spent and, not having their full complement of eggs, do not represent fish at their full spawning potential.

The fecundity estimates for the 54 mature or maturing females ranged from 94 to 3963 ova/female ($\bar{x}$=1482 ova/female); relative fecundity ranged from 190 to 4280 ova/g soma ($\bar{x}$=1829 ova/g soma). Untransformed data from the months of potential active spawning gave the best fit for regressions of fish length vs. fecundity (r = .66, Figure 4.6) and fish weight vs. fecundity (r = .74, Figure 4.7).

Menidia beryllina

One hundred and forty-nine individuals were examined during the study. One hundred and eleven were female, ninety-nine of which possessed mature or maturing ova; thirty-eight individuals were male. Tidewater silversides were collected in all months. Individuals ranged from 36 - 92 mm SL ($\bar{x}$=64mm SL) and wet weights ranged from 0.4 - 9.6 g ($\bar{x}$=3.8g). Of the 111 females, sizes ranged from 44 - 92 mm SL ($\bar{x}$=64) and wet weights from 1.2 - 9.6 g ($\bar{x}$=3.8; Appendix 4C). Scale annuli and length-frequency comparisons indicated individuals were in age classes 0 and I. Though not always consistent, single annuli could be correlated with length-frequency data indicating fish were age I at about 70 mm SL. For specimens examined, the dominant age was 0 (70%). Ln-ln regressions of length vs. weight gave good fit (r = .97, Figure 4.8).

Ovaries of M. beryllina were elongated paired structures suspended by the mesovarium of the dorsal abdominal wall. Sixty-seven percent of the left ovaries were larger than the corresponding right ovaries. Preserved ovaries were always yellow-brown and opaque.

As determined by ova size frequency distributions (Figure 4.3), oocytes $\leq$150 um in diameter represented immature, undeveloped oocytes. Friedman's test (P=.05) did not indicate any significant difference in distributions of oocytes between different regions of the ovary. Like A. mitchilli, primary oocytes were transparent with little to no yolk and a large nucleus that generally occupied 50% of the cell volume. Maturing oocytes (intermediate mode) ranged in diameter from approximately 150 - 325 µm. Developing oocytes were characterized by increasing yolk concentrations, a corresponding more obscure and proportionally smaller nucleus, and a marbled surface appearance of parallel curved lines (whorls). Surface

Figure 4.6 BAY ANCHOVY FECUNDITY (Anchoa mitchilli)

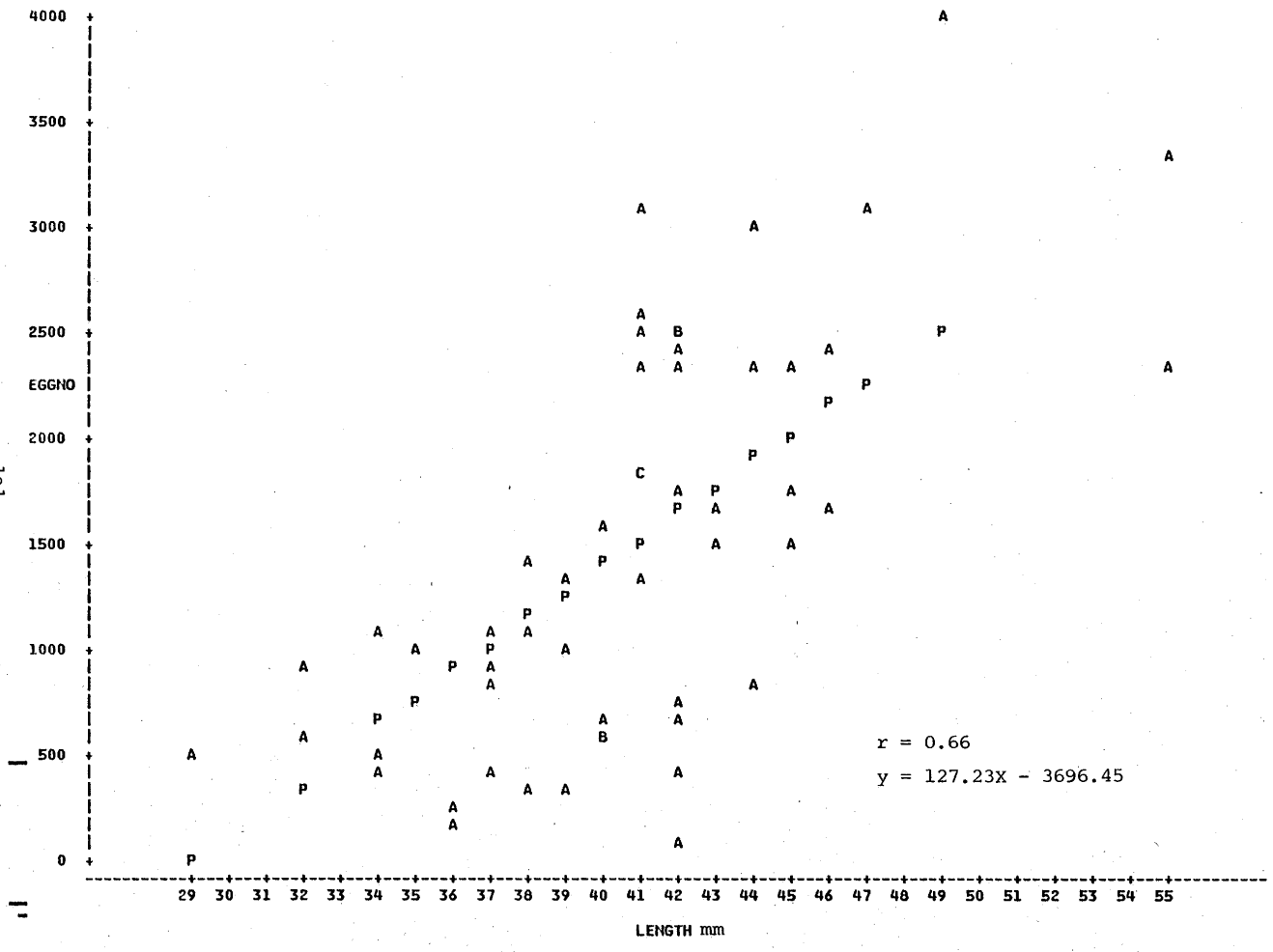


Figure 4.7. BAY ANCHOVY FECUNDITY (Anchoa mitchilli)

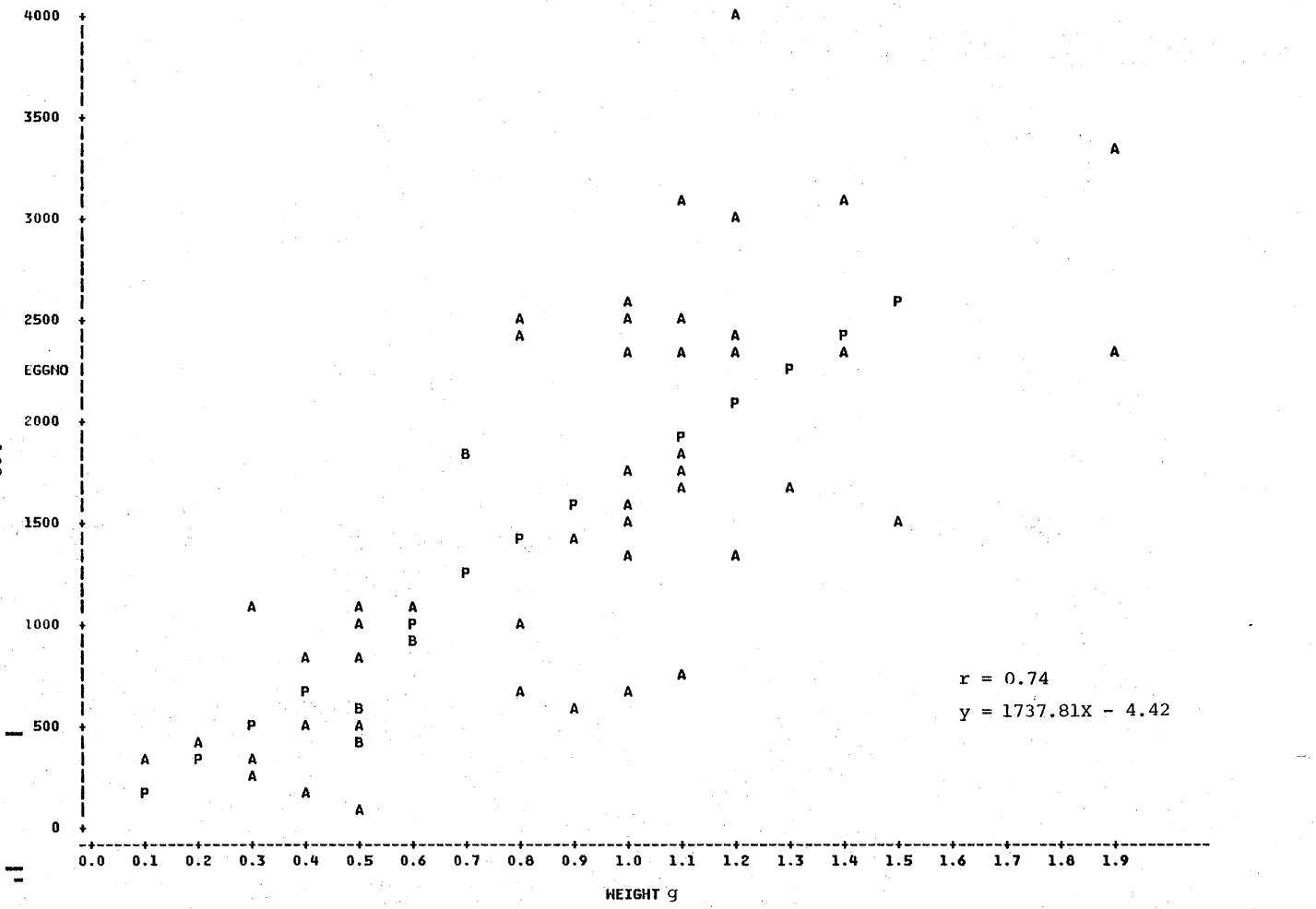
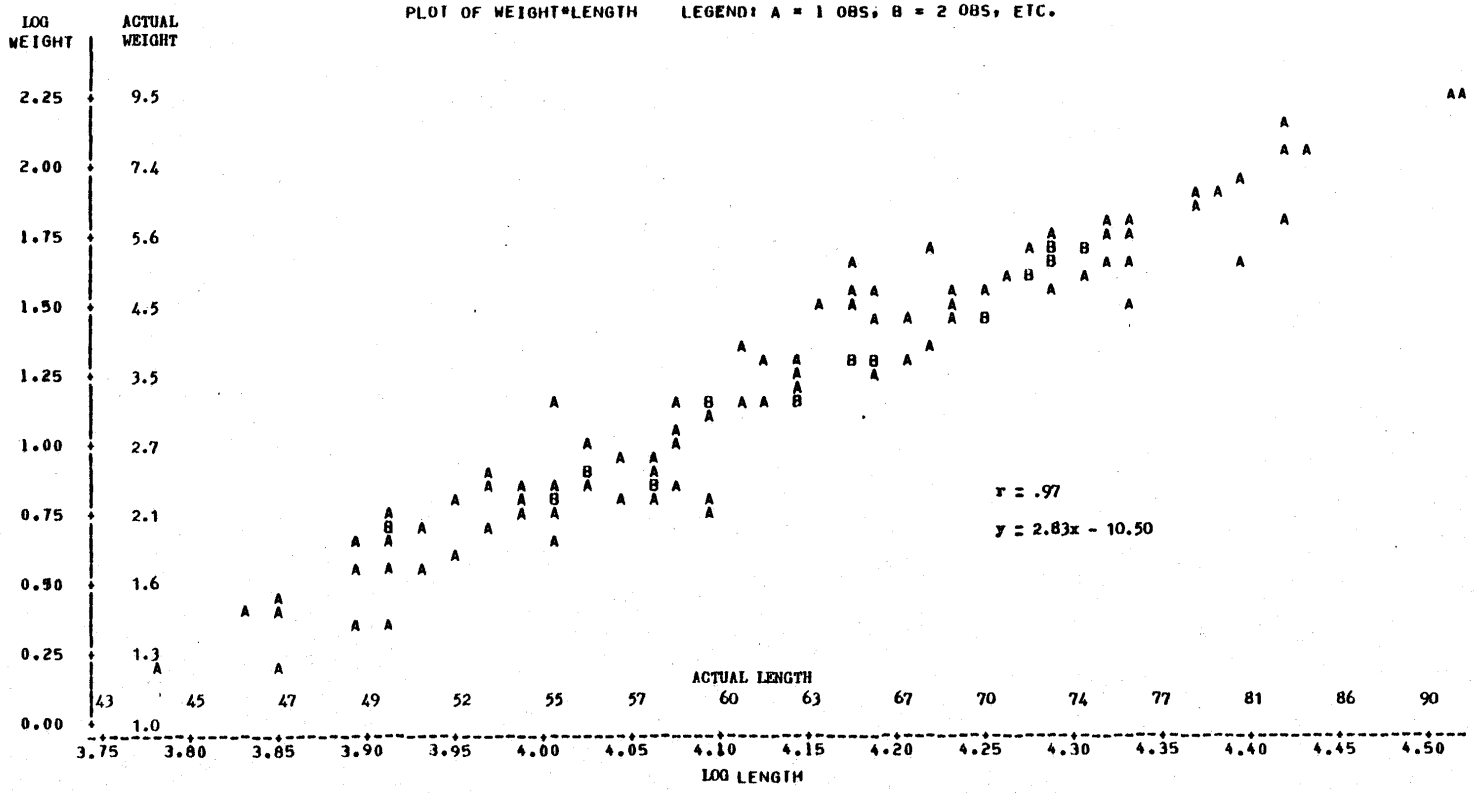


Figure 4.8. LOG-LOG REGRESSION - LENGTH-WEIGHT - MENIDIA BERYLLINA



texture became less apparent with increasing size of oocytes, although it was not uncommon of most oocytes in the most advanced mode(325 - 1150 μm). Marbling was absent in the most mature ova (1000 - 1150 μm) although numerous fat bodies and yolk inclusions were apparent. In addition, near or fully mature oocytes displayed prominant, thin, elongate, sticky threads.

Less developed ovaries and respective oocytes were generally tightly packed and highly adhesive to one another. With maturity and larger ova size diameters, ova became increasingly segregated although meshing of the adhesive threads tended to cause ova aggregations.

Individual gonad indices ranged from 0.22 - 13.48%, although mean gonad indices per month varied from 0.57% (September) to 7.54% (January). Maturation states of females could be approximated using index values, the higher the index, the more mature the female (Figure 4.9). Indices $\leq$1% indicated immature or spent females, i.e. primary oocytes. Females with the majority of maturing ova 350 - 400 μm exhibited indices of about 1 - 3%. Females containing an abundance of rapidly maturing ($\geq$400 μm ova size diameter) or fully mature oocytes (825 - 1150 μm ova size diameters) were characterized by indices greater than 3%. Maturing or ripe females always possessed a variety of oocytes with diameters distributed over the three modes, but immature or spent individuals generally possessed only primary oocytes. Though not abundant, some females considered to be spent were collected in July. Additional spent females were probably scattered throughout other samples, but were not readily recognized as such.

Fecundity estimates ranged from five (all remainder primary oocytes) to 10327 ova/female ($\bar{x}$=2493 ova/female; Appendix 4C). The maximum relative fecundity equaled 1493 ova/g soma ($\bar{x}$=686 ova/g soma). Using fecundity data relevant to only the months of potential active spawning (i.e. gonad indices generally >1%, i.e. March through August 1979; December 1979; January 1980; exclusive of spent individuals), fecundity estimates ranged from 200 - 10327 ova/female ($\bar{x}$=3173 ova/female; Appendix 4D); relative fecundities ranged from 67 - 1493 ova/g soma ($\bar{x}$=754 ova/g soma).

Relative fecundity of all Age 0 individuals (81) ranged from 0 to 1487 ova/g soma ($\bar{x}$=600 ova/g soma) while selected age 0 individuals (55) from active spawning period ranged from 67 to 1487 ova/g soma ($\bar{x}$=687 ova/g soma). Relative fecundity of Age I individuals (30) ranged from 415 to 1493 ova/g soma ($\bar{x}$=876 ova/g soma). Untransformed data for all females collected during the months of potential active spawning gave the best fit for regressions of fish length vs. fecundity (r = .80; Figure 4.10) and fish weight vs. fecundity (r = .83; Figure 4.11).

It was noted that the most mature females were generally those approaching or attaining age class I, but it was not uncommon to find fully mature females as small as 46 - 50 mm SL. Individuals of this size were estimated to be about nine to ten months old.

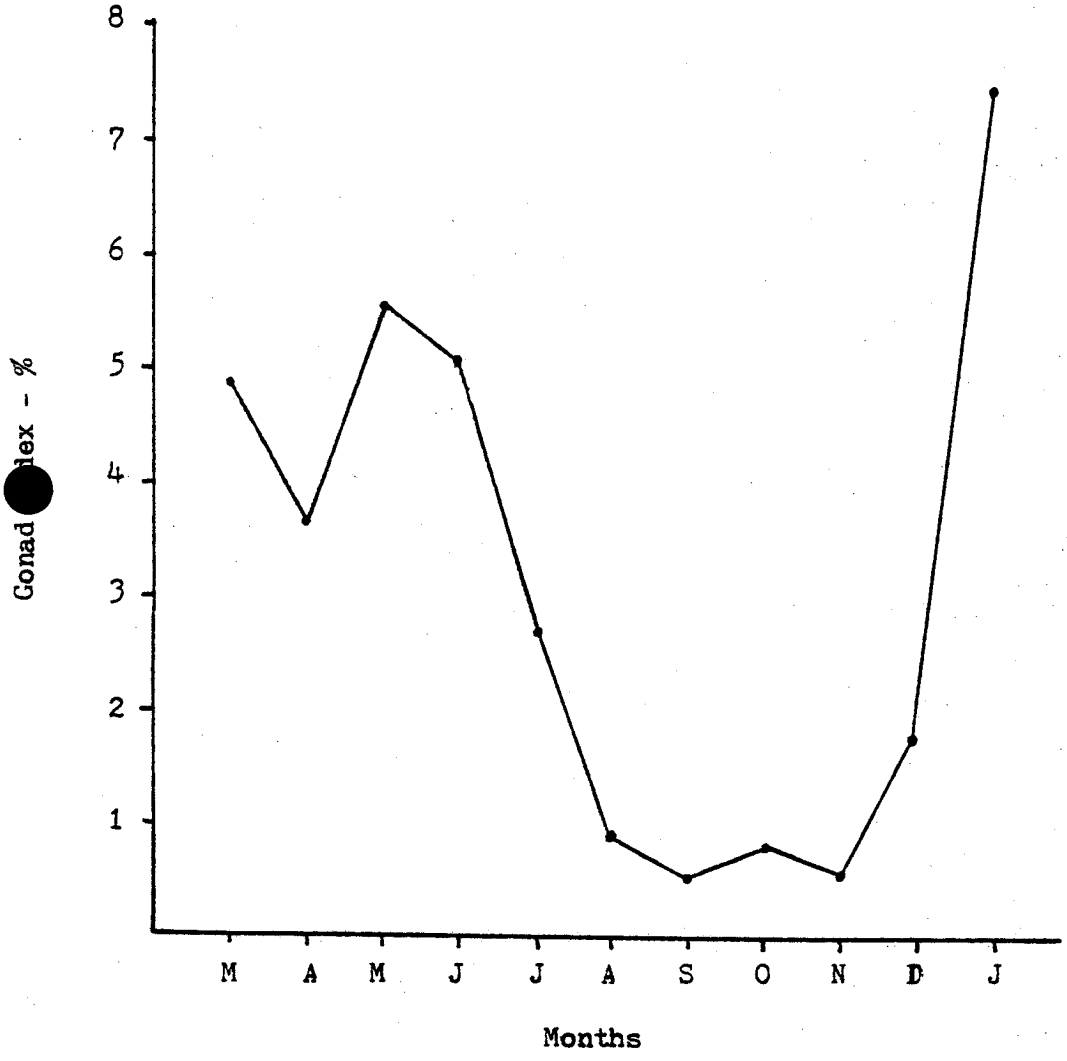


Figure 4.9. Mean gonad index per month for female Menidia beryllina.

Figure 4.10. TIDEWATER SILVERSIDE FECUNDITY (Menidia beryllina)

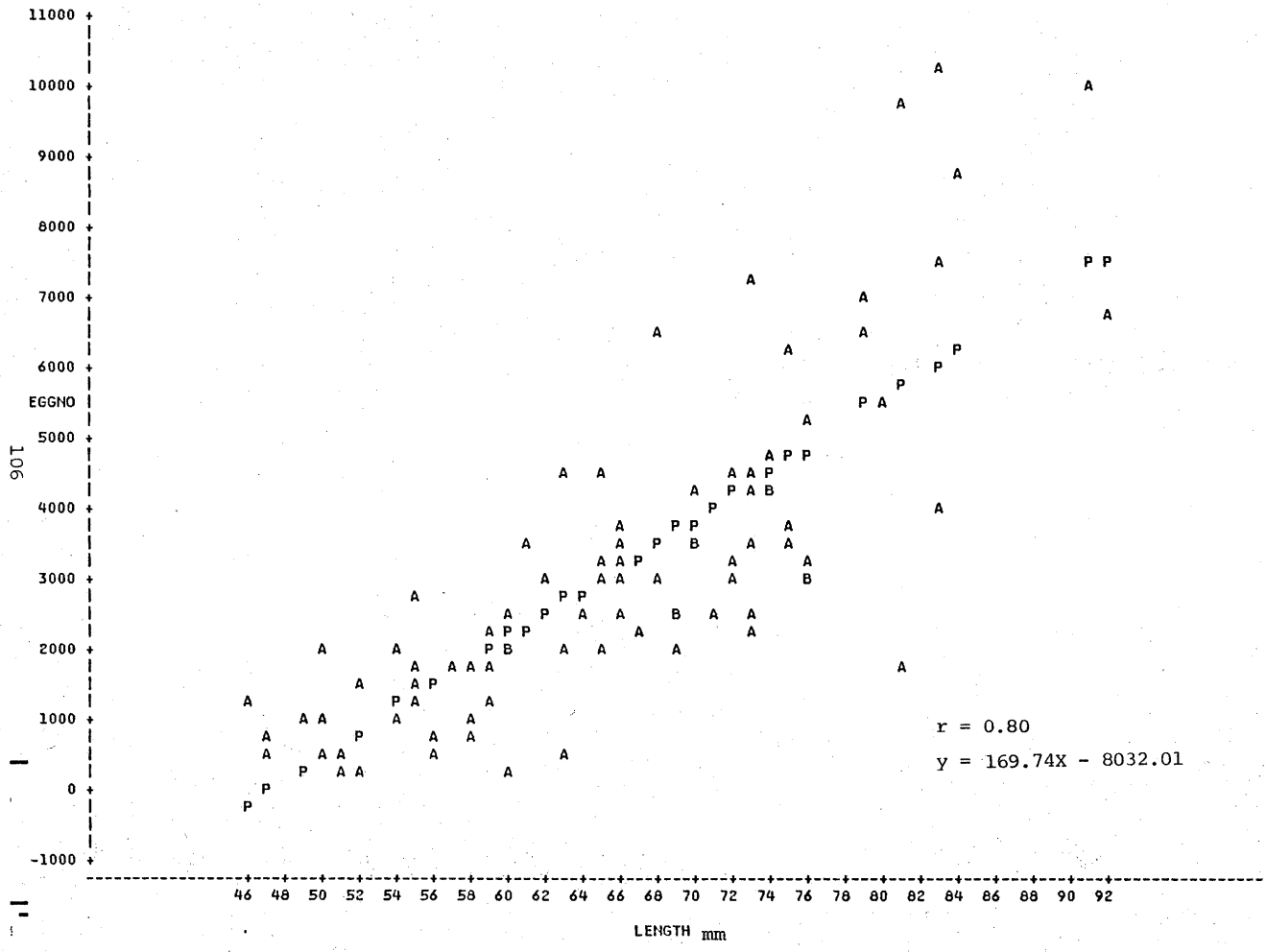


Figure 4.11. TIDEWATER SILVERSIDE FECUNDITY (*Menidia beryllina*)

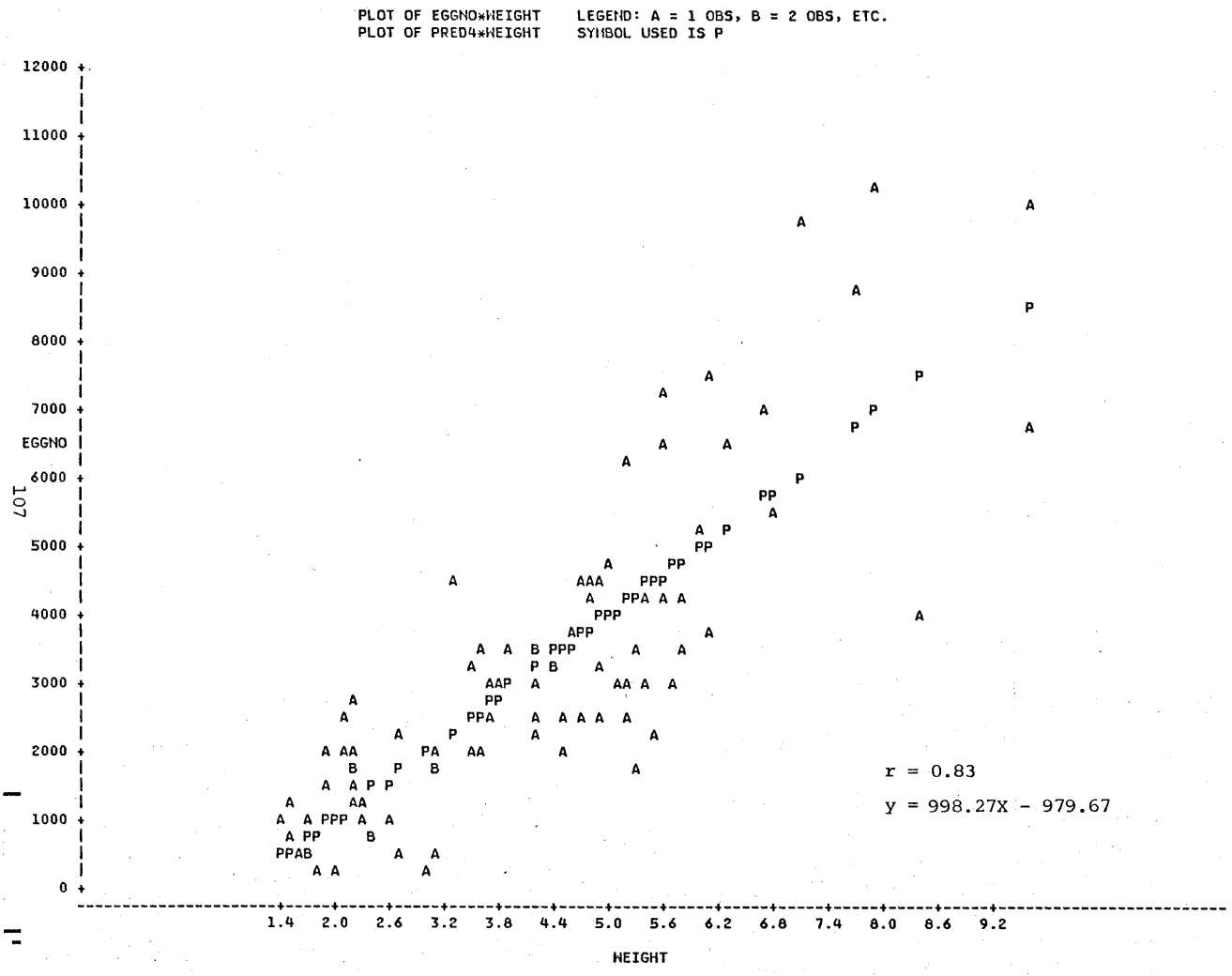
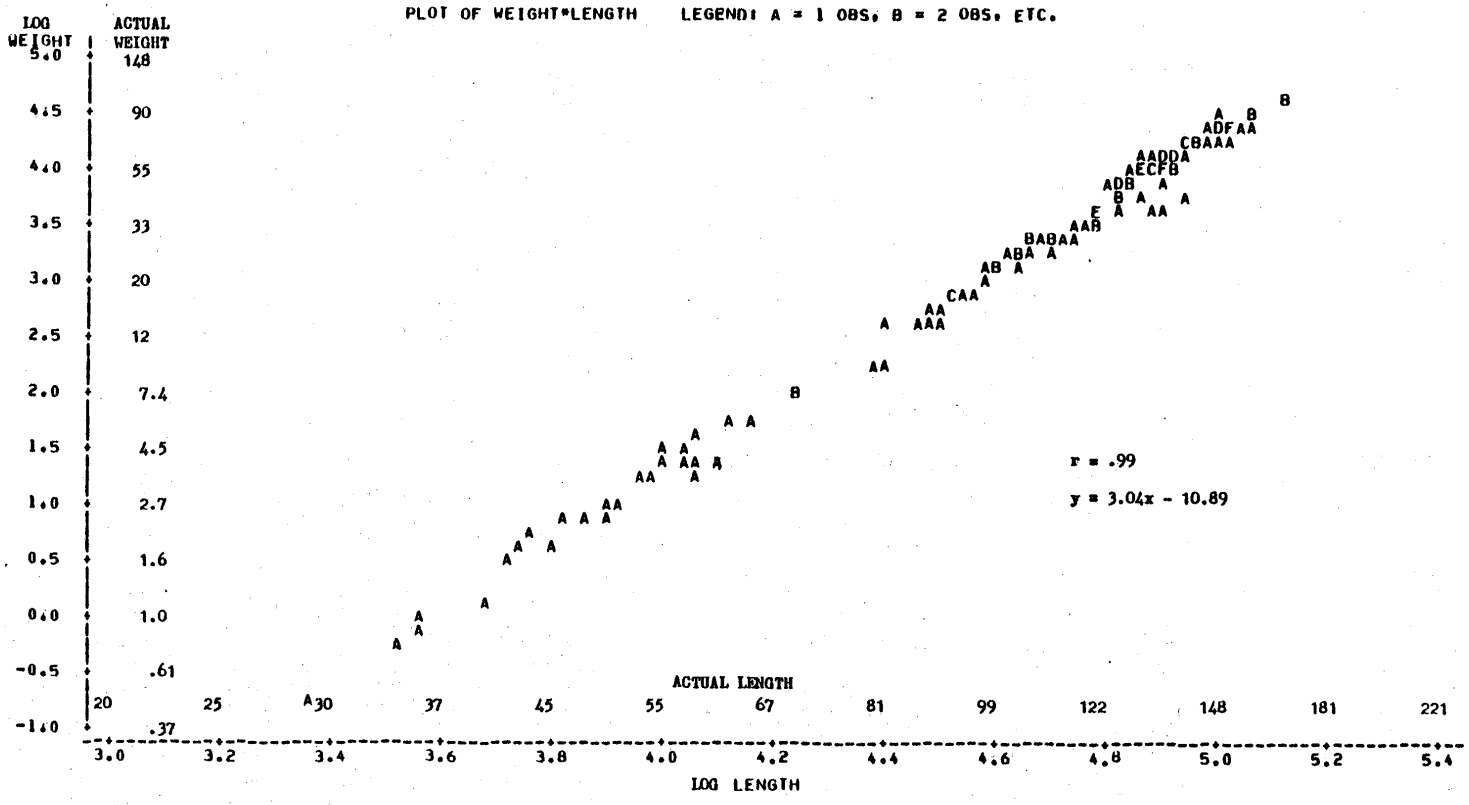


Figure 4.12. LOG-LOG REGRESSION - LENGTH*WEIGHT - BAIRDIELLA CHRYSURA.



Bairdiella chrysura

One hundred and thirty-six individuals were examined during this study. Seventy-three individuals were female, sixty-three individuals were male or some undetermined sex (gonads undifferentiated). Silver perch were collected in all months except March and appeared to be most abundant throughout the fall and early winter. Individuals ranged in size from 29 - 168 mm SL ($\bar{x}$ = 110 mm SL) and wet weights ranged from 0.45 - 99.0 g ($\bar{x}$=39.4g)

Scale annuli and length-frequency comparisons indicated that individuals were predominantly age 0, with only eight specimens representing age I. Though not always consistent, single annuli could be correlated with length-frequency data showing fish to become age I at about 150 mm SL. Ln-ln regressions of length vs. weight gave good fit (r = .99, Figure 4.12).

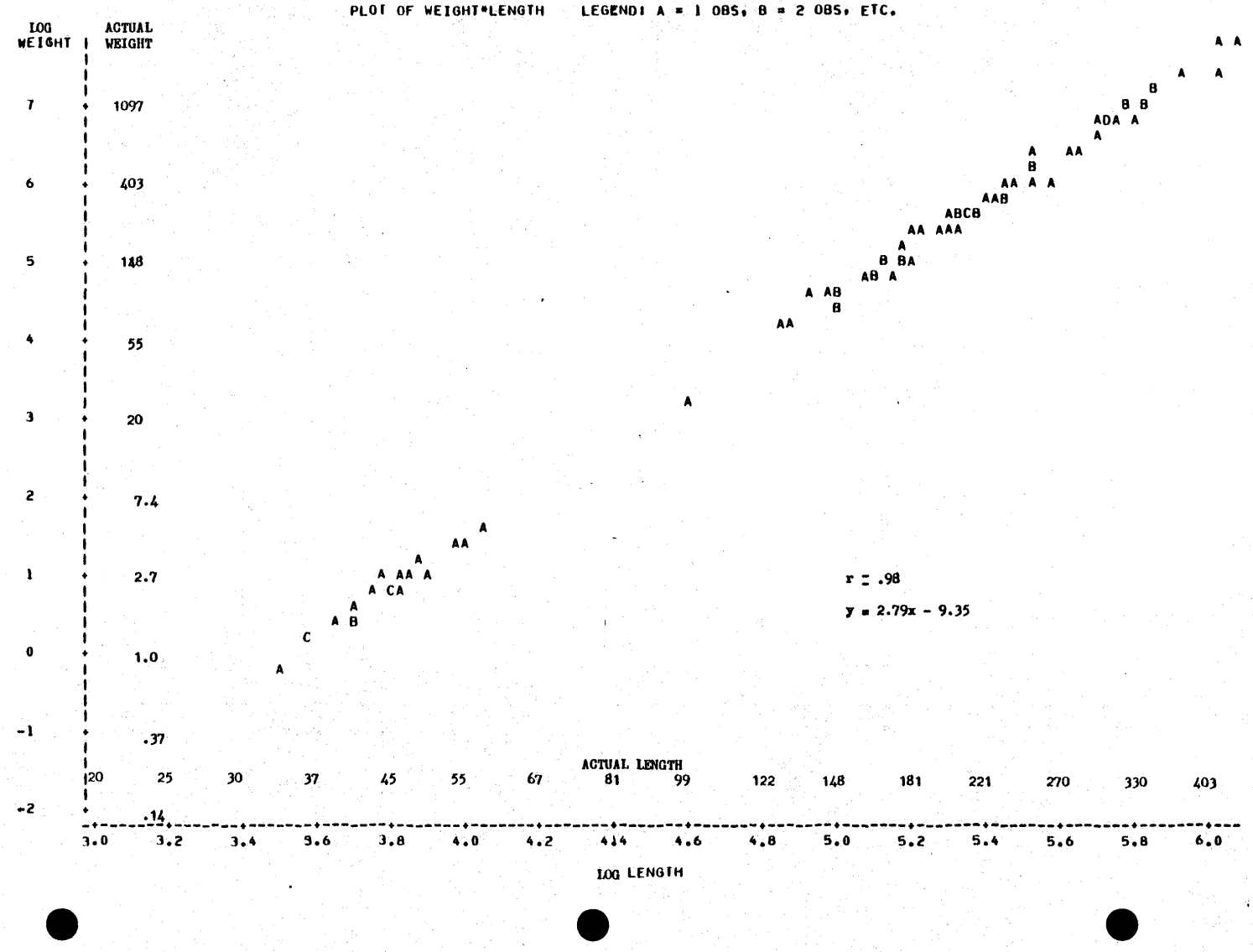
Ovaries were elongated, paired structures supported by the mesovarium of the dorsal abdominal wall. Neither ovary of a pair tended to be larger than the other. Preserved ovaries were opaque, cream to light brown in color. Of all females examined, only four specimens had ovaries that contained oocytes of diameter $\geq$150 µm. The most mature female was collected 15 January 1980 at station B: 133 mm SL, 55.6 g, gonad index 1.9%, ova size diameters $\leq$475 µm. The second most mature female was also collected at station B, but on 23 October 1979: 153 mm SL, 82.5 g, oocytes diameter $\leq$375 µm, gonad index, = 0.9%. Two other fishes possessed ovaries with scattered oocytes with diameters of 150 µm (station A, collected 18 December 1979). All other fishes possessed ovaries containing oocytes $\leq$125 µm, generally $\leq$100 µm. Excepting the gonad index noted above, all other indices were <1%. Such immature ovaries containing primary oocytes did not allow the plotting of ova size frequency distributions. No fecundity counts were conducted because of the lack of specimens that contained mature and/or maturing oocytes.

Pogonias cromis

Eighty-seven specimens were collected, of which thirty-one were female and twenty-one individuals were male. The sex of thirty-five fishes was unknown due to undifferentiated gonads. P. cromis were collected all months except March and April. The greatest number of black drum were collected during the fall and early winter. Individuals ranged from 33 - 438 mm SL ($\bar{x}$=184 mm SL) and wet weights varied from 0.9 - 2372.4 g ($\bar{x}$ = 379g).

Scale annuli and length frequency comparisons revealed forty-nine individuals (56%) were age 0, thirty-two individuals (37%) were age I, and six individuals (7%) were age II. Annuli and length frequencies indicated age class 0 individuals to be up to about 190 mm SL, age I individuals falling between about 190 - 330 mm SL, and age II individuals being about 330 - 430 mm SL. Ln-ln regressions of length vs. weight gave good fit (r = .98, Figure 4.13).

Figure 4.13. LOG-LOG REGRESSION - LENGTH-WEIGHT - POGONIAS CROMIS



Ovaries were elongated, paired structures, generally flush with the dorsal abdominal wall. Sixty-five percent of the left ovaries were larger than the right. Preserved ovaries were opaque, cream to light tan in color. All ovaries contained only primary oocytes, ≤125 µm in diameter. Ova size frequency distributions could not be plotted nor fecundity estimates made due to the deficit of mature females. Gonad indices were always <1%.

Cynoscion nebulosus

Four spotted seatrout were collected. Two were females and two classed as unknown sex due to immature gonads. All specimens were age 0. The largest specimen collected was from station E on 9 September 1979: female, 163 mm SL, 65.5 g. The second female collected was on 17 November 1979 at station L: 146 mm, SL, 47.1 g. Ovaries on both females contained only primary oocytes <25 µm in diameter. Ova size frequency distributions could not be plotted; no fecundity estimates were made due to insufficient numbers of mature females.

IV. DISCUSSION

Anchoa mitchilli

Age and growth data agree with other published accounts of the bay anchovy (Mansueti and Hardy, 1967; Gallaway and Strawn, 1974). Similar age data have been reported for Texas waters (Gunter, 1945) as well as Tampa Bay (Springer and Woodburn, 1960). No fecundity estimates for A. mitchilli from subtropical regions appear to exist in current literature. Stevenson (1958) reported fecundity estimates from Delaware River Estuary (Temperate Region) of 2400 ova/fish (mean length of fish = 62.2 mm). His estimates were, however, based on limited data (15 individuals). Ova diameters of mature ooxytes are comparable with those reported by Kuntz (1913). According to Dr. Edward Houde (personal communication), one might expect fecundity estimates to vary from about 400 - 1000 ova/g soma fish weight. Estimates reported here fall on both sides of this: cumulative data: 41 - 4280 ova/g soma; peak spawning season data: 190 - 4280 ova/g soma. Variability in both absolute and relative fecundities is not uncommon, as noted in a review of fecundity and spawning by Nikolskii (1969). In addition, the rapid turnover of anchovy populations in bay systems is supportive to these estimates, as are reports of extended spawning seasons (Hilderbrand and Shroeder, 1928; Gunter, 1945; Springer and Woodburn, 1960; Kalke, 1972; Johnson, 1973) and large numbers of eggs in the water column as noted by concomitant meroplankton studies of the bay (see Chapter 2 of this report). Based on gonad indices (Figure 4.5) and ova size diameters, the extended spawning season noted for bay anchovies during this study appeared to be from April through July, with maximum spawning, occurring in June. These data also agreed with data reported from the concomitant meroplankton studies. Anchovies may be able to reproduce at ages near three months as reported by Mansueti and Hardy (1967) for populations in Chesapeake Bay. Spawning times and fecundity are known to vary temporally and spatially in response to local influences (Gallaway and Strawn, 1974).

Menidia beryllina

Sizes and ages reported here for the tidewater silverside are consistent with those observed by Springer and Woodburn (1960) in Tampa Bay. Hildebrand and Shroeder (1928) noted ripe females from April to September in Chesapeake Bay and the strong possibility of multiple spawning; along the Texas coast, Gunter (1945) reported evidence of two spawning peaks (spring and fall). For Tampa Bay, Springer and Woodburn (1960) hesitantly reported two spawnings (spring and fall 1957) but then also reported no evidence existed for a fall spawn in 1958. A previous study in the vicinity of Big Bend (Comp, 1977) indicated an extended spawning period for this species. Data collected in this study do not indicate multiple spawning for the time period sampled. However, an extended spawning season was indicated by gonad indices (Figure 4.9) and ova size diameters, i.e. March - July with some spawning still indicated for August 1979. May - June 1979 appeared to be the peak spawn of the 1979 season. For the time period examined, a second and even higher peak (i.e. gonad index = 7.5) occurred in January 1980. Whether January is part of a cyclic, extended spawning period is unknown.

Maturity of females at various lengths (≥46 mm SL) may lend the idea of M. beryllina being able to spawn more than once in a lifetime, with its first spawn occurring at an age of nine to ten months. With suitable environmental and habitat conditions, it appears feasible that silversides could have multiple spawnings in the Tampa Bay area.

Although no reports of fecundity estimates are available in the literature, ova diameters of mature oocytes are comparable with those reported by Hardy (1978). Fecundity of the related species M. audens has been estimated at 44,000 - 59,000 ova/breeding season as a function of multiple spawning (Mense, 1957; Hubbs, 1976).

Bairdiella chrysura

Due to the lack of mature specimens, only a limited amount of data could be amassed concerning silver perch. Results are reasonably comparable to those reported by Gunter (1945), Reid (1954), and Springer and Woodburn (1960).

Age determinations indicated that fish were age I at about 150 mm SL. Hardy (1978) reports that some B. chrysura may mature during their second year; this was taken into account in reference to a single female (collected in January 1980) nearing age I that possessed maturing oocytes of diameters ≥475 μm. Kuntz (1913) has reported mature oocytes at diameters of 660 - 880 um. Gunter (1945) has reported collecting a ripe female from Copano Bay during April. The projected spawning season for silver perch in northern Florida has been reported as May - September (Hardy, 1968). One fecundity estimate has been made by Hildebrand and Shroeder (1927): 140 mm SL female from Chesapeake Bay with 52,800 ova. More intensive and varied sampling techniques might yield the mature fishes that are known to be available in the area.

Pogonias cromis

Like B. chrysura, little is known about this sciaenid other than its general life modes. Simmons and Breur (1962) have examined the life history of black drum in south Texas waters. Along the Gulf coast, P. cromis is thought to spawn from December to June, with 90% taking place during February to March. Further south, in the Florida everglades, black drum are thought to spawn from November to June (Hardy, 1978). One citation lists 6×10^6 eggs as the fecundity estimate of a 1110 mm SL female along the Texas coast (Pearson, 1929). Mature ova diameters are reported as 816 - 1020 um (Hindebrand and Shroeder, 1927).

Age and corresponding lengths of fishes collected in this study are comparable with those reported in the literature. Based on two females of age II, it was indicated that black drum do not become sexually mature until at least past age II; similar findings have been reported by Simmons and Breur (1962).

Cynoscion nebulosus

Collection of four age 0 individuals revealed little concerning the age and fecundity of this species in the Big Bend area. Fortunately, this species has drawn considerable attention from other researchers due to its commercial importance. More fecundity information is known about the spotted seatrout than for the total of all other RIS specimens.

C. nebulosus is known to spawn from March to October, mature ova diameters being between 700 - 980 μm. Fecundity estimates increase dramatically with increase in fish length. In Florida, Tabb (1961) has reported estimates of 15,000 ova for a 325 mm SL fish and more than 1.1×10^6 ova for a 625 mm SL female. Other estimates have been given by Pearson (1929), Hildebrand and Cable (1934), Moody (1950), Miles (1951), and Sundararaj and Sutkus (1962).

V. SUMMARY AND CONCLUSIONS

1) A study was conducted concerning the age and fecundity of five representative important species of fishes (RIS) known to inhabit estuarine waters of Tampa Bay/Hillsborough Bay in the vicinity of the Big Bend power plant. RIS included: bay anchovy Anchoa mitchilli; tidewater siverside Menidia beryllina; siver perch Bairdiella chrysura; black drum Pogonias cromis; spotted seatrout Cynoscion nebulosus.

2) One hundred and eighty-eight A. mitchilli were collected of which sixty were maturing females. All anchovies appeared to represent age class 0, although it is possible that some individuals were approaching or may have attained age I, i.e. 65 - 70 mm SL. A ln - ln regression of length vs. weight gave reasonable good fit ($r = .87$). Ova diameter and gonad indices suggested an extended spawning season of March through September, with maximum spawning occurring in June. Cumulative mean fecundity was estimated to be 925 ova/fish; mean relative fecundity was estimated at 1587 ova/g soma. Data selected from months of most active spawning yielded a mean fecundity of 1482 ova/fish; mean relative fecundity was estimated at 1829 ova/g soma. Untransformed data from the months of potential active spawning gave the best fit for regressions of fish length vs. fecundity ($r = .66$) and fish weight vs. fecundity ($r = .74$). Their fecundity estimates are reasonable considering high population densities of bay anchovy in spite of high turnover rate of the population due to the short life span of an individual.

3) One hundred and forty-nine M. beryllina were examined, of which ninety-nine were maturing females. Although the dominant age class was 0, 30% of individuals examined were age I. A ln - ln regression of length vs. weight gave good fit ($r = .97$). Cumulative mean fecundity equaled 2493 ova/fish, or a mean relative fecundity of 686 ova/g soma. Data selected from months of most active spawning yielded a mean fecundity of 3173 ova/fish; mean relative fecundity was estimated at 754 ova/g soma. These estimates fall within the expected relative fecundity values of about 400 - 1000 ova/g soma. Untransformed data from the months of potential active spawning gave the best fit for regressions of fish length vs. fecundity ($r = .80$) and fish weight vs. fecundity ($r = .83$).

4) For the time period of this study, data for M. beryllina indicate an extended spawning season of March to August. Peak spawining appeared to be from May to June 1979. A second spawning peak (or at least the beginning of another one) was indicated in January 1980. M. beryllina appeared to be able to spawn at the age of nine to ten months although the most fecund individuals were those that had attained age I.

5) One hundred and thirty-six B. chrysura were collected. Of the seventy-three females, all were immature. The most mature female possessed developing oocytes of 475 μm; all other females contained only primary oocytes, generally ≤100 μm. Most individuals collected were age 0. Fish reach age I about 150 mm SL. No fecundity estimates could be made due to the lack of mature females. A ln - ln regression of length vs. weight gave good fit ($r = .99$).

6) Eighty-seven specimens of P. cromis were collected, of which thirty-one were female. Of the fish collected, 56% were age 0, 37% were age I, and 7% were age II. All females were immature, containing primary oocytes ≤ 125 μm in diameter. A ln - ln regression of length vs. weight gave good fit (r = .97).

7) Four individuals of C. nebulosus were collected. Two were immature females, containing primary oocytes ≤ 25 μm in diameter. All specimens were age 0.

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Appendix 4A
FECUNDITY STUDIES
BIG BEND POWER STATION
ANALYSIS FOR SPECIES -- (Anchoa mitchilli)
All females examined during Age - Fecundity Studies.

DATE	STATION	FISH.WT.-OVA.WT	AGE OF FISH	LENGTH OF FISH	WEIGHT OF FISH	NUMBER OF EGG	REL-FECUN
790314	D	3.8191	0	60.0	3.9	2095.3	548.64
790314	D	4.6392	0	68.0	4.7	1918.5	413.53
790410	C	4.9347	0	68.0	5.0	1785.5	361.82
790510	A	1.8317	0	55.0	1.9	2357.0	1286.76
790510	A	1.7193	0	55.0	1.9	3326.0	1934.49
790510	B	0.9746	0	45.0	1.0	1708.5	1753.00
790605	B	0.7640	0	40.0	0.8	677.6	886.93
790605	B	0.8723	0	41.0	1.0	2606.8	2988.43
790605	B	1.0634	0	42.0	1.1	724.0	680.85
790605	B	0.8682	0	41.0	1.0	2504.6	2884.78
790605	B	0.8783	0	40.0	0.9	621.1	707.16
790605	B	0.9337	0	41.0	1.1	3120.6	3342.23
790605	B	1.0092	0	41.0	1.1	1859.2	1842.23
790605	B	0.9645	0	43.0	1.1	1656.8	1717.80
790605	B	0.9830	0	42.0	1.0	667.7	679.27
790410	C	5.0183	0	60.0	5.1	3294.0	656.40
790314	D	4.7502	0	65.0	4.8	1583.8	333.41
790314	D	4.8473	0	68.0	4.9	1423.3	293.62
790731	D	1.0519	0	44.0	1.1	2298.2	2184.76
790731	D	0.7739	0	39.0	0.8	977.9	1263.65
790806	N	1.4617	0	43.0	1.5	1483.0	1014.59
790709	N	1.1290	0	44.0	1.2	2964.3	2625.63
790806	J	1.3532	0	45.0	1.4	2295.1	1696.08
790806	N	0.7521	0	46.0	0.8	2439.4	3243.51
790806	N	1.1659	0	42.0	1.2	2354.8	2019.72
790806	N	1.1601	0	42.0	1.2	2432.5	2096.82
790806	N	1.0754	0	42.0	1.1	1763.6	1639.92
790806	N	0.8739	0	38.0	0.9	1421.2	1626.22
790806	N	1.1787	0	41.0	1.2	1331.1	1129.32
790806	N	0.9701	0	41.0	1.0	2324.1	2395.70
790806	N	1.0995	0	42.0	1.1	0.0	0.0
790806	D	1.1933	0	43.0	1.2	0.0	0.0
790806	D	1.3596	0	47.0	1.4	3071.6	2259.21
790806	D	1.0624	0	42.0	1.1	2510.3	2362.83
790806	D	0.9719	0	40.0	1.0	1566.3	1611.60
790806	D	0.9807	0	39.0	1.0	1292.0	1317.44
790806	D	0.4919	0	29.0	0.5	513.8	1044.50
790806	D	0.5825	0	32.0	0.6	879.7	1510.23
790806	D	0.4986	0	29.0	0.5	0.0	0.0
790806	D	0.7601	0	42.0	0.8	2522.1	3318.07
790806	D	0.4807	0	38.0	0.5	1110.0	2309.17
790806	D	0.9759	0	45.0	1.0	1526.4	1564.14
790806	D	0.6741	0	41.0	0.7	1843.9	2735.33
790806	D	0.6700	0	41.0	0.7	1816.6	2711.39
790806	D	0.2837	0	34.0	0.3	1114.4	3928.13
790806	D	0.3956	0	36.0	0.4	128.0	323.56
790806	D	0.4865	0	37.0	0.5	809.5	1663.95

Appendix 4A (cont.)

790806	D	0.4839	0	35.0	0.5	997.8	2061.90
790806	D	0.5830	0	37.0	0.6	1088.8	1867.63
790806	D	0.3940	0	34.0	0.4	495.0	1256.34
790806	D	0.4962	0	34.0	0.5	403.0	812.17
790806	D	0.5868	0	37.0	0.6	923.7	1574.07
790806	D	0.4886	0	32.0	0.5	614.1	1256.80
790925	A	0.4986	0	35.0	0.5	0.0	0.0
790906	D	0.4972	0	39.0	0.5	0.0	0.0
790906	D	0.4833	0	40.0	0.5	579.9	1199.78
790909	E	0.2939	0	36.0	0.3	272.0	925.48
790909	E	0.2967	0	36.0	0.3	0.0	0.0
790909	E	0.2000	0	29.0	0.2	0.0	0.0
790906	D	0.3829	0	44.0	0.4	841.8	2198.57
790906	D	0.0869	0	39.0	0.1	371.9	4279.95
790906	D	0.2900	0	38.0	0.3	335.0	1155.17
790906	D	0.2935	0	39.0	0.3	0.0	0.0
790906	D	0.1902	0	37.0	0.2	387.0	2034.70
790906	D	0.4948	0	42.0	0.5	94.0	189.98
790906	D	0.4884	0	42.0	0.5	399.7	818.39
790909	W	1.1410	0	49.0	1.2	3963.1	3473.39
790906	A	1.2264	0	46.0	1.3	1661.6	1354.82
790909	M	0.5000	0	31.0	0.5	0.0	0.0
790909	M	0.4000	0	34.0	0.4	0.0	0.0
790806	D	0.7984	0	38.0	0.8	64.0	80.16
791023	D	0.7990	0	41.0	0.8	0.0	0.0
791218	A	0.9935	0	45.0	1.0	0.0	0.0
791018	K	1.1716	0	46.0	1.2	1490.1	1271.86
791018	K	1.2948	0	50.0	1.3	0.0	0.0
791018	K	1.5892	0	51.0	1.6	489.1	307.76
791018	J	1.5932	0	52.0	1.6	0.0	0.0
791018	J	1.2961	0	50.0	1.3	0.0	0.0
791018	J	1.2947	0	51.0	1.3	0.0	0.0
791018	J	1.4943	0	52.0	1.5	0.0	0.0
791018	J	1.3948	0	50.0	1.4	0.0	0.0
791018	J	1.2951	0	51.0	1.3	0.0	0.0
791117	D	1.7937	0	58.0	1.8	0.0	0.0
791117	D	1.4874	0	54.0	1.5	0.0	0.0
791117	D	1.3944	0	53.0	1.4	0.0	0.0
800104	J	1.5914	0	54.0	1.6	0.0	0.0
800104	J	1.3918	0	52.0	1.4	0.0	0.0
800104	J	1.7944	0	56.0	1.8	0.0	0.0
800104	J	1.1931	0	52.0	1.2	0.0	0.0
800127	K	1.5903	0	55.0	1.6	0.0	0.0
800127	K	1.3915	0	52.0	1.4	0.0	0.0
800127	K	1.8877	0	57.0	1.9	0.0	0.0
800127	J	1.6878	0	54.0	1.7	0.0	0.0
800127	J	1.5931	0	53.0	1.6	0.0	0.0
800127	J	1.7901	0	55.0	1.8	0.0	0.0
800127	N	2.8792	0	65.0	2.9	0.0	0.0
800127	N	2.1850	0	58.0	2.2	89.3	40.85
800127	N	2.2879	0	59.0	2.3	0.0	0.0
800127	N	2.7835	0	62.0	2.8	0.0	0.0
800127	N	2.0857	0	58.0	2.1	0.0	0.0
800127	N	2.3842	0	59.0	2.4	0.0	0.0
800127	N	1.6842	0	56.0	1.7	108.5	64.41

Appendix 4B.
FECUNDITY STUDIES
BIG BEND POWER STATION
ANALYSIS FOR SPECIES -- (Anchoa mitchilli)
Mature females March - September

DATE	STATION	FISH.WT.-OVA.WT	AGE OF FISH	LENGTH OF FISH	WEIGHT OF FISH	NUMBER OF EGG	REL-FECUN
790314	D	3.8191	0	60.0	3.9	2095.3	548.64
790314	D	4.6392	0	68.0	4.7	1918.5	413.53
790410	C	4.9347	0	68.0	5.0	1785.5	361.82
790510	A	1.8317	0	55.0	1.9	2357.0	1286.76
790510	A	1.7193	0	55.0	1.9	3326.0	1934.49
790510	B	0.9746	0	45.0	1.0	1708.5	1753.00
790605	B	0.7640	0	40.0	0.8	677.6	886.93
790605	B	0.8723	0	41.0	1.0	2606.8	2988.43
790605	B	1.0634	0	42.0	1.1	724.0	680.85
790605	B	0.8682	0	41.0	1.0	2504.6	2884.78
790605	B	0.8783	0	40.0	0.9	621.1	707.16
790605	B	0.9337	0	41.0	1.1	3120.6	3342.23
790605	B	1.0092	0	41.0	1.1	1859.2	1842.23
790605	B	0.9645	0	43.0	1.1	1656.8	1717.80
790605	B	0.9830	0	42.0	1.0	667.7	679.27
790410	C	5.0183	0	60.0	5.1	3294.0	656.40
790314	D	4.7502	0	65.0	4.8	1583.8	333.41
790314	D	4.8473	0	68.0	4.9	1423.3	293.62
790731	D	1.0519	0	44.0	1.1	2298.2	2184.76
790731	D	0.7739	0	39.0	0.8	977.9	1263.65
790806	N	1.4617	0	43.0	1.5	1483.0	1014.59
790709	N	1.1290	0	44.0	1.2	2964.3	2625.63
790806	J	1.3532	0	45.0	1.4	2295.1	1696.08
790806	N	0.7521	0	46.0	0.8	2439.4	3243.51
790806	N	1.1659	0	42.0	1.2	2354.8	2019.72
790806	N	1.1601	0	42.0	1.2	2432.5	2096.82
790806	N	1.0754	0	42.0	1.1	1763.6	1639.92
790806	N	0.8739	0	38.0	0.9	1421.2	1626.22
790806	N	1.1787	0	41.0	1.2	1331.1	1129.32
790806	N	0.9701	0	41.0	1.0	2324.1	2395.70
790806	D	1.3596	0	47.0	1.4	3071.6	2259.21
790806	D	1.0624	0	42.0	1.1	2510.3	2362.83
790806	D	0.9719	0	40.0	1.0	1566.3	1611.60
790806	D	0.9807	0	39.0	1.0	1292.0	1317.44
790806	D	0.4919	0	29.0	0.5	513.8	1044.50
790806	D	0.5825	0	32.0	0.6	879.7	1510.23
790806	D	0.7601	0	42.0	0.8	2522.1	3318.07
790806	D	0.4807	0	38.0	0.5	1110.0	2309.17
790806	D	0.9759	0	45.0	1.0	1526.4	1564.14
790806	D	0.6741	0	41.0	0.7	1843.9	2735.33
790806	D	0.6700	0	41.0	0.7	1816.6	2711.39
790806	D	0.2837	0	34.0	0.3	1114.4	3928.13
790806	D	0.3956	0	36.0	0.4	128.0	323.56
790806	D	0.4865	0	37.0	0.5	809.5	1663.95
790806	D	0.4839	0	35.0	0.5	997.8	2061.90
790806	D	0.5830	0	37.0	0.6	1088.8	1867.63
790806	D	0.3940	0	34.0	0.4	495.0	1256.34

Appendix 4B. (cont.)

790806	D	0.4962	0	[illegible].0	0.5	403.0	812.17
790806	D	0.5868	0	37.0	0.6	923.7	1574.07
790806	D	0.4886	0	32.0	0.5	614.1	1256.80
790906	D	0.4833	0	40.0	0.5	579.9	1199.78
790909	E	0.2939	0	36.0	0.3	272.0	925.48
790906	D	0.3829	0	44.0	0.4	841.8	2198.57
790906	D	0.0869	0	39.0	0.1	371.9	4279.95
790906	D	0.2900	0	38.0	0.3	335.0	1155.17
790906	D	0.1902	0	37.0	0.2	387.0	2034.70
790906	D	0.4948	0	42.0	0.5	94.0	189.98
790906	D	0.4884	0	42.0	0.5	399.7	818.39
790909	W	1.1410	0	49.0	1.2	3963.1	3473.39
790906	A	1.2264	0	46.0	1.3	1661.6	1354.82

Appendix 4C.
FECUNDITY STUDIES
BIG BEND POWER STATION
ANALYSIS FOR SPECIES -- (Menidia beryllina)
All females examined during Age - Fecundity Studies.

DATE	STATION	FISH.WT.-OVA.WT	AGE OF FISH	LENGTH OF FISH	WEIGHT OF FISH	NUMBER OF EGG	REL-FECUN
790731	Z	2.0924	0	50.0	2.1	4.6	2.18
790316	W	8.8587	0	92.0	9.6	6780.8	765.43
790316	W	5.2565	0	72.0	5.4	2979.9	566.90
790316	W	3.9760	0	70.0	4.2	3425.2	861.47
790316	W	2.1038	0	60.0	2.2	1994.9	948.26
790316	W	5.4530	0	73.0	5.8	4197.2	769.70
790316	W	2.0248	0	60.0	2.1	2417.8	1194.10
790316	W	4.2553	0	65.0	4.4	3353.7	788.11
790316	W	3.2521	0	66.0	3.5	3261.9	1003.01
790316	W	5.4076	0	74.0	5.6	4278.1	791.12
790316	W	4.2661	0	64.0	4.5	2469.0	578.76
790410	Y	3.0380	0	55.0	3.1	1792.9	590.16
790410	Y	3.7570	0	61.0	3.9	3564.3	948.72
790410	Y	1.8657	0	55.0	1.9	1494.6	801.09
790410	Y	1.3576	0	50.0	1.4	1040.8	766.62
790410	Y	3.4741	0	66.0	3.6	3461.6	996.39
790410	Y	5.2073	0	73.0	5.6	7154.9	1374.01
790418	C	2.1224	0	57.0	2.2	1852.8	872.96
790418	C	2.0984	0	55.0	2.2	2874.6	1369.92
790418	C	2.1206	0	58.0	2.2	1831.2	863.52
790510	Y	4.0719	0	65.0	4.7	4380.4	1075.76
790510	Y	4.7911	0	65.0	5.1	3051.1	636.83
790510	Y	4.3575	0	66.0	4.6	3660.1	839.96
790510	Y	5.1588	0	81.0	5.3	1739.8	337.24
790510	Y	4.1844	0	76.0	4.4	3322.9	794.12
790510	Y	2.9957	0	63.0	3.3	4455.2	1487.20
790510	Y	4.0232	0	69.0	4.2	2543.8	632.29
790510	Y	3.5567	0	66.0	3.7	2578.0	724.82
790510	Y	2.1452	0	55.0	2.2	1296.1	604.18
790510	Y	4.9978	0	76.0	5.2	2990.4	598.34
790605	Y	1.5701	0	47.0	1.6	514.2	327.50
790605	Y	1.3761	0	46.0	1.5	1320.6	959.64
790605	Y	1.7409	0	50.0	1.9	1905.9	1094.78
790605	Y	1.6813	0	50.0	1.7	496.3	295.21
790605	Y	2.0695	0	52.0	2.2	1400.0	676.50
790703	X	2.2609	0	59.0	2.3	1290.0	570.57
790703	Y	2.6806	0	59.0	3.1	1850.0	642.21
790703	Y	1.9328	0	54.0	2.1	1939.7	1003.59
790703	Y	1.5923	0	49.0	1.7	1027.6	645.36
790703	Y	2.2860	0	58.0	2.3	119.6	52.34
790703	Y	1.6768	0	51.0	1.7	449.2	267.87
790703	Y	1.9884	0	53.0	2.0	35.1	17.63
790703	Y	2.5513	0	58.0	2.6	954.8	374.24
790703	Y	1.4193	0	47.0	1.5	645.7	454.96
790731	Z	3.5478	0	62.0	3.7	3047.2	858.89
790731	Z	3.0481	0	60.0	3.1	2012.5	660.25
790731	Z	1.9948	0	50.0	2.0	4.0	2.01

Appendix 4C. (cont.)

790731	Z	1.9973	0	50.0	2.0	0.0	0.0
790731	Z	2.2909	0	53.0	2.3	212.2	92.61
790731	Z	1.8959	0	49.0	1.9	0.0	0.0
790807	X	2.6682	0	56.0	2.7	498.8	186.95
790807	X	1.7874	0	52.0	1.8	330.0	184.61
790807	X	2.3664	0	58.0	2.4	644.5	272.36
790909	W	2.1912	0	54.0	2.2	0.0	0.0
790909	W	2.3905	0	56.0	2.4	0.0	0.0
790909	W	1.1933	0	47.0	1.2	0.0	0.0
790909	W	2.2792	0	58.0	2.3	962.3	422.22
791023	W	3.1427	0	62.0	3.2	1094.1	348.13
791023	W	2.2914	0	55.0	2.3	0.0	0.0
791023	W	2.2859	0	56.0	2.3	275.4	120.48
791023	W	3.1869	0	61.0	3.2	0.0	0.0
791023	W	3.1889	0	60.0	3.2	0.0	0.0
791023	W	3.5260	0	63.0	3.6	2213.9	627.89
791120	W	2.8797	0	59.0	2.9	527.1	183.05
791120	W	3.1728	0	63.0	3.2	962.8	303.44
791120	W	1.1935	0	44.0	1.2	0.0	0.0
791120	W	2.5845	0	57.0	2.6	0.0	0.0
791120	W	1.3950	0	49.0	1.4	0.0	0.0
791120	W	2.0870	0	55.0	2.1	592.7	284.00
791120	W	3.6806	0	65.0	3.7	0.0	0.0
791214	X	4.7311	1	71.0	4.9	2458.0	519.54
791214	X	4.6834	1	70.0	4.8	4235.3	904.33
791214	X	4.6495	1	72.0	4.9	4489.7	965.63
791214	X	4.6106	1	69.0	4.7	2522.2	547.05
791214	X	5.1436	1	73.0	5.2	2563.9	498.47
791214	Z	3.7543	0	68.0	3.8	3102.3	826.32
791214	Z	4.1470	1	70.0	4.2	3476.9	838.42
791214	Z	4.7427	1	73.0	4.8	4606.9	971.37
791214	W	3.5602	0	65.0	3.6	2092.4	587.71
791214	W	5.2889	1	74.0	5.4	4149.3	784.53
791214	W	4.0871	0	66.0	4.2	3097.9	757.97
791214	W	5.6276	1	76.0	5.7	2917.3	518.38
791214	W	4.7908	1	72.0	4.9	3135.9	654.56
791214	W	3.4536	0	63.0	3.5	1974.3	571.67
791214	W	8.3037	1	83.0	8.4	4057.5	488.63
791214	W	4.4455	1	69.0	4.5	2011.4	452.45
791214	W	6.0367	1	75.0	6.1	3756.8	622.33
791214	W	5.1467	1	73.0	5.3	3515.4	683.04
791214	W	5.7003	1	75.0	5.8	3402.5	596.91
791214	W	4.1572	0	67.0	4.2	2367.3	569.44
791214	W	2.6736	0	59.0	2.7	2340.9	875.55
791214	W	3.6928	0	67.0	3.7	0.0	0.0
791214	W	5.4428	1	73.0	5.5	2257.9	414.85
800126	W	9.1643	1	91.0	9.6	9982.3	1089.26
800126	W	6.4130	1	79.0	6.7	6968.7	1086.65
800126	W	5.2197	1	68.0	5.6	6419.4	1229.84
800126	W	5.2262	1	76.0	6.0	5148.0	985.04
790807	W	3.0722	0	63.0	3.1	610.3	198.65
790807	W	2.3916	0	53.0	2.4	0.0	0.0
790807	W	1.9883	0	51.0	2.0	200.0	100.59
790807	W	2.2676	0	54.0	2.3	945.3	416.89
790807	W	2.3772	0	56.0	2.4	790.4	332.49
790807	W	2.9869	0	60.0	3.0	199.8	66.88
800126	W	6.4165	1	80.0	6.8	5547.6	864.59
800126	W	5.5531	1	83.0	6.1	7610.6	1370.51
800126	W	6.9179	1	83.0	7.9	10327.4	1492.86
800126	W	4.7985	1	75.0	5.2	6311.5	1315.30

Appendix 4C. (cont.)

800126	M	7.1543	1	84.0	7.7	8785.9	1228.06
800126	M	6.5422	1	81.0	7.1	9650.3	1475.08
800126	M	5.8728	1	79.0	6.3	6440.5	1096.67
800126	M	4.7171	1	74.0	5.0	4676.3	991.36

Appendix 4D.
FECUNDITY STUDIES
BIG BEND POWER STATION
ANALYSIS FOR SPECIES --. (Menidia beryllina)
Mature females December - August.

DATE	STATION	FISH.WT.-OVA.WT	AGE OF FISH	LENGTH OF FISH	WEIGHT OF FISH	NUMBER OF EGG	REL-FECUN
790316	W	8.8587	0	92.0	9.6	6780.8	765.43
790316	W	5.2565	0	72.0	5.4	2979.9	566.90
790316	W	3.9760	0	70.0	4.2	3425.2	861.47
790316	W	2.1038	0	60.0	2.2	1994.9	948.26
790316	W	5.4530	0	73.0	5.8	4197.2	769.70
790316	W	2.0248	0	60.0	2.1	2417.8	1194.10
790316	W	4.2553	0	65.0	4.4	3353.7	788.11
790316	W	3.2521	0	66.0	3.5	3261.9	1003.01
790316	W	5.4076	0	74.0	5.6	4278.1	791.12
790316	W	4.2661	0	64.0	4.5	2469.0	578.76
790410	Y	3.0380	0	55.0	3.1	1792.9	590.16
790410	Y	3.7570	0	61.0	3.9	3564.3	948.72
790410	Y	1.8657	0	55.0	1.9	1494.6	801.09
790410	Y	1.3576	0	50.0	1.4	1040.8	766.62
790410	Y	3.4741	0	66.0	3.6	3461.6	996.39
790410	Y	5.2073	0	73.0	5.6	7154.9	1374.01
790418	C	2.1224	0	57.0	2.2	1852.8	872.96
790418	C	2.0984	0	55.0	2.2	2874.6	1369.92
790418	C	2.1206	0	58.0	2.2	1831.2	863.52
790510	Y	4.0719	0	65.0	4.7	4380.4	1075.76
790510	Y	4.7911	0	65.0	5.1	3051.1	636.83
790510	Y	4.3575	0	66.0	4.6	3660.1	839.96
790510	Y	5.1588	0	81.0	5.3	1739.8	337.24
790510	Y	4.1844	0	76.0	4.4	3322.9	794.12
790510	Y	2.9957	0	63.0	3.3	4455.2	1487.20
790510	Y	4.0232	0	69.0	4.2	2543.8	632.29
790510	Y	3.5567	0	66.0	3.7	2578.0	724.82
790510	Y	2.1452	0	55.0	2.2	1296.1	604.18
790510	Y	4.9978	0	76.0	5.2	2990.4	598.34
790605	Y	1.5701	0	47.0	1.6	514.2	327.50
790605	Y	1.3761	0	46.0	1.5	1320.6	959.64
790605	Y	1.7409	0	50.0	1.9	1905.9	1094.78
790605	Y	1.6813	0	50.0	1.7	496.3	295.21
790605	Y	2.0695	0	52.0	2.2	1400.0	676.50
790703	X	2.2609	0	59.0	2.3	1290.0	570.57
790703	Y	2.8806	0	59.0	3.1	1850.0	642.21
790703	Y	1.9328	0	54.0	2.1	1939.7	1003.59
790703	Y	1.5923	0	49.0	1.7	1027.6	645.36
790703	Y	1.6768	0	51.0	1.7	449.2	267.87
790703	Y	2.5513	0	58.0	2.6	954.8	374.24
790703	Y	1.4193	0	47.0	1.5	645.7	454.96
790731	Z	3.5478	0	62.0	3.7	3047.2	858.89
790731	Z	3.0481	0	60.0	3.1	2012.5	660.25
790807	X	2.6682	0	56.0	2.7	498.8	186.95
790807	X	1.7874	0	52.0	1.8	330.0	184.61
790807	X	2.3664	0	58.0	2.4	644.5	272.36
791214	X	4.7311	1	71.0	4.9	2458.0	519.54

Appendix 4D. (cont.)

791214	X	4.6834	1	70.0	4.8	4235.3	904.33
791214	X	4.6495	1	72.0	4.9	4489.7	965.63
791214	X	4.6106	1	69.0	4.7	2522.2	547.05
791214	X	5.1436	1	73.0	5.2	2563.9	498.47
791214	Z	3.7543	0	68.0	3.8	3102.3	826.32
791214	Z	4.1470	1	70.0	4.2	3476.9	838.42
791214	Z	4.7427	1	73.0	4.8	4606.9	971.37
791214	W	3.5602	0	65.0	3.6	2092.4	587.71
791214	W	5.2889	1	74.0	5.4	4149.3	784.53
791214	W	4.0871	0	66.0	4.2	3097.9	757.97
791214	W	5.6276	1	76.0	5.7	2917.3	518.38
791214	W	4.7908	1	72.0	4.9	3135.9	654.56
791214	W	3.4536	0	63.0	3.5	1974.3	571.67
791214	W	8.3037	1	83.0	8.4	4057.5	488.63
791214	W	4.4455	1	69.0	4.5	2011.4	452.45
791214	W	6.0367	1	75.0	6.1	3756.8	622.33
791214	W	5.1467	1	73.0	5.3	3515.4	683.04
791214	W	5.7003	1	75.0	5.8	3402.5	596.91
791214	W	4.1572	0	67.0	4.2	2367.3	569.44
791214	W	2.6736	0	59.0	2.7	2340.9	875.55
791214	W	5.4428	1	73.0	5.5	2257.9	414.85
800126	W	9.1643	1	91.0	9.6	9982.3	1089.26
800126	W	6.4130	1	79.0	6.7	6968.7	1086.65
800126	W	5.2197	1	68.0	5.6	6419.4	1229.84
800126	W	5.2262	1	76.0	6.0	5148.0	985.04
790807	W	3.0722	0	63.0	3.1	610.3	198.65
790807	W	1.9883	0	51.0	2.0	200.0	100.59
790807	W	2.2676	0	54.0	2.3	945.3	416.89
790807	W	2.3772	0	56.0	2.4	790.4	332.49
790807	W	2.9869	0	60.0	3.0	199.8	66.88
800126	W	6.4165	1	80.0	6.8	5547.6	864.59
800126	W	5.5531	1	83.0	6.1	7610.6	1370.51
800126	W	6.9179	1	83.0	7.9	10327.4	1492.86
800126	W	4.7985	1	75.0	5.2	6311.5	1315.30
800126	W	7.1543	1	84.0	7.7	8785.9	1228.06
800126	W	6.5422	1	81.0	7.1	9650.3	1475.08
800126	W	5.8728	1	79.0	6.3	6440.5	1096.67
800126	W	4.7171	1	74.0	5.0	4676.3	991.36

CHAPTER FIVE

OYSTER SPAT STUDIES IN LOWER TAMPA BAY

BY

R. HARRY BLANCHET

CHAPTER FIVE

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I. INTRODUCTION

This study examined the settling of oyster spat over one spawning season in the Big Bend area of Tampa Bay. Oyster spat panels were set for alternate two-week periods of March 13, 1979 to January 29, 1980 (Table 5.1).

The Virginia or American oyster (Crassostrea virginica Gmelin) is only one of several oysters of the family Ostreidae occurring on the west coast of Florida. These include Ostrea equestris (Say), the crested oyster or horse oyster, which is often associated with C. virginica in oyster beds (Galtsoff, 1964). The early set of this species can be differentiated by the relatively borad, low, symmetrical umbo of the horse oyster dissoconch (Ranson, 1960). Crassostrea, by contrast, has a high, pointed umbo which is at an angle to the axis of the shell. The other osyter possibly in the area is Ostrea frons. This species was described by Forbes (1967). No specimens of either species of Ostrea were recorded throughout the course of this project. Butler (1955) did report co-occurrence of these species in Pensacola Bay, as did Menzel et al. (1966) in Apalachicola Bay. It is possible that some specimens were misidentified as C. virginica especially during times of heavy setting.

Table 5.1. Sampling periods for oyster spat study.

Stations	Date Set	Date Recovered
A to E	March 13, 1979	March 27, 1979
E	April 10, 1979	April 24, 1979
A to D	April 10, 1979	April 26, 1979
A to E	May 10, 1979	May 25, 1979
E	April 26, 1979	June 19, 1979
A to D	June 6, 1979	June 19, 1979
A to E	July 3, 1979	July 17, 1979
A to E	July 31, 1979	August 14, 1979
A to E	August 28, 1979	September 14, 1979
A to E	September 25, 1979	October 9, 1979
A to E	October 23, 1979	November 6, 1979
A to E	November 20, 1979	December 4, 1979
A to E	December 18, 1979	January 2, 1980
A to E	January 15, 1980	January 29, 1980

II. MATERIALS AND METHODS

Ten spat panels were set at each of the five meroplankton sampling stations (A through E, see Chapter II) during the daytime sampling trip. The panels, 10 cm squares of asbestos roofing tile, were held in slots cut in a rack made of cypress wood (Figure 5.1). Two columns of five panels were held with a space of 5 cm between each panel. The racks were strapped by stainless steel hose clamps to a concrete-filled cinder block, with a pair of 2 X 10 X 50 cm wooden braces embedded in the concrete to add stability. A rope bridle led from this apparatus to the surface of the water, where a 15 cm styrofoam float marked the position. Panels were permanently marked with station and replicate number on the white, painted side. This side was always put into the rack facing down. The upper, unpainted, smooth surface was the only one examined. Preference of oyster larvae for various angles of substrate has been examined by many investigators with no consistent results. Several field investigators have found that oysters prefer the upper surface of a horizontal plate for settling (Butler, 1955; Shaw, 1967), while others have reported a preference for lower surface (Medcaf, 1955; Crisp, 1967). Ritchie and Menzel (1968) found that larvae did not settle heavily on any surface with strong (50 foot candles) light. For purposes of this study, the upper surface of the panel was chosen to be examined as turbidity of the water in the study area, depth of the stations and the shading characteristics of the rack design were considered sufficient to eliminate any light bias.

Upon recovery, spat panels were placed in a foam-lined bucket filled with seawater from the stations. Care was always taken to prevent abrasion of the panels, and no signs of significant abrasion were noted during the analysis. Samples were held overnight in the buckets and transported to the laboratory. By nine A.M. of the following day, they were set up in the wet table area of the laboratory, and a thin stream of seawater from the laboratory's system was added to each bucket for aeration and circulation. Enumeration of spat was generally started the same day, and all stations were examined within three days. Examination of panels was accomplished using a Bausch and Lomb stereo dissecting microscope at 6.6X, with close examination of specimens at 30X. The complete upper surface of each panel was counted. Numbers of oysters on the upper surface of each panel, random size measurements, and observations on the abundance of other fouling organisms were recorded. Coverage of the panels by oysters was calculated by finding the mean area of the oysters measured at a station, multiplying this value by the number of oysters on each panel, dividing by the area of a panel (100 cm^2), and multiplying by 100 to get a percent of panel area covered. This is only a relative measure, as some oysters were growing on top of others, and the average oyster was considered to be circular for area calculations. Coverage estimations were given in increments of 0.5%.

Limitations of Methods

Sampling was conducted only on alternate two-week periods, and so the data may not completely reflect the fluctuations in spatfall during

study period. In some of the samples, barnacles had covered the surface of the panels to the extent that all spat found were growing on barnacles rather than the panel surface. Hence, a longer holding period would not have been appropriate. Finucane and Campbell (1968), MacKenzie (1970) and many other workers have shown high mortality in young oysters due to overgrowth, fouling, and predation. Even with the two week holding period used in this study, mortality probably affected the numbers of spat counted, so that numbers actually represent settlement minus some unknown mortality factor.

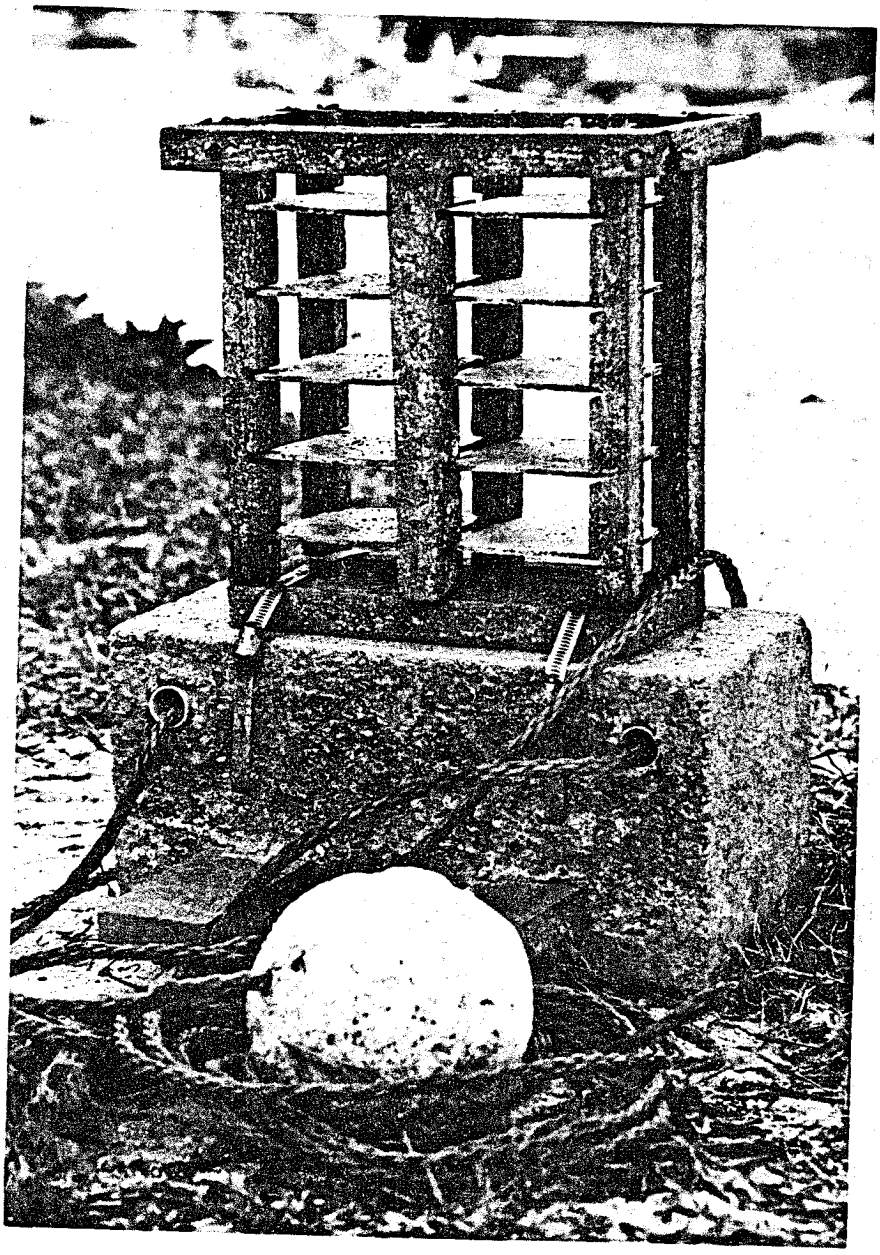

Figure 5.1. Oyster spat sampling apparatus used in this study.

III. RESULTS

Oyster spat were first found on panels recovered from April 24 and occurred last on samples recovered on December 4, 1979. Very few oysters were found on panels recovered in December. Abundance and percent coverage of oyster spat in the samples is shown in Table 5.2. Spatfall at all stations was very light compared to the numbers found by Finucane and Campbell (1968) in Old Tampa Bay. Stations A and B (intake and discharge canals) showed the greatest spatfall in June samples. Station B, though, had no spat in July, and very few in August. Station C (offshore of the intake canal) had more spat in June and July than at other times, but spatfall at this station was lightest of all the stations. Station D (middle Hillsborough Bay) had no heavy spatfall until August, and numbers were highest in September. June values for Station E (Tampa Bay) are questionable since the station was set longer than normal, but spatfall peaks in July and October were noted.

Data on growth of oyster spat can only be estimated, since the exact date of settling of the spat was unknown. However, some information can be gained from examination of size data (Table 5.3) since the samples were held in the field for a consistent period of time and no significant growth occurred while holding in the laboratory. Samples examined after three days of holding in the seawater system still had abundant spat of 0.3 mm diameter, which is the size of freshly settled larvae (Loosanoff, et al., 1966).

The largest specimens were found in samples before September, and the average size of spat on the collectors was also largest in the first part of the season. Growth during this period seems comparable to findings in Old Tampa Bay and Galveston Bay of 2 to 2.6 mm of growth per week (Finucane and Cambpell, 1968; Hopkins, 1931). Spat set after September showed little growth; the largest oyster recorded from September to December was only 1.5 mm diameter.

Table 5.2 Abundance and percentage coverage of oyster spat per panel.

Date	- A - $\bar{x}$ Den	$\bar{x}$ Cov	- B - $\bar{x}$ Den	$\bar{x}$ Cov	- C - $\bar{x}$ Den	$\bar{x}$ Cov	- D - $\bar{x}$ Den	$\bar{x}$ Cov	- E - $\bar{x}$ Den	$\bar{x}$ Cov
3/27	0	0	0	0	0	0	0	0	0	0
4/24	+	+	+	+	+	+	+	+	5.5	.46
4/26	4.2	.44	6.6	0.92	2.6	.45	8.6	.4	-	-
5/25	*	*	21.0	0.9	.88	.22	.5	.2	11.3	.47
6/19	60.1	0.5	182.1	1.23	10.6	0.45	2.9	0.4	8.5**	1.5
7/17	14.7	0.5	.0	.00	30.9	2.75	2.8	0.45	44.5	1.75
8/14	4.6	0.5	.1	.05	2.0	0.5	18.5	0.5	6.4	0.5
9/14	10.3	0.5	2.5	.04	2.5	0.4	59.0	0.5	3.0	0.5
10/9	0.6	0.3	.2	0.1	0.2	0.1	3.0	0.45	54.75	0.5
11/6	*	*	3.0	0.45	3.0	0.45	9.0	0.5	8.3	0.5
12/4	.1	0.05	0.4	0.15	0	0	0	0	6.5	0.5
1/2/80	0	0	*	*	0	0	0	0	0	0
1/29/80	0	0	0	0	0	0	0	0	*	*
Average	9.46	.25	13.6	.344	4.39	.443	8.69	.28	13.5	.61

*Station lost.
+Samples collected two days after schedule.
**Data questionable - station probably set for 8 weeks.

Table 5.3. Mean and maximum diameter of oyster spat measured at each station. (mm)

Date	Station A $\bar{x}$	A max.	B $\bar{x}$	B max.	C $\bar{x}$	C max.	D $\bar{x}$	D max.	E $\bar{x}$	E max.
3/27	0		0		0		0		0	
4/24	+		+		+		+		.41	1.8
4/26	.59	2.4	3.90	8.0	.65	2.2	1.42	2.9	-	-
5/25	*		2.21	4.5	.69	2.5	.58	0.7	.86	2.1
6/19	.67	2.4	.85	2.1	1.20	6.3	.86	1.8	4.23**	9.5
7/17	.54	5.3	0		3.24	7.2	2.00	4.1	1.74	6.2
8/14	.73	4.8	.30	.3	.50	0.9	.52	2.2	1.18	3.2
9/14	.46	0.6	.38	0.6	.53	1.3	.45	1.3	.58	1.3
10/9	.53	0.6	.45	0.5	.37	0.7	.32	0.5	.50	1.2
11/6	*		.58	1.5	.83	1.4	.78	1.5	.55	1.4
12/4	.50	0.5	.95	1.5	0		0		.64	1.1
1/2/80	0		*		0		0		0	
1/29/80	0		0		0		0		*	

*Station lost
+Samples collected two days after schedule.
**Data questionable - station probably set for 8 weeks.

IV. DISCUSSION

Finucane and Campbell (1968), Butler (1965), and other workers on the west coast of Florida have noted greatest spatfall from May to August. Time of peak spatfall is quite variable from year to year (Loosanoff and Engle, 1940; Loosanoff, 1966) and in general, our data reflect the trends reported by other workers.

The lack of spat in the samples from station B in July and August may have been due to heavy siltation in the discharge canal, or the temperature recorded here, which were very near or over the recorded thermal tolerance for oyster larvae (Calabese and Davis, 1970). However, the thermal limits of southern oysters may be different from the Long Island populations studied by these workers.

The decrease in size of the spat noted in the late summer and fall samples may have been due to short-term fluctuations in the availability of mature larvae, or to decreased growth rates. Unfortunately, no data are available on the food supply for the spat over this study. It is known that populations of the larger species of phytoplankton (net plankton) go through a series of blooms through the summer in the Big Bend area (TECO, 1977), but the dynamics of the nannoplankton in the area are virtually unknown.

V. SUMMARY AND CONCLUSIONS

1) This study covered one season of spatfall in the Big Bend region of Tampa Bay.

2) The spatfall began in April and continued until December, 1979.

3) Heaviest spatfall was in June, but there was some spatial variation.

4) A secondary increase in spatfall was recorded in September and October, 1979.

5) The largest oysters were found in early part of the spawning season with smaller specimens found later indicating a slower growth rate.

6) Samples were only taken two weeks per month. Hence, some short term variation in settling may have been missed.

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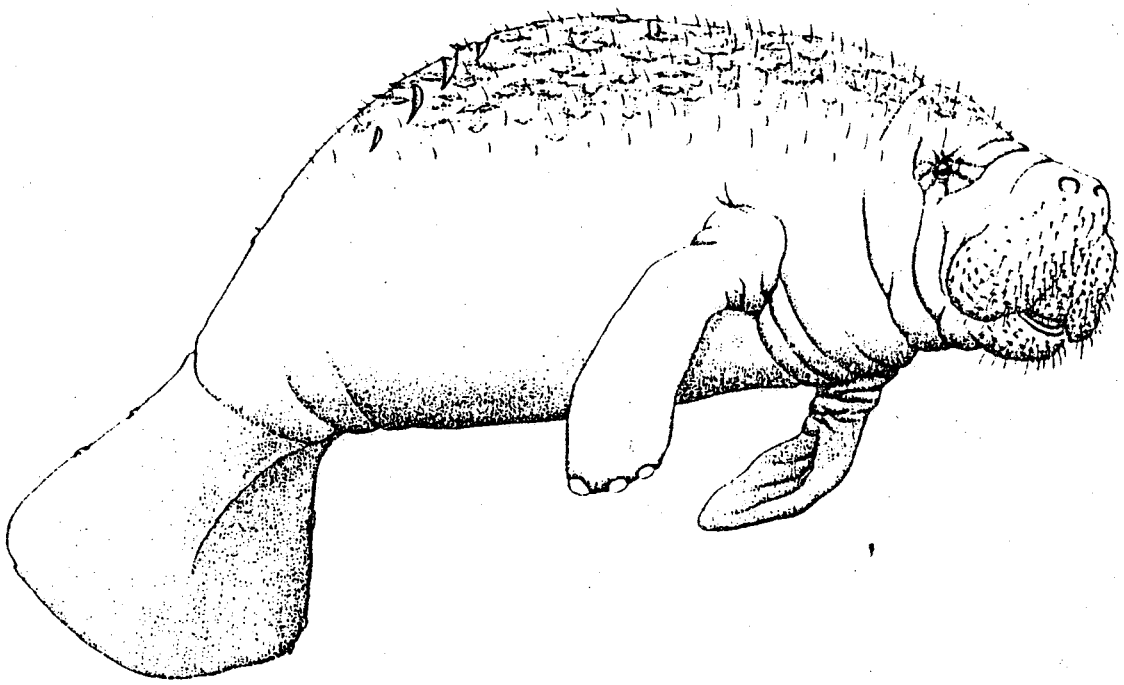
APPENDIX 2

MANATEE STUDY

STUDIES OF THE WEST INDIAN MANATEE (*Trichechus manatus*) IN TAMPA BAY (FLORIDA)



A TECHNICAL REPORT

BY

GEOFFREY W. PATTON

EDITED BY: SELVAKUMARAN MAHADEVAN

June 18, 1980

MOTE MARINE LABORATORY
1600 CITY ISLAND PARK
SARASOTA, FLORIDA 33577

ABSTRACT

Airplane, boat and ground observations of the endangered West Indian manatee, Trichechus manatus Linnaeus, were conducted in the Tampa Bay (Florida) area. The purposes of the study were to: 1) document the use of the Big Bend Power Generating Plant's warm water discharge by manatees and 2) determine the significance of the site as a winter refuge, compared to other area refuges. Temperature grid measurements, dive time measurements and submerged aquatic vegetation surveys were also conducted. The power plant effluent was found to attract manatees during the colder months but fewer animals than a phosphate plant located on the Alafia River. A marked shift in distribution followed the passage of the season's first cold front and winter sightings outside of warm-water refuges were typically restricted to brief warming spells. The manatees were not found to orient to particular temperature levels within the discharge canal. The boat survey procedure was found to be inadequate to accurately count manatees; nevertheless, regular use of the discharge canal by manatees was established by the survey.

LIST OF PARTICIPANTS

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I. INTRODUCTION

A. Natural History.

The order Sirenia is composed of one species of dugong (Dugong dugon) and three species of manatees, all of the genus Trichechus (T. manatus, T. senegalensis and T. inunguis). The only manatee indigenous to North America is T. manatus. Its range extends in coastal waters throughout the Caribbean Sea, the Gulf of Mexico and the southwestern Atlantic Ocean. U. S. sightings outside of Florida are rare. Within its range, the manatee is most generally observed in rivers, channels, bays and passes. Sightings offshore barrier islands are periodically reported and may indicate seasonal migration (Hartman, 1979). One animal was even reported killed off Bimini in 1904 (Husar, 1977).

Manatees are bulky, fusiform mammals resembling walruses but without tusks or any remnant of hind limbs. The propulsive tail is flat, broad and fan-shaped. The forelimbs are paddle-like and are used for maneuvering, propulsion, feeding, social touching and more. They have five internal digits in both forelimbs, sparse hair, tiny auditory canals without external ears, an umbilicus, a common uro-genital slit and separate anus. Manatees are sexually dimorphic with the uro-genital slit being closer to the umbilicus in the male.

Reproduction in manatees is poorly understood. Studies now in progress are yielding additional information. A herd of males generally collects around an estrous female manatee. The female ultimately becomes receptive to the repeated male advances and may mate with many before becoming disinterested. The gestation period is not accurately known but most investigators place it at more than a year (Applied Biology, 1977; Hartman, 1979). The young are highly dependent, often needing to be lifted to the surface for their first breath and suckling for more than a year. Juveniles seem to finally become independent at two to three years by which time the mother may have produced another calf. The only positive age record is that of a display animal born in captivity 32 years ago still living at its home in Bradenton, Florida.

Manatees will eat nearly any plant in the water even including shoreline terrestrial vegetation within reach. Daily consumption can exceed 100 pounds for adults.

Manatees' predilection for fresh water is commonly known. Some have been observed drinking from hoses and sewage outfall pipes.

Manatees communicate with vocalizations but the full complexity and meaning behind the sounds is still unknown. Also unknown are the animals' hearing range and intelligence level. They are currently viewed as being little more than mildly social with other members of their species, having a limited repertoire of interactive patterns. While often seen alone, cold-weather aggregations occur near warm-water discharges of springs and industries. While at times demonstrating curiosity about man's activities, manatees generally ignore other animals. Interspecific interactions are typically limited to a few small parasites, some grazing fishes, and man.

Accurate estimates of historic population sizes are unavailable. Hartman (1971) suggests that there were likely several thousand manatees in North America before the appearance of the white man. The numbers probably decreased steadily until the first protective legislation was enacted early this century. The current population trend is unclear but stringent protective measures still seem to be warranted. Prevailing major mortality factors include collision with boats and barges, flood control gates and intentional molestation. Pollution and coastal development have probable effects in alteration of habitat, contamination of water quality and increased encounters with humans.

Earlier speculation of manatees being economically valuable resources for meat or aquatic vegetation clearing are currently disclaimed. Increasingly, however, manatees are being recognized as a unique wildlife resource, prospectively valuable for biomedical and ecological research.

B. Study Objectives.

This report summarizes the study findings of the West Indian manatee (Trichechus manatus) in the Tampa Bay area conducted between February 1979 and February 1980 by Mote Marine Laboratory (MML). The studies are part of a 316 Demonstration[1] for Tampa Electric Company's Big Bend Power Station (Proposed Unit No. 4) at Ruskin, Florida (Figure 1). Stone and Webster Engineering Corporation is conducting the Demonstration for Tampa Electric Company (TECO).

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[1]Section 316. Federal Water Pollution Control Act. Amendments of 1972.

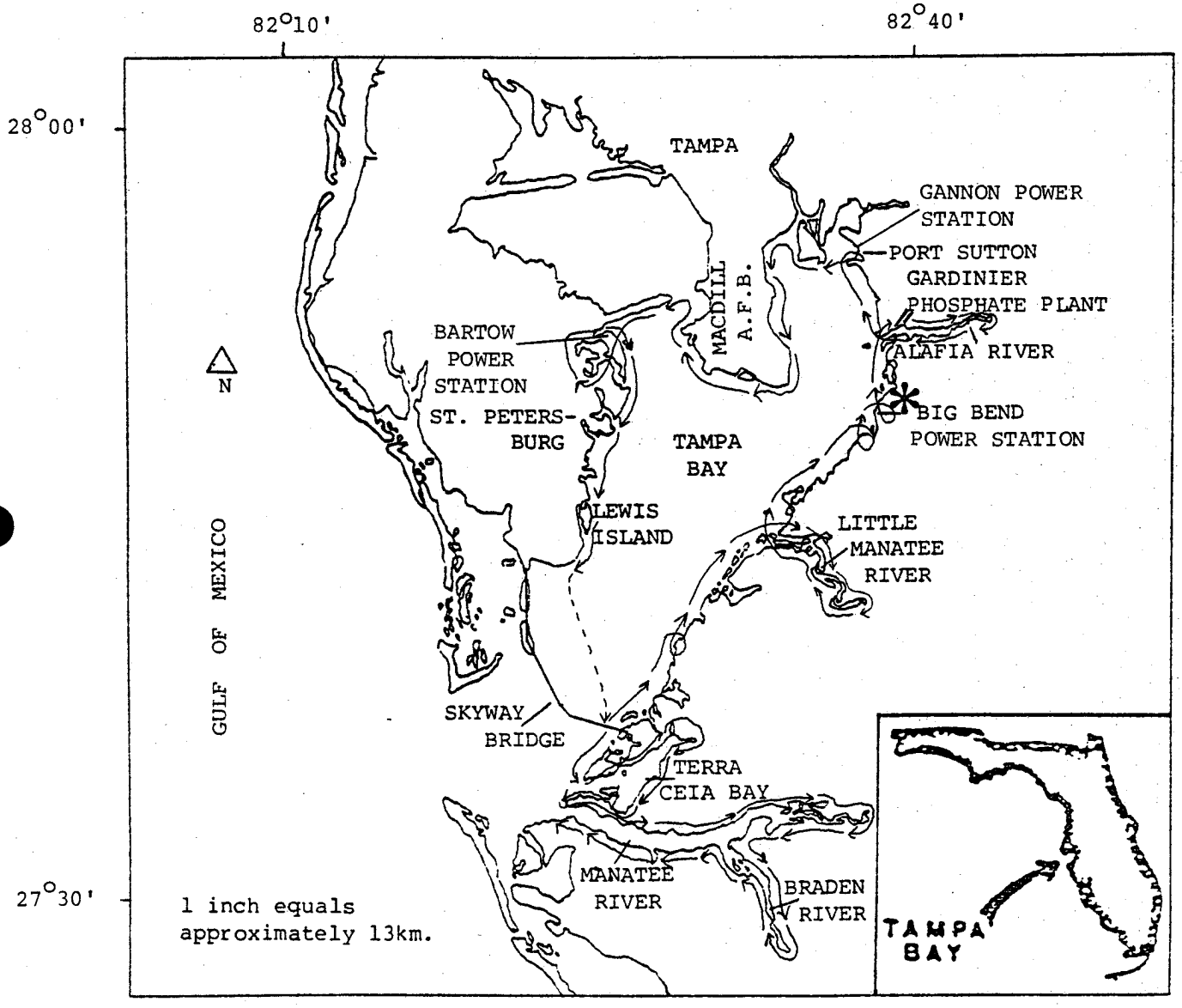

Figure 1. Tampa Bay showing the location of Tampa Electric Company's Big Bend Power Station. The aerial survey path is shown by the solid arrows.

Manatees were reported to use the Big Bend discharge as a winter warm-water refuge (TECO, 1979 a-e). As the manatee is an endangered species, protected by state[2] and federal[3] regulations, a better understanding of the relationship between manatees and the warm-water effluent was sought to provide impact assessment information. The general objectives of the studies were:

1) to document the manatees' use of the warm-water effluent as a winter refuge, and
2) to determine the significance of the site as a winter refuge, compared to other refuges available in the area.

To address the general objectives, the following studies were conducted: 1) Boat Surveys, 2) Aerial Surveys, 3) Structure Surveys, 4) Temperature Grid Surveys, 5) Dive Time Measurements, and 6) Grassbed (Submerged Aquatic Vegetation) Surveys. Manatee surveys performed from boats were conducted to establish the incidence of the animals in the power plant area. Aerial surveys were conducted to determine the relative abundance and distribution of manatees throughout the Tampa Bay area. Surveys from the top of the power plant structure were performed to determine manatee abundance and distribution in the discharge canal. Temperature measurements were taken to determine whether manatees oriented to particular isotherms in the warm effluent. Dive times were measured to validate the procedure used in the boat surveys. Submerged aquatic vegetation was surveyed to locate possible manatee feeding sites.

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[2] Some applicable state regulations include the Florida Manatee Sanctuary Act, 1978 and Section 370.12(2) Florida Statutes.

[3] Some applicable federal regulations include the U.S. Marine Mammal Protection Act, 1972 and the Endangered Species Act, 1973, as amended.

II. MATERIALS AND METHODS

The sampling dates for all of the study programs are shown in Table 1.

A. Boat Survey Program, Phase 1: February 28-June 5, 1979
Phase 2: November 15, 1979-February 12, 1980

Boat observations for manatees were conducted once every two weeks generally beginning between 8:00 a.m. and 10:00 a.m. local time.

i) Station Locations.

The four manatee boat survey stations initially designated by S & W are shown in Figure 2. Station 1 was located near the discharge flumes in the discharge canal. Station 2 was located 1.5 km west of the end of the discharge canal. Station 3 was located in Apollo Embayment (refer to Figure 3), and Station 4 was located approximately 2 km north of Station 2, out of the normal area of thermal influence.

One-time relocation of the initial stations was permitted during the second phase to better define the relationship between manatees and the warm effluent. Therefore, new manatee boat survey stations corresponding to Temperature Grid Stations 4, 8, 24 and 26 (Figure 3) were established on December 12, 1979 based on earlier sightings from the various study programs. Station 26 was located 0.3 km west of the end of the discharge canal. Station 24 was located 76 meters inside the west (open) end of the discharge canal. Station 8 was located between the boat dock and Unit 1 (western) discharge and Station 4 was located between Unit 3 discharge and the eastern end of the discharge canal.

ii) Methods.

Observations were made from a fore- and aft-anchored boat with eye elevation of about 3-1/2 meters from the water surface. The horizontal field of vision was divided into six equal compass segments, using a Weems and Plath hand bearing compass to select segment landmarks. Most of the stations had convenient landmarks for the individual segments. Where there were none, or when fog or rain prevented seeing the landmarks, a hand bearing compass was used to delineate the segments. The same landmarks were used to assure accurate replication. Beginning with a randomly selected segment, the number of manatee noses sighted during a two minute period was recorded for each segment, proceeding in a clock-wise direction around the compass.

Table 1. MANATEE PROJECTS FIELD SAMPLING DATES

1979															
February	23	24	25	26	27	28	1	2	3	4	5	6	7	8	
						A									
March	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
					A										
March	23	24	25	26	27	28	29	30	31	1	2	3	4	5	
					A										
April	6	7	8	9	10	11	12	13	14	15	16	17	18	19	
					A										
April	20	21	22	23	24	25	26	27	28	29	30	1	2	3	
					A										
May	4	5	6	7	8	9	10	11	12	13	14	15	16	17	
					A										
May	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
					a	a	A								
June	1	2	3	4	5	6	7	8	9	10	11	12	13	14	
					A										
June	15	16	17	18	19	20	21	22	23	24	25	26	27	28	
	B													b	
June	29	30	1	2	3	4	5	6	7	8	9	10	11	12	
	B													b	
	E														
July	13	14	15	16	17	18	19	20	21	22	23	24	25	26	
	b	B												B	
		E													

Table 1. Continued.

| | | |

Table 1. Continued.

December	28	29	30	31	1	2	3	4	5	6	7	8	9	10	
	b	B	V	B	a d f	A D F	b	V b	B		C	C	C	B	
1980															
January	11	12	13	14	15	16	17	18	19	20	21	22	23	24	
	C	V			A D f		B	V				F C	V	B	
January	25	26	27	28	29	30	31	1	2	3	4	5	6	7	
				V b	A b D F	b	V b B	b	b	B	C	C	V	B	
February	8	9	10	11	12	13	14	15	16	17	18	19	20	21	
	C		V	b	b A D F	b	b								
February	22	23	24	25	26	27	28	29							
		C													

*Cancelled

LEGEND:

A Boat Survey

B Aerial Survey

C Dive Time Study

D Structure Observations

E Grass Bed Survey

F Temperature Grid

V Cold Front Passage

Lower case letters (a, b, etc.) indicate sampling postponed.

Underlining indicates 48 hr. pre- and post-bracketing of the regularly scheduled flights.

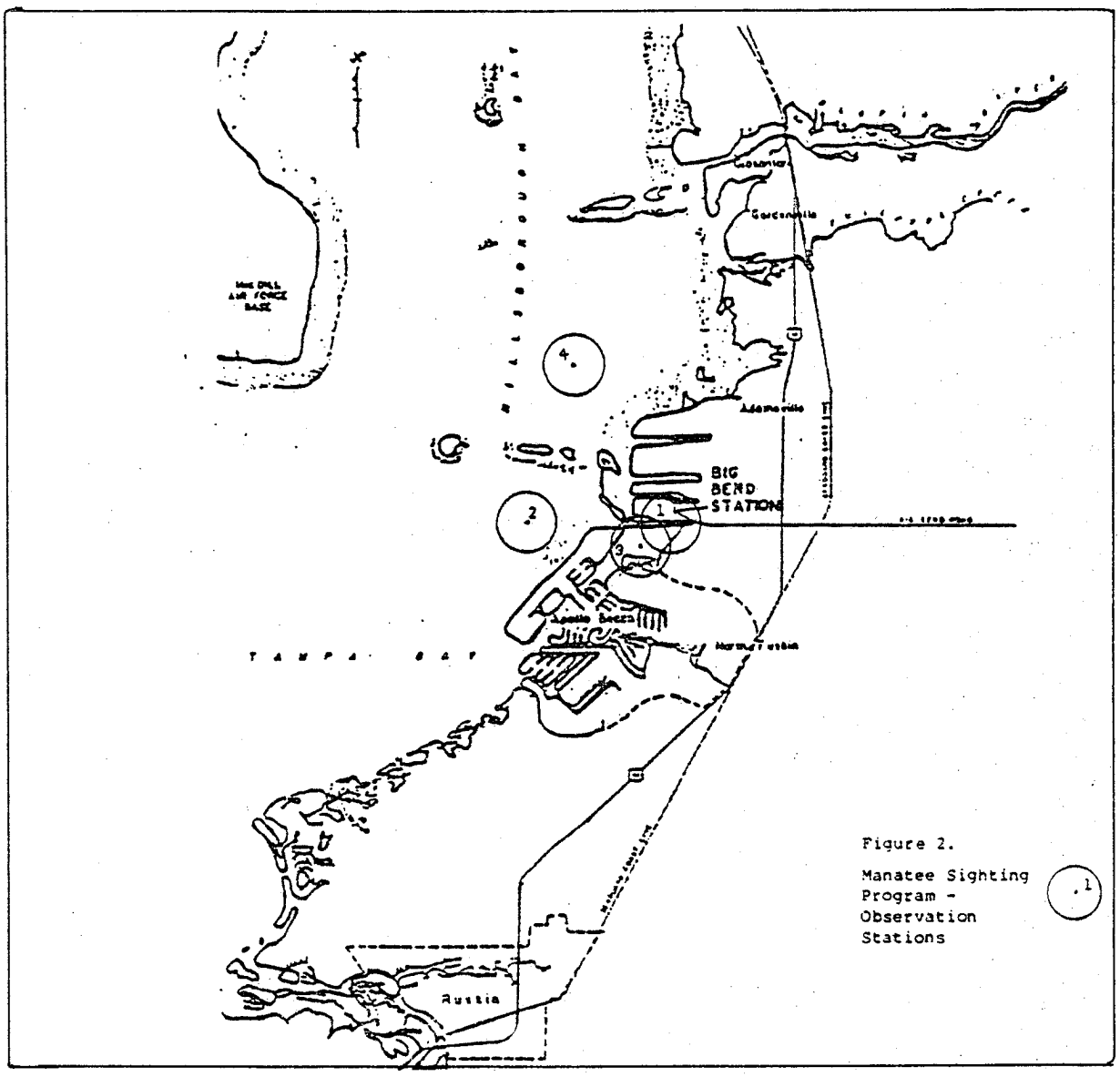


Figure 2.

Manatee Sighting Program - Observation Stations

1 cm. = approx. 946 m.

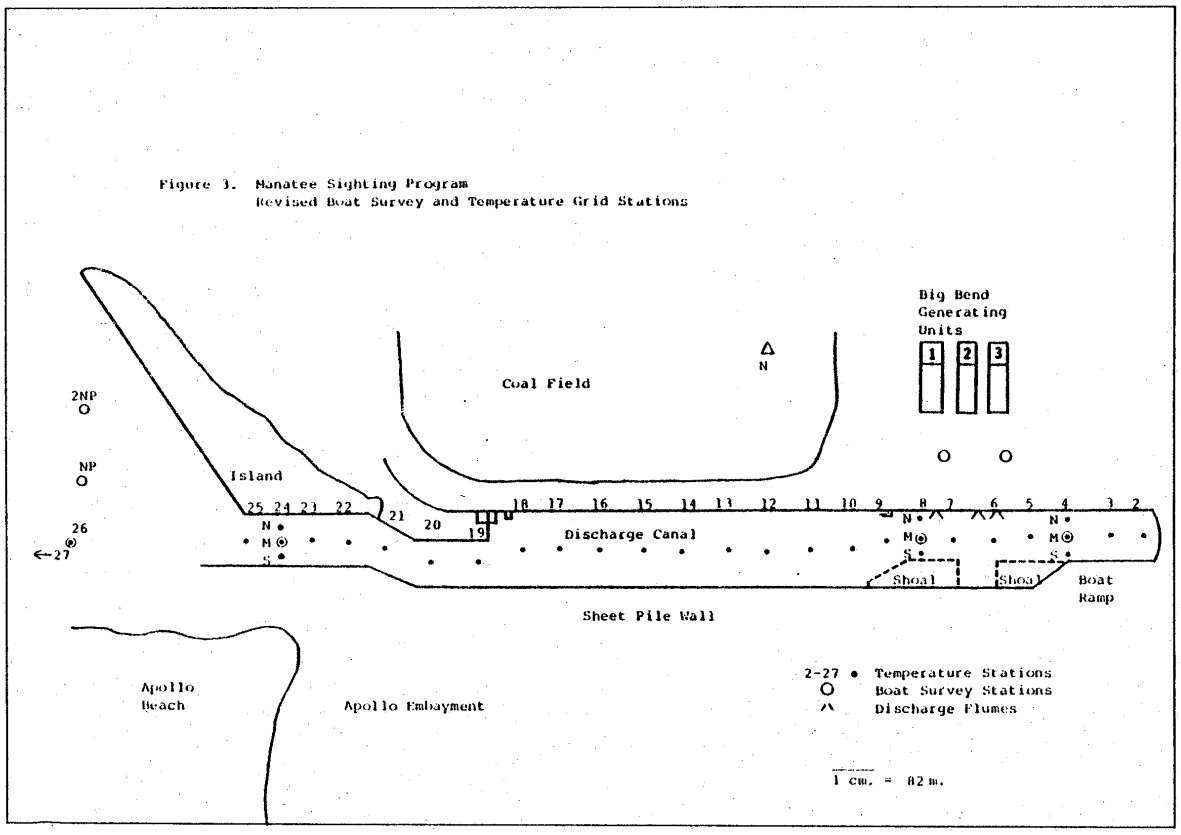


Figure 3. Manatee Sighting Program
Revised Boat Survey and Temperature Grid Stations

Three cycles of the compass were made to provide replicate observations. This procedure was repeated for each station. The "horizon" (maximum possible distance for discriminating a manatee nose) was estimated and recorded for each replicate of each segment. Horizon estimates were adjusted each sampling day to account for the varying weather conditions and for temporary obstructions like shoals which were too shallow (due to the tide phase) to permit occupation by manatees. In addition, qualitative observations (occurrence at other locations, unusual behavior, feeding observations, etc.) were recorded. Individuals identified by scars, social groupings, or other means (e.g., specific isolated location) were noted. Boats anchored or operating within the "horizon" of the observations were counted. Observations of other officially-designated threatened or rare and endangered species were noted along with the number of boats observed within the "horizon". The data were recorded by an assistant to the primary observer (Patton).

B. Aerial Survey Program, Phase 1: June 15-November 14, 1979
Phase 2: November 15, 1979-February 12, 1980

Aerial surveys for manatees were conducted biweekly during Phase 1 and weekly during Phase 2 generally on Thursdays starting shortly after sunrise. Additional survey flights were conducted in Phase 2 following the passage of cold fronts. Cold front flights were only conducted if they occurred more than 48 hours from a scheduled trip and did not coincide with boat survey dates. Flights were postponed if: 1) wind speed or gusts exceeded 37 km/hr; 2) Visual Flight Rules (VFR) were not in effect, or 3) severe weather was forecast for the observation period. A number of postponements and one cancellation (12/13/79) were necessary for the above-stated reasons (Table 1).

i) Location.

The survey path is generally depicted in Figure 1 . The surveys began on the southeastern Tampa Bay coastline at Bishop Harbor (north of the Skyway Bridge) and continued to Port Sutton in the north. The surveys continued around the coastline of Interbay Peninsula, but were sometimes interrupted by traffic at MacDill Air Force Base. The surveys continued north and west up Interbay Peninsula to Gandy Bridge, at which point, the surveys continued approximately southwest to the western shore of Tampa Bay at the Bartow Power Station. From this point, the surveys continued southerly, along the shoreline, to the Lewis Is.-Little Bayou area, at which point the surveys were discontinued until the starting point was reached.

Following the 7/14/79 survey, the flight path was extended to include Terra Ceia Bay and the Manatee-Braden River complex. These areas were surveyed immediately following the completion of the original path, beginning at the southeastern end of the Skyway Bridge southerly to Terra Ceia Bay, circumnavigating the Terra Ceia shoreline, then south to the Manatee River. Both north and south shorelines of the Manatee River were surveyed to the shallow headwaters. The Braden River was surveyed south to the dam, located south of State Road 70.

ii) Methods.

Surveys were flown generally following the two meter isobath. Concentrated observations were made by circling the plane at: 1) the mouth of the Little Manatee River, 2) County Park Beach, 3) Big Bend Power Station, 4) the mouth of the Alafia River, 5) Bartow Power Plant, and whenever manatees were sighted (other than single animals sighted in water of good clarity). Circling was continued until all manatees were counted or it was determined that no manatees were present. The plane was flown at an altitude of 153 meters at a speed of 80 km per hour. The aircraft used were a Cessna 150 and several different Cessna 172's, all high-wing aircraft. The observer always sat in the right front seat and wore polarized sunglasses to reduce glare effects and improve through-water visibility. The location, number and approximate life stage (adult or calf) of sighted manatees were recorded on standardized data sheets (maps; see Appendix C). Manatee locations were indicated on the maps by "X" marks. Additional data recorded included: date of survey, begin and end times for each segment of the flight path, water clarity, surface conditions, sky conditions, number of adults, number of calves, and total number of manatees sighted. For the purpose of this study, calves were defined to be approximately (or less than) one-half the length of accompanying adults. Water clarity was estimated from the air for each flight path segment according to the following scheme:

Excellent	greater than 3 meters
Good	2 to 3 meters
Fair	3/4 to 2 meters
Poor	less than 3/4 meter

Surface conditions were classified according to the scale presented in Table 2. Sky conditions were reported as percent cloud cover. Percent cloud cover, air temperature, and wind speed and direction were obtained from Tampa International Airport through the U.S. Weather Service Station at Ruskin, Florida.

Table 2. Surface Conditions Scale.

Scale	Effects Observed at Sea
0	Sea like mirror.
1	Ripples with appearance of scales, no foam crests.
2	Small wavelets; crests of glassy appearance, not breaking.
3	Large wavelets; crests begin to break; scattered whitecaps.
4	Small waves, becoming longer, numerous whitecaps.
5	Moderate waves, taking longer form; many whitecaps, some spray.
6	Larger waves forming; whitecaps everywhere, more spray.
7	Sea heaps up; white foam from breaking waves begins to be blown in streaks.
8	Moderately high waves of greater length; edges of crests begin to break into spindrift; foam is blown in well-marked streaks.
9	High waves; sea begins to roll; dense streaks of foam; spray may reduce visibility.

(Adapted from the Beaufort Scale which is not suited for near-shore use.)

Aerial surveys were generally conducted by the same observer (Patton), however, on two occasions (10/6 and 11/27/79) the surveys had to be conducted by an experienced alternate (Phillips).

C. Structure Survey Program, Single Phase: November 15, 1979-February 12, 1980

Observations were conducted from atop the electrostatic precipitator for Unit 3 (easternmost unit) at the Big Bend Power Station. These observations were carried out on the Phase 2 Boat Survey days (Table 1) following completion of the boat work. Observations were conducted for two hours, concentrating on location and abundance of manatees in the discharge canal. Jenson 7 X 50 power binoculars were used to monitor particular individuals and groups of manatees. Data were recorded on standardized maps and included date of survey, begin and end times, number of adults, number of calves, and total number of manatees observed. Notes on behavior (particularly response to boats and dive frequencies) were recorded.

D. Temperature Grid Survey Program, Single Phase: November 15, 1979-February 12, 1980

Water temperature measurements were taken in the nearplant area of the Big Bend Power Station on the Phase 2 Boat Survey days (after Shane, 1978). Temperature Grid station locations are shown in Figure 3. Surface and bottom temperatures were measured using a Markson Model 5650 Digital Thermometer with a YSI Model 703 probe. The digital thermometer was calibrated before each day's use with a Fisher -2 to 68^{o}C ASTM precision mercury thermometer. Data recorded on standardized data sheet (maps) included date of survey, begin and end times, number of adults, number of calves, and total number of manatees observed. Air temperature was entered later from U. S. Weather Service data. Water temperature was also measured at the location of manatees sighted during surface survey work.

E. Dive Time Program, Phase 1: June 15 - September 30, 1979
Phase 2: November 15, 1979 - February 23, 1980

The two-minute boat survey segment observation period employed in the Boat Survey Program was based on preliminary data from earlier studies by the U.S. Fish and Wildlife Service. In order to verify the suitability of the two minute observation periods, a program of dive time measurements was undertaken with comparisons of summer and winter dive times. While the summer dive time program was originally intended to be limited to two stations, manatee inavailability necessitated extensive search efforts and the opportunistic measurement of

dive times wherever the animals could be located. The winter dive times were acquired from animals in two areas: the mouth of the Alafia River and the Big Bend Power Station discharge canal (Figure 1). Observations were conducted from both the shoreline and boats.

Dive times were measured from the moment the nose first broke the surface to the next appearance of the manatee's nose, using an electronic clock/stopwatch/calculator (Canon LC Cardquartz). Dive time measurements were made to the nearest 0.1 second but were rounded off to the nearest whole second. Additional information recorded on standardized field data sheets included: date of survey, three-letter identifier, begin and end times of the observation period, air and water temperatures, and the presence or absence of grassbeds. Incidental notes on behavior, inter- and intra-specific associations, interactions with boats and identification clues (e.g., scar patterns) for individual animals were also recorded on the field data sheets.

F. Submerged Aquatic Vegetation (SAV) Survey, Single Phase; June 15, 1979 - February 12, 1980

The location of SAV within the aerial survey portion of Tampa Bay was determined, giving special attention to areas surveyed by boat or plane. The distribution determination included a thorough examination of available literature, interviews with knowledgeable persons, and corroboration with aerial survey data. The survey did not include a field sampling program, so taxonomic identification of the observed SAV was not done.

The SAV survey was restricted to the original aerial survey area; i.e., that part of Tampa Bay north of the Skyway Bridge (Figure 1).

G. Data Reduction/Analysis

i) Boat Survey Program.

Data analysis consisted of averaging the nose counts for the three replicates and rounding up of any fractions (e.g., 10.9 to 11 and 10.1 to 11) as a better approximation of the actual number of manatees present. This approach parallels that of Shane (1978) excepting her use of a single sample per station and my rounding up being employed to bring the results into closer agreement with incidental (non-systematized) counts (i.e., a single sighting during only one of the replicates would otherwise be rounded down to zero manatees observed, thereby underestimating abundance).

ii) Aerial Survey Program.

All sightings of manatees were tabulated by flight path segments (Table 5) and presented on two maps (Figures 4 and 5) summarizing the locations and numbers of manatees (after National Fish and Wildlife Laboratory, USF & WS, draft).

iii) Structure Survey Program.

Data analysis consisted of compiling the predominant areas of manatee use into a single outlined area. This results in a map showing all of the areas used by manatees during the structure observations.

iv) Temperature Grid Survey.

Data analysis consisted of calculation and tabulation of the mean temperature and range at each station and manatee location.

v) Dive Time Program.

Data analysis consisted of tabulation of the recorded ranges for individuals and their respective mean dive intervals.

vi) Submerged Aquatic Vegetation Survey.

Two sets of aerial photographs taken during regular manatee aerial surveys (6/29 and 12/20/79) were used to produce SAV distribution rough draft maps. On the flights following these two dates, independent observers made necessary corrections. The resultant maps were then combined into a single map incorporating distribution data from the literature sources and interviews.

III. RESULTS AND DISCUSSION

A. Boat Survey Program.

A total of 72 manatees were observed during the boat surveys (Table 3). A maximum of 10 manatees was counted at Big Bend in one day. This is far lower than counts at some other Florida warm-water effluent areas (Rose, 1979; Shane, 1978; Shane, 1979), but the results clearly demonstrate the regular use of the Big Bend Power Station as a warm water refuge during the winter months.

Observations of other threatened or rare and endangered species recorded included the ubiquitous presence of brown pelicans (Pelecanus occidentalis) (nearly every station on every sampling day), two incidental sightings of bottlenose dolphins (Tursiops truncatus) and one American bald eagle (Haliaeetus leucocephalus).

The station relocation (starting 12/12/79*) added some data on manatee movements in the vicinity of the discharge canal but more stations would be needed to adequately define the movements of manatees entering and leaving the canal. One suggested approach would be to have a radio-equipped observer on the plant superstructure coordinating extensive boat observations to estimate numbers of manatees.

Boat use for fishing and general recreation in the area of the discharge canal is frequently heavy (Table 4). This is due in large measure to the presence of an area used as a boat ramp at the eastern end of the discharge canal (see Figure 3) and the numbers of fish attracted into the warm water during the winter. On a number of occasions, commercial fishing boats were observed working nets within the discharge canal. One commercial fisherman stated that his net was 30 feet deep, sufficient to reach the bottom. This intensive use during the winter poses potential threats to manatees. On numerous occasions, boats travelling at high speed traversed areas where manatees had been seen just moments before. Many investigators (see especially Hartman, 1979) report varying responses of manatees to boats. While the animals appear to generally avoid the boats successfully (see the discussion under Structure Surveys), the presence of propeller scars on many manatees evidences limited ability.

---

* N.B., all dates presented in this fashion are month/day/year.

Table 3. Summary of the numbers of manatees observed during the MML boat surveys. (Refer to text for data analysis techniques.) The total divided by three replicates yields an estimate of manatee abundance based on the boat survey technique.

Date of Observations mo./da./yr.	Stations 1	2	3	4	Total for Day	Est. Abund. by boat survey (T ÷ 3)	Field Estimate*
2/28/79	6	0	0	0	6	2	3-5
3/13/79	9	0	0	0	9	3	2-6
3/27/79	1	0	0	0	1	1	1
4/10/79	0	0	0	0	0	0	0
4/24/79	0	0	0	0	0	0	0
5/8/79	0	0	0	0	0	0	0
5/24/79	0	0	0	0	0	0	0
6/5/79	0	0	0	0	0	0	0
11/20/79	4	0	0	0	4	2	3
12/4/79	22	0	0	0	22	8	5-9
Total	42	0	0	0	42	16	14-24

	Stations 4	8	24	26			
12/18/79	25	2	0	0	27	10	7-10
1/2/80	0	0	0	0	0	0	0
1/15/80	2	0	0	0	2	1	2
1/29/80	1	0	0	0	1	1	3
2/12/80	0	0	0	0	0	0	0
Total	28	2	0	0	30	12	12-15

Total number of manatee sightings during Boat Survey Program: 72

*Best estimate of actual number of animals present in the overall area, based on field notes.

Table 4. Summary of the numbers of boats counted during the MML boat surveys.

- Boats in Horizon -

Date	Stations 1	2	3	4	Total	Est. Abund. by boat survey (T ÷ 3)	Field Estimate*
2/28/79	8	0	0	0	8	3	4-6
3/13/79	0	0	0	0	0	0	0
3/27/79	1	0	0	0	1	1	1
4/10/79	1	1	0	0	2	1	2
4/24/79	2	2	0	0	4	2	2
5/8/79	0	0	0	0	0	0	0
5/24/79	0	0	0	0	0	0	0
6/5/79	6	0	0	0	6	2	3-5
11/20/79	22	1	0	0	23	8	11-14
12/4/79	6	0	0	0	6	2	3-4
Total	46	4	0	0	50	19	26-34

	Stations 4	8	24	26			
12/18/79	7	6	5	1	19	8	11-17
1/2/80	1	9	8	0	18	7	10
1/15/80	7	9	7	0	23	9	7-8
1/29/80	2	0	3	0	5	2	4-5
2/12/80	1	10	8	0	19	8	6-7
Total	18	34	31	1	84	34	38-47

*Best estimate of actual number of boats present in the overall area, based on field notes.

B. Aerial Survey Program.

Eighty-eight manatee herd sightings representing 319 adults and 36 calves were recorded over the duration of the aerial study. This calf to adult ratio of 0.113 is higher than other surveys in this and other areas. NFWL (draft) reports ranges of 0.009 to 0.049. Odell (1979) reported a ratio of 0.055 for Collier and Monroe Counties but NFWL points out Irvine and Campbell's (reported 1978) ratio of 0.105 for the area. On several occasions an adult was observed accompanied by two relatively large calves of about equal size. Whether these calves were twins, an example of adoption, or just happened to be together is unknown. Hartman (1979) discussed evidence of both twinning and foster parenthood in manatees. A summary of the manatee sightings by date and flight path segment is presented in Table 5 and mapped in Figures 4 and 5. The herd size frequently is comparable to other recent studies (Table 6).

Sixty-six dolphin herd sightings representing 140 animals are summarized in Table 7. Frequency distribution histograms of manatee and dolphin herd sizes are presented in Figures 6 and 7, respectively. No direct comparisons of individual flights are appropriate as portions were not always completely surveyed due to weather and air traffic considerations.

While it would be speculative to affix any firm estimate on the manatee population of Tampa Bay, it can be stated that 55 manatees were observed on February 7, 1980. Hartman (1974) observed 10 manatees during the summer in an area (Tampa Bay and areas west of the Skyway Bridge/Causeway) roughly comparable to that of the present study. Based on these and other data, he estimated summer and winter manatee abundances of 40 and 30 animals, respectively. Considering the moderately to highly turbid conditions in Tampa Bay which may cause animals to be missed during aerial surveys, I agree with Blair Irvine (USF & WS, pers. comm.) that manatee numbers in the study area may sporadically exceed 60 animals.

The manatees sighted during the aerial surveys were almost exclusively on shoals or following contours separating near-shore shoals from the four to six meter typical bay depths. While the survey flight path concentrated on the shallower area, deeper dredged areas like shipping channels, marinas and ports, which are reported by others (Shane, 1978; NFWL, draft) as likely manatee haunts, were included with limited results. Manatee sightings in the deeper areas were almost exclusively limited to winter aggregations at warm-water refuges.

As can be seen in Figure 5, the Gardinier Phosphate Plant (refer to Figure 1 for location) was the most important warm-water refuge in the survey area based on the number and frequency of sightings. The three power plants ranked: Big Bend, second; Bartow, third; and Gannon, fourth.

Table 5. Summary of numbers of manatees by date and flight path segment sighted during the MML aerial surveys. (See Appendix C for segment maps.)

Date	Code	Segment 1	2	3	4	5	6	7	8	9	10	Total
6/15/79	A	0	0	0	0	0	-	-	-	-	-	0
6/29/79	B	0	0	0	0	0	-	-	-	-	-	0
7/14/79	C	4	0	5	0	0	-	-	-	-	-	9
7/26/79	D	0	3	0	0	0	2	0	0	0	0	5
8/9/79	E	0	1	0	0	0	0	2	1	0	0	4
8/23/79	F	0	4	1	0	0	4	0	2	0	0	11
9/6/79	G	0	0	0	0	0	7	-	-	-	-	7
9/20/79	H	0	0	0	0	0	0	0	4	0	0	4
10/6/79	I	2	0	0	0	0	4	0	0	0	0	6
10/18/79	J	0	0	0	-	-	0	1	1	0	0	2
11/1/79	K	0	0	0	0	0	0	0	4	0	0	4
11/15/79	L	0	1	4	6	0	0	4	0	0	0	15
11/27/79	M	0	0	0	0	0	0	0	0	0	0	0
11/29/79	N	0	0	4	1	0	0	0	0	0	0	5
12/7/79	O	0	0	6	-	-	0	0	0	0	0	6
12/20/79	P	0	0	10	1	0	0	0	0	0	0	11
12/26/79	Q	0	0	20	0	0	0	0	0	0	0	20
12/29/79	R	0	0	25	-	-	0	0	0	0	0	25
12/31/79	S	0	0	17	0	0	0	0	0	0	0	17
1/5/80	T	0	0	15	0	0	0	0	0	0	0	15
1/10/80	U	0	0	35	-	-	0	0	0	0	0	35
1/17/80	V	0	0	13	2	0	0	0	0	0	0	15
1/24/80	W	0	0	32	0	0	0	0	1	0	0	33
1/31/80	X	0	0	14	5	0	0	0	0	0	0	19
2/3/80	Y	0	0	28	4	0	0	0	0	0	0	32
2/7/80	Z	0	0	54	1	0	0	0	0	0	0	55
Totals		6	9	283	20	0	17	7	13	0	0	355

- = not surveyed

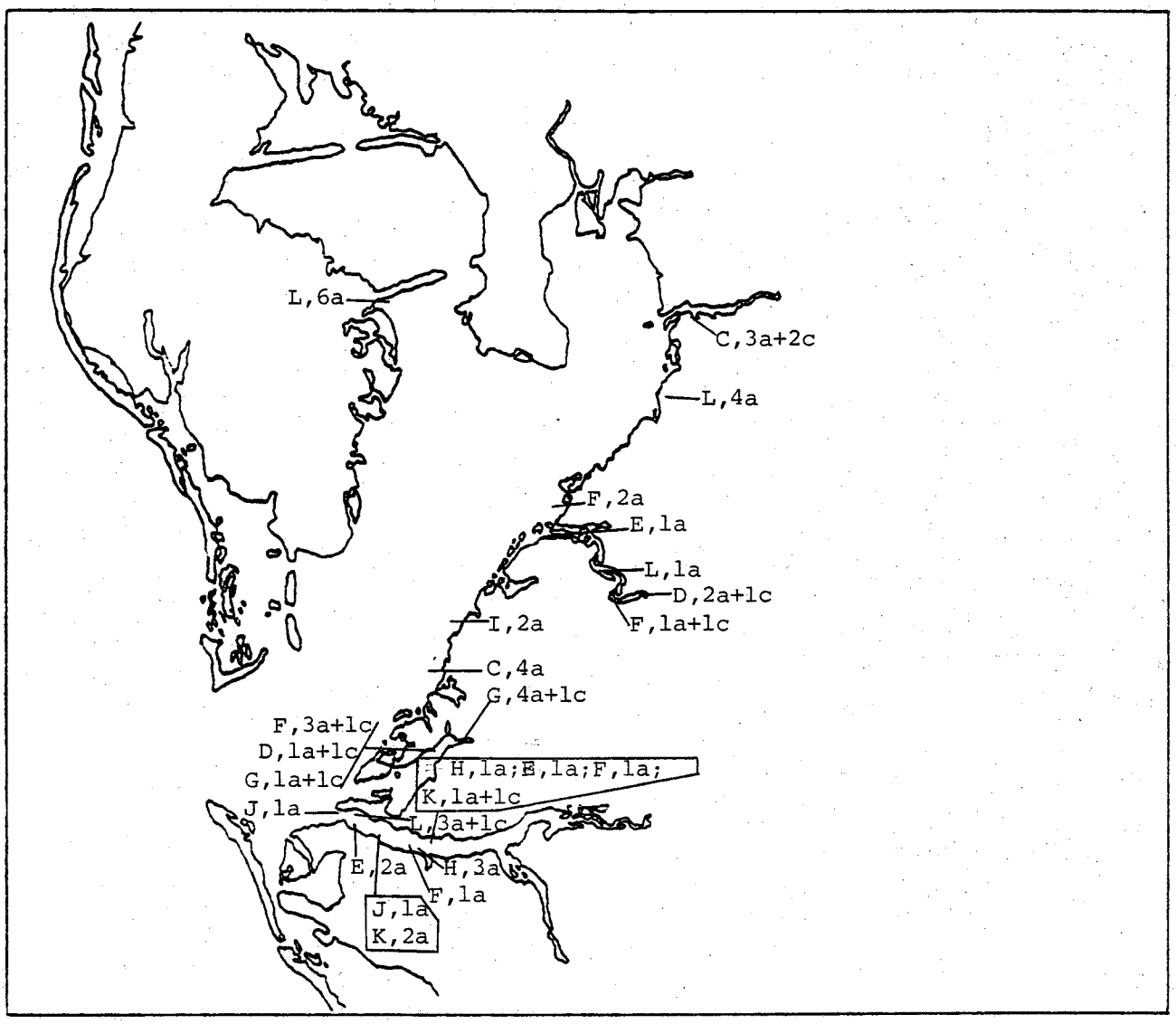


Figure 4. Warm weather (June 15 to November 15) manatee aerial sightings. Flights are alphabetically coded per Table 5 and indicate number of adults (a) and number of calves (c) in herds. Notice that manatees were occasionally sighted at the same location on different dates.

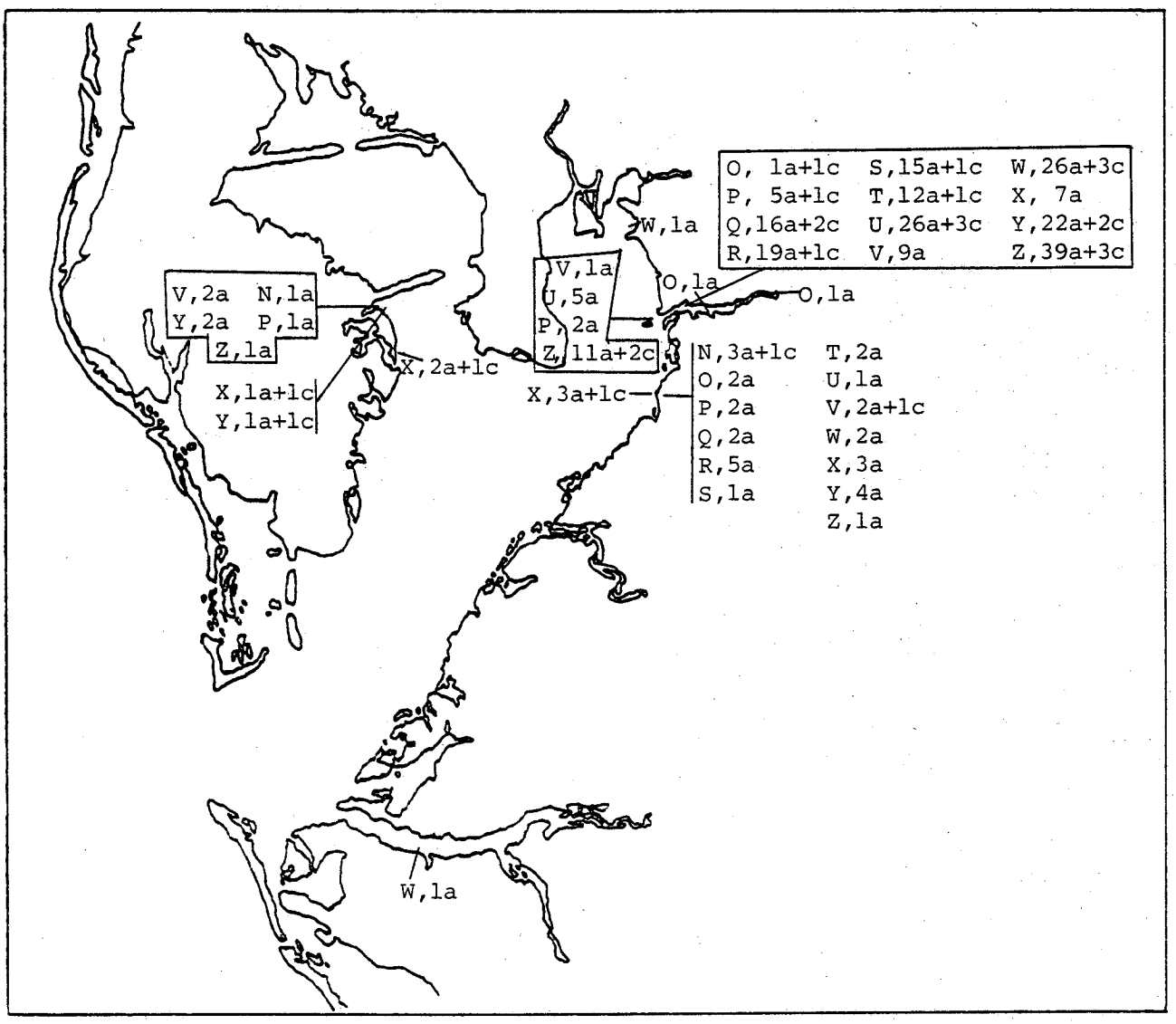


Figure 5. Cold weather (November 27 to February 7) manatee aerial sightings.

Table 6. Frequency, as percent of total sightings, of different sized manatee herds sighted during MML aerial surveys (after NFWL, draft). (Studies are of various areas.)

	HERD SIZE					REFERENCE
	1	2	3	4	>4	
PERCENT	53	17	13	6	11	Hartman, 1979
	46	24	11	5	14	Odell, 1979
	63	20	8	3	6	NFWL-BLM Pilot Study, 1979
	35	30	11	8	16	Reynolds, in press, Shoreline survey
	25	35	18	10	12	Canoe survey
	32	32	13	8	15	Combined shoreline + canoe survey
	34	25	13	10	18	MML, 1979-80

Table 7. Summary of numbers of dolphins by date and flight path segment sighted during the MML aerial surveys. (See Appendix C for segment maps.)

Date	Flight Path Segment										Total
	1	2	3	4	5	6	7	8	9	10	
6/15/79	0	0	0	0	0	-	-	-	-	-	0
6/29/79	0	0	0	0	0	-	-	-	-	-	0
7/14/79	0	0	0	0	0	-	-	-	-	-	0
7/26/79	2	4	1	1	0	0	3	0	0	0	11
8/9/79	2	7	1	0	0	1	0	3	0	0	14
8/23/79	2	3	3	0	0	2	0	0	0	0	10
9/6/79	1	1	1	8	1	0	-	-	-	-	12
9/20/79	3	0	2	1	0	0	0	0	0	0	6
10/6/79	0	0	0	0	0	0	0	0	0	0	0
10/18/79	0	0	0	0	0	0	0	0	0	0	0
11/1/79	0	0	0	0	0	0	0	0	0	0	0
11/15/79	0	4	0	0	0	0	0	0	0	0	4
11/27/79	0	0	0	0	0	0	0	0	0	0	0
11/29/79	0	0	0	0	0	2	0	0	0	0	2
12/7/79	0	3	0	0	0	0	0	0	0	0	3
12/20/79	6	0	0	0	0	0	0	0	0	0	6
12/26/79	0	0	0	1	0	0	0	0	0	0	1
12/29/79	0	0	0	-	-	0	0	0	0	0	0
12/31/79	0	1	0	2	0	0	0	0	0	0	3
1/5/80	0	0	0	0	1	0	0	0	0	0	1
1/10/80	0	2	1	-	-	3	1	0	0	0	7
1/17/80	0	2	2	13	0	0	0	0	0	0	17
1/24/80	0	0	0	0	0	0	0	0	0	0	0
1/31/80	2	0	3	0	0	0	1	0	0	0	6
2/3/80	0	0	0	11	0	0	1	2	0	0	14
2/7/80	0	0	0	6	11	5	1	0	0	0	23
Totals	18	27	14	43	13	13	7	5	0	0	140

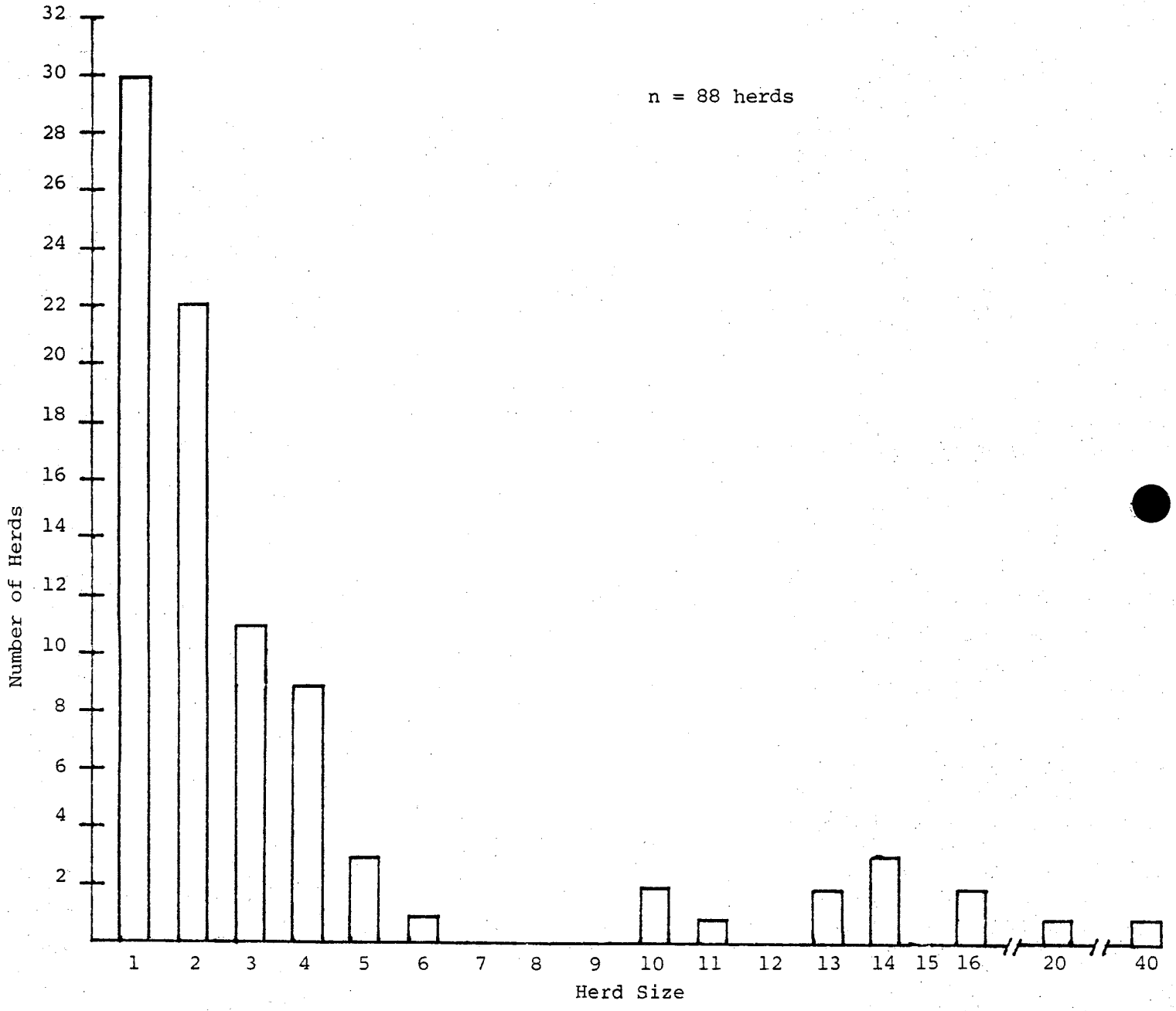


Figure 6. Frequency distribution histogram of different sizes of manatee herds sighted during the MML aerial surveys. All of the herds having more than six animals were sighted at the Alafia River. A herd was defined as having the distance between individuals less than the distance between groups.

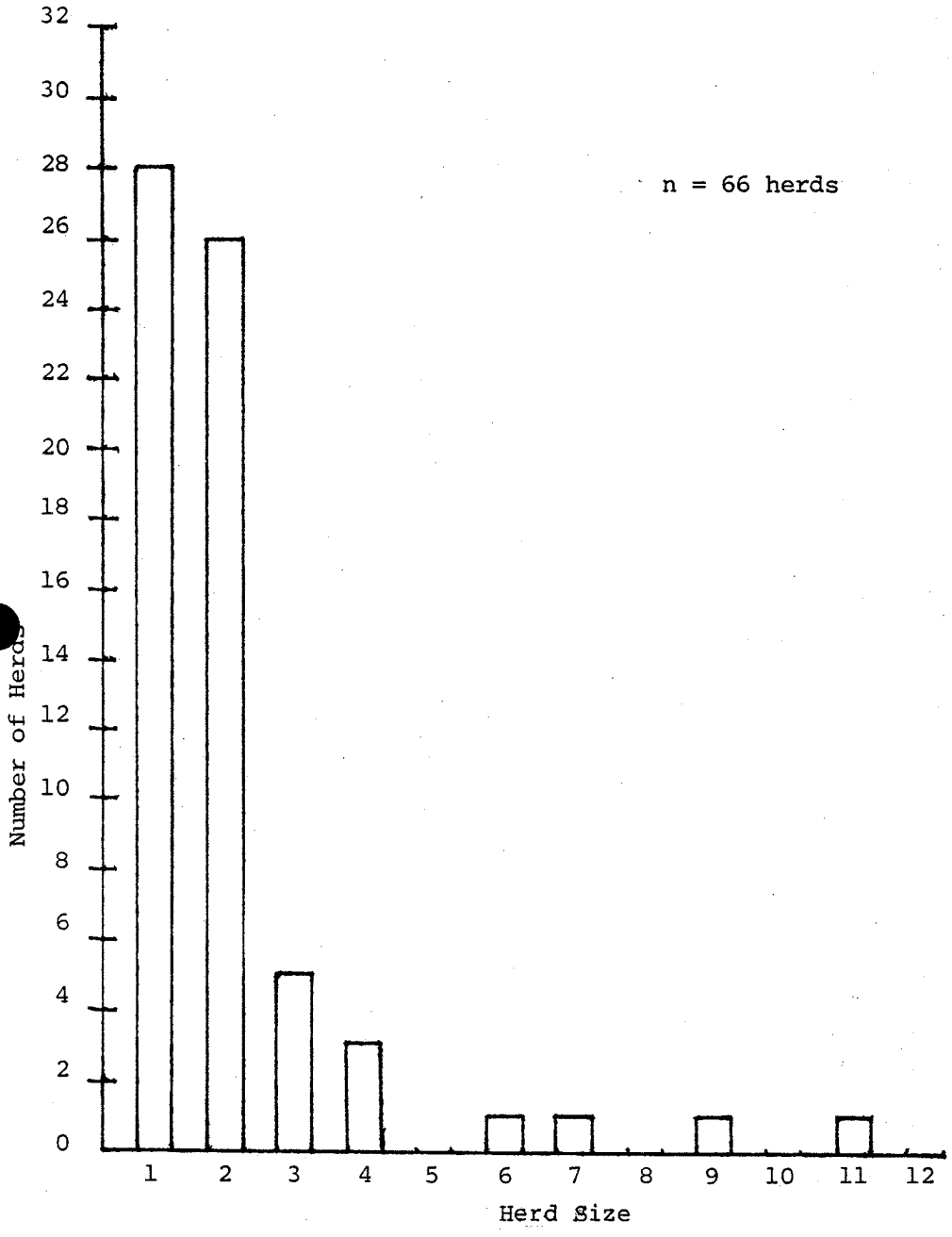


Figure 7. Frequency distribution histogram of different sizes of dolphin herds sighted during the MML aerial surveys.

Some distinct seasonal patterns are indicated by the data. Following the November 15 flight, only a single manatee was observed south of the Skyway Bridge in fourteen surveys where 32 were seen over the previous 12 flights. The same pattern was evident for the area between Apollo Beach and the Skyway Bridge with 15 animals sighted through the mid-November flight and none afterwards. Conversely, no manatees were observed at any of the warm water refuges prior to the November 15 flight. This dramatic shift in distribution pattern was apparently precipitated by the passage of the season's first significant cold front early on the 14th of November. The 9 cold front flights shown in Table 1 were characterized by manatee sightings being generally restricted to the warm water refuges. During brief warming trends, manatees were frequently observed 0.5 to 5 km away from the refuges, but it appeared that they reoccupied the refuge areas on the next cold front passage.

While NFWL (draft) states the belief that normally larger herds of dolphins would be more likely to be seen, this did not seem to be true in my surveys. Dolphins were observed in nearly all areas of Tampa Bay, especially the river mouths and on or near flats. Manatees, however, were seldom encountered around Interbay Peninsula (MacDill Air Force Base) or the St. Petersburg bayshore, except during the winter near the Bartow Power Plant. The reasons for this are unclear but may be related to the greater shoreline development in north and western Tampa Bay.

C. Structure Survey Program.

Nineteen manatees were observed in the Big Bend discharge canal during the seven structure surveys. No manatees were present on two occasions (1/2/80 and 2/12/80). On a third occasion, only 15 minutes of observation of a single animal were made before it was lost, presumably out of the canal. The circumscribed areas of manatees' use are depicted in Figure 8. Figure 9 shows the area of regular manatee use compiled from all data (i.e., inclusive of boat surveys, aerial surveys, etc.). It should be noted that the animals could be encountered in any portion of adequate depth (generally > 1m) in the discharge canal.

The area adjacent to the boat ramp appears to be avoided by manatees. During the structure observations, manatees were observed to surface until boats started up or approached, then the animals would submerge until the motors were turned off or the boats cleared the area. With many boaters showing little regard for the manatees' presence, the sirenians' evasive action seemed necessary to avoid being hit.

Figure 8. Discharge canal showing area of manatee use from structure observations.

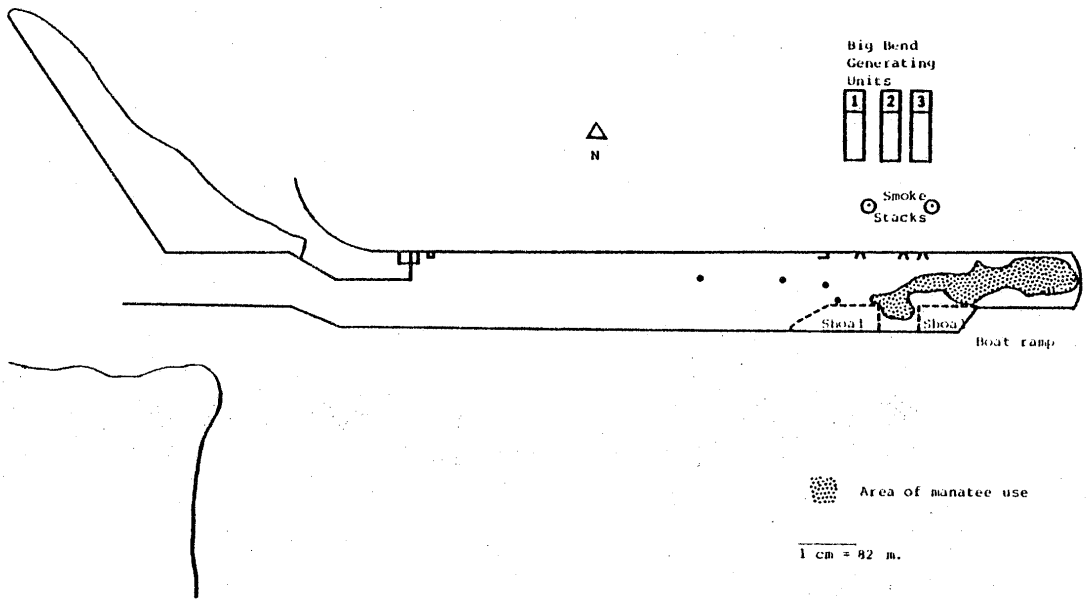
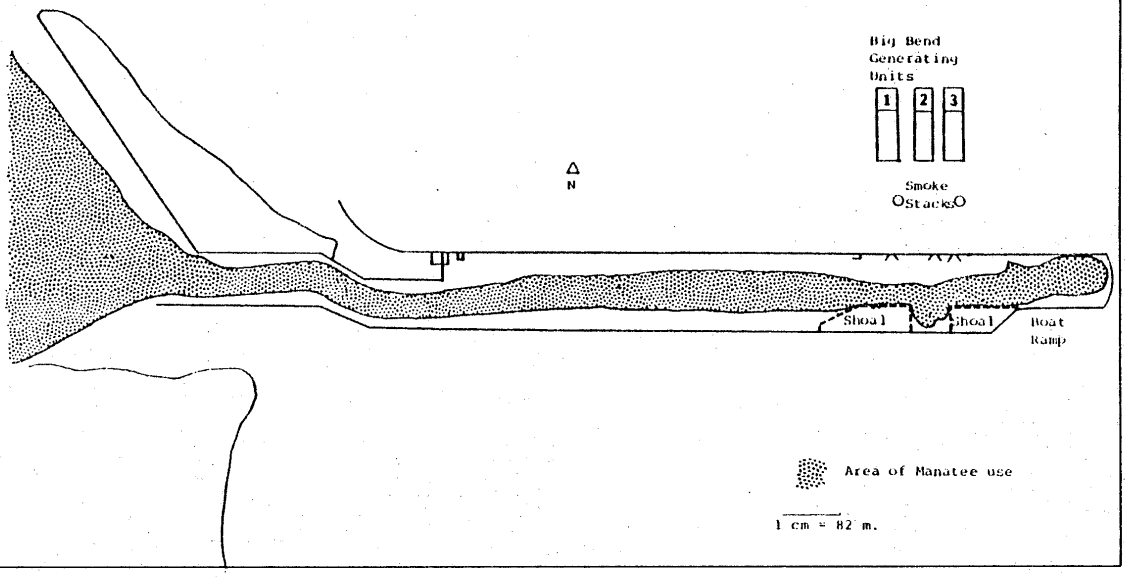


Figure 9. Discharge canal showing area of manatee use from all program observations.



Fishermen also presented some hazard to the manatees, often casting right over areas where they surfaced. On the other hand, many people expressed concern and consideration for the animals and decried the boaters' common disregard. Some people were even observed setting up lounge chairs by the ramp for the sole purpose of watching the manatees.

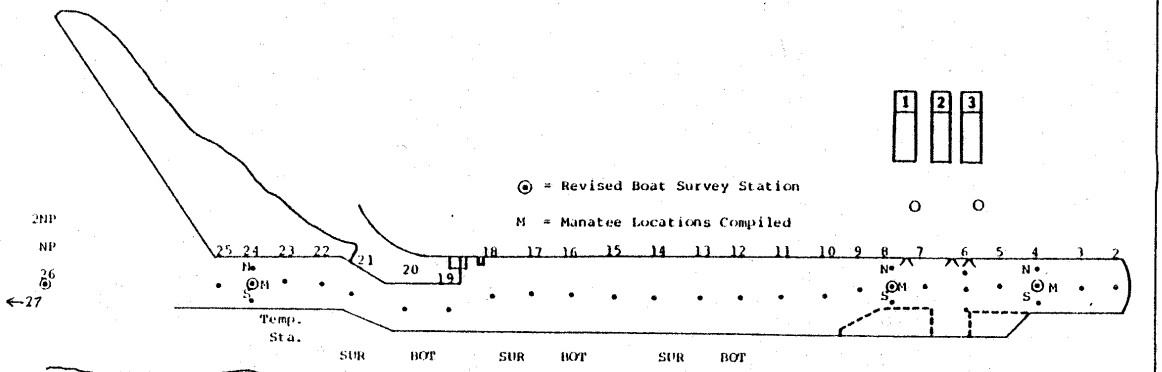
D. Temperature Grid Survey.

Water temperatures recorded during the study ranged from 28.7°C in the discharge canal during preliminary measurements on 11/19/79 to a low of 12.7°C on 2/4/80 when Unit 2 had been suddenly shut down and intake water was still being circulated. The low of 12.7°C in the discharge canal indicates that Stations 27, NP and 2NP (Figure 10), which were intended to provide ambient bay temperatures, were not far enough afield. To remedy this, Dr. Bill Johnson of Tampa Electric Company provided temperatures recorded by the intake water monitor. (There may be some recirculation but it is believed to only minimally alter ambient water temperatures.) These are plotted (Figure 11) along with monthly mean air temperatures to illustrate the interrelationship of air and water temperatures to aerial manatee counts in Tampa Bay. The obvious upward count trend in response to falling ambient temperatures may indicate that animals were 1) moving south to Tampa Bay, or 2) holding here on their northward spring migration (Gunter, 1942; Moore, 1951b), or 3) retreating to warm water sites from a diffuse local distribution (Odell, pers. comm.).

Manatees may be highly sensitive to relatively small differences in temperatures (Shane, 1978; G. Rathbun and B. Irvine, pers. comm.). To provide insight into the relative temperature of the various locations in the discharge canal, differences in temperatures ($\triangle$T's) calculated from the highest temperature recorded on a day's sampling are tabulated in the Appendix A (Table A-1) and the mean $\triangle$T's for each station are given in Figure 10. The $\triangle$T's at all manatee locations where temperatures for the discharge were available indicate that the animals do not locate within the Big Bend discharge canal in response to specific temperature levels. Rather, it appears that the animals prefer low current areas (current measurements were not, however, taken).

Two events which may have affected the data warrant discussion. First, on 11/19/79, it was observed that the tidal creek flowing into the eastern end of the discharge canal was 6.7°C cooler than the canal temperature. Secondly, the previously mentioned shutdown of Unit 2 on 2/4/80 depressed water temperature at stations 6N, 6M, and 6S but readily mixed within the canal and depressed the overall canal temperatures by about 2°C. For these reasons the 2/4/80 data were not included in the $\triangle$T analysis.

Figure 10. Mean △T's from Base Temperature (°C)



	SUR	BOT		SUR	BOT		SUR	BOT
4N.	0.3	0.6	13.	0.3	0.4	.		
M.	0.4	0.7	24N.	0.6	0.7	.		
S.	0.3	0.7	M.	0.5	1.3	.		
6N.	0.5	0.6	S.	0.5	1.3	.		
M.	0.3	0.5	26.	5.0	5.4	.		
S.	0.2	0.2	27.	4.9	5.2	.		
8N.	0.3	0.3	NP.	4.0	7.4	.		
M.	0.4	0.2	.			.		
S.	0.2	0.1	.			M's.	1.17	0.85

1 cm. = 82 m.

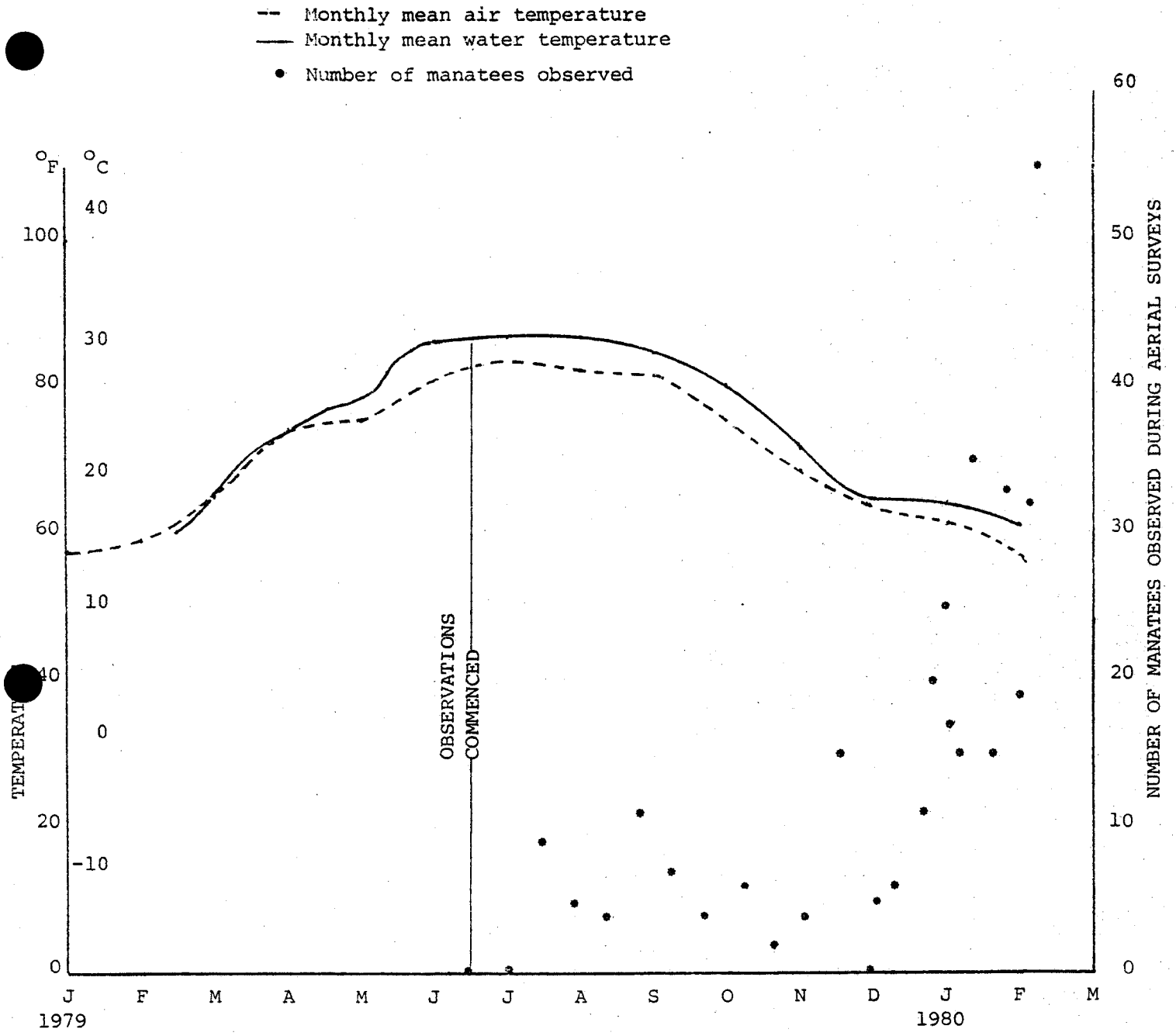


Figure 11. Increase in manatee sightings with decreasing temperature.

E. Dive Time Program.

Most of the summer dive times were taken for animals in the Manatee River. Winter dive times were measured at the mouth of the Alafia River near Bird Island and in the discharge canal at Big Bend.

Four hundred twenty-five manatee dive times were recorded, 168 during the summer and 257 in the winter, representing 14 and 15 animals respectively. Up to three hours and fifty-five minutes of continuous observation on a single animal was performed. The dive times ranged from 3 seconds to 15 minutes 59 seconds with summer and winter means of 1 minute 26 seconds and 2 minutes 59 seconds, respectively. A summary of the results is presented in Table 8. Of particular interest are the extreme variability of dive durations and some general patterns discernible from the data, a portion of which is depicted in Figure 12. Three sets of typical behavior are shown with their respective dive patterns: loitering, surface resting, and bottom resting.

The loitering animals (both summer and winter) seemed alert, but were not engaged in any specific behavior. The vertical diving (bottom resting) animals tended to stay submerged for long periods of time (often >10 minutes) and took 2 to 4 breaths, 20 to 40 seconds apart upon surfacing. They slipped slowly backwards under the surface for all but the last of these breaths, when they moved forward while exhaling and inhaling and then continued forward, arching their exposed back and heading straight down, often exposing the tail momentarily. Surface resting animals remained inactive for extended time periods, either just below the surface or with their backs exposed.

The animals seen in the discharge canal were mostly surface or bottom resting or loitering. Except for resting, minimal social interactions (muzzling, mostly) and moving in or out of the canal, no other activities were observed. No evidence of submerged vegetation in the discharge canal was encountered (hence, precluding feeding activities).

The Dive Time Program was conducted to evaluate the appropriateness of a 2 minute observation time for the Boat Survey Program. It is readily evident from the variability of the Dive Time data that quite different counts can occur for the same number of animals.

Table 8. Summary of results of manatee Dive Time Observations during Summer, 1979 and Winter, 1979-80.

Date	Animal Identifier Code	adult or calf	Total Time Observed (hrs:min:sec)	Total # of dives measured	Dive Time Range (min:sec)	Mean (min:sec)	Apparent Activity	At Big Bend Power Station (*)
Summer 1979:								
8/21	LON	a	0:05:00	1	1:08	1:08	Swimming	
8/26	BAC	c	0:21:38	6	0:33-3:35	1:53	Loitering Feeding +	
8/26	BCA	a	0:16:14	10	0:35-5:02	1:37	Loitering	
8/26	BBA	a	0:17:52	6	0:57-7:53	2:59	Loitering	
8/26	BDA	a	0:03:33	2	0:33-3:33	2:03	Loitering	
8/26	BEA	a	0:12:38	3	0:26-7:33	4:13	Loitering	
9/26	DIS	a	0:02:32	4	0:10-1:00	0:37	Feeding	
9/26	WZC	c	0:58:05	50	0:11-4:14	1:09	Loitering near mating herd	
9/26	WZY	a	0:58:11	53	0:03-3:34	1:05	Loitering near mating herd	
9/27	KAR	a	0:05:12	2	1:12-4:00	2:36	Swimming	
9/27	JEA	c	0:03:00	3	0:17-1:45	1:00	Swimming	
9/28	KAR	a	0:19:48	11	0:04-3:30	1:48	Loitering	
9/28	JEA	c	0:19:48	9	0:46-3:28	2:12	Loitering	
9/28	JUV	a	0:12:45	8	0:47-2:22	1:36	Loitering	
Winter 79-80								
1/7	ABB	a	3:55:14	52	0:12-15:59	4:31	Bottom resting	*
1/8	KLA	a	0:44:01	21	0:23-4:20	1:53	Loitering (feeding?)	
1/8	MNA	a	0:05:12	2	1:19-3:53	2:36	Swimming	
1/8	MNC	c	0:05:17	3	1:13-2:43	1:45	Swimming, cruising, then stopped	
1/8	LPA	a	0:04:24	3	1:10-2:00	1:28	Swimming	

Table 8 (Continued). Summary of results of manatee Dive Time Observations during Summer, 1979 and Winter, 1979-80.

Date	Animal Identifier Code	adult or calf	Total Time Observed (hrs:min:sec)	Total # of dives measured	Dive Time Range (min:sec)	Mean (min:sec)	Apparent Activity	At Big Bend Power Station (*)
1/9	MMA	a	0:27:54	9	0:17-13:01	3:06	Resting	*
1/22	SSA	a	0:38:30	13	0:18-6:15	1:40	Loitering	*
1/22	SSC	c	0:38:45	17	0:14-4:57	1:42	Loitering	*
1/22	TOA	a	0:27:39	12	0:12-4:39	1:49	Loitering	*
2/5	SBA	a	1:01:48	15	0:14-15:38	4:07	Bottom resting	*
2/19	BNA	a	1:30:18	24	0:14-13:34	2:56	Resting & loitering	*
2/19	BQA	a	0:11:08	3	0:19-10:17	3:43	Loitering	*
2/19	ABB	a	2:20:12	41	0:13-12:52	3:25	Bottom resting	*
2/23	BRA	a	0:40:59	19	0:18-5:32	2:09	Surface resting	*
2/23	SMA	a	0:53:46	23	0:11-4:54	2:20	Surface resting	*

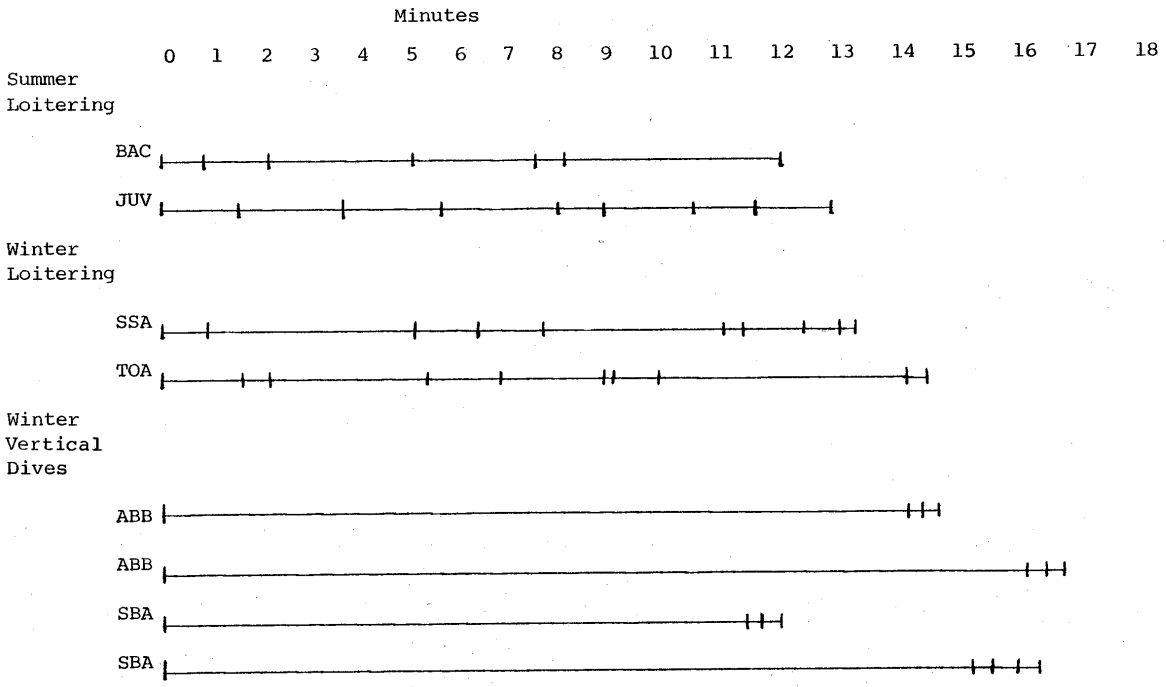


Figure 12. Comparison of Typical Dive Time Patterns: Loitering vs. Vertical Dives (bottom resting). Vertical marks show surfacings of individual manatees indicated by 3-letter identifiers. The Winter Vertical Dives pattern was only observed in the Big Bend Discharge Canal.

This is especially true with the relatively small number of animals frequenting Big Bend. One suggested solution to better estimate the numbers of manatees in this area would be to lengthen either the duration of segment observation or the amount of replication or both. Little purpose would be served in lengthening the observation time without extensive statistical analyses of dive times in the specific area. Based on some preliminary calculations, I feel that variability will remain too high for any reasonable observation time. Increased replication, on the other hand, would balance out the variability. The tediousness of conducting such extended surveys would, however, be an obstacle.

Shane (1979) discussed her use of the boat survey and other surface survey methods. She recommended ten minute estimated counts as being preferable, but the Winter Vertical Dive pattern observed at Big Bend indicates that the observation period would require modification for areas of differing behavioral patterns (e.g., feeding vs. bottom resting areas). The previously stated approach of untimed, extended estimated counts from a boat with the aid of a radio-equipped observer on the plant superstructure, seems best for use at Big Bend.

F. Identified Animals.

During the above studies, only seven manatees were individually identified due to the turbid water in Tampa Bay and the low percentage of the area's population closely encountered. Seven animals were closely observed and had markings which were recorded on standardized silhouettes. Two of the seven animals were observed on two different occasions with all sightings in the discharge canal. It is probable that more than two manatees use Big Bend's discharge canal regularly as a winter refuge.

G. Associates.

Extensive balanid barnacle patches were observed on some manatees but not others (Odell, in a personal communication, indicates these are probably Chelonibia manati). One was closely seen to have a coating of brown scum.

Pelicans and mullet are ubiquitous in the Big Bend area but no interactions with manatees were observed. Hartman (1979) discussed associates including remoras, Echeneis nauclates. Other fish commonly associated with manatees include two Sparidae, pinfish, Lagodon rhomboides, and sheepshead, Archosargus probatocephalus.

A unique associate that has not been reported in the literature, to my knowledge, was spotted and photographically documented on November 20, 1979. Three cobia, Rachycentron canadus, were observed closely accompanying a manatee that appeared to have just entered the discharge canal. These fish are known by sportsmen to be superb gamefish which are sought in the vicinity of navigational buoys and offshore structures. Apparently, these fish were thigmotactically attracted to the manatee. One fisherman, when told of this occurrence, profferred the opinion that cobias might stay with the manatee to catch crabs fleeing the sirenians' bottom disturbances. Whatever the specific reason, the cobias seemed to have been led into warmer water by the manatee.

A cobia was seen with another manatee from the plant superstructure and a large fish, possibly a cobia, was observed with another manatee on a third occasion. It is doubtful that this association is restricted to this area. S. Shane (pers. comm.) has observed a large fish accompanying a mother manatee and calf. The calf was swimming above the mother and the fish below, preventing identification.

H. Submerged Aquatic Vegetation.

Little information exists in the literature on the distribution of SAV within Tampa Bay. Two historical sources (Phillips, 1960; and Sykes, 1966) (Note that literature cited for this part of the study is in Appendix B.) state that SAV in Tampa Bay is restricted to depths of less than 2 meters. Sykes additionally charted the SAV and presented a map showing the SAV's distribution and density in Tampa Bay. Other information that is available (see Appendix B) is largely the results of site specific studies performed for regulation of industrial development.

Information from the MML staff, R. Lewis (Mangrove Systems, Inc.), local fishermen, and preliminary drafts of the National Wetlands Inventory maps were used to map SAV in Tampa Bay (refer to Figure 13). These results closely concur with that of Phillips (1960) and Sykes (1966) who state that SAV in Tampa Bay is generally restricted to < 2 meters. This is likely due to the high turbidity levels in Tampa Bay preventing enough sunlight penetration to maintain bottom attached vegetation. In general, SAV is generally restricted to those areas of the bay bottom which can be seen from the air, i.e., the shallow flats. Other researchers concur in this conclusion (e.g., Lewis, pers. comm.). One possible exception to this may be the area immediately southwest of Apollo Beach where I observed some deeper dark patches. This area is normally not clear enough to make out the bottom

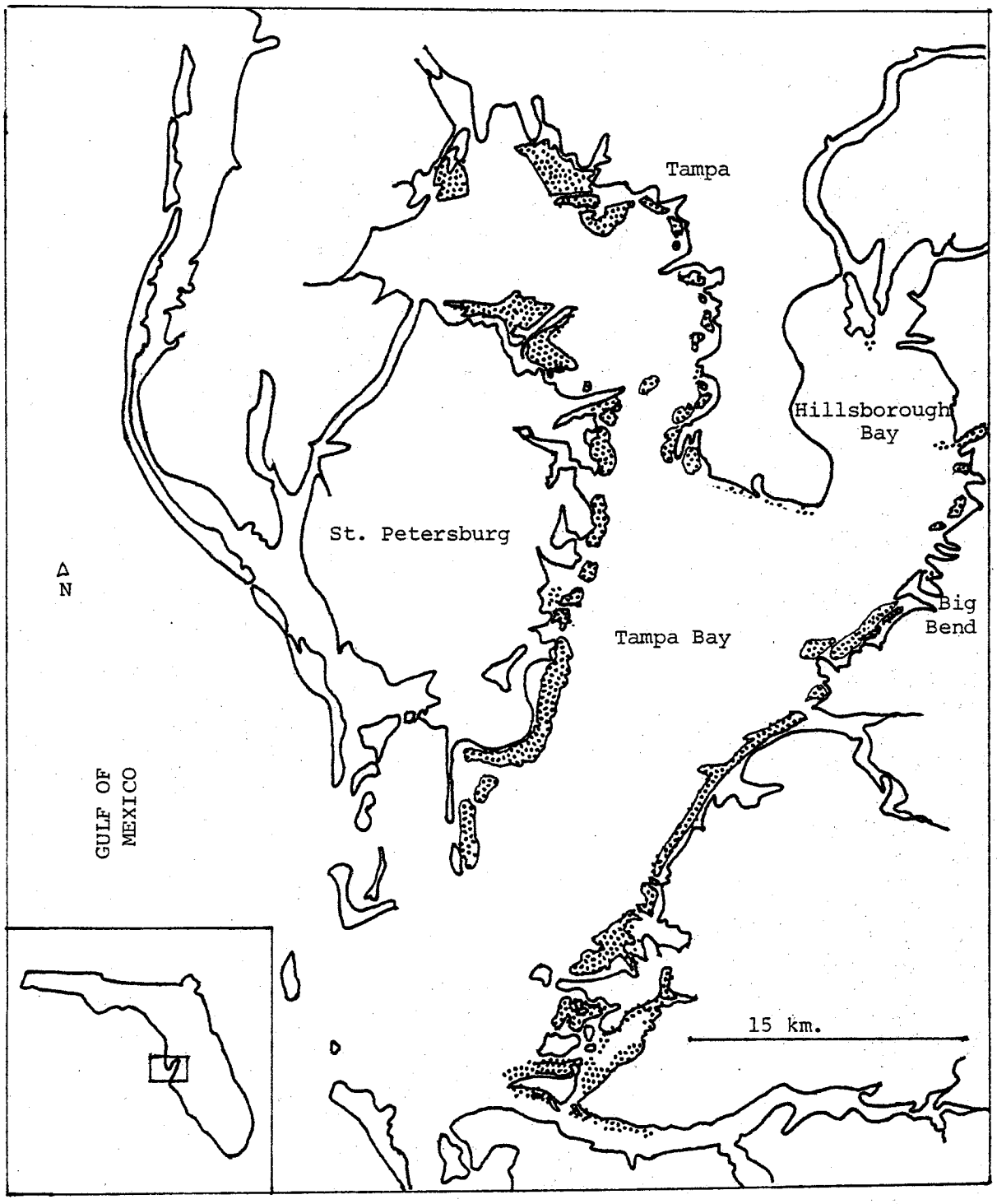


Figure 13. Location of Submerged Aquatic Vegetation (SAV) in Tampa Bay. (Density and species composition is likely seasonally variable with the distribution less variable.)

and it may be that these patches were merely holes or rocks. Lewis (pers. comm.) suggested that there may be holes in the area that collect drift red or brown algae. While no field sampling was included in this study, the reports of Phillips (1960) and Lewis (1977) indicate that the SAV observed was likely the seagrasses Syringodium filiforme, Halodule wrightii, Ruppia maritima and Thalassia testidinum.

Hartman (1979) exhaustively discussed manatee feeding. In the present studies, feeding manatees were observed regularly during the summer on SAV flats in the mouth of the Manatee River. A number of manatees were observed feeding on water hyacinths (Eichornia crassipes) at the S.R. 70 bridge over the Braden River during the summer. The only feeding manatees observed during the winter were at the mouth of the Alafia River where unidentified SAV appears to be well established in the vicinity of the spoil islands. No manatees were observed feeding in the Big Bend area. The food sources and feeding patterns of the Tampa Bay winter manatee population are unknown.

IV. SUMMARY AND CONCLUSIONS

Boat, aerial, structure, temperature, dive time and grassbed surveys in Tampa Bay were conducted by Mote Marine Laboratory to: 1) document the use by manatees of the thermal effluent at Big Bend Power Station, and 2) determine the site's significance as winter refuge, compared to other refuges available in the area. A summary of the findings are:

1) Seventy-two manatee sightings in the warm-water discharge canal were recorded during boat surveys in the colder months. The boat survey technique did not provide firm abundance estimates. Best direct observation estimates indicated an abundance range in the discharge canal of zero to 10 manatees.

2) Eighty-eight manatee herd aerial sightings representing 319 adults and 36 calves were recorded. The highest manatee count during one survey was 55. Sightings in the Big Bend Discharge Canal ranged from zero to five.

3) Sixty-six dolphin herds representing 140 animals were sighted from the air.

4) Manatees were generally sighted on flats or following the edges of shoals except in winter aggregations at warm-water refuges.

5) The greatest numbers of manatees sighted during aerial surveys were at the Gardinier Phosphate Plant on the Alafia River.

6) Manatees were observed regularly feeding in the mouth of the Manatee River during the warmer months and at the mouth of the Alafia River during the colder months.

7) Nineteen manatees were observed in the discharge canal during the structure observations. Sightings during the structure surveys ranged from zero to seven manatees.

8) Water temperatures in the discharge canal from November 19, 1979 to February 12, 1980 ranged from 28.7°C to 12.7°C.

9) Four hundred twenty-five manatee dive times were recorded, 168 summer and 257 winter. The dive times ranged from 3 seconds to 15 minutes 59 seconds with summer and winter means of 1 minute 26 seconds and 2 minutes 59 seconds, respectively.

10) Three notable dive patterns were observed (loitering, surface resting and vertical diving). Winter vertical-diving (bottom resting) manatees demonstrated a pattern of a long dive followed by a series of two to four brief dives while respiring. This was a consistent pattern for several individuals over extended sets of dives.

11) Seven animals were closely observed and had markings which were recorded on standardized silouettes. Two identified animals were seen on more than one occasion at the plant. It is probable that more manatees use the discharge canal regularly as a winter refuge.

12) A previously unreported manatee associate was the cobia (Rachycentron canadus) which accompanied the large mammals in the discharge canal.

13) Submerged aquatic vegetation (SAV) in Tampa Bay was charted (Figure 13) and generally found to occur in less than 2 meters of water.

The conclusions from these findings are:

1) Manatee sightings were most common in the mouth of the Manatee River during the warmer months and shifted to the warm-water refuges during the colder months.

2) The Big Bend Power Station ranked second in importance as a warm-water refuge after the Gardinier Phosphate Plant (Figure 1).

3) The manatees demonstrated predictable responses to cold fronts and warming trends by moving into warm water during cold weather and venturing out during warming spells.

4) Aerial sightings of manatees increased as ambient water and air temperatures decreased.

5) The eastern end of the discharge canal (except for the boat ramp region which was avoided) appeared to be the area of most regular manatee use.

6) Distribution of manatees within the discharge canal did not appear to correlate with specific temperature levels.

7) The boat survey procedure, while inadequate to accurately count manatees at Big Bend, was effective in establishing the regular use of the warm-water discharge by manatees.

8) Use of the discharge canal by boaters and fishermen is periodically intense and potentially threatening to manatees.

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APPENDIX A

ΔT's from Base Temperature by Station.

Table A-1. ΔT's from Base Temperature (highest temperature recorded that date) by station. Note that station means were computed without the data for 2/4/80 , as discussed in text. All differences are in °C.

Stations	11/19/79	11/20/79	12/4/79	12/18/79	1/2/80	1/22/80	1/29/80	2/4/80	2/12/80	$\bar{x}$ (excluding 2/4)	n
4N				0/0.5		0.9/1.6	0.2/0.2	0.4/0.4	0.2/0.6	0.3/0.6	4/4
M	0.6/	0.3/	1.1/	0/0.2		0.7/1.6	0.1/0.2	0.4/0.5	0.1/0.8	0.4/0.7	7/4
S				0.1/0.4		0.5/1.4	0.4/0.3	0.3/0.5	0/0.7	0.3/0.7	4/4
6N				0.2/0.3		0.1/0.1	0/0.2	7.8/7.55	1.8/1.7	0.5/0.6	4/4
M			0.8/	0.1/0.3		0.2/0.65	0.3/0.2	0.8/4.6	0.1/0.9	0.3/0.5	5/4
S				0.1/0.1		0.3/0.3	0.2/0.1	0.35/5.3	0.1/0.3	0.2/0.2	4/4
8N				0.6/0.6	0/0.1	0.2/0.2	0.1/0	0.3/0.2	0.4/0.5	0.3/0.3	5/5
M			0.8/	0.6/0.6	0.1/0.1	0/0.1	0/0	0/0.3	0.3/0.2	0.4/0.2	6/5
S				0.5/0.1	0/0	0.2/0.1	0.2/0	0.1/0.3	0.15/0.2	0.2/0.1	5/5
13	0.45/		0.4/	0.5/0.5	0.1/0.1	0.1/0.4	0/0.1	0.1/0.1	0.55/0.7	0.3/0.4	7/5
24N				0.6/1.2	0.2/0.2	1.1/1.4	0.2/0.2	0.2/0.3	0.7/0.7	0.6/0.7	5/5
M			0.4/	0.6/3.4	0.2/0.2	1.1/2.1	0.1/0.2	0.2/0.3	0.7/0.7	0.5/1.3	6/5
S				0.6/3.4	0.2/0.1	1.1/2.3	0.1/0.1	0.3/0.15	0.7/0.7	0.5/1.3	5/5
26				4.4/5.9	1.0/1.0	7.4/7.3	2.5/6.2		2.9/6.6	5.0/5.4	5/5
27	2.1/	8.1/		6.0/6.0	0.7/0.9	7.45/7.4	5.5/6.5			4.9/5.2	6/4
2	6.7/1.3		1.2/				0.1/0.2				
3			1.1/	0/0.7							
5			0.9/								
7	0/	0.2/	0.4/								
9	0.2/		0.7/								
10			0.5/								
11			0.5/								
12			0.4/								
14		0.05/	0.3/								
15			0.8/								
16			0.6/								
17			0.3/								
18	0.6/	0/	0/								
19			0.1/								
20	0.5/		0.7/								
21	0.5/	0/	0.4/								
22			0.5/								
23	0.55/		0.5/								
25	0.5/	0/	0.7/								
NP					3.0/8.3	3.7/7.1	5.7/ 9/8.9		3.8/6.7	4.0/7.4	4/3
2NP											
5.5S	5.6/										
2.5M	6.0/										
2N						1.7/2.2					
3.5 M's	(manatee locations)						0.1/			1.1/0.8	7/5

(surface/bottom)

_____ = manatees observed at this station, this date.

APPENDIX B

GRASS BED (SUBMERGED AQUATIC VEGETATION) SURVEY

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APPENDIX C

AERIAL SURVEY SEGMENT MAPS

Manatee Sighting Program (310.74)

Segment 1

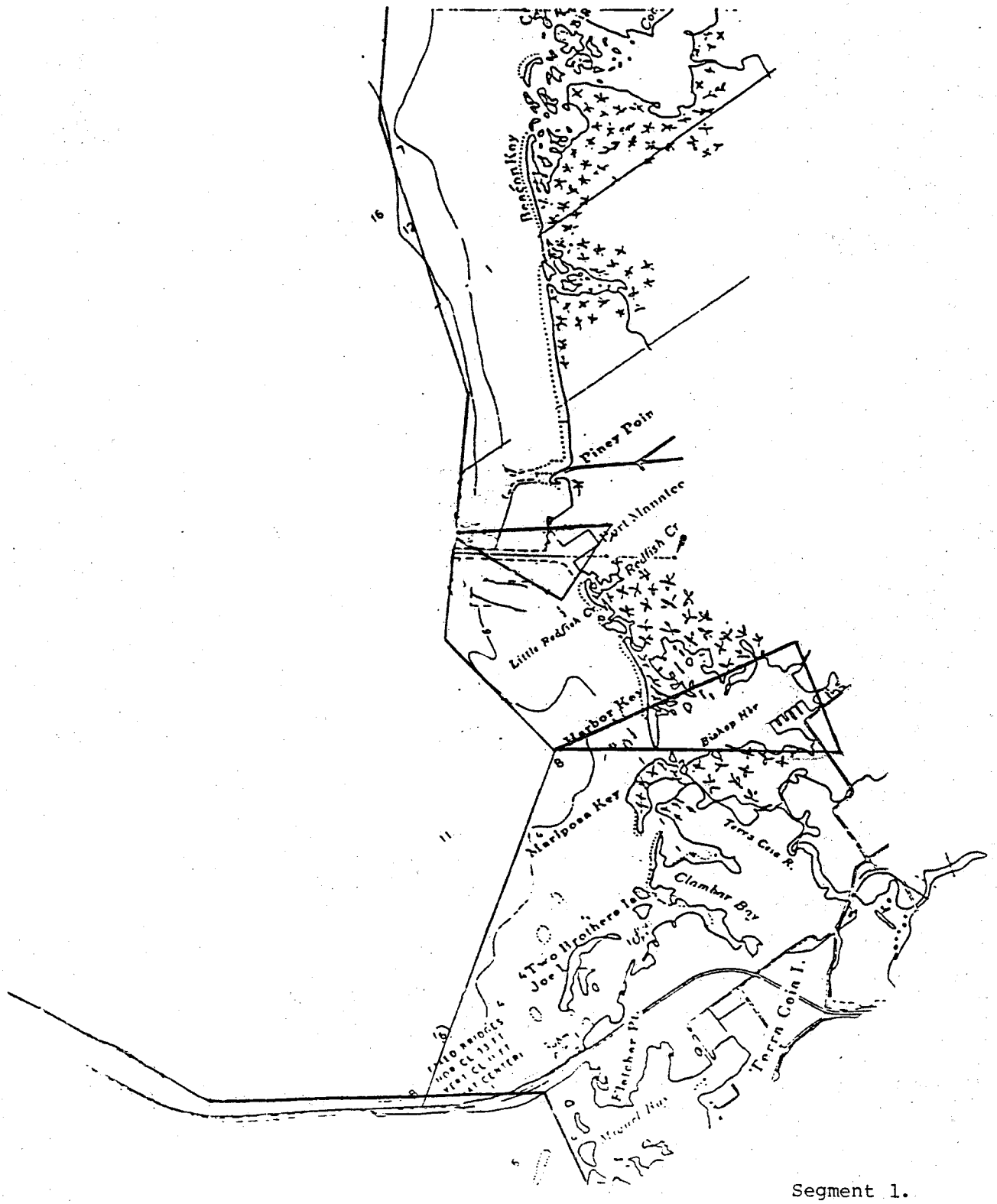
Date Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 1.

Data Recorded by

Checked by

Manatee Sighting Program (310.74)

Segment 2

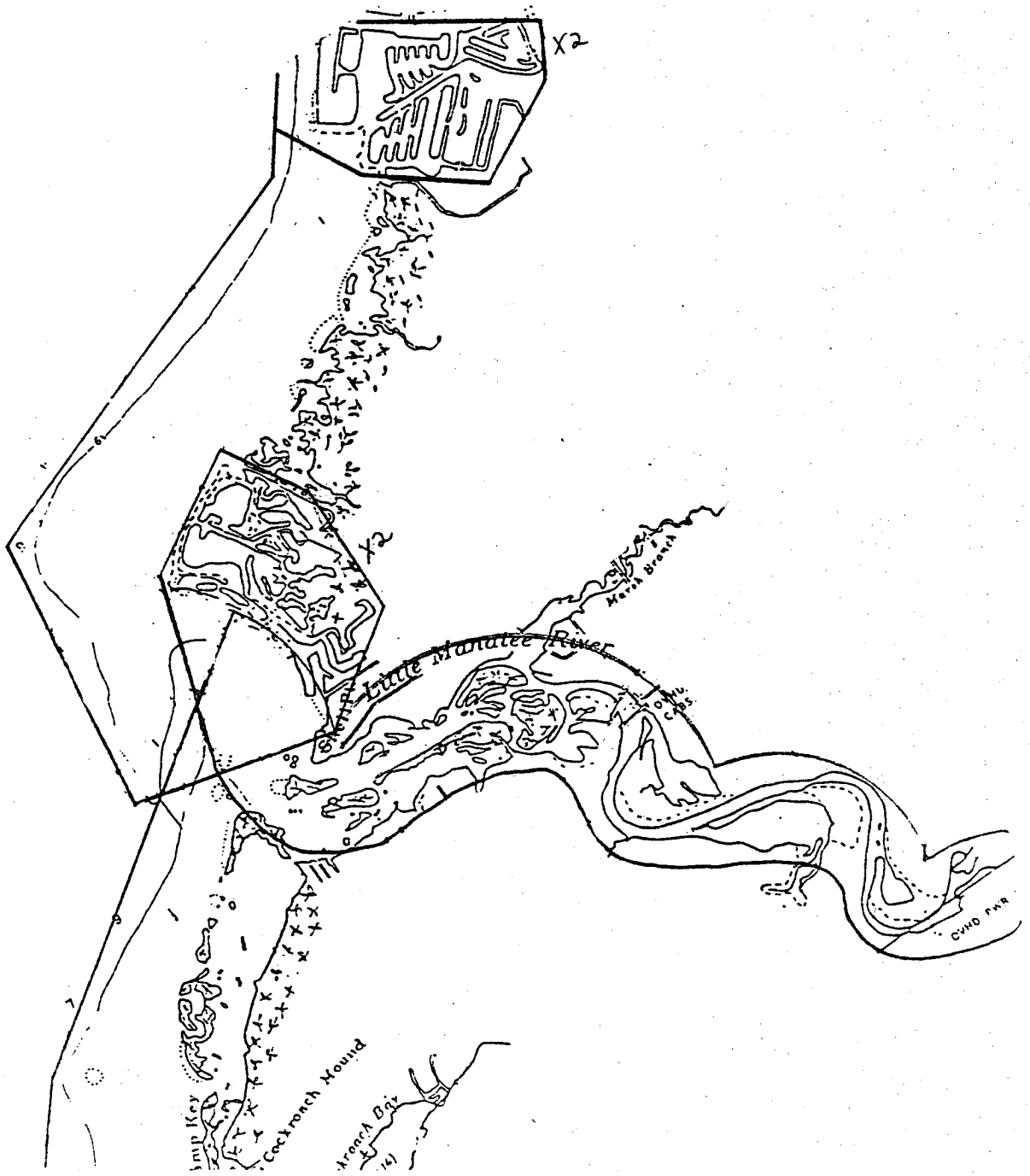
Date: Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 2.

Data Recorded by ____ Checked by ____

Manatee Sighting Program (310.74)

Segment 3

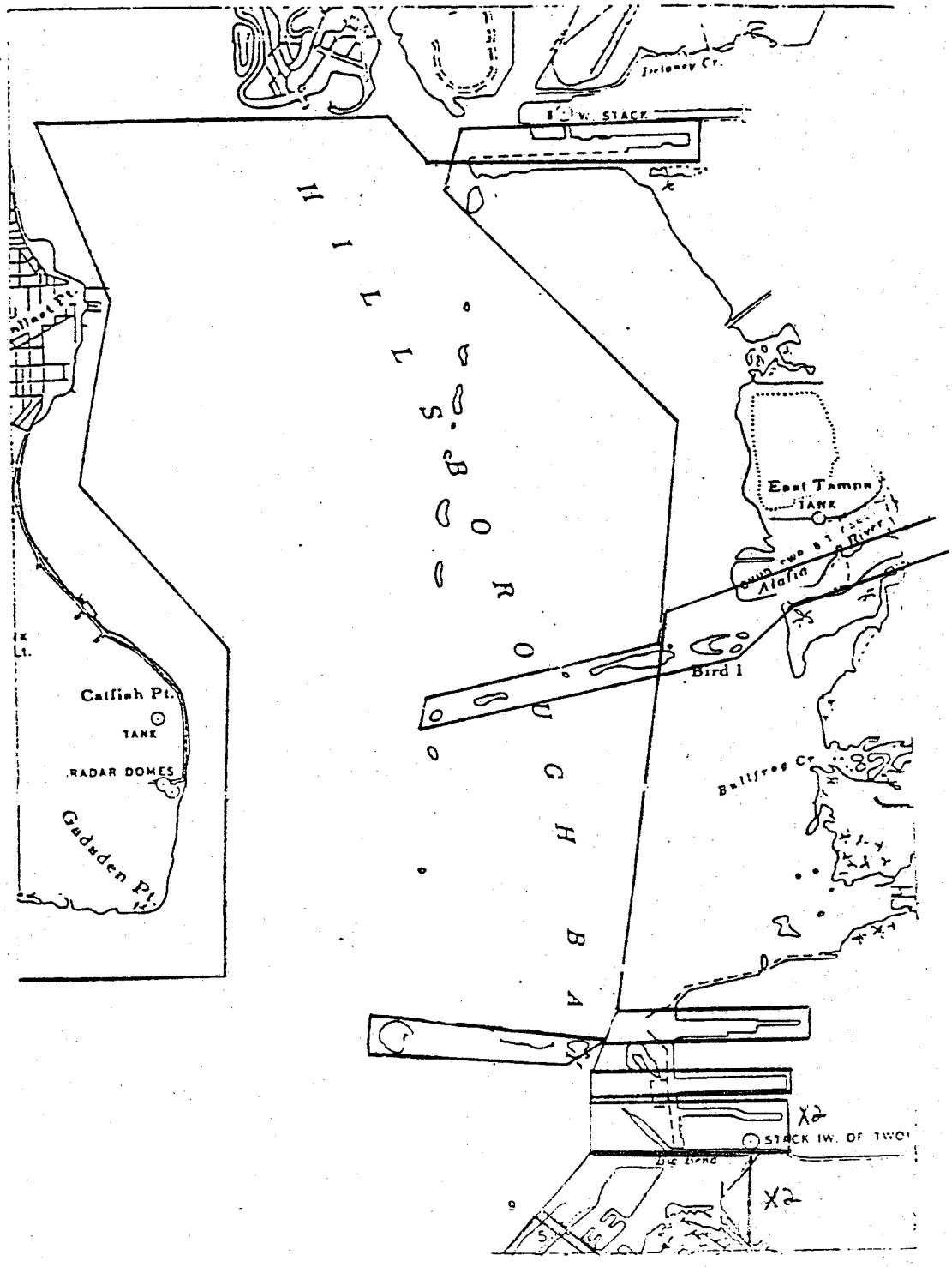
Date Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 3.

Data Recorded by

Checked by

Manatee Sighting Program (310.74)

Segment 4

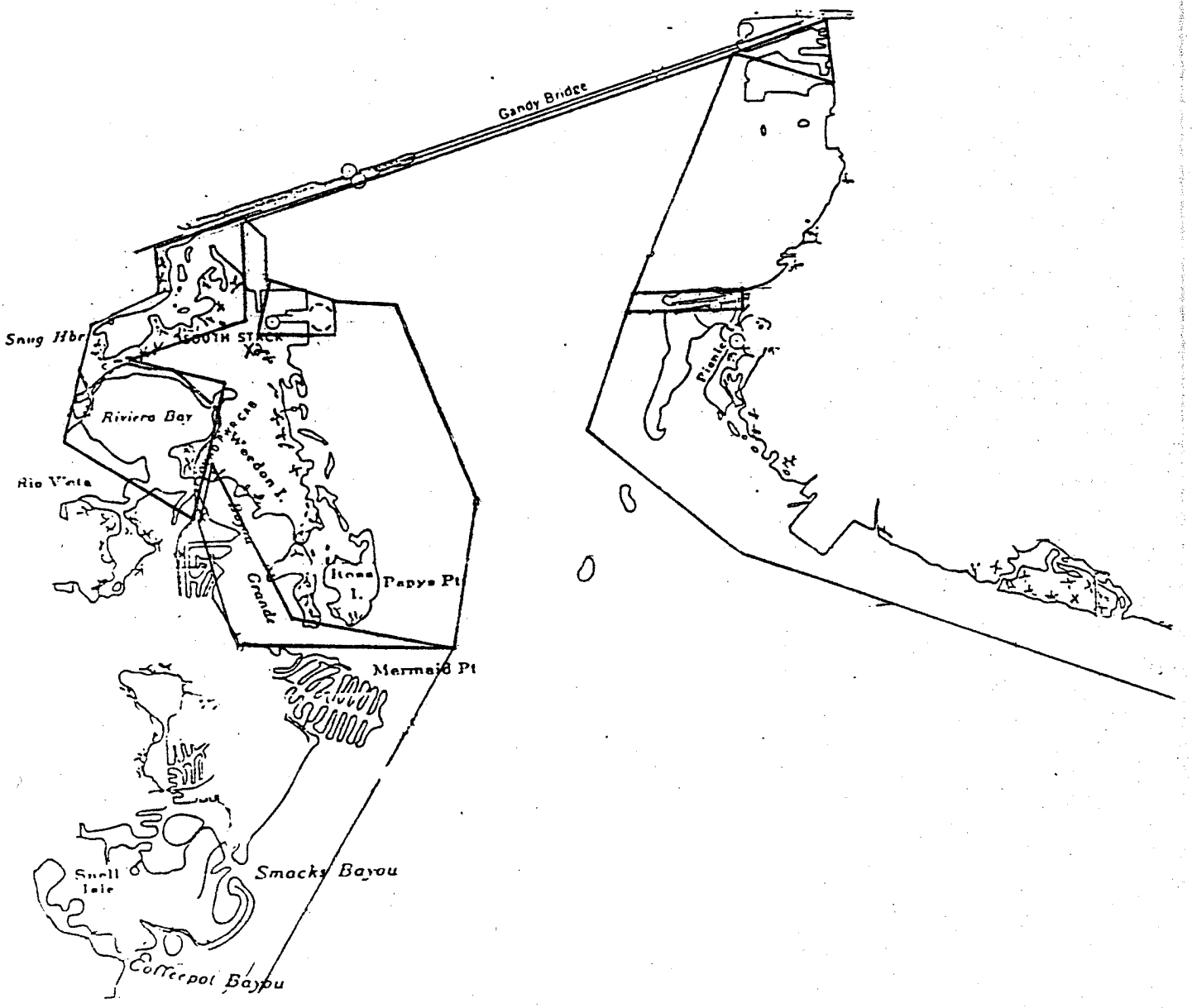
Date Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 4.

Data Recorded by

Checked by

Manatee Sighting Program (310.74)

Segment 5

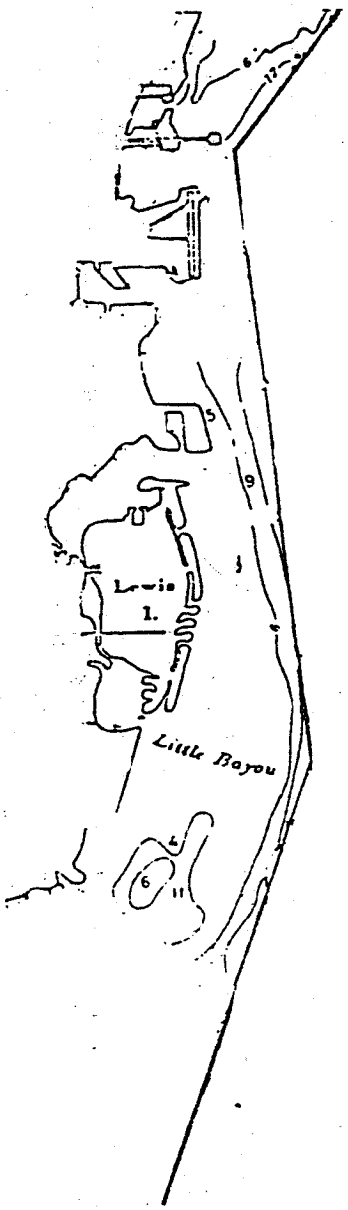
Date Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 5.

Data Recorded by

Checked by

Manatee Sighting Program (310.74)

Segment 6

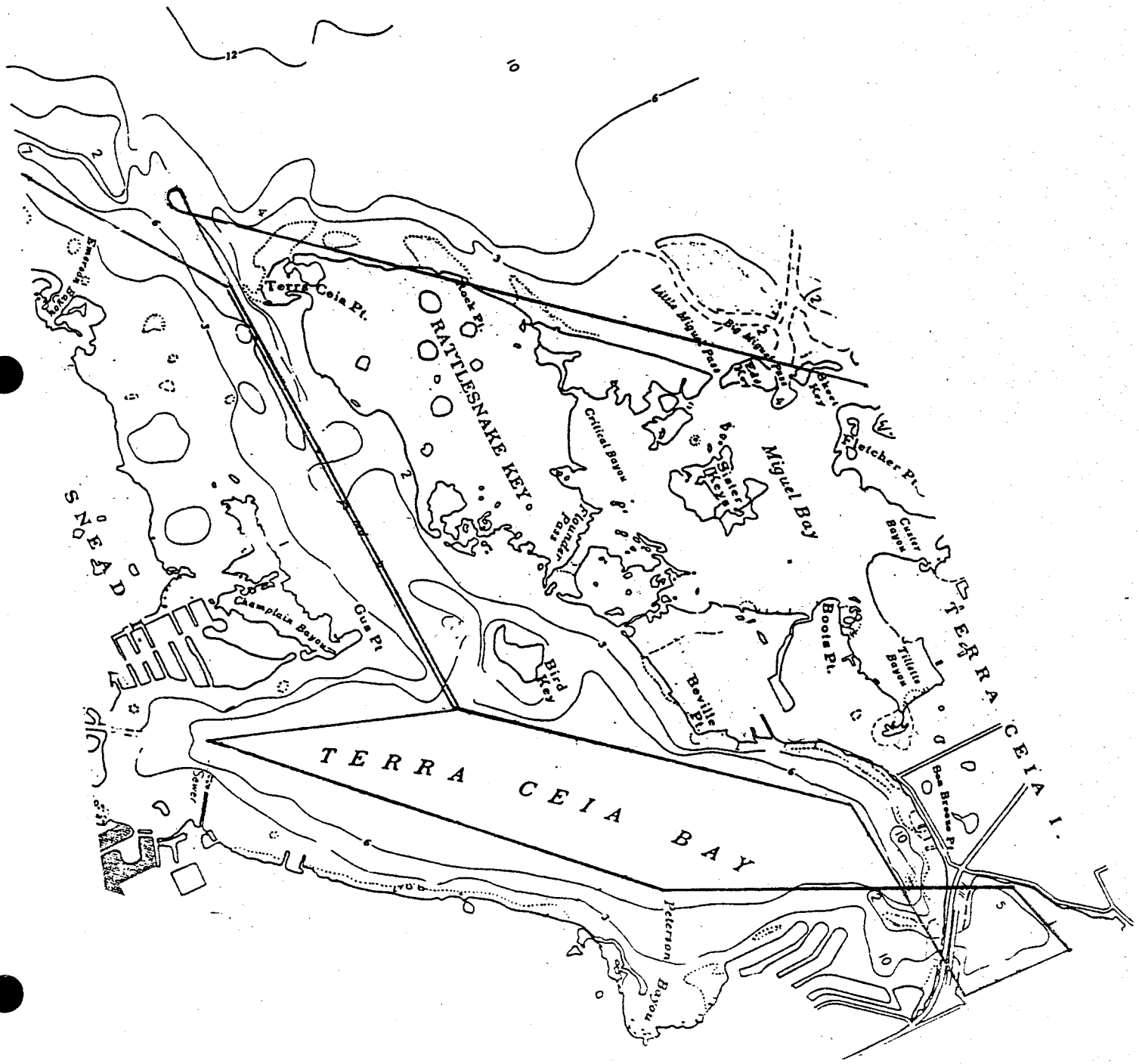
Date: Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 6.

Data Recorded by _____ Checked by

Manatee Sighting Program (310.74)

Segment 7

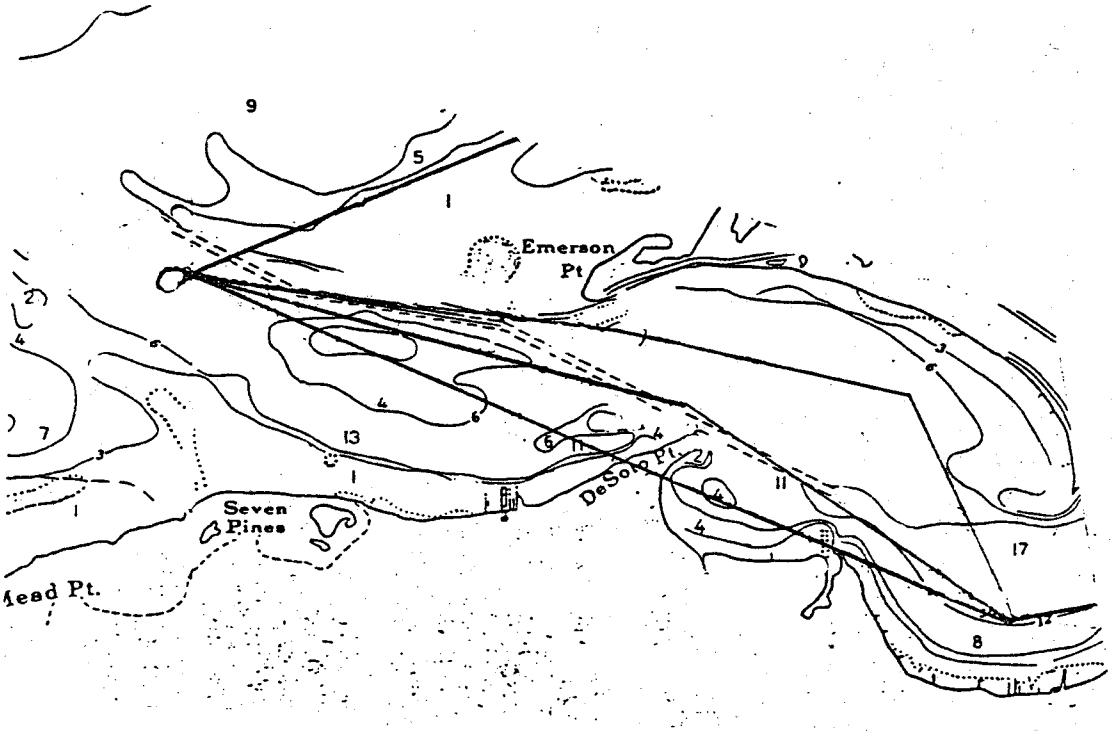
Date: Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 7.

Data Recorded by

Checked by

Manatee Sighting Program (310.74)

Segment 8

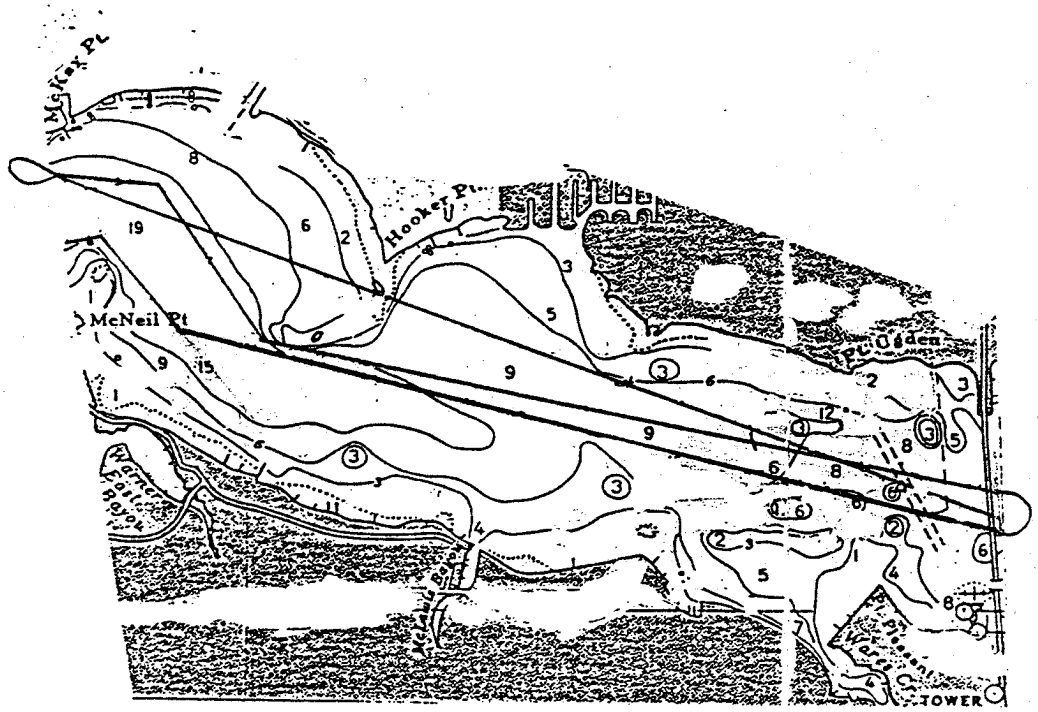
Date: Mo. | Day | Yr. 19 | Time Start | Time End

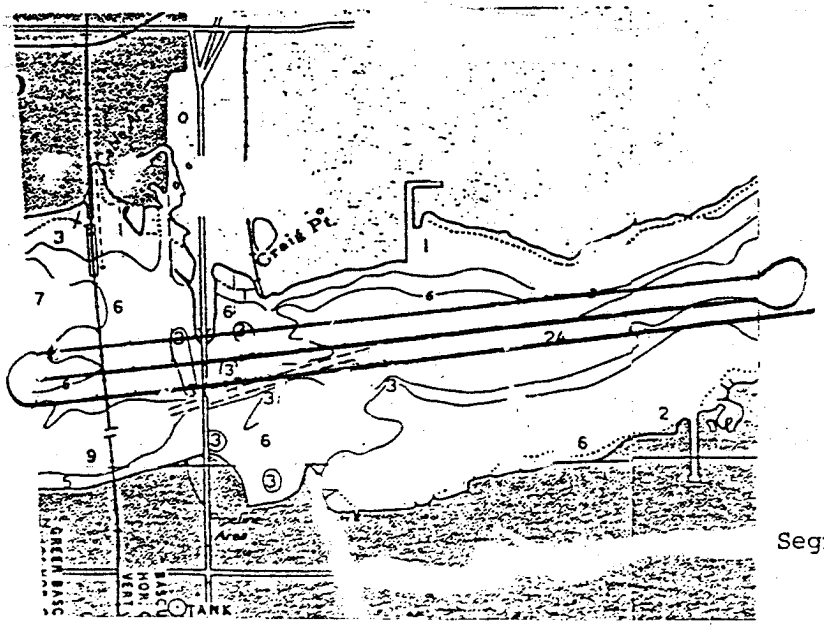
Wind Dir. | Wind Speed (knots) | Sky Cond. (%)

Water Clar. | Sur. Cond. | Air Temp. (± C°)

Manatees sighted: adults | calves | total

Notes:





Segment 8.

Data Recorded by

Checked by

Manatee Sighting Program (510.74)

Segment 9

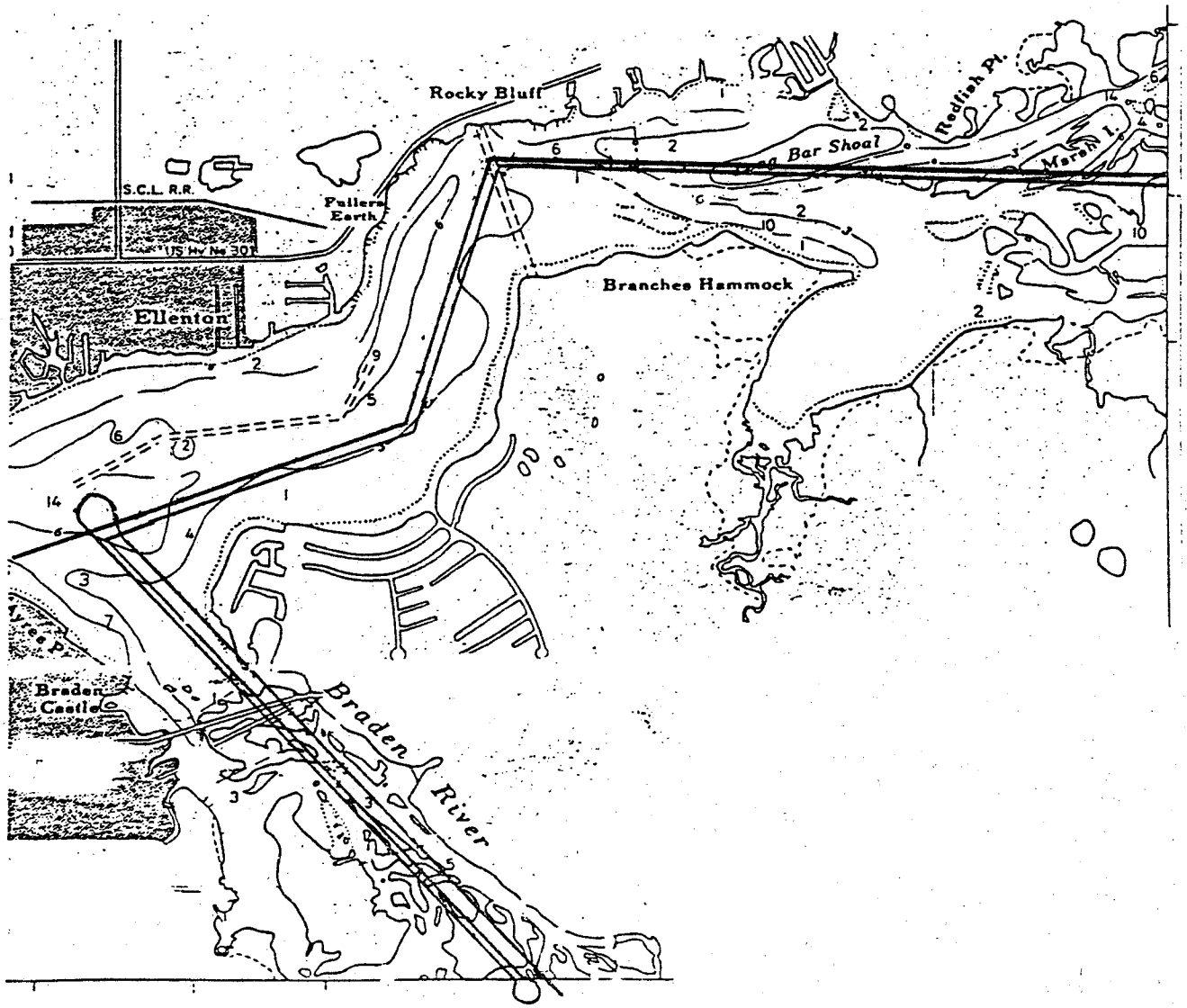
Date: Mo. ____ Day ____ Yr. 19__ Time Start ____ Time End ____

Wind Dir. ____ Wind Speed ____ knots Sky Cond. ____ %

Water Clar. ____ Sur. Cond. ____ Air Temp. ____ ± C°

Manatees sighted: adults ____ calves ____ total ____

Notes:



Segment 9.

Data Recorded by

Checked by

Manatee Sighting Program (310.74)

Segment 10

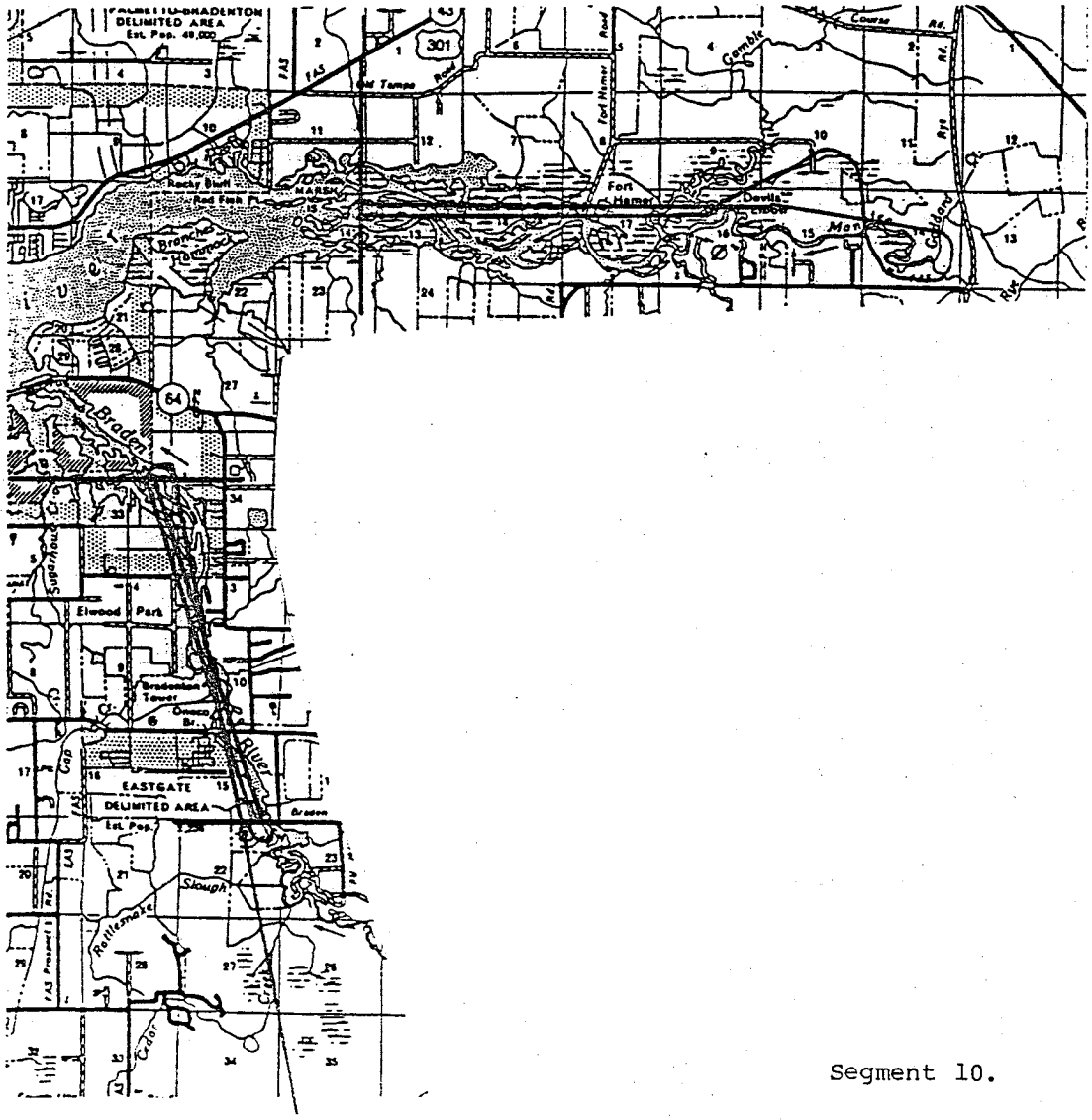
Date Mo. [ ] Day [ ] Yr. [19] Time Start [ ] Time End [ ]

Wind Dir. [ ] Wind Speed [ ] knots Sky Cond. [ ] %

Water Clar. [ ] Sur. Cond. [ ] Air Temp. [ ] ± C°

Manatees sighted: adults [ ] calves [ ] total [ ]

Notes:



Segment 10.

Data Recorded by

Checked by

APPENDIX 3

STUDIES TO DEVELOP AN INTAKE DESIGN FOR REDUCING ENTRAINMENT LOSSES

STUDIES TO DEVELOP AN INTAKE DESIGN FOR REDUCING ENTRAINMENT LOSSES UNIT NO. 4 - BIG BEND STATION TAMPA ELECTRIC COMPANY

FEBRUARY 1980

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS

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SECTION 1

INTRODUCTION

Tampa Electric Company (TECO) is presently planning the addition of a fourth generating unit at the Big Bend Station. The site is located on the eastern shore of Tampa Bay in North Ruskin, Florida. Region 4 of the U.S. Environmental Protection Agency (EPA) has expressed concern for losses of organisms due to the operation of the Unit No. 4 cooling water intake.

Early in 1979, TECO requested Stone & Webster Engineering Corporation (S&W) to conduct a multi-phase evaluation of various intake technologies, which, as an alternative to closed-cycle cooling at Unit No. 4, might be applied to mimimize the losses of organisms at the station. The regulatory process provides the opportunity to demonstrate that emerging technology represents the Best Available Technology (BAT) for intake structure. Thus, the primary objective of this study is to demostrate that fine-mesh screening is an intake technology appropriate to this site which, in comparison to cooling towers, is the BAT.

Specific tasks involved in the evaluation included:

1. The review of available intake technologies which might be applied to Big Bend Station to minimize losses;

2. The selection of organism protection systems which have the potential for biological effectiveness and engineering reliability, and conduct a more detailed, site-specific evaluation of these systems;

3. The evaluation of the need for additional studies to verify the effectiveness and reliability of the selected system;

4. The performance of studies, if warranted.

Efforts involved in the first three tasks have been completed and are discussed in detail in Sections 2 through 4. It has been determined that a fine-mesh screening system, specifically a modified, dual-flow traveling screen, has the potential for reducing the loss of organisms at Big Bend. Preliminary biological studies were conducted in 1979, as described in Section 5. Based on the results of these studies, additional studies are planned for 1980 to more fully evaluate the fine-screening concept. A description of the 1980 test facility and proposed methodologies are presented in Section 6.

SECTION 2

PRESENT INTAKE DESIGN AND OPERATION

The cooling water system serving Units Nos. 1, 2, and 3 at the Big Bend Station is generally termed "once-through with dilution". Each unit has a heat rejection rate of about 2 x 10^9 Btu/h during full-load conditions. Each condenser is independent of all others and is cooled by water withdrawn from the intake canal, passed through the condenser, and released to the discharge canal. In the discharge canal, the water released from each unit mixes with ambient water and flows westerly. At the west end of the canal, water at ambient temperatures is introduced by the dilution pump where further mixing occurs, and the resulting discharge flows west into Hillsborough Bay. The schematic diagram of this movement of water with corresponding flow rates is shown on Figure 2-1.

Each unit draws 537 cfs of circulating water. A 25-ft-deep intake channel draws water from a 35-ft-deep ship access channel. Each unit is serviced by a screenwell structure equipped with two half-size circulating water pumps, each with a capacity of 268.5 cfs. Figure 2-2 illustrates the screen and pump arrangement. The screen is suspended from a platform and is surrounded by water on all sides. The screening arrangement is of the "No-Well" type, in which the pump suction is connected directly to the screen via a transitional section and turning vanes.

Upstream of the screens there are no trash racks. However, a coarse-mesh fixed screen extends to el 5.0 ft to intercept floating debris.

Each traveling screen is 7 ft wide and is equipped with 3/8-in. (9.5-mm) mesh. The screens are operated once each shift to remove debris with a front-wash high pressure spray. The screens typically travel at a speed of 13.8 fpm. The spray pressure is about 80 psi. Observations indicate that debris consists primarily of jelly fish (ctenophores), crabs, leaves, and sea grass.

Water for each unit is drawn through two traveling water screens and is pumped through two 72-in.-diameter pipes to the condenser. The water velocity along and across the screen (at the face of the mesh) is non-uniform and varies between 0.5 and 3.0 fps.

Flows in the intake channel equal 1,611 cfs with the existing three units and will total 2,148 cfs with the addition of Unit No. 4. Due to progresive withdrawal of water by the Units Nos. 1-3 intakes, (see Figure 2-1) the velocity in the channel decreases from a maximum of 0.42 fps at the Unit No. 1 intake to 0.14 fps at the Unit No. 3 intake.

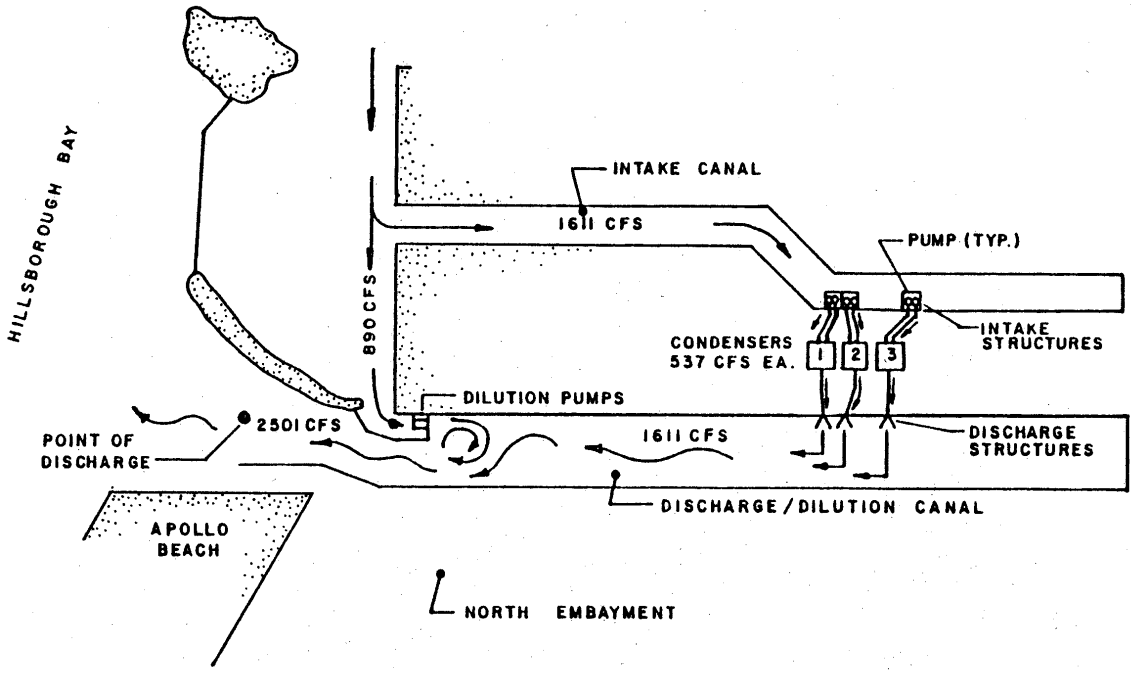


FIGURE 2-1

MOVEMENT OF BAY WATER THROUGH PLANT AND DILUTION SYSTEM

BIG BEND STATION, UNITS 1-3
TAMPA ELECTRIC COMPANY

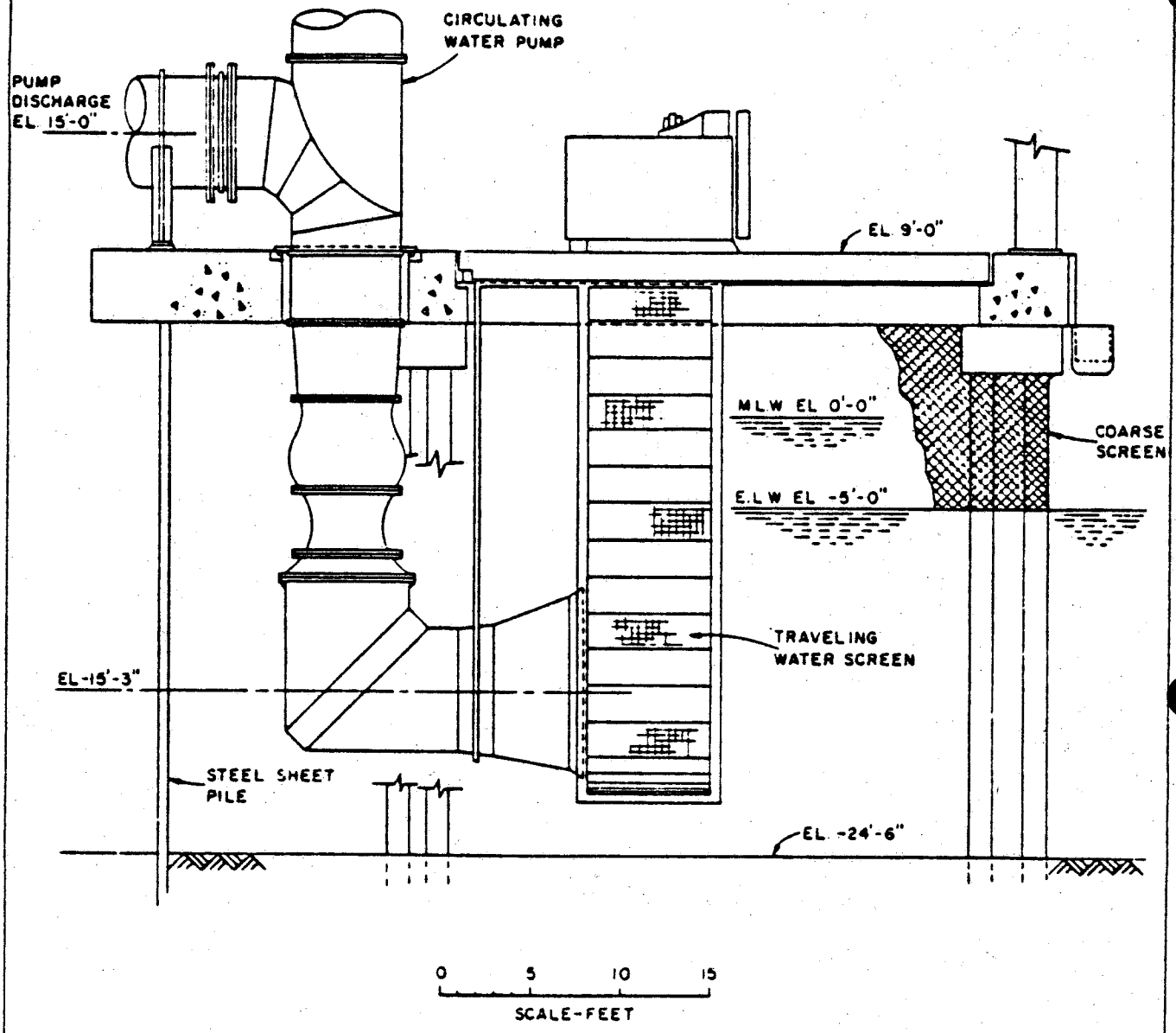


FIGURE 2-2

SCREENWELL ARRANGEMENT

BIG BEND STATION
TAMPA ELECTRIC COMPANY

SECTION 3

SUMMARY OF IMPINGEMENT AND ENTRAINMENT EXPERIENCE

3.1 INTRODUCTION

The evaluation of alternative intake technologies requires an understanding of the abundance and occurrence of those species/life stages which are to be protected at a specific site. The following discussion summarizes pertinent information on existing impingement and entrainment experience at Big Bend Station.

Impingement and entrainment monitoring was conducted at Big Bend Station from January 1976 to March 1977. Additional studies began in 1979 and are ongoing. Data from the earlier studies were presented in the Big Bend 316 Demonstration (TECO 1977). For the purposes of this report, the following discussion of impingement and entrainment has been limited to the Representative Important Species (RIS) listed below:

Common Name	Scientific Name
Bay anchovy	Anchoa mitchilli
Black drum	Pogonias cromis
Silver perch	Bairdiella chrysura
Spotted seatrout	Cynoscion nebulosus
Scaled sardine	Harengula jaguana
Tidewater silverside	Menidia beryllina
Stone crab	Menippe mercenaria
Pink shrimp	Penaeus duorarum
American oyster	Crassostrea virginica
Blue crab	Callinectes sapidus

The rationale for RIS selection is presented in detail in the Unit No. 4 316 Demonstration Prospectus (S&W 1979), along with pertinent life history information.

3.2 IMPINGEMENT MONITORING

A total of 9,946 fish representing 60 species were collected from the screens of one operating unit during impingement sampling between January 1976 and March 1977 (TECO 1977). The total numbers of fish and invertebrates of each RIS impinged are given in Table 3-1. The average rate of impingement

was 321 fish per unit per sampling day. Five species accounted for 85.6 percent of the total number of fish impinged. Impingement rates were highest during the summer and winter months.

Bay anchovy was the most abundant fish collected during the impingement study, constituting 41 percent of the total number of fish impinged. The average impingement rate for the bay anchovy was 130 per day. The majority (97 percent) of the specimens were collected between October 1976 and March 1977. Adult bay anchovies were abundant in the Big Bend area from October through December 1976 and in February and March 1977.

Silver perch was the second most abundant fish species impinged, constituting 30.4 percent of the total. The average impingement rate was 98 fish per unit per sampling day, resulting in an estimated loss of 35,770 fish annually. Of the 3,000 specimens collected, 76 percent were impinged at night, primarily between April and September, with peak impingement occurring in July.

None of the remaining representative important fish species were impinged in appreciable numbers. Thus, impingement of scaled sardine, tidewater silverside, spotted seatrout, and black drum is not considered to be a concern at Big Bend.

Of the invertebrate RIS, pink shrimp was the most abundant species impinged during the monitoring period, comprising 35 percent of the total invertebrate catch. A total of 3,320 individuals (107 organisms per unit per sampling day) were impinged over the 15 month sampling period. Peak impingement occurred during February, June, July, and August 1976. Approximately 68 percent of the total number were impinged at night. Based on the impingement rate calculated for this species, it was estimated that 25,773 individuals (approximately 920 lb) would be lost annually due to impingement at each unit. This number represented approximately 0.23 percent of the 1975 Tampa Bay shrimp landing (TECO 1977).

3.3 ENTRAINMENT MONITORING

Monthly sampling of the plant discharge was conducted to collect data on plankton abundance. Estimates of the number of organisms entrained by the plant were calculated by adjusting for the flow rate of the plant during that time.

Engraulid and sciaenid eggs accounted for 73 and 26 percent, respectively, of all eggs collected during the 15-month ichthyoplankton study at Big Bend. Engraulid larvae dominated the collections, accounting for 87 percent of the total larval catch. Larval sciaenids were second in abundance, comprising 4 percent of the total larvae collected (TECO 1977).

Eggs were first taken in early March and were collected through late October. Peak densities occurred from April through July. Larvae were collected from late March through early November. The estimated numbers of anchovy eggs and larvae entrained by the plant in 1976 are 2.9×10^{10} and 2.3×10^{10}, respectively. Peak egg entrainment occurs in May, and peak larval entrainment

occurs in August. The number of eggs estimated to be entrained by both the plant and the dilution pumps in 1976 represented an estimated 2.2 percent of the total eggs produced in the study area (TECO 1977).

Eggs and larvae of the scaled sardine were present within the Big Bend study area from late April through August. Eggs were most numerous in May, but densities of eggs and larvae were always low, indicating that the waters in the vicinity of the plant may not represent a major spawning area for this species. The estimated numbers of scaled sardine eggs and larvae entrained by the plant in 1976 are 6.0×10^8 and 2.5×10^7, respectively. The number of eggs entrained by the plant and dilution pumps in 1976 was estimated to represent 0.22 percent of the total scaled sardine eggs produced in the study area.

Sciaenid eggs and larvae comprised 26 and 4 percent, respectively, of the total number collected. Eggs of silver perch, spotted seatrout, and black drum were generally more numerous than larvae. The data suggest that these species spawned within the study area.

No sciaenid eggs or larvae were collected from late November through January. Low numbers of eggs and larvae were collected during February. Peak abundance of eggs occurred in March, April, and July. Larval abundance peaked in April, May, and late July. The estimated numbers of sciaenid eggs and larvae entrained by the station in 1976 are 5.6×10^{10} and 6.2×10^8, respectively. Due to taxonomic problems within the drum family, no estimate of entrainment with respect to the drum populations in the study area could be made.

Of the invertebrate RIS, the American oyster and the stone crab appear to be the most susceptible to entrainment. Oyster larvae have not been a notable component of meroplankton collected at Big Bend; thus, no estimates of entrainment are available for this species.

The stone crab is an important commercial species. Larvae were found during entrainment monitoring from April through October. The estimated number of stone crab larvae entrained by the three units (5.0×10^9) and the dilution pump (1.9×10^9) from January to December 1976 constituted less than 10 percent of the entrainment estimate for all decapod larvae (TECO 1977).

Entrainment of pink shrimp and blue crab larvae at Big Bend does not appear to be appreciable. Low numbers of larvae of each species were collected at the study site during entrainment monitoring.

TABLE 3-1

TOTAL VERTEBRATES AND INVERTEBRATES
IMPINGED AT BIG BEND STATION
(ONE UNIT)
JANUARY 1976 - MARCH 1977

	Vertebrates					Invertebrates				
	January-March	April-June	July-September	October-December	January-March	January-March	April-June	July-September	October-December	January-March
Total No.	315	1,339	2,504	1,852	3,936	2,454	1,064	2,529	1,293	2,024
No. of Sampling Days	6	7	6	7	5	6	7	6	7	5
Estimated No. Impinged per Sampling Day	52.5	191.3	417.3	264.6	787.2	409.0	152	421.5	184.7	408.4

SECTION 4

EVALUATION OF ALTERNATIVE INTAKE DESIGNS FOR BIG BEND STATION

4.1 INTRODUCTION

A wide range of organism protective systems or devices are available which might be considered for possible application at Big Bend Station. Various alternatives can be broadly grouped into four categories, depending on their mode of operation: diversion devices, behavioral barriers, physical barriers, and collection systems. It is evident from the discussion in Section 3 that any system installed at Big Bend must act to protect planktonic life forms which have limited or no self-motility. Accordingly, only systems which actively collect planktonic organisms, or have unique features which permit the passive movement of organisms past a point of water withdrawal, were given serious consideration in the evaluation of alternative intake designs for Big Bend.

In general, diversion devices rely on an active avoidance response by organisms in order to be effective. Therefore, most diversion systems were dropped from serious consideration. An angled, fine-mesh traveling screen, which would incorporate features for safely collecting and removing those organisms not capable of diversion, was considered for possible use as discussed in Section 4.2.

Behavioral barriers, such as lights, sound, air bubble curtains, hanging chain barriers, etc, were not considered for Big Bend due to their limited effectiveness with larger organisms and low potential for preventing entrainment losses.

Physical barriers include various infiltration systems (radial wells, artificial filter systems, and porous dikes) and wedge-wire screens. Infiltration intakes were not seriously considered for Big Bend due to unresolved clogging problems and/or unsuitable soil conditions at the site. While potential clogging problems exist with wedge-wire screens, it was believed that this system deserved a more thorough evaluation because of its potential for biological effectiveness as discussed in Section 4.3.

Collection systems include pumping and netting devices and various types of traveling screens. Since traveling screens can be designed to incorporate a fine screening medium (e.g., 0.5-mm) and other features which limit the time that an organism is in contact with the system, it is believed this alternative design could be effective at Big Bend, as discussed in Section 4.4.

4.2 ANGLED, FINE-MESH TRAVELING SCREEN

Various fish protection devices exist which are designed to alter flow conditions in such a way that fish which are capable of reacting to the induced hydraulic conditions will be guided by the device. Such structures

are known as diversion devices and include louvers, stationary angled screens, traveling angled screens, inclined plane screens, revolving drum screens, and horizontal traveling screens. Each of these devices was evaluated for possible application at the Big Bend Station. Most were eliminated from serious consideration for one of three reasons:

1. The device does not protect early life stages of fish or invertebrates.

2. The technology has not been completely developed.

3. The device is not commercially available at present.

One device, the angled, fine-mesh traveling screen, was believed to have potential for effective application at Big Bend and therefore, was considered further. The following sections present a description of this device and summarize available information on system effectiveness.

4.2.1 Biological Evaluation

The angled, fine-mesh traveling screen is designed to act as a diversion device for juvenile, adult, and larger larval fish and a collection device for eggs and early larvae. Various studies have been conducted which demonstrate that the screen offers a good potential for effectively handling all life stages with low mortality resulting from the diversion or collection process. Most of these studies were conducted to determine specifically either the diversion efficiency or the impingement survival of organisms collected on the traveling screens. Therefore, the two types of study programs are discussed separately. Diversion studies are described below. Impingement survival studies are discussed in Section 4.4.

Angled Screen - Diversion Studies

Several studies have been conducted which indicate that an angled diversion screen concept (see Figure 4-1) is highly effective in diverting late larval, juvenile, and adult fishes to bypasses. Most recently, Stone & Webster Engineering Corporation (S&W) (1976a; 1976b; 1977) has completed studies which have led to the development of an angled screen diversion and fish-transportation system that is incorporated into the design of two large power plants situated on Lake Ontario, one of which is operational.

Several major research programs have been conducted to evaluate the potential of an angled screen, leading to a bypass, for effectively diverting juvenile and adult fish and, thereby, minimizing impingement at power plant intakes. The first evaluations were conducted for the Southern California Edison San Onofre Station (Schuler 1973; Schuler and Larson 1974). In these studies, 5/8-in. mesh screens were found to be unacceptable due to poor-to-fair guidance efficiency (0 to 70 percent) of the northern anchovy (Engraulis mordax), a primary test species. Moderate-to-good guidance efficiency (60 to 90 percent) of other test species was obtained with a screen set at 45 deg to the approach flow, an approach velocity of 2.0 fps, and a bypass velocity of 1.5 to 4.0 fps (higher guidance efficiencies corresponded to higher bypass velocities). This was also the best setting for anchovies, which were guided with 30 to 70 percent efficiency.

The angled screen was not considered further at San Onofre Station because of the large bypass flow required to yield good guidance efficiencies in the test facility. However, design limitations at the station permitted only one approach velocity (2 fps) to be tested: this velocity being the minimum possible. Therefore, it should not be concluded from the San Onofre studies that angled screens would not be effective at other sites. It is possible that the same or other species could be effectively guided along angled screens under different conditions, particularly lower velocities and smaller screen mesh sizes.

Later studies by S&W have shown that angled screens can be effective. The S&W studies were conducted for a number of utilities operating large power plants on Lake Ontario and the Hudson River (Taft et al 1976). In studies with Lake Ontario species (the alewife being the primary species of concern), it was found that an angled screen, set at a 25-deg orientation to the flow at equal approach and bypass velocities ranging from 0.5 to 3.0 fps, was 100 percent effective in diverting 1- to 6-in.-long fish to a 6-in.-wide bypass under all conditions tested, including low water temperature (S&W 1977). As a result of these findings, a complete diversion and transportation system, incorporating pipe and pumping components, has been developed to return fish safely to the lake. Similar results were obtained by S&W (1976a) during studies with Hudson River species (striped bass, white perch, and Atlantic tomcod ranging in length from 2 to 6 in.). Under the same design and hydraulic conditions given above, the angled screen was found to be 100-percent effective in guiding these species to a 6-in-wide bypass. Results of 1-week mortality studies showed that survival of bypassed fish was greater than 96 percent (Taft et al, 1976).

Although angled screens have not been otherwise evaluated for steam electric station screenwell application, they have been utilized at several hydroelectric facilities for guiding upstream and downstream migrants. At the North Fork Project on the Clackamas River in Oregon, angled traveling screens are installed at two locations along a 2-mi-long fish ladder (Gunsolus and Eicher 1970). Downstream migrants - primarily chinook (Oncorhynchus tshawytscha) and coho (O. kisutch) salmon and steelhead trout (Salmo gairdneri)- enter the fish ladder at the North Fork Dam via a downstream migrant channel. From this point, they can pass either through an open port in a gate system or can travel farther downstream where they are diverted by a set of angled screens and bypassed to the fish ladder. The width of the approach channel is 10 ft. The two traveling screens (0.14-in. mesh, 16-gauge wire cloth) are each 11 ft wide and are set in tandem with a 2-ft-center pier between them. The screens are oriented at a 22-deg angle to the flow. The average depth of water in front of the screens is 30 ft. This arrangement has been found to be highly effective in diverting downstream migrants without impingement, provided that the total screen flow does not exceed 500 cfs.

The second angled-traveling screen installation is located just upstream of the fish ladder entrance (2 mi downstream from the North Fork Dam at the foot of the Cazadero Dam). This single screen is 7 ft wide and is set at a 45-deg angle to the flow. The structure is utilized to separate downstream migrants from the ladder flow for subsequent introduction to a 5-mi-long pipeline. This pipeline transports the fish safely to a free-fall discharge just below the last dam in the complex, the River Mill

Dam. Both angled traveling screen installations at the North Fork complex have been functioning effectively for nearly 18 yr.

In addition to diversion studies with juvenile and adult fishes, there is recent evidence which indicates that fine-mesh angled screens can be used to guide larval fish to bypasses. Naturally, the ability of larvae to guide along a screen will be influenced by environmental and hydraulic conditions and will vary between species. Therefore, at this time, it is not possible to make generalizations about the effectiveness of larval diversion systems at power plant intakes. However, successful diversion has been achieved with a number of species, as discussed below, indicating that the concept of diverting larvae merits further investigation.

Pavlov and Pakhorukov (1973) have reviewed fish protection research which has been conducted in the USSR, including studies with larvae and early juvenile fishes. Two types of fine-mesh diversion screens have been evaluated in laboratory and full-scale studies. One type is an angled, stationary screen which leads to a fish bypass and utilizes a moving water jet device for cleaning. The second type is a conical screen which leads to a central bypass and also has a water jet cleaning device which rotates around the periphery of the screen.

Results of studies with the angled stationary screen design have shown that high diversion efficiencies can be achieved. In one study, 10- to 40-mm-long mosquitofish (Gambusia sp.) were guided very effectively to a bypass over a range of hydraulic conditions (Pavlov and Pakhorukov 1973). Through-mesh screen velocity varied from 0.50 fps to 1.3 fps. Guidance efficiency was affected by approach velocity and bypass flow. However, under all conditions, the efficiencies were high (greater than 75 percent, and as high as 98 percent).

Laboratory and large-scale studies of conical screens with internal bypasses have also shown high fish diversion efficiencies (Pavlov and Pakhorukov 1973). Experiments with several species measuring 9.5 to 50 mm in length have shown very effective guidance along model and full-scale conical screens when the screen mesh (1- to 3-mm) was angled 8 to 12 deg to the approach flow with approach velocities as high as 2.95 fps.

Mortality among verkhovka averaged 8 percent, and the other species displayed no mortality 48 hr after testing. It would appear from the results of these Russian investigations that the potential exists for guiding larval fish as small as 10 mm long with fine-mesh angled screens. However, the conical and flat panel screens investigated do not offer effective solutions to entrainment losses of non-motile organisms, since there is no reliable method for removing the non-motile organisms that become impinged on the screen mesh. The Russian experiments are presented only to demonstrate the potential guidance efficiency of angled, fine-mesh screens. A traveling, angled screen design would be required to ensure protection of early life forms.

One final study conducted in the U.S. supplies data which shows that small fish are capable of guiding along fine-mesh screens. These data come from horizontal traveling screen evaluations conducted in Oregon (Prentice and Ossiander 1974). The fish guiding screen face measured 27 ft and

was set at a 30-deg angle to the approach flow. The screen cloth consisted of 2.5-mm wire mesh with a net open area of 60 percent. Experiments with 70- and 170-mm spring chinook salmon (O. tshawytscha) fingerlings showed generally greater than 97 percent diversion efficiency (no impingement) at 0.5- and 1.5-fps approach velocities under day and night conditions (Prentice and Ossiander 1974).

4.2.2 Engineering Evaluation

Angled traveling screens incorporating coarse mesh (e.g., 9.5-mm) have been shown to be reliable from an engineering viewpoint. Such screens have not been utilized with fine mesh to date; however, it is believed that such an application would be feasible. Unfortunately, due to the biological limitations discussed above, it was determined that the angled-screen concept did not offer the most effective means for reducing organism losses at Big Bend Station. Therefore, a detailed engineering evaluation was not conducted.

4.2.3 Conclusions

On the basis of the preceding discussion, it is clear that an angled-screen system would offer a potentially effective means of minimizing the impingement of juvenile and adult fishes at Big Bend. The effect on invertebrates is unknown. Since impingement does not occur to any great extent at the site, this benefit is of little additional value over the existing screening system.

From an entrainment viewpoint, all organisms not diverted by the screens would become impinged on the fine-mesh screen, and would have to be collected and removed gently for return to Hillsborough Bay. As discussed in Section 4.4, a simpler and less costly screening system (modified traveling screen) exists which can achieve the same goal with equal or better potential for organism survival. Therefore, the angled, fine-mesh screen is not considered to offer the most cost-effective solution to potential entrainment losses at Big Bend Station.

4.3 WEDGE-WIRE SCREENS

Wedge-wire screens (Figure 4-2) are in wide use today in applications other than the filtration of water for cooling purposes in power plants. However, the recent concern for the protection of small organisms at power plant intakes has resulted in biological and engineering evaluations of these screens for such a purpose (Bason 1978; Cook 1978; Vigander 1978). For this reason, it was felt that wedge-wire screens should be evaluated for possible application to Big Bend Unit 4.

4.3.1 Biological Evaluation

Biological research on cylindrical, wedge-wire screens indicates that they could be relatively effective in preventing the entrainment of fish

eggs and most larvae at power plants, provided that the screen slot size is small (approximately 0.5 to 1.0 mm), the through-slot velocity is low (approximately 0.5 fps), and a relatively high velocity cross-flow exists to carry organisms around and away from the screen (Bason 1978). In laboratory studies, Hanson et al (1977) found that entrainment of fish eggs (striped bass), ranging in diameter from 1.8 to 3.2 mm, could be eliminated with a wedge-wire screen incorporating 0.5-mm slot openings. However, striped bass larvae, measuring 5.2 to 9.2 mm (4 to 20 days old), were generally entrained through a 1-mm slot at a level exceeding 75 percent within 1 minute of release in the test flume. Larval tests were conducted in a static mode with no crossflow passing the screen. It was concluded that, since positive rheotaxis was observed among these early larvae, a crossflow would act to reduce entrainment to some extent.

At Big Bend, current velocities are very low, and, therefore, it could be expected that the early life stages of fish and invertebrate Representative Important Species may be highly susceptible to entrainment. If a small slot size (0.5 to 1.0 mm) and slot velocity (0.5 fps) could be achieved, entrapment or impingement of juvenile and adult fish and invertebrates would not be expected to occur. Therefore, the wedge-wire screen alternative described below would appear to offer a means of minimizing impingement. However, this feature is of limited value at Big Bend since impingement does not presently occur to any great extent.

4.3.2 Engineering Evaluation

For the purpose of the engineering evaluation, a general wedge-wire screen intake arrangement was designed and is described in Section 4.3.2.1. The important criteria for evaluating the engineering reliability of the wedge-wire screening system are discussed in Section 4.3.2.2, and the generic screen arrangement is evaluted on the basis of these criteria at three locations: offshore, in the intake canal, and in the vicinity of the coal barge slip.

4.3.2.1 General Arrangement and Feasibility

A general arrangement of a wedge-wire screen intake system for possible application to Big Bend Unit 4 is shown on Figure 4-3. This scheme would be designed to supply 537 cfs cooling water flow to Units Nos. 4 through 24 submerged wedge-wire screen intakes. The screens would have 1 mm slot openings with a maximum through-slot flow velocity of 0.5 fps. Each of the screen cylinders would be 6 ft long and 6 ft in diameter with a solid, conical endpiece incorporated to provide smooth flow streamlines. The screens would be laterally spaced about 15 ft on centers to minimize flow interaction between the screens. The screen system would be oriented with each screen axis parallel to the ambient current direction. The screens would be located 5 ft above bottom to minimize interference resulting from siltation.

This general design was evaluated for use at a number of locations in the site area in an attempt to identify a location which would minimize engineering design and operational problems, as described below. Prior

to detailed consideration of the use of wedge-wire screens at Big Bend, more comprehensive studies would have to be conducted to address site-specific problems which could occur at the possible locations described generally below. However, it is possible to identify common operational problems which would occur regardless of intake location and which would, consequently, make the reliable application of wedge-wire screens at Big Bend questionable.

Marine biofouling is expected to occur on the screens. A Monel alloy or Type 316 steel screen material could be employed to minimize corrosion. However, these materials have no effect on biofouling, which could produce a serious problem with intake flow reliability. Recently copper-nickel alloys have been tested and shown to be effective in minimizing biofouling.

There is a potential for debris clogging of the screens by fine coal particles at intake locations near the coal barge slip in the plant embayment. The presence of other particulates in the water of Hillsborough Bay may cause screen clogging. Also, abundant jelly fish (primarily ctenophores), sea grass, and crabs could result in heavy clogging of the screens. In these cases, the screens would have to be removed and cleaned manually since normal backwashing procedures have not proven to be a solution to this problem. Screen backwashing would have to be accomplished by forcing air out through the intake screens from an onshore compressor and a series of air pipelines. The backwashing system would be designed so that eight of the screens could be backwashed simultaneously.

An ambient current of at least 1 fps is desired to provide some capacity for self-cleaning of the screens (Hanson et al, 1977). This current is not available in the plant embayment area where essentially all current velocity is induced by the plant cooling water intake flow. A current velocity of up to 0.5 fps is provided by tidal circulation in Tampa Bay at the mouth of Hillsborough Bay. The low values of ambient current velocity would not remove backwashed material from the intake area, thus increasing the potential for screen clogging, increasing backwashing frequency, and reducing backwashing effectiveness.

The adoption of the wedge-wire screen intake system would require the construction of a backup intake system to provide cooling water flow reliability. This would involve installing an intake, similar to those existing at Units Nos. 1 through 3, equipped with traveling screens and automatic gates. Two circulating water pumps would be required drawing flow from an intake bay that is normally supplied through a 9-ft-diameter pipeline from the wedge-wire screens. A booster pump to the main circulating water pump would be provided to supply the necessary power to overcome pipe friction and intake head losses.

A hydraulic model study would be required to optimize the header pipe design at the screens to achieve equal flow withdrawal from the screens. In situ pumping tests of at least one year duration should be conducted prior to adoption of this scheme for the purpose of studying the impact of biofouling, debris accumulation, and backwashing on screening efficiency and reliability.

The only power plant installation having long-term operational experience with the wedge-wire screen is the Big Sandy Power Plant in Louisa, Kentucky. The flow rate ranges from 11,000 to 30,000 gpm. Screen slot openings are 3.5 mm, and the screens are 12 ft long and 2 ft in diameter. The Unit No. 1 screens were installed in 1963, and the Unit No. 2 screens were placed in 1968. The Big Sandy River is a small stream. The water is generally clean; however, during floods the river carries a significant amount of debris. Screens, located about 133 ft from shore, have operated satisfactorily. Clogging from fine coal particles has required manual screen cleaning. The operational experience at this plant is not directly applicable to Big Bend due to a significant difference in flow rate, the presence of a marine environment at Big Bend, and the use of smaller slot openings (1-mm) at Big Bend.

There is no operational experience of this screen system with a once-through cooling system. Power plant applications to date have been limited to closed-cycle cooling.

4.3.2.2 Alternative Locations for a Wedge-Wire Screen Intake

Due to the known problems inherent in the design and operation of wedge-wire screens, it was felt that alternative locations with different characteristics should be evaluated in the hope that one site might be identified as a potentially acceptable location.

Figure 4-4 shows the three alternative locations evaluated for a wedge-wire screen intake to service Unit No. 4. The feasibility of installing such an intake system at each of these locations is discussed below.

Location 1 - Tampa Bay

Water depths are shallow in Tampa Bay, and the closest point for a cooling water intake is about 2.3 mi from the existing intake bays. However, at this location, the clearance above the screens would be only about 5 to 7 ft at mean low water and about 2 to 4 ft at extreme low water. Additional depths of 2 to 4 ft are available about 4 mi from the existing intake bays. Navigational buoys would be required at any potential navigational hazard created by the screens. There is no clear environmental advantage to placing the intake screens in Tampa Bay as opposed to the plant embayment, since organism densities are similar and current velocities are low in both locations. The potential for screen clogging from suspended particulates in the cooling water flow would be reduced from an embayment screen location. Cost considerations significantly favor an embayment location over the Tampa Bay locations.

Location 2 - Intake Canal

Placing the wedge-wire screens in the intake canal would increase the maximum channel flow velocity by 33 percent, from 0.42 to 0.56 fps. At this location, impingement of fish on the screens would not occur. However, entrainment of smaller organisms could increase at the intakes of Units Nos. 1, 2, and 3 due to the increase in organism density in the canal. The self-cleaning nature of the screens would not be improved by the low

current velocity. There is a potential for clogging of the screens from coal particles. It is not anticipated that the current passing the screens would cause an increase in the effectiveness of self-cleaning and backwashing because of low velocities. Although cost considerations favor this location, it is unlikely that use of wedge-wire screens for Unit No. 4 would produce any significant reduction in overall station entrainment with Unit No. 4 operation in conjunction with the operation of Units Nos. 1, 2, and 3.

Location 3 - Coal Unloading Area

The screens would be located about 4,600 ft from the intake bays at the existing bottom elevation about 50 ft beyond the dredged shipping channel. The tops of the screens would be about 20 ft below mean low water and could be marked with buoys, if necessary. However, it is not likely that this location would present a hazard to navigation. There is a significant potential for screen clogging by coal particles due to the proximity of the coal barge slip. Operation of the dilution pumps would not improve the self-cleaning capacity of the screens due to the small magnitude of the induced cross-flow velocity but could reduce the necessity for frequent backwashing due to the removal of some debris through the pumps.

4.3.3 Conclusions

There are potentially serious operational problems associated with the use of wedge-wire screens at Big Bend. Biofouling, clogging from coal particles, reduced self-cleaning potential due to low ambient current velocities, reduced backwashing effectiveness, and dredging difficulty are potential problems with this system. Significant testing would be required before adoption of this alternative so that actual operational problems could be identified and resolved. Due to the need for a backup intake system to provide cooling water flow reliability and for booster pumps to the main circulating water pumps to overcome pipe friction and screen losses, this system is considerably more expensive than other intake alternatives.

Based on known problems and unresolved issues, the wedge-wire intake system is not recommended for further consideration as an intake alternative at Big Bend.

4.4 COLLECTION AND REMOVAL SCREENS

Collection systems are designed to actively collect organisms entrapped within an intake system. These include various types of traveling water screens as discussed below.

4.4.1 Biological Evaluation

Three types of traveling water screens are considered to be practical and have the potential for alleviating entrainment and impingement losses at Big Bend:

1. Center-flow screens
2. Modified, through-flow, traveling screens
3. Dual-flow screens

From the viewpoint of impingement of juvenile and adult fishes, each screen has different features which may influence its effectiveness. These are discussed in Sections 4.4.1.1 to 4.4.1.3. However, sufficient data are not available to distinguish one screen from another with respect to the effectiveness of fine-mesh screening in collecting and removing small organisms. This aspect is discussed in Section 4.4.1.3, and the results apply to all three screen types as well as the fine-mesh traveling screen described in Section 4.2.

4.4.1.1 Center-flow Screens

Only one power plant in the U.S. presently utilizes center-flow screens from which biological data have been collected. This is the Central Power and Light Company's Barney Davis Station located on Laguna Madre in Corpus Christi, Texas. The screens (Figure 4-5), which are operated continuously, have an overhead 40 to 60-psi spraywash system. From 1975 to 1977, biological sampling was conducted to determine species composition and mortality. Of about 12,000 organisms collected in 1977, 86 percent were recovered alive (Murray and Jinnette 1978). Average survival of the bay anchovy and gulf menhaden, the dominant fish species, over the year was 69 and 90 percent, respectively.

Considering the fragile nature of the species, which has been successfully collected with good survival, the center-flow screen is considered to be a viable alternative for the collection of juvenile and adult fishes at Big Bend. This conclusion is further supported by the results of the modified traveling screen evaluations discussed below, since the center-flow screen is essentially the same as the modified screen in terms of the manner in which fish are handled. Unfortunately, center-flow screens contain an embayment which may be a biologically undesirable feature since it can entrap smaller organisms and not permit their escape.

4.4.1.2 Modified, Through-flow Traveling Screens

Conventional traveling screens can injure fish because of the multiple sources of stress to which fish are exposed. Modifications to existing conventional traveling screens include fish lifting buckets, low pressure spray wash systems and continous operation of the screens (Figure 4-6). Operating experience at the Surry Power Station on the James River, utiliz-

ing modified conventional traveling screens, has shown a high degree of success in collecting fish while maintaining low impingement mortality (White and Brehmer 1975). Short-term holding studies (approximately 15 minutes) show that, on the average, survival of 58 fish species was 98.3 percent. Average survival of marine fish species was 93.4 percent. A number of species collected at Surry also occur at Big Bend. These species and their survival rates are listed below:

Common Names	Scientific Name	Percent Survival
Tidewater silverside	Menidia beryllina	94.6
Bay anchovy	Anchoa mitchilli	82.0
Tarpon	Elops saurus	100.0
Silver perch	Bairdiella chrysura	100.0
Sheepshead minnow	Cyprinodon variegatus	100.0
Rough silverside	Membras martinica	81.7
Crevalle jack	Caranix hippos	85.7
Spotted seatrout	Cynoscion nebulosus	60.0
Spot	Leiostomus xanthurus	96.7
Atlantic croaker	Micropogon undulatus	82.7
Striped mullet	Mugil cephalus	100.0
Hogchoker	Trinectes maculatus	96.5
Blackcheek tonguefish	Symphurus plagiusa	66.7

On the basis of these short-term survival data, it appears that the modified traveling screens have provided an effective means for minimizing fish impingement mortality at Virginia Electric Power Company's Surry site. However, it should be pointed out that short-term survival studies alone may not adequately reflect possible longer term mortality. Impingement survival data collected for five species at a power plant on the Hudson River suggest that consideration of latent mortality (96 hr) is required for an adequate assessment of impact, particularly among less hardy species. For example, at Bowline Point Generating Station, initial survival of young-of-the-year white perch and striped bass was high, ranging from 81-98 percent and 89-98 percent, respectively. Mortality increased, however, during the holding period, with survival after 96 hr ranging from 55-56 percent (white perch) and 52-81 percent (striped bass). Similar trends were noted at Roseton and Danskammer Point Generating Stations (King, Hutchinson and Huggins 1977).

Survival potential thus appears to be species-specific. While initial survival may be a valid indication of impingement damage for certain species, latent survival is probably the best indication of damage for fragile species such as clupeids.

It is believed that the modified traveling screen offers a potentially effective means of minimizing losses of juvenile and adult fishes. The possible use of these screens for protecting fish eggs and larvae is discussed in Section 4.4.1.4.

4.4.1.3 Dual-Flow Screens

There are no operational data on the biological effectiveness of dual-flow screens. However, the principles of the center-flow and through-flow traveling screens, which contribute to their effectiveness in minimizing losses of organisms, also apply to the dual-flow screen. Therefore, the dual-flow screen should be potentially effective for use at Big Bend. Unlike center-flow screens, dual-flow screens do not contain an embayment, which is undesirable from a biological point of view. In addition, modifications for protecting fish eggs and larvae (i.e., fine-screening) can be incorporated on dual-flow screens. Thus, the following discussions relating to the potential for protecting fish eggs and larvae apply to the dual-flow screens.

4.4.1.4 Fine Screening of Eggs and Larvae

The studies conducted at the Central Power and Light Barney Davis Station in Corpus Christi, Texas, also evaluated survival of some larval fish. Here, bay anchovy and gulf menhaden are the dominant fish collected from 0.5-mm-mesh center-flow screens. These fish range in length from 15 to 30 mm, and immediate mortality studies indicate high survivorship of these fragile species (Murray and Jinnette 1978).

Several laboratory and field studies also demonstrate the potential for high survival of ichthyoplankton following impingement. In 1977, Consolidated Edison Company of New York sponsored an evaluation of a fine-mesh, through-flow traveling screen at the Indian Point Generation Station - Unit 1 on the Hudson River (Ecological Analysts, Inc. 1977). One traveling water screen was backfitted with 2.5-mm nylon mesh and modified with fish buckets, a low pressure spray header, and a collection trough on the rear side of the screen. Collection efficiency studies were conducted with 12- and 14-day-old, post-yolk-sac, hatchery-reared striped bass (Morone saxatilis) with mean lengths of 7 to 9 mm. Survival estimates were obtained with late post-yolk-sac (mean length of 15 mm) and early juvenile (mean length of 19 mm) striped bass. In all tests, the screen approach velocity was approximately 0.9 fps and the screen travel speed was 10 fpm. The results of these studies showed that 7 to 9 mm larvae were not effectively retained by the 2.5-mm mesh. It was concluded that 10- to 18-mm larvae may be the smallest size that can be collected on mesh of this size.

Initial and latent (96-hr) survival estimates of late post-yolk-sac larvae washed from the screen were 68 and 47 percent, respectively. Initial and latent survival estimates of early juveniles were 100 and 88 percent, respectively (Ecological Analysts, Inc. 1977).

The Indian Point study results are relatively consistent with those obtained in laboratory and field studies conducted by the Tennessee Valley Authority (Tomljanovich, Heuer, and Voightlander 1977). In these studies, the effects of screen mesh size, water velocity, and impingement duration on the efficiency of screening and mortality of 10 species, including largemouth bass (Micropterus salmoides) and smallmouth bass (M. dolomieui), were evaluated. It was determined that of the screen sizes tested, 0.5-mm yielded the highest screening efficiency (90 percent of larval fish with lengths as small as 5.5 to 7.5 mm). Smallmouth bass showed greater than 95 percent survival at 48 hr under all test conditions. Largemouth bass exhibited higher latent mortality at impingement durations greater than 8 minutes. Latent survival of this species averages 91.6 percent at an approach velocity of 0.5 fps, but dropped to 66.4 and 49.3 percent at velocities of 1.0 and 1.5 fps, respectively. In general, a negative relationship was found between fish survival and impingement duration and velocity, indicating that the longer the impingement time and/or the higher the velocity, the lower the survival rate.

Additional studies by Tennesse Valley Authority further substantiate the survival potential of larvae following impingement on a fine-mesh screen. Tomljanovich and Heuer (1979) have demonstrated that survival of 3 to 19-day-old larvae (mean total lenth of 5 to 14 mm) of 5 species can be high under conditions which are achievable in a power plant intake structure. Four species, paddlefish (Polyodon spathula), northern pike (Esox lucius), white sucker (Catastomus comersoni), and channel catfish (Ictalurus punctatus) showed greater than 90 percent survival 24 hr after impingement, air exposure, and spilling into a collection trough. Walleye (Stizostedion vitreum) and largemouth bass tested under the same conditions showed 24-hr survival rates of greater than 62 percent (adjusted for control mortality). Higher survival (69 to 97 percent) was obtained when the duration of air exposure was reduced from 3 minutes to 1 minute. The only species which did not perform well was the striped bass; however, control mortalities were also very high and much of the mortality observed was attributed to the problems of maintaining this fragile species under laboratory conditions.

In other laboratory studies (Sazaki et al 1972; Skinner 1974), it was found that steelhead trout ranging in length from 22 to 36 mm could be impinged for up to 50 minutes at 1.5 fps and still exhibit greater that 90-percent survivorship. Survival decreased rapidly when impingement time exceeded 10 minutes for both king salmon (Oncorhyncus tshawytscha; 36-56 mm) and steelhead trout when velocity increased to 2.5 fps. Striped bass were found to exhibit close to 100 percent survival with impingement times up to 4 minutes at screen approach velocities of less than 0.8 fps. This same study suggests that it may be feasible to impinge striped bass eggs for up to 6 minutes at velocities of up to 0.8 fps with egg survival of over 80 percent.

Prentice and Ossiander (1974) present data which indicate that chinook salmon fry, ranging in size from 26 to 170 mm, can be impinged on 0.7 mm-mesh

screen for up to 15 minutes at water velocities up to 1.5 fps with greater than 94 percent survival (18-hr observation). With a screen approach velocity of 0.5 fps, survival of the smallest fish was virtually 100 percent for impingement up to 60 minutes. At higher velocities, they found greatly decreased survival when impingement time was increased to over 15 minutes (i.e., at 0.5 fps, survival was independent of impingement time; but at 1.5 fps, survival decreased as impingement time increased from 6 to 60 minutes).

Thus, from a biological viewpoint, it would appear that the concept of impinging and removing eggs and larvae from fine-mesh traveling screens with relatively high survival is a viable one which could effectively reduce entrainment losses at Big Bend.

4.4.1.5 Conclusions

It is evident from the preceding discussions that either the center-flow or the modified traveling screen has the potential for gently collecting and removing organisms at Big Bend for return to their natural environment. The type of screen envisioned for use at this site would be dual-flow design presently in use at Units Nos. 1 through 3. Due to the excellent operating experience of these screens at Big Bend, they are preferred for use in possible fine-screening applications at this site. These screens also have a biological advantage in that their support structures do not create embayments which might entrap fish and invertebrates. For this reason, the dual-flow screen is preferred biologically over the center-flow screen, which has a greater potential for entrapment. Further, given low screen face velocities and free passage around the dual-flow screen, it is possible that early life stages with only limited swimming ability might be able to actively avoid impingement.

4.4.2 Engineering Evaluation

Because of the potential biological effectiveness of dual-flow screens modified with fine mesh in gently collecting and removing fish, eggs and larvae, as well as the excellent operating experience of these screens already in service at Big Bend Station, these screens represent the preferred system (design) at Big Bend.

The dual-flow (double-entry, single exit) screen is similar in concept to the center-flow screen. It has several advantages:

1. Debris cannot carry over into the cooling water system.

2. Because two faces are utilized in screening water, there is a greater screening area available for a given screen width than with through-flow screens.

A variation of the dual-flow screen, known as the No-Well arrangement, is presently used in several Southern power plants including Big Bend. This arrangement has obvious cost and construction advantages since the screens can be suspended from a platform that is supported by piles. By connecting the pump suction directly to the screen via a transition

and turning vanes, the need for a typical screenwell is eliminated. Another arrangement consists of installing the screen through a sheet pile barrier wall and installing the circulating water pumps in a wet well downstream.

These arrangements result in cost savings related to excavation and concrete structures. However, these arrangements, have applications only in warm water climates where there are no problems associated with icing.

Dual-flow screens could be installed with suitable distances between them to allow the free passage of fish in the resulting low velocity areas. Further, the through-mesh velocities could be kept low enough to allow larval avoidance, and fine-mesh openings could be used to collect any impinged organisms. However, as with other screens, design modifications would be required to permit utilization of fine mesh. To ensure reliability during continuous operation with fine mesh, heavy-duty components (chains, bushings, sleeves, motors, baskets) would be required. Adequate sealing between screen baskets and between the baskets and guides would have to be incorporated to minimize the loss of organisms in these areas. A low-pressure spray system would be needed to gently remove organisms from the screen and lifting buckets. Also, to achieve uniform velocity distribution along and across the screens, model tests are required to incorporate the proper transitions leading from the screens to the pumps and the proper baffles to distribute the flow evenly.

Since this concept of screening is already in use at the Big Bend Station, and since the three screen types evaluated cannot be distinguished biologically, the dual-flow screen was selected as the preferred system for further development at Big Bend Station.

4.5 CONCLUSIONS

On the basis of the biological and engineering evaluations presented in this section, it was determined that the most cost-effective alternative for protecting aquatic organisms at Big Bend would be a system of modified dual-flow screens incorporating fine mesh. Available data on the potential biological effectiveness of such a system at Big Bend are encouraging. Section 4.6 describes an intake design incorporating dual-flow screens which would be utilized at Big Bend Unit No. 4 if the results of the field studies described in Sections 5 and 6 indicate that fine-mesh screening is a viable method for reducing organism losses at the site.

4.6 PROPOSED INTAKE DESIGN OF FINE-MESH DUAL-FLOW SCREENS

The intake would consist of a trash rack and screen structure located in front of the proposed Unit No. 4 screenwell. A typical layout is shown on Figure 4-7. The structure would be supported on piles and extend out approximately 30 ft into the channel from the existing screenwells. The bottom would be at el -24.5 ft and the deck would be at el +9 ft. Flow would enter the structure passing through vertical trash racks with 2-in. clear spacing. The racks would be provided with a common rake which traverses the deck of the screenwell on rails. There would be a total of 3 dual-flow traveling water screens located downstream of the trash racks. Flow

passing through these screens would then enter coarse-mesh screens similar to the existing screens and circulating water pumps.

The new dual-flow screens would be designed for continuous operation, and the 10-ft-long screen panels would be equipped with fine mesh. The distance between the ascending and descending screens faces would be 9 ft, and the design screen face velocity would be 0.5 fps at full flow.

High and low pressure spray systems would be provided on each screen. The low pressure system would wash organisms off the screen mesh lifting trays into an organism trough located on the ascending side of each screen. Additional sluicing flow, if required, would be provided such that a velocity of 2 to 3 fps would be maintained in the troughs which would manifold into a common trough. The common trough then would transition to a pipe to return the organisms to Tampa Bay. The high-pressure spray system, located on the descending side of each screen, would wash debris into debris troughs and then empty into trash baskets.

Construction would be performed in the wet and would consist of excavation, driving necessary piles and sheeting, fabricating the operating deck, and then installing the equipment. Any maintenance required on the screens below the operating deck would require lifting of the screens with a bridge crane which would span the screens and truck aisle. Screenwash pumps, located downstream of the cutoff wall, require a total of 170 hp or 100 kW. The 3 dual-flow screens require a total of 22 hp or 15 kW. The total annual energy requirement for this scheme is approximately 960 MWh. However, this total does not consider any energy required for the crane or the trash rake.

The new fine-mesh, dual-flow screens would discharge through the sheetpile cutoff wall, which traverses the new screenwell and is connected to shore by a sheetpile wall on each side. In the event of excessive screen clogging, relief gates would be provided through the cutoff wall which open on a -2-ft head differential to supply the station flow. Coarse mesh (3/8-in. opening) screens would be maintained and function as a backup in the event the new screens clogged and the relief gates opened. Screenwash pumps are located downstream of the cutoff wall.

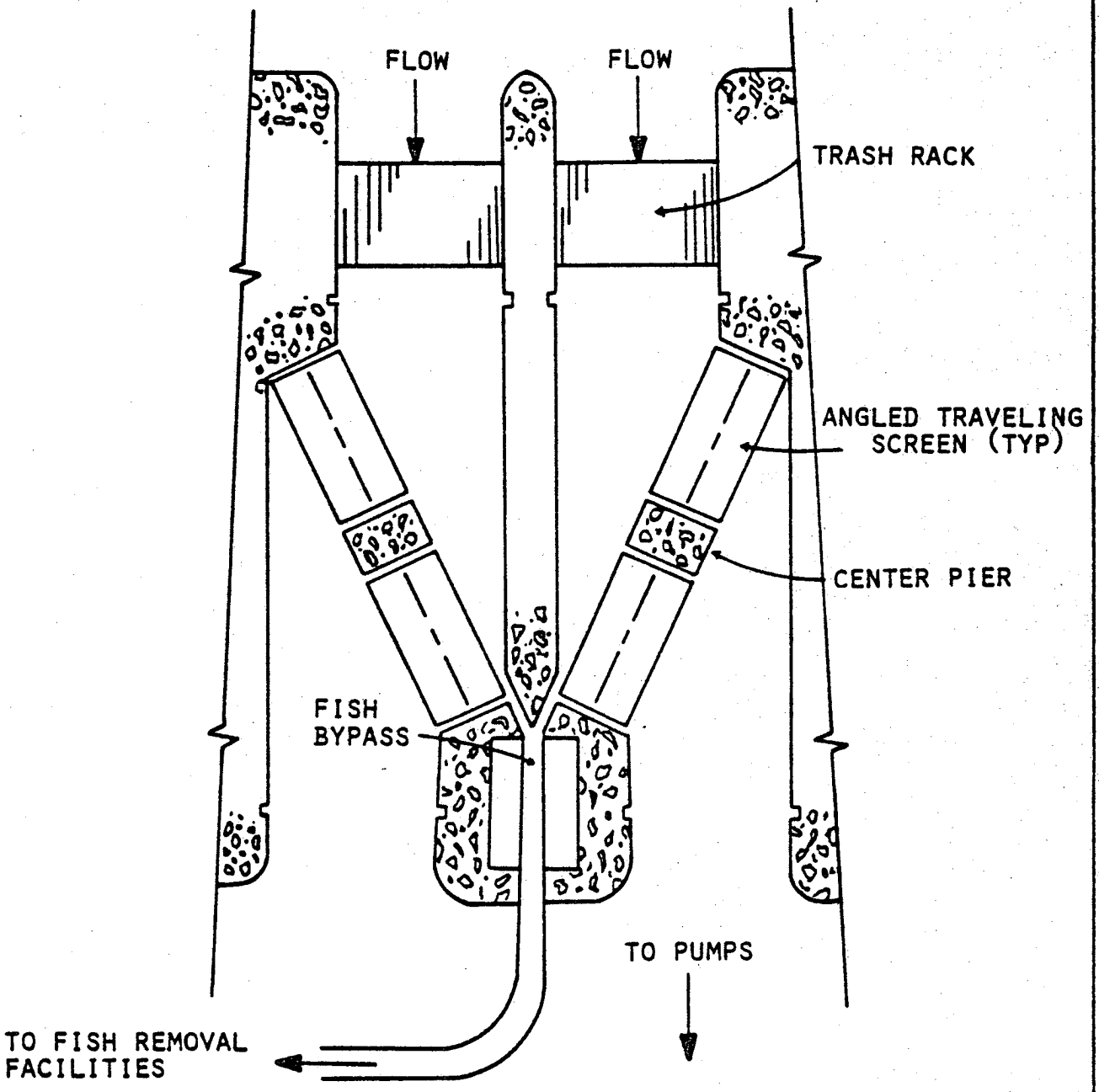


FIGURE 4-1

ANGLED DIVERSION SCREEN CONCEPTUAL DESIGN

BIG BEND STATION
TAMPA ELECTRIC COMPANY

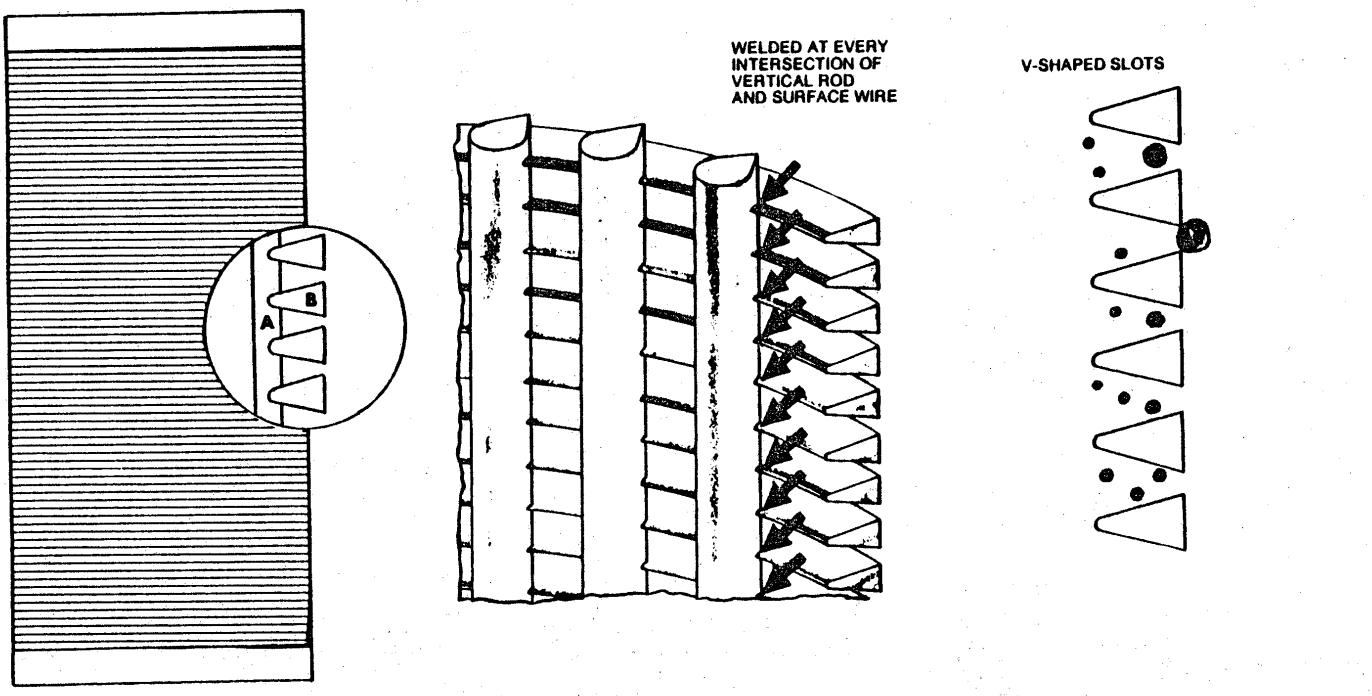
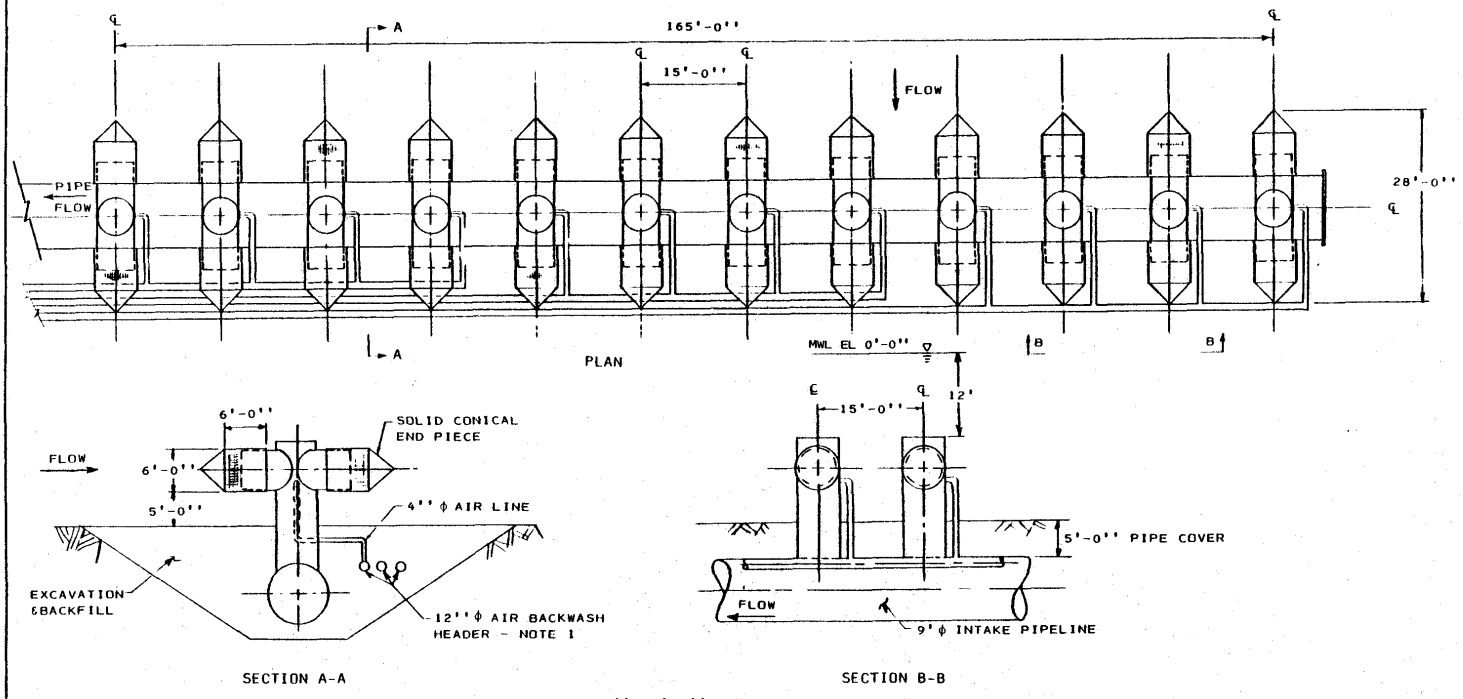


FIGURE 4-2

GENERAL LAYOUT OF
WEDGE-WIRE SCREEN

BIG BEND STATION
TAMPA ELECTRIC COMPANY



SCALE: 1''=10'-0''

NOTE: 1. HEADER PIPE DIMENSION TO BE SIZED BY A HYDRAULIC MODEL STUDY.

FIGURE 4-3

OFFSHORE ARRANGEMENT
WEDGE-WIRE SCREENS INTAKE

BIG BEND STATION
TAMPA ELECTRIC COMPANY

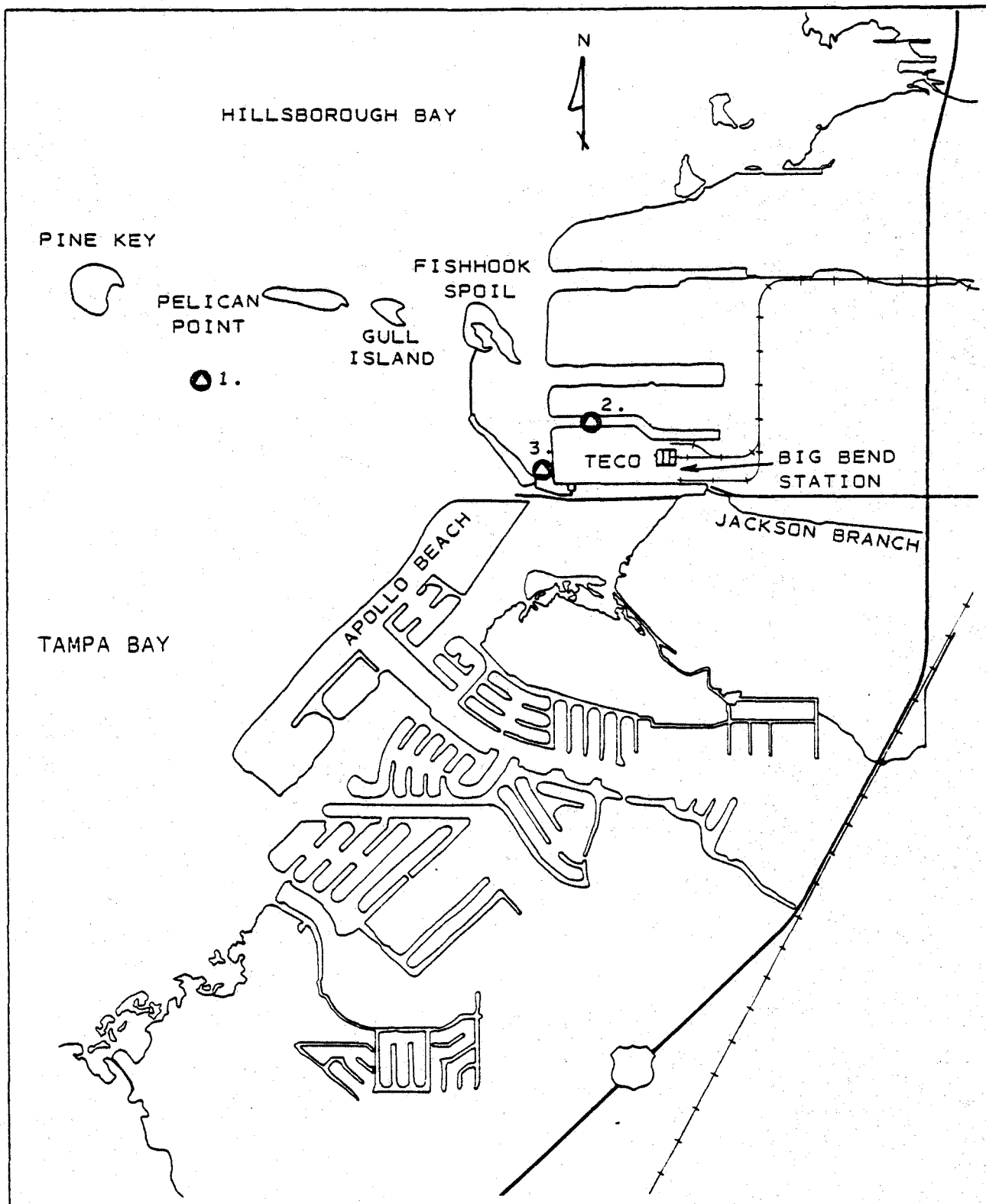


FIGURE 4-4

ALTERNATIVE LOCATIONS FOR WEDGE-WIRE SCREENS

BIG BEND STATION
TAMPA ELECTRIC COMPANY

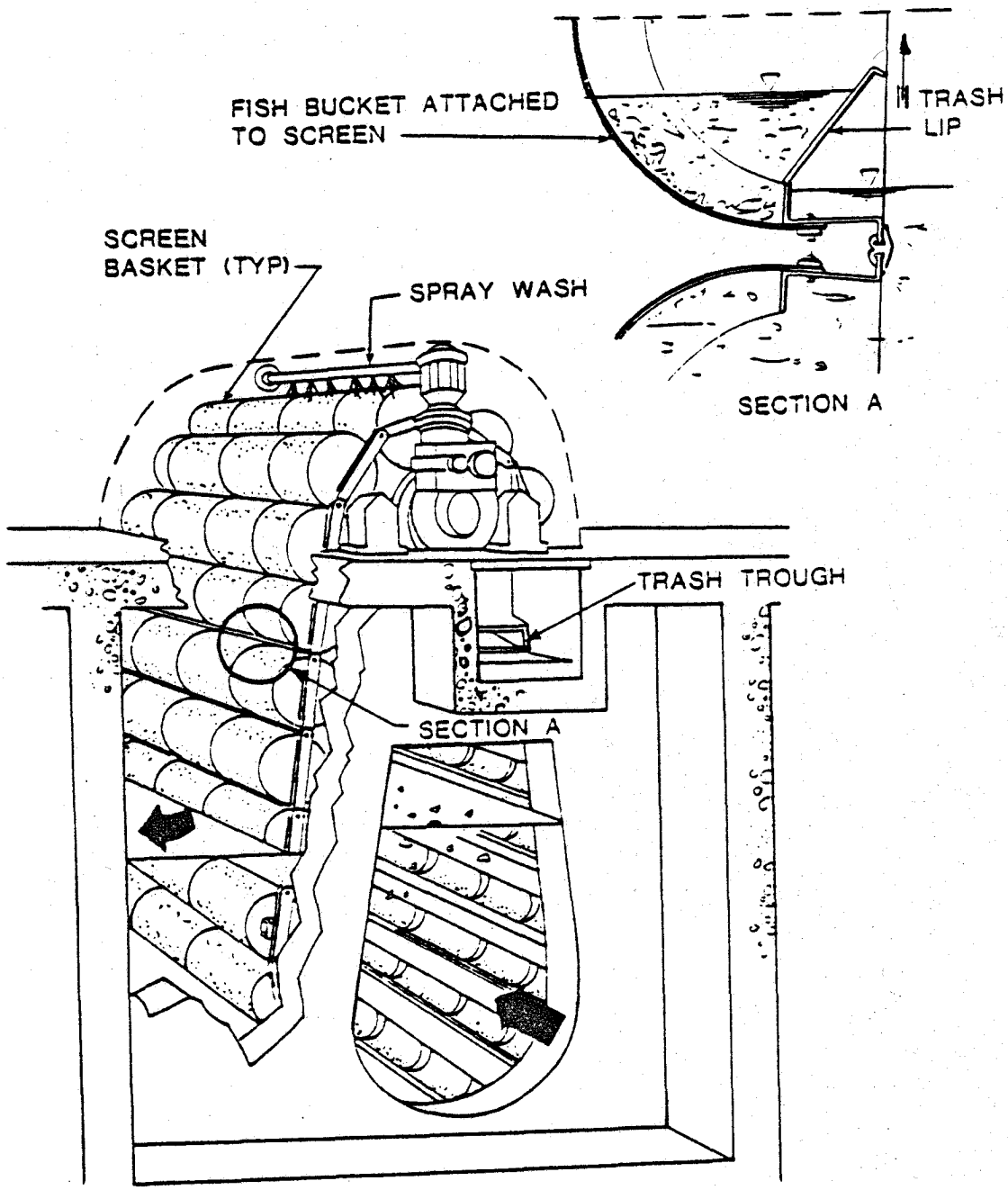
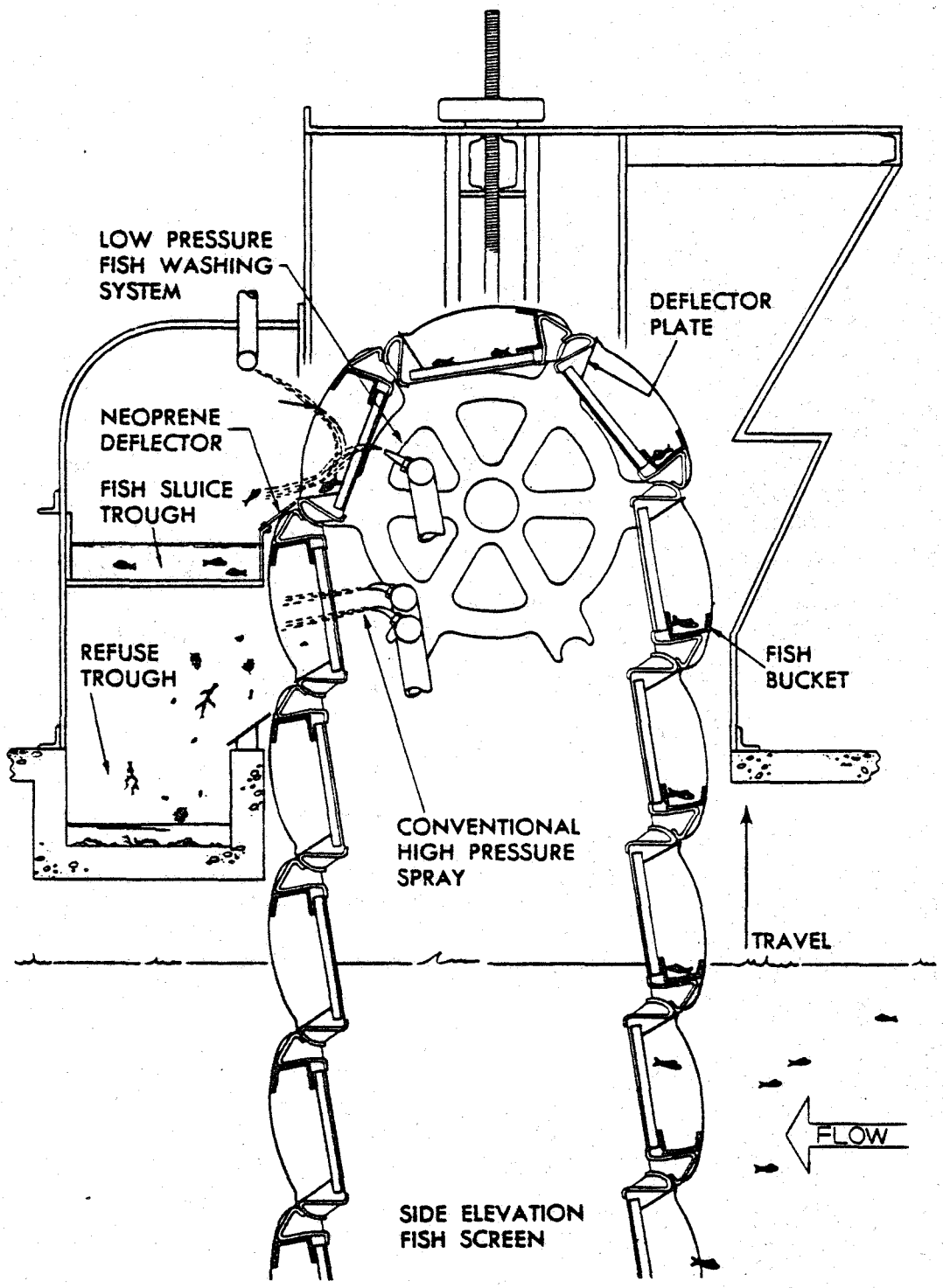


FIGURE 4-5

CENTER FLOW TRAVELING SCREEN

BIG BEND STATION
TAMPA ELECTRIC COMPANY



COURTESY OF ENVIREX

FIGURE 4-6

MODIFIED CONVENTIONAL
TRAVELING SCREEN

BIG BEND STATION
TAMPA ELECTRIC COMPANY

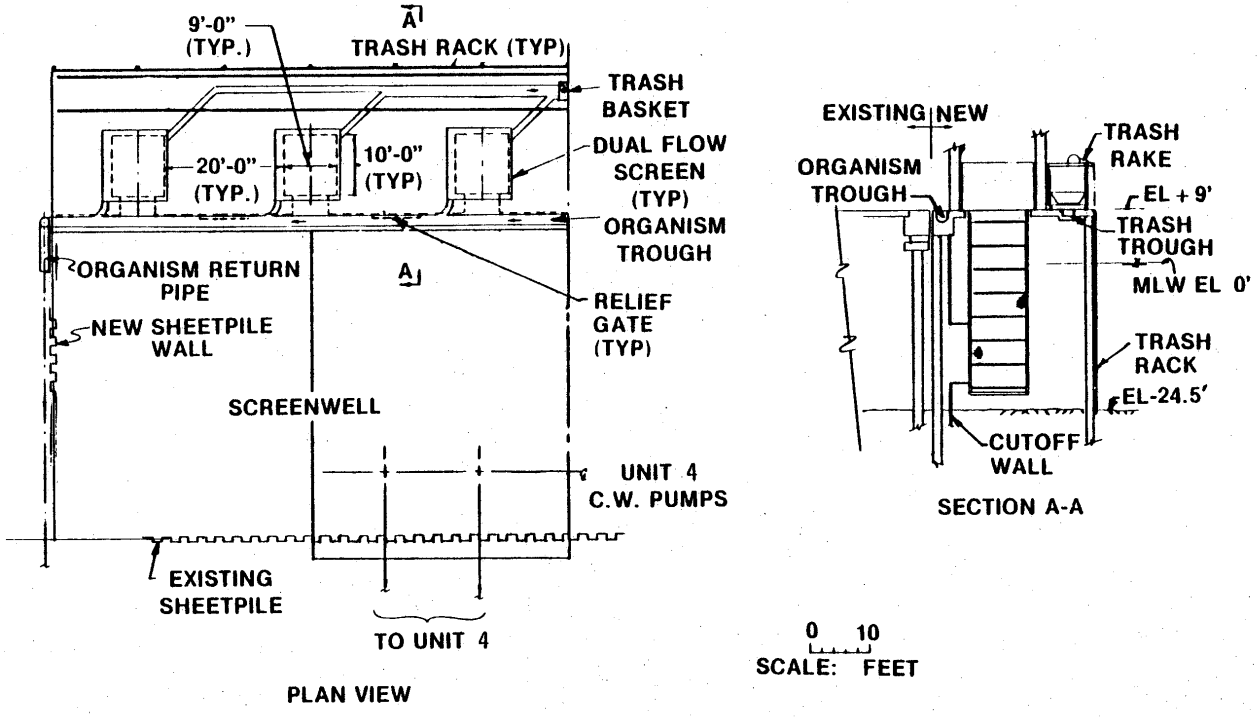


FIGURE 4-7

TYPICAL LAYOUT OF DUAL-FLOW SCREENS AT UNIT 4

BIG BEND STATION
TAMPA ELECTRIC COMPANY

SECTION 5

1979 PRELIMINARY FINE-MESH SCREENING STUDIES

5.1 INTRODUCTION

As discussed in Section 4, the utilization of a fine-mesh screening system at Big Bend Unit No. 4 (specifically, dual-flow screens) is believed to offer a potentially effective means of reducing the loss of aquatic organisms.

Early in 1979, Tampa Electric Company proposed to test the fine screening concept for possible use at Big Bend Station. Accordingly, a preliminary study program was conducted at Big Bend from July through September 1979. The program involved two separate study efforts:

1. A partial fine-mesh backfit of an existing traveling screen at Unit No. 1.

2. A flume study in which various test organisms were impinged on a fine-screen panel over a range of impingement velocities and durations.

The objective of these studies was twofold:

1. To determine whether available Representative Important Species (RIS) are capable of surviving impingement on a fine-mesh screen under conditions of existing screen design.

2. To determine the relationship between specific velocity/impingement duration conditions and survival rate.

The decision to conduct two separate studies was based on the fact that the use of one of the existing screens at Big Bend for a partial backfit evaluation would not permit changes in screen rotation speed or impingement velocity. With fine-mesh panels incorporated, velocities could be in excess of 3 fps and, in general, would exceed values which would be selected for a fine-screening installation. Therefore, it was believed that mortality estimates from the 1979 study would be higher than would be observed if a dual-flow screen were specifically designed to collect planktonic organisms.

To obtain a clearer understanding of the effects of impingement on organism survival, the flume study was conceived to permit testing under known and controlled conditions. Velocity and impingement durations were selected as the primary variables of interest in the flume since, at a given power plant water flow requirement, the design velocity determines the number and size of traveling screens needed, and the acceptable upper impingement duration limit determines the slowest speed at which the screen can rotate. Since fine-mesh screens must rotate continuously, it is desirable from a maintenance and cost standpoint to minimize the size and number of screens

and to operate them at the slowest speed possible. Therefore, test parameters were selected to cover a range of values which would have a good potential for protecting organisms and would also be practical to achieve at Big Bend Station Unit No. 4.

The ultimate goal of the partial backfit and flume studies was to supply information which would serve as a basis for deciding whether to continue with additional fine screening studies at Big Bend in 1980. The rationale for making this decision was established as follows:

1. If positive results (in the form of acceptable survival values) are obtained from both the partial backfit and flume studies, proceed with additional studies in 1980.

2. If the partial backfit study yields negative results, but flume survival rates are good, proceed with 1980 studies since backfit conditions are very conservative.

3. If both backfit and flume studies yield negative results, cancel plans for further studies.

As discussed in the following sections, acceptable survival rates were observed for several RIS both in the flume and on the partially backfitted screen. Therefore, 1980 studies have been planned (see Section 6).

5.2 FLUME STUDY

As previously described, the Flume Study was conducted to evaluate impingement survival potential of available RIS under known and controlled conditions. The following is a description of the test flume, test procedures, and results obtained.

5.2.1 Test Facility Description

The test flume was located adjacent to the dilution pumps at the Big Bend Station (see Figure 2-1). This location was selected due to its close proximity to an existing laboratory facility, which was being utilized at the same time for Dilution Pump Viability Study. Lawler, Matusky and Skelly Engineers (LMS) were responsible for collecting test organisms and monitoring their latent survival in both studies. Details of their efforts are presented in Appendix A. Flume testing was conducted by Stone & Webster Engineering Corporation (S&W) ecologists.

As shown in Figure 5-1, the test flume was approximately 2 ft wide, 2 ft deep, and 20 ft long. The flume was divided into two 1-ft-wide channels to allow two tests to be run concurrently and, thereby, facilitating testing. The two channels were identical in design and received flow from a common upstream reservoir.

Water depth in the flume was adjusted by a common downstream gate, while flow control was achieved by adjusting the rpm of the 50-hp supply pump (maximum flow = 1,000 gpm). By regulating flows and water depths, it

was possible to achieve test velocities in the two channels ranging from 0.1 to 2.0 fps. Water for the flume was withdrawn from the intake bay directly in front of the dilution pumps. The water was strained through a 250-micron-mesh basket to prevent clogging of the test screens in the flume and to block the passage of organisms into the flume which could contaminate the test samples.

At the upstream end of the flume, a series of adjustable flow straighteners were supplied to aid in the establishment of relatively uniform flow patterns in the two channels. Since specific velocities were being tested, it was important to ensure a uniform velocity field in the area of the test screen panels. These panels, which were contained within a single-support frame, were located 8 ft downstream of the flow straighteners and consisted of 0.5-mm nylon mesh. The screen frame was mounted on a track which allowed the frame to be manually guided into and out of the flow at the appropriate time intervals. The bottom of the frame contained organism lifting buckets (one for each screen panel), which were similar in design to those which would be utilized on a fine-mesh traveling screen. The entire screen frame assembly and guide slot were designed such that, in the lowered position, the screen panels were completely sealed around the edges to prevent organism escape.

Located immediately downstream of the test panels was an inclined screen which acted to contain any organisms which might escape the test area as the screen panels were raised. This allowed for accurate accounting of test organisms during the study program.

5.2.2 Test Procedures

Testing consisted of impinging available fish and invertebrate species/life stages on the fine-mesh test panels at various approach velocities over different lengths of time (duration). The specific velocity and duration values shown in the test matrix below were selected to cover the range of conditions which could be achieved with a full-scale, fine-mesh traveling screen installation at Big Bend.

		Impingement Duration (mins)				
		2	4	6	8	16
Velocity (fps)	0.5					
	1.0					
	1.5					
	2.0					

This matrix was intended to cover all possilbe test conditions for all species. Based on preliminary tests with each species, the matrix was reduced for that species to permit more observations to be gathered under conditions of reasonable survival.

The testing plan was established daily and was based on the availability of test organisms (collected by LMS on previous nights) and data requirements for each species/life stage as determined by the results of testing to that date.

Prior to each test, the desired approach velocity was estalished in each of the two test channels by adjusting pump rpm and water depth. The nominal velocity was then verified by actual measurements with a velocity meter.

Once the velocity conditions were established, testing of each available species/life stage began. Paired test lots were transported from the holding laboratory to the flume for testing. Each lot was introduced into one of the flume's channels at mid-depth as close to the screen panel as possible, thus encouraging impingement. Swimming behavior was observed whenever possible and recorded on flume data sheets. At the termination of the test, the entire screen basket was raised, and any organisms remaining on the screen panel were immediately washed into the lifting bucket. Larval fish were removed from the lifting bucket with a turkey baster, whereas smaller organisms were siphoned off. After removal, the test lots were returned to the LMS laboratory for counting, observation of initial survival, and subsequent holding of live organisms for determination of latent mortality.

In general, each test series also involved two control lots. A "laboratory control" was placed in a container and was simply held in the laboratory. "Flume controls" were transported to the flume and gently introduced into the lifting bucket in the raised position. After a duration equal to the longest test of the series, these control organisms were removed, returned to the laboratory, and held for 48 hr under the same conditions as the laboratory controls and test lots.

At the completion of the study, the data were statistically analyzed, as described in the next section.

5.2.3 Results of Flume Study

Flume studies were conducted from August 22 to September 19, 1979. Table 5-1 presents a breakdown of the 147 observations by taxa and testing type. Four taxa were available for testing: anchovy, shrimp, crab zoea, and drum. Unfortunately, organism abundance was low throughout the study and it was not possible to conduct the number of tests which had been planned.

The analysis of these data focused on the overall survivorship of test organisms (i.e., the initial survivorship plus the long-term survivorship). The most dramatic source of variability in the study was the differential response of the four taxa. Table 5-2 presents descriptive statistics by taxa. Shrimp had the highest survival, anchovy had the lowest survival, and crab zoea and drum had more intermediate survival. The frequency distribution of survivorship is presented for anchovy, shrimp, and zoea in Figures 5-2, 5-3, and 5-4, respectively.

The data were partitioned by taxa to investigate the influence of the experimental conditions on the survival. Since the study was viewed as exploratory, the potential independent variables included all those which may have had some effect on the survival. Impingement duration and velocity of the water were the independent variables for which the experiment was designed. Since not all test groups were held for 48 hr, the duration of holding was included. Other explanatory independent variables included: the initial survival, the number of organisms remaining at the end of the test, the number of organisms tested and the order of testing.

A least squares linear model was developed to test the influence of the independent variables on the survival for anchovy, shrimp, and zoea. Drum could not be further analyzed since only four observations were made. The data sets for each of the taxa were further limited to achieve a balance of the observations over the test conditions included in the statistical model. This balance is necessary to obtain reasonable estimates of the coefficients of the model. The results of the statistical model are discussed by taxa, since it was necessary to use different models for each taxa given the available observations.

The anchovy showed the least survival under the test conditions and as such, testing focused on the least severe combinations of impingement duration and water velocity. The statistical model utilized 26 out of the 36 screening observations (Table 5-1) at velocities of 0.5 and 1.0 fps, and impingement durations of 2 and 4 minutes.

The anchovy data contain many observations with zero survival; for example, of the 26 tests used in the statistical analysis, 13 had zero survival. These zero observations were well distributed over the velocity/duration combinations. Because of the number of zero observations, transformations of the dependent variable had little effect on the significance of independent variables or the proportion of variability in survival explained by the model. Therefore, the analysis on the untransformed data is presented.

The least squares analysis shows that the velocity, duration, and their interaction can be judged significant at p less than 0.1, as are the number of organisms tested and the holding duration (Table 5-3). Further interpretation of the results of the statistical analysis suggests that the significance of the latter two variables, the number of organisms tested and the holding duration, is probably indicative of experimental technique. For example, the survival increases with increased holding duration, contrary to expectation. This may reflect development of a better ability to hold organisms, since experiments with less than 48 hr holding duration tend to occur early in the testing.

Interpretation of the important design variables of velocity and duration indicates that the combination of 0.5-fps velocity and 2-minute impingement duration had better survival than the remaining test conditions; moreover, there was no difference between 0.5 fps and 4 minutes, 1.0 fps and 2 minutes, and 1.0 fps and 4 minutes velocity/duration combinations (Figure 5-5). The qualitative conclusion that 0.5 fps and 2-minute impingement duration is better than all other conditions, which are not different from one another,

does not depend upon the transformation of the dependent variable. To test the influence of the zero observations, an additional analysis was conducted for only the non-zero observations. This analysis produced the same qualitative pattern.

These statistical analyses indicate that anchovy are sensitive to impingement, with a small percentage of the individuals surviving. These analyses further indicate that the most desirable operational mode of the fine-mesh screen would be a 2-minute impingement duration and a water velocity of 0.5 fps.

The shrimp were the hardiest among the taxa tested (Table 5-2). The statistical model used for the shrimp analysis was similar to that previously described for anchovy except that all test organisms were held to 48 hr. Thus, holding duration was not included as a variable in the model. Since the shrimp had high survivorship, testing concentrated on the more stressful water velocities and longer impingement durations. The statistical model utilized 45 of the 59 observations (Table 5-1) at velocities of 1.5 and 2.0 fps and 2, 4, and 8 minutes of impingement.

The results of the statistical analysis are presented in Table 5-4, which shows that the highest proportion of the variability was accounted for by the number of organisms tested and the number of organisms remaining after the test. Since these variables were correlated with velocity and impingement duration, a second analysis (Table 5-5) was conducted which included only velocity, impingement duration, and their interaction. Comparison of the two analyses shows that the sums of squares associated with velocity and impingement duration are increased by eliminating the other independent variables.

The velocity variable is more important than duration or the interaction in explaining differences in survival (Table 5-5). Consequently, Figure 5-6 presents the least squares mean value and confidence interval for 48-hr survivorship at 1.5 fps and 2.0 fps. Figure 5-6 also presents the observed survivorship for comparison with the model estimates. The major reason for the higher survivorship at 2.0 fps is the absence of low survivorship tests which occurred at 1.5 fps.

The statistical analysis indicates that the shrimp is a hardy group able to withstand velocities up to 2.0 fps and impingement durations of 8 minutes with high survivorship. Thus, less stringent conditions of lower velocity and shorter impingement duration would reasonably be expected to produce higher survivorship.

The zoea showed survival intermediate to the anchovy and shrimp (Table 5-2). The least squares linear model utilized 18 of the 20 observations at velocities of 0.5 and 1.5 fps and impingement durations of 2 and 4 minutes. Table 5-6 presents the results of the statistical analysis of all 18 observations and suggests that velocity is an important variable in explaining survivorship. This difference is due to 3 of the 8 observations at 0.5 fps having survival less than 10 percent, while only 1 out of 10 of the observations at 1.5 fps had survival less than 10 percent.

Because of the limited number of observations available, the results of the analysis may be strongly influenced by these few low survival observations. As a result, the distinction between 0.5 fps and 1.5 fps may be artificial, and it would be reasonable to expect survivorship to be lower at 1.5 fps. Other studies with fine-mesh screen-impingement survival support this hypothesis (S&W 1979). Therefore, the low survival tests were removed from the analysis, and the results presented in Table 5-7 were obtained. This second analysis suggests there is no difference between 0.5 and 1.5 fps with respect to survival.

Given the preliminary nature of this study and the fact that low survival tests tended to have lower accountability of organisms, the results in Table 5-7 appear reasonable. Therefore, the survival of zoea can be estimated as the mean of all tests conducted (Table 5-2) rather than the mean at 0.5 and 1.5 fps.

The fourth taxa tested was drum, and only 4 observations were made due to the limited availability of the organisms for testing. The drum had survivorship similar to the zoea, with a mean survivorship of 42 percent and a median survivorship of 53 percent (Table 5-2). Since only 4 observations were made for this taxa, no statistical hypotheses could be tested.

5.3 PARTIAL FINE-MESH SCREEN BACKFIT STUDY

The concept of partially backfitting an existing traveling screen with fine mesh was conceived with the idea that, although velocity and impingement duration conditions would be relatively extreme, much would be learned about the mechanical operation of the system. Also, if good survival of organisms was obtained, the potential for high survival under more reasonable design conditions (as would be proposed for Big Bend Station) would be excellent. A description of the test facility, test procedures, and the results obtained follows.

5.3.1 Test Facility Description

For the purpose of this study, one of the traveling screens at Unit No. 1 was modified to incorporate the key components of a fine-screening system, as follows (see Figure 5-7):

1. Six panels of the existing 9.5-mm-mesh screen baskets were overlaid with 0.5-mm nylon mesh (the coarse mesh served as a support network for the fine mesh).

2. Organism lifting buckets were attached to the standard debris lip of the six baskets, with fine mesh glued directly to the inner edge of the buckets.

3. The lifting buckets were divided laterally into three equal segments to allow separate collection of organisms which have passed through different velocity fields.

4. An internal low-pressure spraywash system was installed to gently rinse organisms into the lifting buckets as each panel passed on its ascending run.

5. An external low-pressure spraywash system was installed to gently rinse the contents of the lifting buckets into a collection trough.

6. Finally, the existing high-pressure spraywash system, which normally cleans the coarse mesh on the ascending run, was moved to the descending run; a temporary sluiceway was installed to carry debris to an existing debris basket.

The partial backfit was designed such that all spraywash pressures could be adjusted individually, thereby allowing for optimization during the study program. This capacity for optimizing the system under actual operating conditions at Big Bend was considered to be one of the major benefits of the backfit study.

A description of the Big Bend traveling screen design is given in Section 2. Design parameters which were of primary importance in the partial backfit study were the screen travel speed and the flow rate. The travel speed of 14 fpm translates into a maximum-impingment duration of approximately 3.5 minutes, assuming an organism impinges at the water surface on the descending run of the screen. The flow rate into the screen is 270 cfs which, if uniformly distributed, would result in a screen-face velocity of less than 1.0 fps. However, due to the direct connection of the circulating water pump to the dual-flow screen (Figure 2-2), the velocity distribution is skewed, with the highest values occurring at the pump suction. Measurements taken over the entire area of the screen indicate that the velocity ranges from values of less than 0.5 fps (near the water surface and at the end of the screen farthest from the pump) to values in excess of 3.0 fps. It is for this reason that the results of survival studies would be considered conservative. Also, the observation that velocities decrease with increased distance from the pump led to the idea of separating the lifting buckets into three segments. It was hoped that if velocity had a strong influence on organism survival, a trend would become evident when test groups from each segment were held separately for comparison.

5.3.2 Test Procedures

During the study program, two methods of sampling were utilized: one was designated as a "manual wash" and the other as an "automatic wash." In both cases, preparation for sampling involved rotating the traveling screen through several revolutions to permit the high-pressure debris spray to remove as much debris as possible from the mesh and lifting buckets.

Automatic washing involved the use of the two low-pressure sprays for removing collected organisms from the fine-mesh screen panels. After the screen had rotated several times for cleaning, the external and internal spray pressures were quickly adjusted to 10 and 5 psi, respectively, and

were then shut off. As the top of the first fine-mesh screen panel came into line with the spray system, both spraywashes were activated and remained on until all six fine-mesh screen panels had been washed into the collection trough. The sprays were then shut down and the water and organisms in the trough slowly drained into the collection area. Most of the water entering this area drained out through a 0.5-mm mesh screen which retained the organisms. When most of the water had drained, the remaining water containing a concentration of organisms was slowly drawn off via a 1-in. plastic hose into a transport bucket with a screened overflow. At this point, sampling was completed.

Manual wash samples were collected without the use of the low-pressure spraywashes. The purpose of this procedure was to individually collect organisms from the three lateral segments of the lifting buckets in hope of identifying possible differences in mortality resulting from velocity effects, as discussed previously.

As with the automatic wash, the screen was rotated several times and cleaned. The next time the six fine-mesh panels reached the sampling area, the screen was stopped, and three of the screen panels were gently washed down by hand into the segemented lifting buckets. The contents of the buckets were then siphoned into one of three transport containers, according to segment.

Following the collection of both sample types, transport containers were delivered to the LMS laboratory facility for sorting, identification, determination of initial survival, and holding for up to 96 hr (for determination of latent survival). A detailed description of LMS laboratory procedures is given in Appendix A.

During the study, an attempt was made to obtain survival data for RIS life stages. However, due to a paucity of organisms, it was necessary to group species and to add other species to the study.

At the completion of the study, the data obtained were subjected to statistical analysis, as described below.

5.3.3 Results of Partial Fine-Mesh Screen Backfit Study

From August 14, 1979, to September 25, 1979, four taxa were tested for survival following impingement on fine screens. The four taxa were zoea, shrimp, fish eggs, and fish larvae. The primary objective was to estimate overall survival, including initial impingement survival and holding survival under the automatic and manual washing schemes.

The testing program resulted in a total of 463 observations, with 93, 95, 115, 156 for shrimp, fish larvae, fish eggs, and zoea, respectively. The shrimp were necessarily partitioned from the other taxa for analysis because no determination was made of the initial number which survived impingement. Qualitative observations indicated few or no dead shrimp in most collections. For the other three taxa, determinations were made of the number which were

initially alive and dead and of survivorship after laboratory holding. Table 5-8 presents descriptive statistics by taxon for the study. Zoea had the highest initial survival, followed by fish eggs and then larvae. The shrimp, for which no initial survival determination was made, had the highest holding survival; followed by zoea, fish eggs, and then fish larvae.

A least squares analysis of covariance was performed to test for differences with the type of wash, either manual or automatic. First, however, analyses of the manual wash observations was conducted to test for differences in the three screen sections. Two analyses were conducted, one for shrimp (Table 5-9) and one for the other taxa (Table 5-10). These analyses indicate that there is no significant difference ($p \geq 0.05$) in the initial or holding survival associated with the particular screen section. Thus, subsequent analyses consider the variability associated with the screen section in the residual variance.

Two analyses of covariance were then performed to test for differences in the wash type. Table 5-11 presents the results for holding survival of shrimp, which indicate a difference between washing types. The manual wash had a mean survival of 0.50 with a standard error of 0.051, while the automatic wash had a mean survival of 0.69 with a standard error of 0.024. The average holding time for shrimp was 49 hr.

Table 5-12 presents the initial and holding survival for the other three taxa. In general, the manual wash had lower survival than the automatic wash. However, the difference was a function of the taxon, and the average holding times were different for each taxa. Therefore, an analysis was performed for each taxon to ensure that this conclusion was upheld at the mean holding time for each taxon.

The automatic wash had the higher survival for all cases in which the wash types were significantly different ($p \leq 0.05$). The fish larvae did not show significant differences in initial and holding survival, and the fish eggs showed no significant differences for the initial survival.

Since the prototype study will use a wash system more similar to the automatic wash, an estimate was made of the survivorship based only on the automatic tests. Table 5-13 presents the results of this analysis. The results for the automatic wash are quite similar to the results of all tests presented in Table 5-8.

5.4 CONCLUSIONS

As stated previously, the purpose of the 1979 preliminary fine-mesh screen investigations was to determine whether selected RIS are capable of surviving impingement to a degree that would warrant further research into the feasibility of utilizing this technology at Big Bend. Based on the results presented above, as well as the information given in Section 4, it is believed that the concept of fine screening has a definite potential for reducing entrainment losses at Big Bend.

While it is evident that some species or life stages may be more susceptible to impingement stress and mortality than others, it would appear from the 1979 data that, with the exception of the anchovy, survival of many species could be high at Big Bend. It is also believed that anchovy survival can be increased through improved design features and operating conditions. As a result, the decision was made to proceed with a Prototype Fine-Mesh Screen Study in 1980. As described in the next section, many of the potential improvements in system design and operation, which were identified during the preliminary studies, have been incorporated into the prototype system.

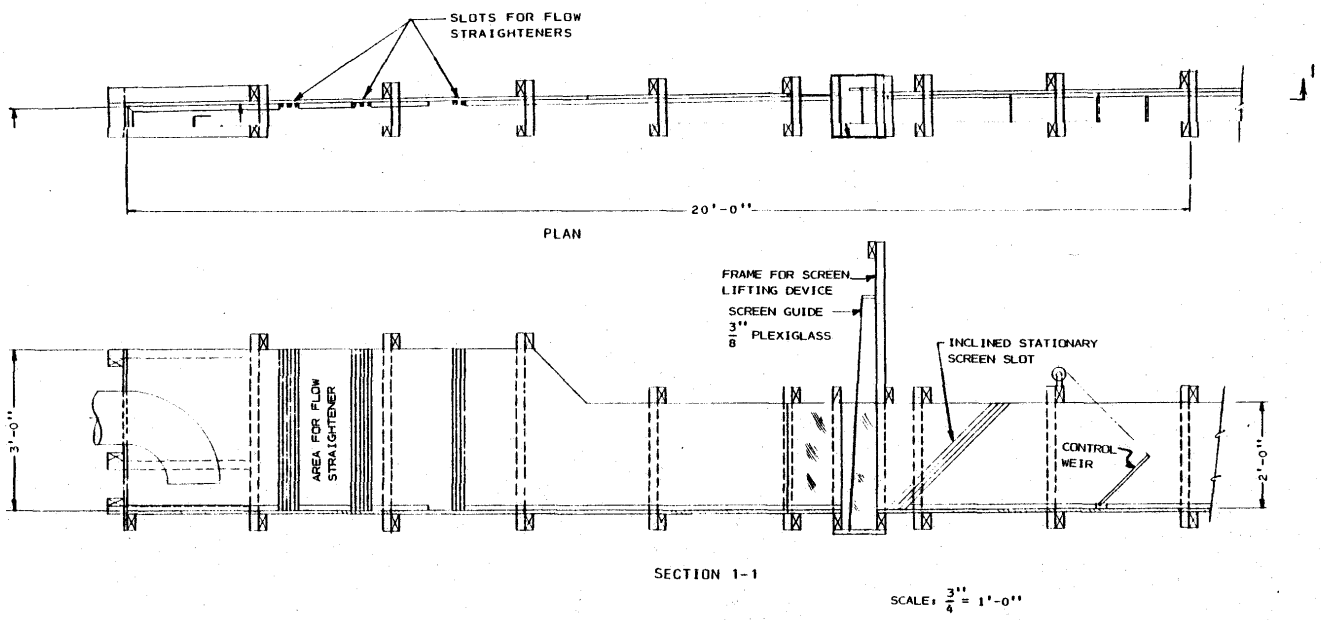


FIGURE 5-1

IMPINGEMENT SURVIVAL STUDY
TEST FLUME DESIGN

BIG BEND STATION
TAMPA ELECTRIC COMPANY

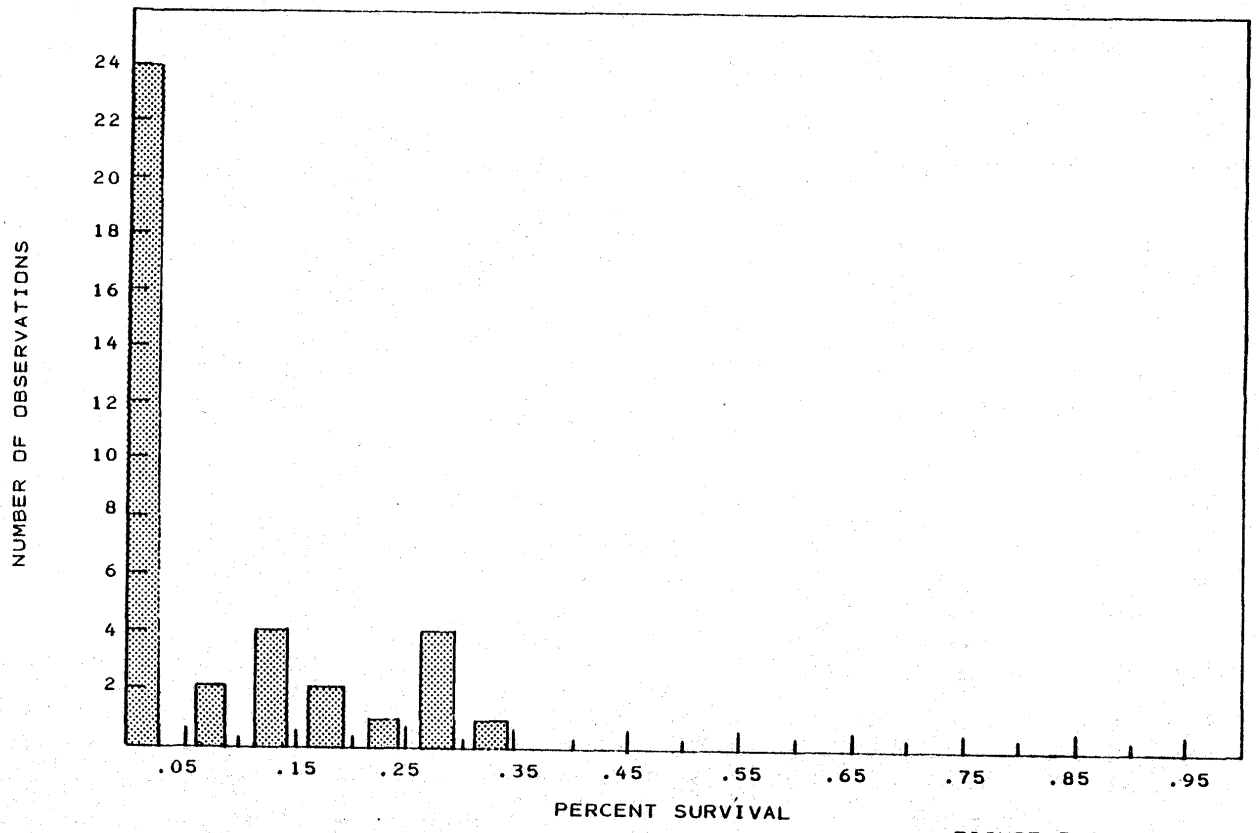


FIGURE 5-2

DISTRIBUTION OF SURVIVAL OBSERVATIONS FOR ANCHOA SP.

BIG BEND STATION
TAMPA ELECTRIC COMPANY

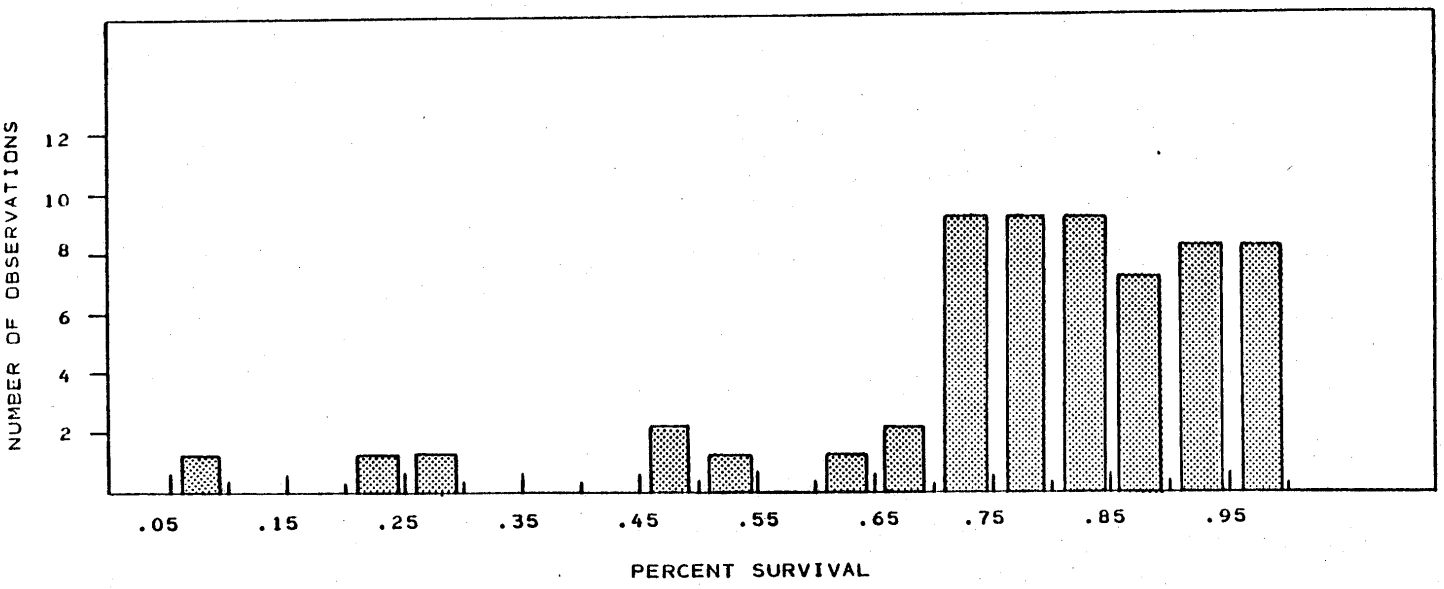


FIGURE 5-3

DISTRIBUTION OF SURVIVAL OBSERVATIONS FOR SHRIMP

BIG BEND STATION
TAMPA ELECTRIC COMPANY

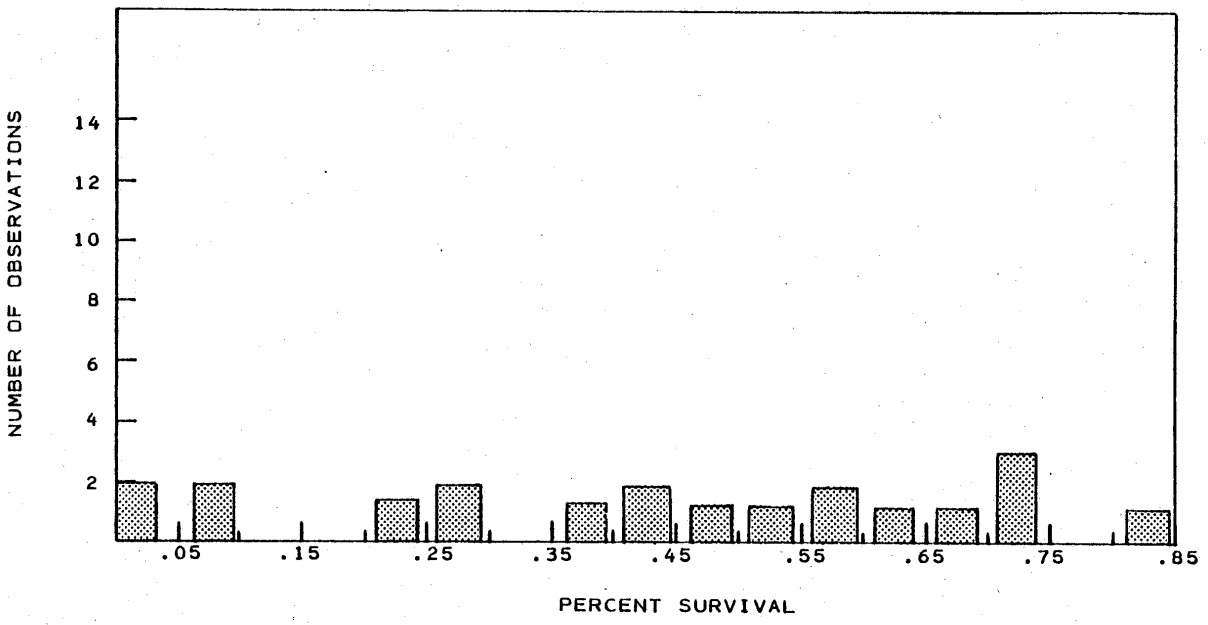


FIGURE 5-4
DISTRIBUTION OF SURVIVAL OBSERVATIONS FOR ZOEA

BIG BEND STATION
TAMPA ELECTRIC COMPANY

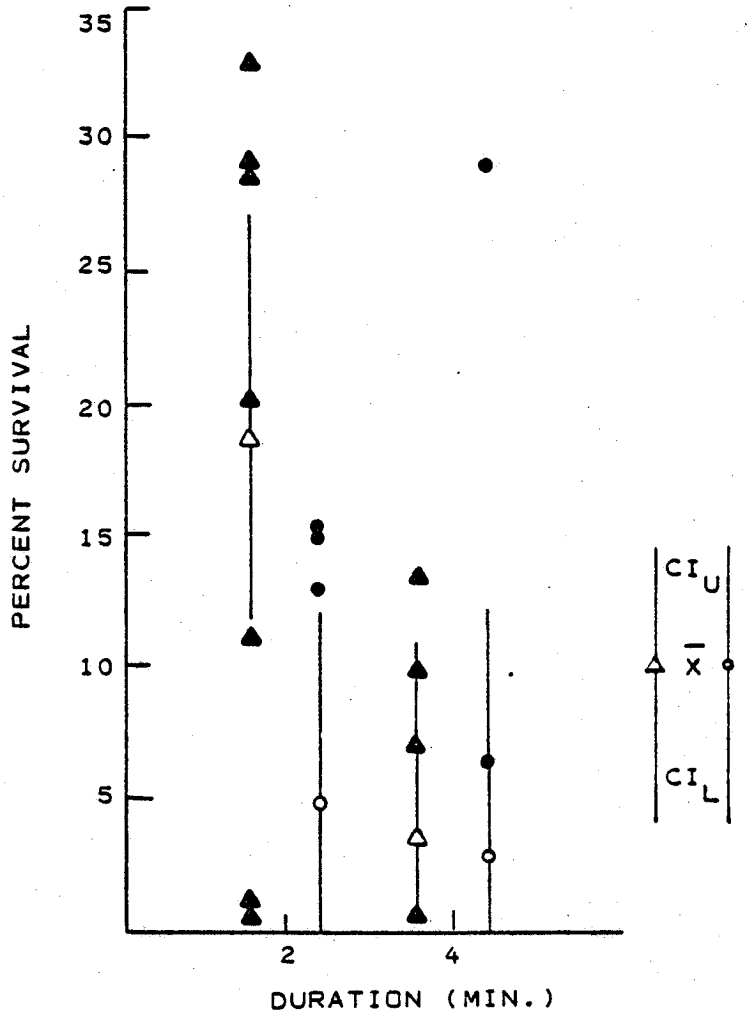


FIGURE 5-5

ANCHOA SP. SURVIVAL DATA AND LEAST SQUARES MEAN AND 95% CONFIDENCE INTERVAL

BIG BEND STATION
TAMPA ELECTRIC COMPANY

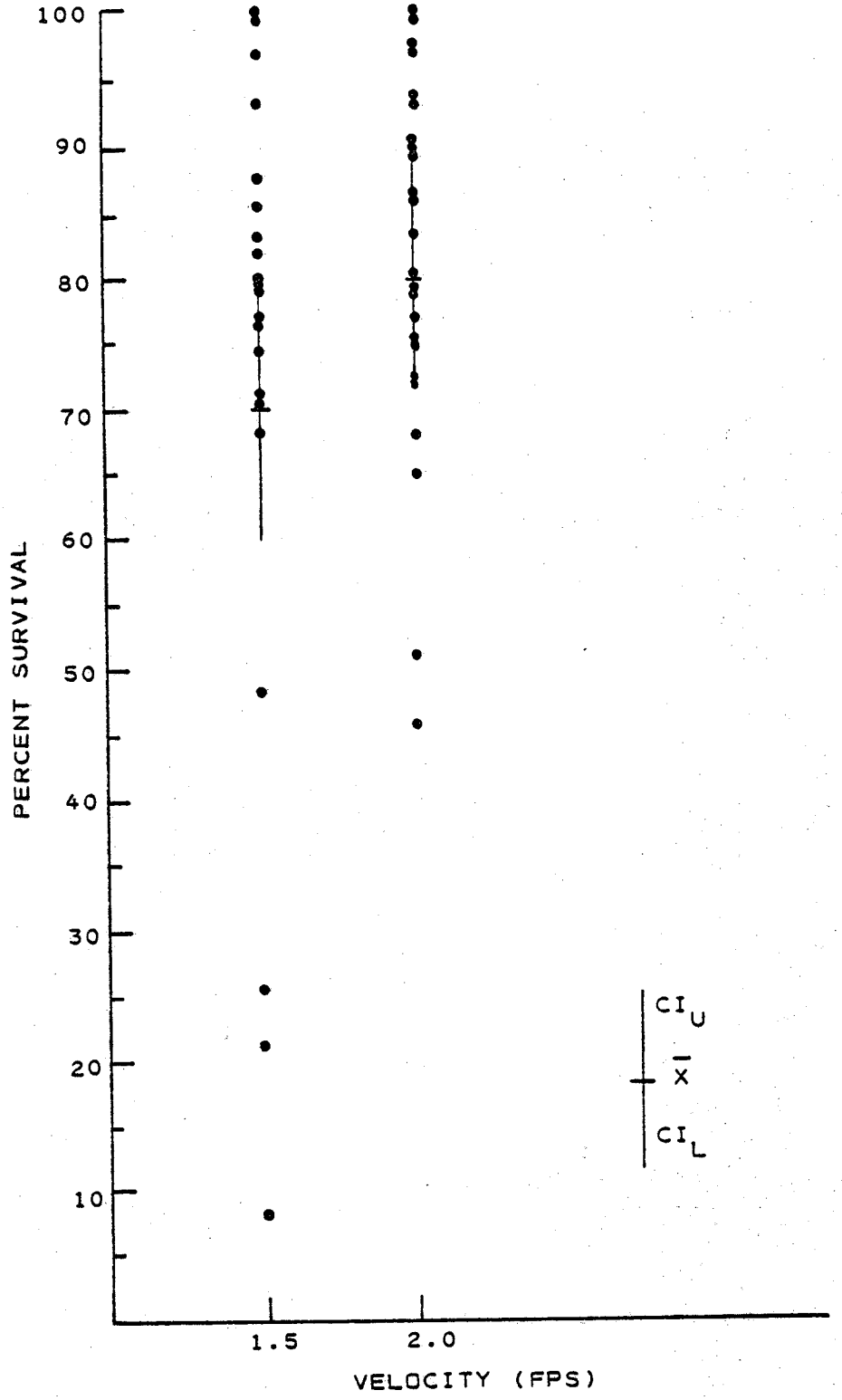


FIGURE 5-6

SHRIMP SURVIVAL DATA AND LEAST SQUARES MEAN AND 95% CONFIDENCE INTERVAL

BIG BEND STATION
TAMPA ELECTRIC COMPANY

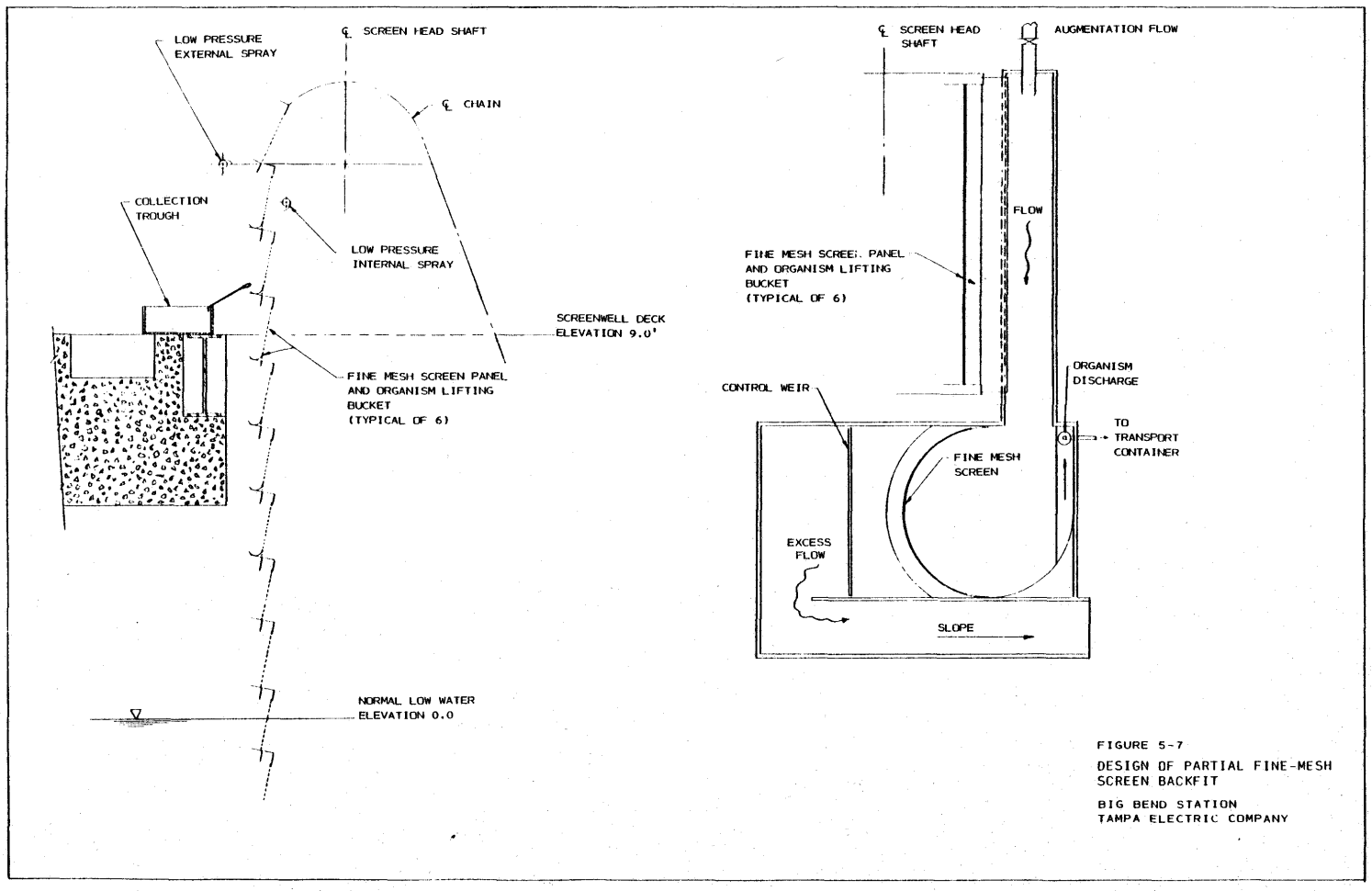


FIGURE 5-7

DESIGN OF PARTIAL FINE-MESH SCREEN BACKFIT

BIG BEND STATION
TAMPA ELECTRIC COMPANY

TABLE 5-1

DISTRIBUTION OF SAMPLING EFFORT
IMPINGEMENT FLUME STUDY

TAXA	TYPE OF TEST			
	With Screen	Field Control	Lab Control	Total
Anchovy	36	7	5	48
Shrimp	59	7	5	71
Zoea	20	3	1	24
Drum	4	0	0	4
TOTAL	119	17	11	147

TABLE 5-2

DESCRIPTIVE STATISTICS
SCREEN IMPINGEMENT SURVIVAL, PERCENTAGE

Taxa	Minimum	Maximum	Median	Mean
Anchovy	0	33	0	<1 (0.07)
Shrimp	9	100	80	77
Zoea	3	83	46	43
Drum	0	60	53	42

TABLE 5-3

RESULT OF LEAST SQUARES LINEAR MODEL ANALYSIS FOR ANCHOA SP.

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	α-Probability
Velocity (V)	1	0.01714	3.424	0.08
Impingement duration (D)	1	0.03095	6.180	0.02
V x D	1	0.02461	4.915	0.04
Testing sequence	1	0.00153	0.306	-
Number of organisms tested	1	0.01945	3,884	0.07
Number of organisms remaining	1	0.01089	2.176	0.16
Initial survival	1	0.01393	2.783	0.11
Holding time	1	0.04528	9.043	0.01
RESIDUAL	17	0.08513		
TOTAL	25	0.30898		

TABLE 5-4

RESULTS OF FULL LEAST SQUARES LINEAR MODEL FOR SHRIMP

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	α-Probability
Velocity (V)	1	0.02870	1.374	0.25
Impingement duration (D)	2	0.03192	0.375	-
V x D	2	0.03192	0.764	-
Testing sequence	1	0.00656	0.314	-
Number of organisms tested	1	0.28651	13.713	< 0.01
Number of organisms remaining	1	0.47786	22.871	< 0.01
Initial survival	1	0.09243	4.424	0.04
RESIDUAL	35	0.73127		
TOTAL	44	1.84691		

TABLE 5-5

RESULTS OF REDUCED LEAST SQUARES LINEAR MODEL FOR SHRIMP

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	α-Probability
Velocity (V)	1	0.19033	5.066	0.03
Impingement duration (D)	2	0.08198	1.091	0.35
V x D	2	0.19560	2.603	0.09
RESIDUAL	39	1.46522		
TOTAL	44	1.84691		

TABLE 5-6

RESULTS OF FULL LEAST SQUARES LINEAR MODEL ANALYSIS FOR ZOEA

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	α-Probability
Velocity (V)	1	0.22804	8.175	0.02
Impingement duration (D)	1	0.00723	0.259	-
V x D	1	0.01882	0.675	-
Testing sequence	1	0.00188	0.067	-
Number of organisms tested	1	0.02019	0.724	-
Number of organisms remaining	1	0.00101	0.037	-
Initial survival	1	0.08829	3.165	0.11
RESIDUAL	10	0.27895		
TOTAL	17	0.92782		

TABLE 5-7

RESULTS OF FULL LEAST SQUARES LINEAR MODEL ANALYSIS
FOR ZOEA - LOW SURVIVAL OBSERVATIONS DELETED

Variable	Degrees of Freedom	Sums of Squares	F-Ratio	α-Probability
Velocity (V)	1	0.05044	4.345	0.08
Impingement duration (D)	1	0.05471	4.712	0.07
V x D	1	0.06932	5.971	0.05
Testing sequences	1	0.00016	0.014	-
Number of organisms tested	1	0.01167	1.005	0.35
Number of organisms remaining	1	0.00001	0.000	-
Initial survival	1	0.05670	4.884	0.07
RESIDUAL	6	0.06966		
TOTAL	13	0.34323		

TABLE 5-8

DESCRIPTIVE STATISTICS FOR SURVIVAL BY TAXON

Taxa	Sample Size	Initial Proportion Surviving		Proportion Surviving Holding	
		Mean	Standard Deviation	Mean	Standard Deviation
Zoea	156	0.66	0.26	0.47	0.26
Shrimp	93	*	*	0.66	0.24
Fish Eggs	119	0.20	0.24	0.32	0.36
Fish Larvae	95	0.05	0.11	0.07	0.22

*No determination was made for initial survival.

TABLE 5-9

ANALYSIS OF COVARIANCE FOR SHRIMP TO
TEST FOR DIFFERENCES IN SCREEN SECTIONS (MANUAL WASH)

Variable	Degree of Freedom	Sum of Squares	F-Ratio	α-Probability
Screen section	2	0.1017	2.199	0.15
Holding time	1	0.4461	19.289	0.0007
RESIDUAL	13	0.3006		
TOTAL	16	1.0463		

TABLE 5-10

ANALYSIS OF COVARIANCE FOR ZOEA,
FISH EGGS, AND FISH LARVAE TO TEST FOR
DIFFERENCES IN SCREEN SECTIONS (MANUAL WASH)

a. Initial Survival

Variable	Degree of Freedom	Sum of Squares	F-Ratio	α-Probability
Screen section	2	0.0190	0.201	-
Species	2	1.4806	15.707	0.0000
Holding time	1	0.5237	11.111	0.0011
RESIDUAL	163	7.6824		
TOTAL	168	19.4735		

b. Holding Survival

Variable	Degree of Freedom	Sum of Squares	F-Ratio	α-Probability
Screen section	2	0.03340	0.279	-
Species	2	0.2912	2.415	0.0925
Holding time	1	0.4742	7.867	0.0056
RESIDUAL	163	9.8271		
TOTAL	168	13.8388		

TABLE 5-11

ANALYSIS OF COVARIANCE FOR
SHRIMP TO TEST FOR DIFFERENCES IN WASH TYPE

Variable	Degrees of Freedom	Sum of Squares	F-Ratio	α-Probability
Wash	1	0.5333	11.877	0.0009
Holding time	1	0.8762	19.515	0.0000
RESIDUAL	90	4.0407		
TOTAL	92	5.3819		

TABLE 5-12

ANALYSIS OF COVARIANCE FOR
ZOEA, FISH EGGS, AND FISH LARVAE
TO TEST FOR DIFFERENCES IN WASH TYPE

a. Initial Survival

Variable	Degrees Freedom	Sums of Squares	F-Ratio	α-Probability
Wash	1	0.1586	3.383	0.0667
Species	2	3.9021	41.608	0.0000
Wash x species	2	0.1612	1.718	0.1808
Holding time x species	2	0.5566	5.934	0.0029
Holding time	1	0.1858	3.963	0.0472
RESIDUAL	361	16.9278		
TOTAL	369	44.8949		

b. Holding Survival

Variable	Degrees Freedom	Sums of Squares	F-Ratio	α-Probability
Wash	1	2.0112	29.838	0.0000
Species	2	0.4882	3.621	0.0277
Wash x species	2	0.6639	4.924	0.0078
Holding time x species	2	0.7409	5.496	0.0045
Holding time	1	0.9281	13.769	0.0002
RESIDUAL	361	24.3341		
TOTAL	369	39.5510		

TABLE 5-13

SUMMARY STATISTICS FOR AUTOMATIC WASH BY TAXON

Taxa	Number of Observations	Mean Holding Time (hr)	Initial Survival		Holding Survival	
			Mean	Standard Deviation	Mean	Standard Deviation
Zoea	74	49	0.70	0.25	0.56	0.25
Shrimp	76	49	-	-	0.69	0.23
Fish Eggs	76	13	0.22	0.25	0.42	0.35
Fish larvae	51	7	0.04	0.10	0.08	0.24

SECTION 6

1980 PROTOTYPE SCREEN STUDIES

6.1 DESCRIPTION OF TEST FACILITY

The general site plan for the test facility is shown on Figure 6-1. The test screen will be situated on a platform located in the intake channel immediately upstream of the existing pipe bridge. Stairs from the pipe bridge will provide access to the screen. As shown on Figure 6-1, laboratory facilities will be located on the north side of the intake channel, approximately 150 ft from the screen facility.

Figure 6-2 shows a more detailed plan of the screen operating deck. The prototype screen will be of the dual-flow type and will incorporate all of the features required for fine screening. Seals will be incorporated between screen baskets and between the baskets and the side frame to prevent the loss of organisms in these areas. The screening medium will be 0.5-mm square mesh made of polyester.

The screen will be capable of operation at speeds up to 28 fpm. On automatic control, the screen will run continuously at 7 fpm; as differentials across the screen reach 4 and then 6 in., the speed will increase to 14 and 28 fpm, respectively. On manual control, the screen can be operated at speeds between 0 and 28 fpm. Three speeds of 7, 14, and 28 fpm have been selected for study. These speeds correspond to maximum impingement durations of approximately 7, 4, and 2 minutes, respectively.

Flow through the screen will be supplied by a bow thruster pump located under the test platform and connected directly to the screen via a transition section (Figure 6-3). The pump will be belt-driven by a 250-hp motor located on the deck. Assorted pulleys will allow for flow adjustments. Given the size of the pump and motor, flows ranging from 8,270 to 50,000 gpm can be achieved. Since the test screen will be 2 ft wide, these flows will correspond to screen face velocities ranging from approximately 0.25 to 1.5 fps.

The discharge flow from the pump, composed of fine-screened water, will be conveyed by a pipe to a location far enough downstream in the intake channel to prevent recirculation (Figure 6-1). At the point where the pipe passes under the pipe bridge, two taps will be installed in the pipe to allow for the insertion of a flow-measuring device (for verification of velocities) and an organism sampler which will be used to determine the collection efficiency of the fine-mesh screen. A work platform will be provided directly above this location to allow for the recording of pitometer measurements and the collection of biological samples.

A floating platform will be installed directly in front of the upstream (ascending) side of the test screen and will be accessible by ladder. This platform will be used for observing the location and movement of organisms as individual screen baskets clear the water surface. It may

also serve as a sampling location and work station from which the need for additional spray systems can be evaluated.

The test screen will incorporate shallow lifting buckets on each 2-ft screen basket. Initially, two low-pressure spray headers will be installed for removing organisms from the screen mesh and lifting buckets. A screenwash pump with a strainer will be located on the operating deck and will take suction from the bow thruster discharge pipe. Since the lifting bucket design is new and has not been evaluated under field conditions, it is not known whether one or both of these sprays will be required to completely remove collected organisms. Regardless, it is assumed that an effective spray arrangement will be derived during preliminary testing and that organisms will be successfully washed into the collection trough.

Once in the trough, the organisms will flow by gravity into a primary collection tank from which they can be drained into one or more secondary collection tanks, which will also serve as transport containers. As shown on Figure 6-1, a land-based laboratory will be established for processing of all screen samples. The facility will be equipped with organism holding containers, water quality monitoring equipment, and office and storage space. All monitoring of initial and latent survival will be conducted in this facility. Further identification and sorting required subsequent to latent survival studies will be completed at the offices of the field contractor.

6.2 PROPOSED SAMPLING METHODOLOGIES

6.2.1 Introduction

Since the prototype screen program constitutes an exploratory research project, it is difficult to narrowly define the procedures which will be required to achieve the objectives of the study. Therefore, the proposed methodologies outlined below can only serve as guidelines, and are subject to change pending results of early testing. Every attempt has been made to identify those engineering and environmental factors which might influence the survival potential of impinged and collected organisms. Given the present understanding of fine-mesh screen (FMS) systems, the testing methodologies have been developed to account for the effects of these factors within the framework of the final statistical design.

It is planned that the study program will be conducted in three phases: Phase 1 will require intensive sampling over a 4-week period as part of a preliminary screen evaluation and shakedown; Phase 2 will involve intensive sampling on a relatively routine daily schedule over a 6-week period. Phase 2 is scheduled to coincide with the period of high organism density at Big Bend. Phase 3 will involve routine sampling one week per month over a 4-month period at a time when organism abundance is lower than during Phase 2. A schedule of the study program is shown on Figure 6-4.

6.2.2 Representative Important Species (RIS)

During the study program, emphasis will be placed on obtaining survival data for the RIS life stages listed below:

SPECIES	LIFE STAGE
Bay anchovy	Egg, yolk-sac larvae, post-larvae
Black drum	Egg, yolk-sac larvae, post-larvae
Silver perch	Egg, yolk-sac larvae, post-larvae
Spotted seatrout	Egg, yolk-sac larvae, post-larvae
Scaled sardine	Egg, yolk-sac larvae, post-larvae
Tidewater silverside	Egg, yolk-sac larvae, post-larvae
Stone crab (Xanthids)	Zoeal stages, megalops
Pink shrimp	Post larval stages
American oyster	Larvae
Blue crab	All life stages

Due to the difficulty in identifying live crab zoea, no attempt will be made to sort and hold zoea by species. Rather, zoea will be held as groups and identified at the completion of the survival studies. It is hoped that stone crab zoea will be in great enough abundance to yield meaningful survival data when sorted from other Xanthid species.

Other species may be held as well if space and manpower are available. However, the RIS species/life stages will always take priority over others. The decision to include or exclude in the study any species not listed above will be made on the basis of abundance and available time.

6.2.3 Laboratory Facilities

Stone & Webster Engineering Corporation (S&W) will collect samples from the prototype screen in accordance with the previously described schedule. A subcontractor will supply and operate an adjacent land-based laboratory facility for holding test organisms as part of latent mortality studies. The facility will be designed to:

1. Permit sorting, counting, identification, and determination of initial mortality of planktonic organisms.

2. Hold selected organisms for up to 96 hr to determine latent mortality.

The laboratory facilities will be set up and operated primarily by the field contractor with assistance from S&W. The final details of the organism-holding facility design will depend upon the outcome of the preliminary studies discussed in Section 6.2.4.

Ambient filtered intake water will be supplied to the laboratory via a system of pumps, filters, and piping. A redundant water supply system will be installed as a backup in the event of a system failure. This water will either pass through the organism-holding containers (once-through) or serve as a water bath for maintaining ambient temperatures in a closed system. Initially, the system will be designed for a once-through flow.

Temperature will be monitored continuously. The water supply system will also incorporate provisions for easy cleaning and maintenance. All system components will be nontoxic and properly seasoned prior to use.

The organism-holding system will be designed to make maximum utilization of space, have easy access, and allow for the individual containment of many organisms. Provisions may be made for aerating these compartments.

S&W personnel will collect samples from the prototype screen and deliver them to the Contractor. The capacity of the holding facility will be sufficient to accommodate 96-hr mortality tests for up to 8 RIS life stages at one time. In addition, space will be available for concurrent holding of test organisms from the Preliminary Studies described below as well as control organisms to be used during all phases of the study program.

6.2.4 Preliminary Studies

The prototype screen evaluation will be conducted in three phases, as previously described. Prior to phased testing, a brief series of studies will be conducted which will supply essential data and guidance in finalizing laboratory design and procedures to be used during the study program (Phases 1 through 3). These Preliminary Studies are addressed below as three specific tasks:

> Task 1: Determine whether the RIS to be tested can be maintained in a closed (static), rather than an open (flow-through), holding system.
>
> The use of a closed holding system, in which organisms are held in solid containers, appears to offer many advantages over a flow-through system. These advantages include better control of disease, reduced handling mortality, and ease of enumeration. The ability of each species/life stage under consideration to survive in a closed system will be determined preliminarily through a literature survey and contacts with active researchers. If a closed system appears to be feasible, an experiment will be conducted which will involve holding each species/life stage under both open and closed conditions and comparing mortality over 96 hr. If the closed system yields equal or better results for the organisms tested, such a system will be utilized throughout the remainder of the study.

Task 2: Determine the feeding requirements of the species/life stages to be tested.

Feeding of a large number of different organisms is a cumbersome and time-consuming task. Further, the presence of uneaten food and fecal matter contributes to the deterioration of water quality in holding containers. If feeding could be reduced without affecting the survival potential of the test organisms, manpower requirements would be reduced and water quality would be more easily maintained.

Prior to Phase 1, information will be gathered from the literature and other researchers relative to the feeding requirements of test organisms while they are being held for 96-hr mortality observations. If available information does not provide a definite answer, a brief study will be conducted in which mortality among fed and unfed test organisms will be closely monitored and compared. It is hoped that the study will provide sufficient data to determine the feeding requirements of the test organisms.

Since it will not be known to what extent feeding will be required until testing actually begins, feeding strategy and necessary equipment will be completely available prior to Phase 1.

Task 3: Develop criteria for survival for each species/life stage.

Results of 1979 FMS studies at Big Bend indicate that there is a need to clearly define survival criteria for the test organisms, particularly for zoea and fish eggs. Therefore, prior to Phase 1, a literature review and discussions with other researchers will be conducted, and the information obtained will serve as the basis for selecting survival criteria.

Data obtained from these three tasks will be used in finalizing methodologies to be used during the regular testing program. Therefore, it is not possible at this time to develop a detailed study plan. It is possible, however, to describe general prototype screen sampling and laboratory methodologies for determining latent mortality among test organisms collected from the screen, as described below.

6.2.5 Regular Testing Program

The primary objective of the FMS study will be to determine the survival of the RIS following impingement and removal from the prototype screen. Two primary variables which should affect mortality are velocity of the flow entering the screen and screen travel speed, which determines impingement duration. During the study, organisms will be collected from the screen at several velocities and travel speeds. Velocities have been tentatively identified as 0.5 and 1.0 fps; screen travel speeds of 7, 14, and 28 fpm will be studied initially. These design points were selected on the basis of the 1979 study results (Section 5) as well as engineering considerations relating to operation and maintenance requirements and costs. Other variables which may affect organism survival are addressed below.

While final methodologies have not been developed for screen testing and latent mortality studies, the following is an example of anticipated sampling procedures.

Prior to sampling, the bow thruster pump and screen (Figure 6-3) will be set at the desired operating point for the specific test being conducted. The low-pressure spraywashes will be preset at the proper pressure and then shut off until the sample is taken. Once the screen is in full operation and the movement of water and organisms through the test facility is in steady-state, sampling will begin by turning on the low-pressure sprays, allowing the contents of the screen baskets to be rinsed into a collection trough for a predetermined period of time, and then shutting off the sprays. The duration of spraywashing will differ for each water velocity/screen travel speed condition and will be set such that at each condition, the total volume of water sampled by the prototype screen is equivalent.

Organisms washed into the collection trough will be carried into a primary collection area (Figure 6-2). In this area, large debris (leaves, shells, ctenophores) will be removed as the area drains. Once the water level reaches el + 9 ft-6 in., the sample will be concentrated to the point where it can be drawn down into a secondary collection and transport container. The drawdown will be slow and gentle to avoid turbulence in the drain line and container.

Once the sample has been completely transferred, the container will be sealed and transported to the land-based laboratory for sorting and latent effects studies.

At the time of each sample, the following information (as a minimum) will be recorded: date; time; air temperature; water temperature of the intake, screen sluiceway, and collection areas; tidal stage and measured height; wind direction and velocity; dissolved oxygen of intake and collection area water; screen travel speed; screen flow velocity (nominal); pump rpm; location and pressures of all sprays in operation during the collection period; any unusual sampling problems which occurred; and any other information which is deemed important.

The procedures for processing a screenwash sample from time of entry into the laboratory to the end of the latent-effects holding period have not been firmly established. A preliminary indication of anticipated procedure follows:

1. Place transport container(s) in a water bath and record temperature immediately.

2. When RIS are abundant, stir or agitate sample to obtain a homogeneous distribution of organisms and draw off volumetric subsample.

3. Maintain primary sample in water bath with aeration or water flow and hold for later processing.

4. Immediately begin sorting subsample, in a water bath, into species/life stages, concentrating on RIS species first.

5. Individuals of each species/life stage should be placed in a separate container for transfer to the holding area; organisms will be sorted to the lowest taxonomic level possible without delaying initiation of holding or adding incremental stress to the test organisms.

6. Once 30 organisms of a species/life stage have been counted and recorded, transfer them immediately to holding container; this "lot" of 30 organisms will represent one sample for the latent-effects study of that species/life stage.

7. If "stunned" organisms occur in the subsample, they will be treated in the same manner as the live organisms, but will be held as a separate, additional, latent-effects sample.

8. Continue sorting until samples of all RIS life stages have been placed in holding containers; the location of all organisms must be carefully documented.

9. Sort the remainder of the subsample by species, recording numbers of live, stunned, and dead organisms on data sheets. (These data will be used to determine "initial survival.")

10. If the primary sample is no longer needed, it will be preserved for later analysis.

11. Check all organisms now in the holding facility at 3, 6, 12, 18, 24, 36, 48, 60, 72, 84, and 96 hr; record number live and dead at each check, as well as any abnormal occurrences (e.g., missing organisms).

12. Preserve all organisms which die during the holding period in labeled vials.

13. At the completion of the holding period, record final number, live and dead, and preserve each in a labeled vial.

14. Water quality parameters will be recorded frequently during all holding experiments and will include, as a minimum, salinity, conductivity, temperature, dissolved oxygen, pH, and ammonia.

15. At the end of each latent-effects test, all vials will be rechecked and all organisms will be identified (to species, if possible), categorized to life stage, measured, and counted.

These procedures are preliminary and are subject to change in the interest of improving data quality or reducing manpower requirements.

In addition to the above sample analysis, attempts will be made to collect, sort, and hold control organisms. These control organisms will be collected with a minimum of sampling-induced stress using techniques such as light trays, plankton nets, or other gear. The controls will consist of the

same species and number of individuals as held in the regular screen sample testing and also will be sorted, held, and analyzed in the same fashion. Control organisms will be collected no more than 12 hr prior to initiating holding.

Once the Contractor has established approved techniques for collecting and handling control organisms, a regular interval for holding controls will begin. During Phases 1 and 2, two replicate controls for each available species life stage will be held, beginning each fourth sampling day. During Phase 3, two replicate controls for each available species life stage will be held on Monday and on Friday of the week of screen sampling.

As previously discussed, the regular testing program is divided into three phases. The duration of each sampling period will vary by phase. The proposed sampling durations are shown on Figure 6-4. The breakdown of samples per day for each phase is as follows:

Phase	Maximum No. Samples/Day	Total No. of Sampling Days	Total No. Samples
1	6	20	120
2	6	30	180
3	6	20	120
TOTAL			420

In addition to the above prototype screen samples, sampling efforts are planned, as defined below:

1. Prototype Screening Efficiency

   To determine the efficiency of the prototype screen in preventing the passage of organisms either through the 0.5-mm mesh or various sealed areas in the screen assembly, samples of the screened water will be taken. Samples will be preserved and processed in the laboratory. Laboratory analysis will consist of enumeration, identification to species or lowest feasible taxonomic level, determination of life stage, and size measurements.

   Six samples will be collected (over a 2-day period) in a 250-μ-mesh plankton net during Phase 1 of the study. Results obtained will be used to establish a suitable intensity of sampling for Phases 2 and 3 of the study. The Phase 1 samples will be processed immediately after collection and the data will be examined to determine whether major "leaks" exist in the screening assembly which must be found and filled prior to resumption of testing. Once the screen is operating as designed (i.e., filtering to the level expected with a 0.5-mm mesh), subsequent efficiency test data will be taken and analyzed to determine the species/life stages which are not effectively collected by the screen and would therefore still be subject to entrainment at Big Bend Station.

2. Spraywash Efficiency

Since the spraywash system being incorporated into the prototype screen is a new design, the efficiency of the system in washing organisms into the collection will be investigated. Samples will be collected in a 500-μ plankton net and preserved for analysis by the Contractor. Laboratory analysis will consist of enumeration, identification to species or lowest feasible taxonomic level, determination of life stage, and size measurements.

Six samples will be collected (over a 2-day period) during the preliminary shakedown phase of the study. Results from these samples will be used to establish the intensity of sampling in Phases 2 and 3. The samples in Phase 1 will be analyzed immediately after collection. Subsequent spraywash efficiency sampling can not be defined. However, sufficient sampling will be conducted over the study period to verify that little or no loss of RIS organisms occurs in the high-pressure debris spray.

3. Determine Ability of RIS to Survive Exposure to Air

Past studies have shown that some organisms, particularly in their early life stages, are very sensitive to air exposure. Since the prototype screen has the potential for exposing impinged organisms to the air for short periods of time (several minutes), it is desirable to determine how this additional stress factor might influence overall mortality resulting from collection and removal from the FMS. Accordingly, early in Phase 1 a study will be conducted in the laboratory in which available RIS life stages will be exposed to the air for up to 3 minutes and then held for observation of latent mortality. Past research at Big Bend indicates that Anchoa mitchilli may be particularly sensitive to air exposure. Since the anchovy is the most abundant ichthyoplankton at Big Bend, emphasis will be placed on testing this species.

Testing will consist of placing small lots of organisms in holding containers with screened bottoms, lifting the containers out of the water for different periods of time (from 10 sec to 3 minutes), returning them to water, and monitoring mortality for 96 hr.

The data obtained from this study effort will be used to determine the need for an additional low-pressure spraywash. To minimize air exposure, the wash would be located at a point just above mean high water and would be designed to rinse impinged (exposed) organisms from the screen mesh into the water-filled lifting bucket. In this way, the organisms would now remain in water while traveling upward to the spraywash located at operating deck elevation.

4. Plankton Net Sampling

Plankton net samples will be collected adjacent to the prototype screen structure during the Phase 2 and Phase 3 screen testing program. These data will be used to compare the relative meroplankton impingement rates at the various screen test conditions with the abundance of meroplankton organisms measured in the immediate vicinity of the prototype structure. Samples will be collected using the same techniques used in the 1979 meroplankton study. Four replicate samples will be collected on one day during each week of screen sampling. Collections will be made between the 0.5-fps and 1.0-fps sampling with the prototype. Samples will be preserved for future processing. Laboratory analysis for RIS will consist of enumeration, identification to species or lowest feasible taxonomic level, determination of life stage, and size measurement (fish larvae only).

6.2.6 Statistical Analysis

Results of the 1980 study will undergo statistical analyses similar to the 1979 Preliminary Studies. The primary objective of the 1980 study is to estimate the initial and latent impingement survival of the RIS; therefore, the analysis will focus on parameter estimation.

Variables will be tested for their significance in explaining variation in the survival of test organisms. At present, the potential explanatory variables can be classified as describing the age and condition of the organisms or as describing the conditions of screen operation. A discussion of the variables which will be monitored in the 1980 study is found in Section 6.2.5.

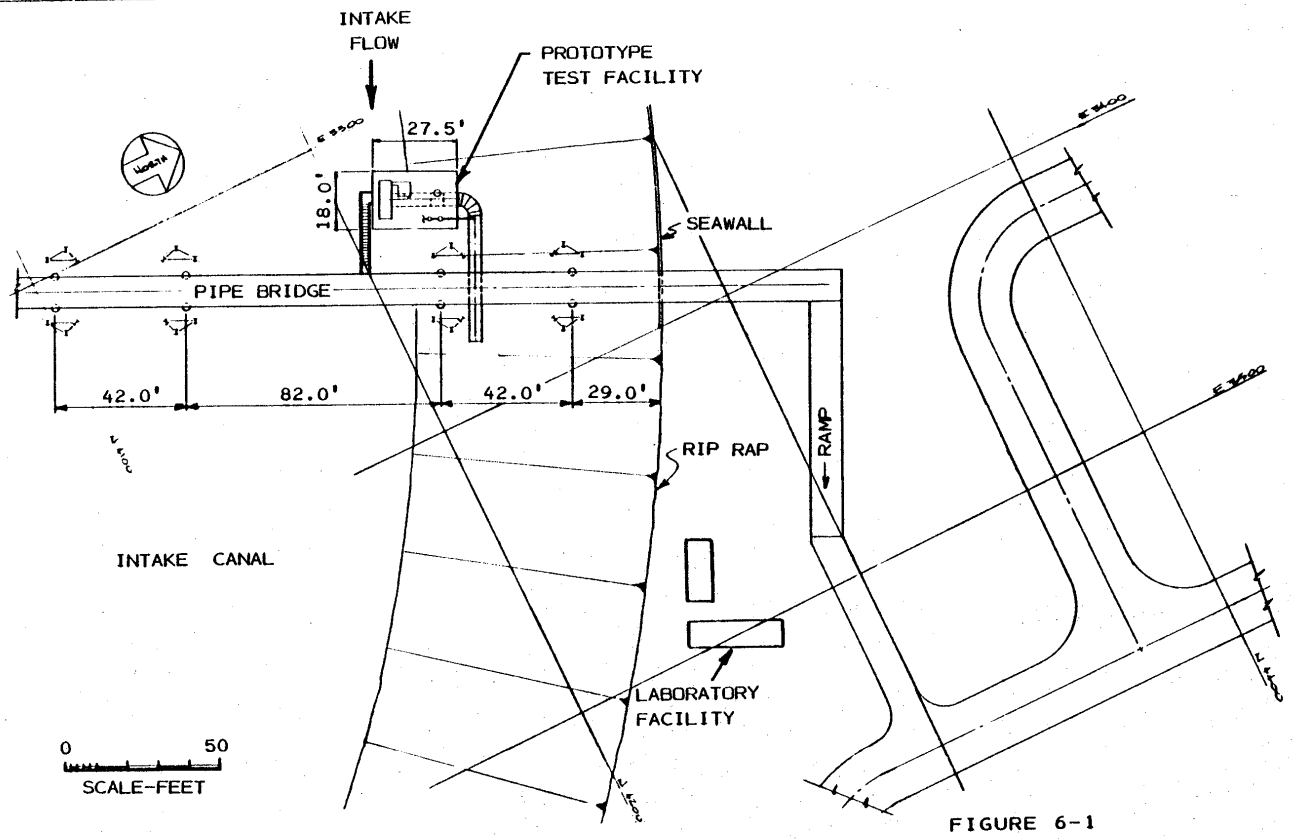


FIGURE 6-1

SITE PLAN
FINE MESH SCREEN PROTOTYPE

BIG BEND STATION
TAMPA ELECTRIC COMPANY

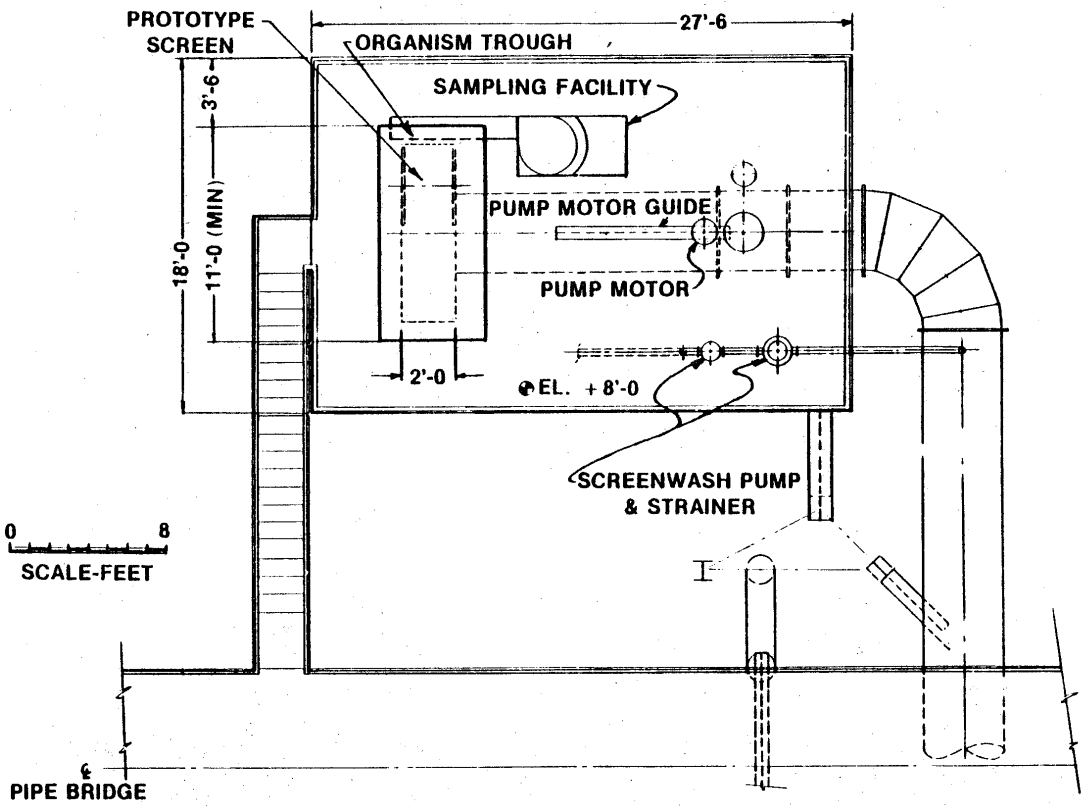


FIGURE 6-2

DECK ARRANGEMENT-
FINE MESH SCREEN PROTOTYPE

BIG BEND POWER STATION
TAMPA ELECTRIC COMPANY

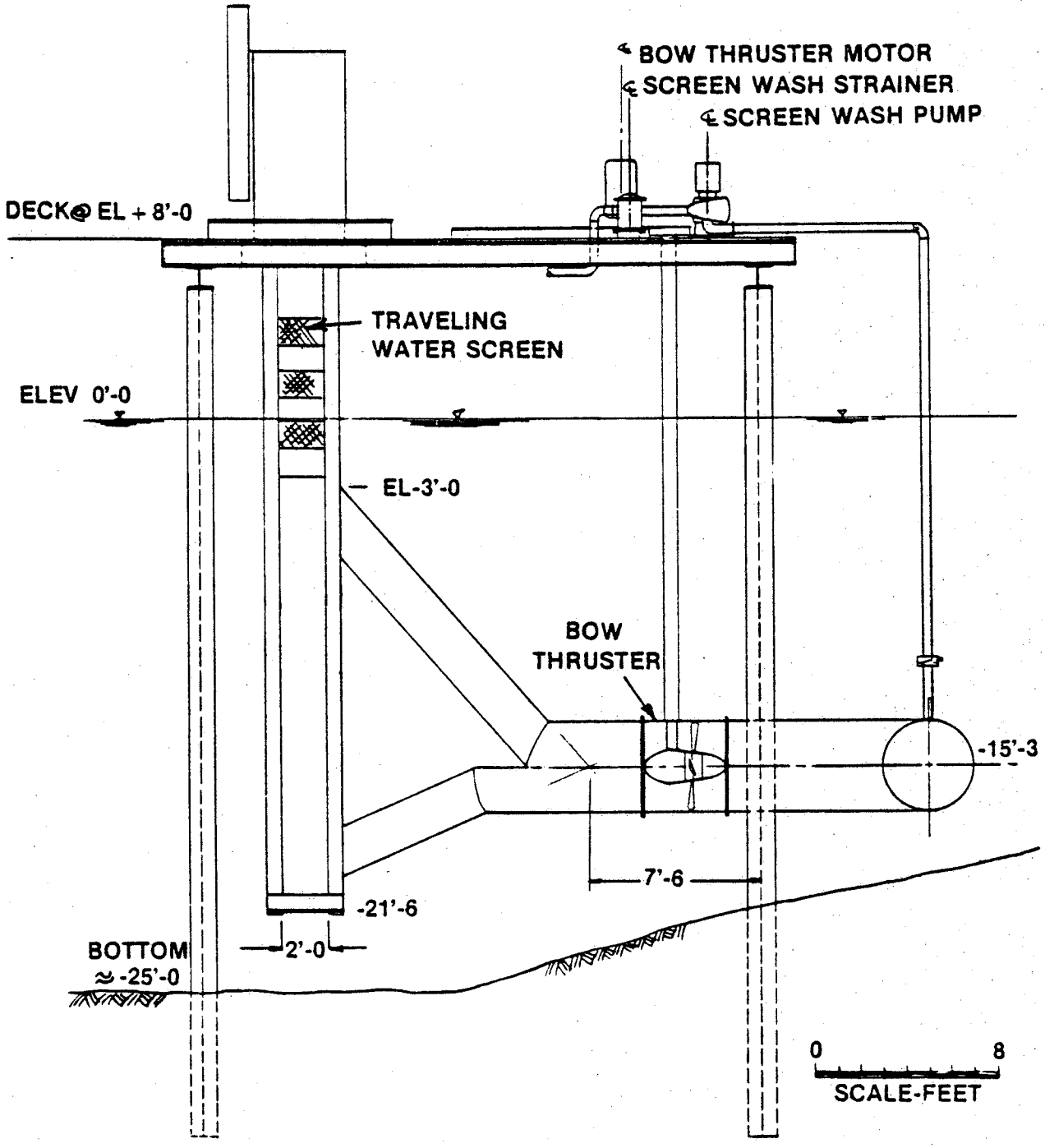
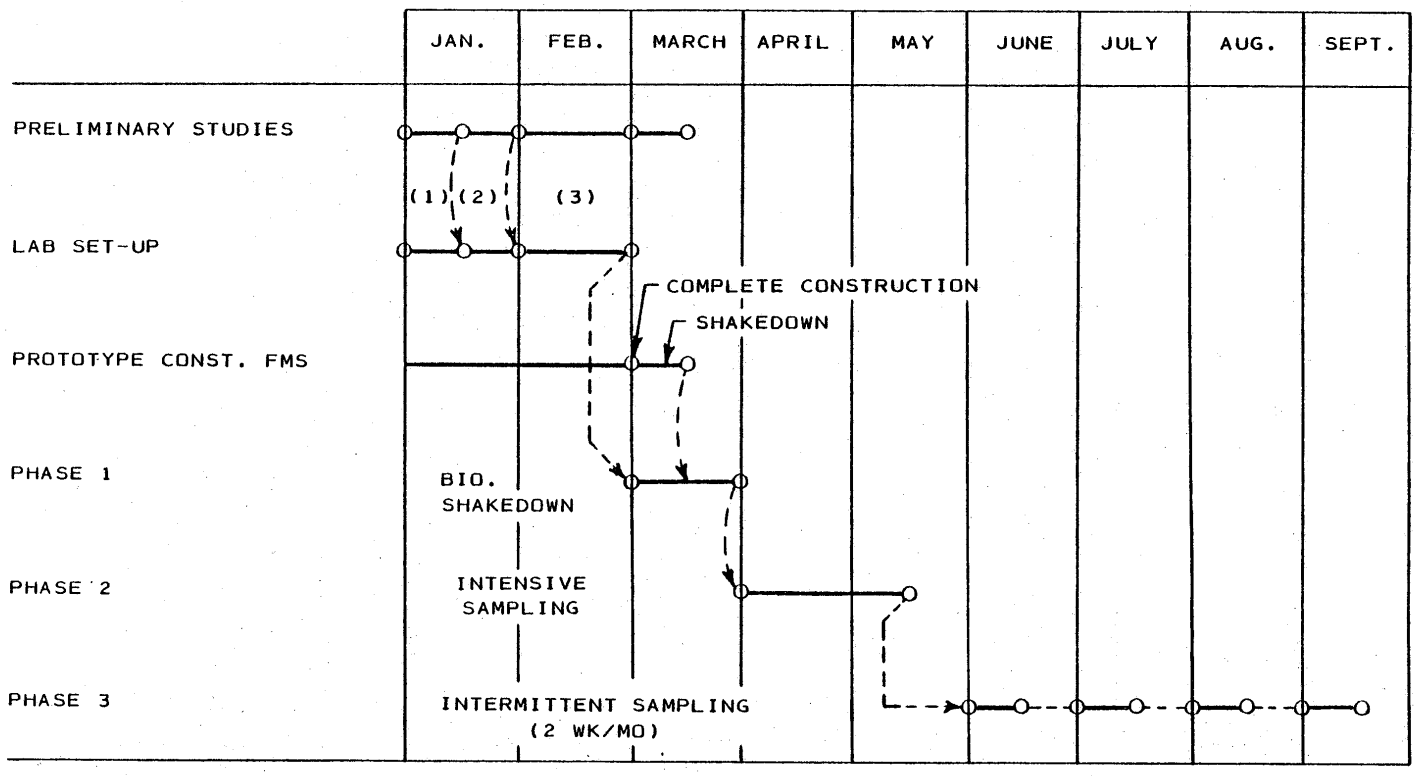


FIGURE 6-3

PROFILE ARRANGEMENT-
FINE-MESH SCREEN PROTOTYPE

BIG BEND STATION
TAMPA ELECTRIC COMPANY



(1) PRELIMINARY LAB DESIGN
(2) FINALIZE LAB DESIGN
(3) LAB CONSTRUCTION

FIGURE 6-4

SCHEDULE - PROTOTYPE
FINE-MESH SCREEN STUDY

BIG BEND STATION
TAMPA ELECTRIC COMPANY

SECTION 7

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APPENDIX

STONE & WEBSTER ENGINEERING CORP.

APPENDIX A

FINAL REPORT

FINE MESH SCREEN STUDIES

January 1980

LMSE-80/0031&389/002

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CHAPTER 1.0

INTRODUCTION

Lawler, Matusky & Skelly Engineers (LMS) participated in an environmental study conducted by Stone & Webster Engineering Corporation (S&W) at the Big Bend Power Station, Tampa Electric Company, during the summer and early fall of 1979. The purpose of the study was to determine the benefit of removing meroplanktonic organisms from cooling waters before passage through both condenser tubing and heated discharge water, using fine mesh screening and then returning the organisms to Tampa Bay.

The Fine Mesh Screen (FMS) studies involved two routes of investigation: the Six-Panel Screen Study and the Impingement Flume Study. The purpose of this report is to describe field and laboratory procedures used in conjunction with these Fine Mesh Screen studies.

For the Six-Panel Screen Study, meroplankton were collected by S&W from six traveling screen panels which had been retrofitted with 500 m nylon mesh; organisms were delivered to the LMS facility and selected groups were isolated and held for a specified time interval to determine impingement mortality. Laboratory procedures for this study are described in Sections 3.2.1.1 and 3.2.2.1 of this report. For the Impingement Flume Study, S&W constructed and operated an impingement flume, wherein selected groups of meroplankton, supplied by LMS, could be impinged on 500 m nylon mesh at specific water velocities and for selected impingement durations. LMS collected organisms to be impinged and delivered them to S&W for flume testing. After impingement testing was completed, LMS held the organisms recovered from the flume for specified time intervals to determine immediate and latent impingement mortality. Laboratory

procedures for Impingement Flume Studies are reviewed in Sections 3.2.2.2 and 3.2.1.2 of this report. In both studies LMS provided the original validated data sheets to S&W for subsequent analysis of impingement mortality.

Initial experimental design for both studies called for the use of bay anchovy (eggs, yolk-sac larvae, and postlarvae), sciaenid larvae and stone crab larvae (zoeal stages only). Due to the irregular occurrence of all the above forms, subtitutions were made with zoeal stages of other crabs, eggs and larvae of any species of fish collected, and shrimp. The organisms for impingement studies were collected by running the LMS plankton collecting device (larval table) in an "open-nose" mode (Section 2.2, see also LMS 1980) or by using the larval trap (Section 2.3).

CHAPTER 2.0

TEST ORGANISM SAMPLING GEAR AND PROCEDURES

2.1 INTRODUCTION

The objective of the Fine Mesh Screen-Impingement Flume Study required that fish and crab larvae be collected with minimum damage for the Impingement Flume Study. Most planktonic organisms have classically been collected using large nets towed at low velocity to minimize damage to the organisms. Mortality for striped bass (Morone saxatilis) caused by various collection methods has been evaluated by McGroddy and Wyman (1977) and by O'Connor and Schaffer (1977). Mortality for other species has been evaluated by Cada and Hergenrader (1978).

All of these researchers reported that when nets were used to collect organisms, mortality increased with increasing water velocity through the net during the collection. McGroddy and Wyman (1977) have shown that it is feasible to use a larval table to reduce collection mortality. A form of this device was employed to collect the organisms used to evaluate the mortality associated with the operation of the Big Bend Dilution Pump in the Dilution Pump Viability Study (LMS 1980). When the device was not being used for DPVS, it was used to collect organisms for the Fine Mesh Screen Study. In addition to the larval table, a light trap was constructed so as to use the positive phototropic response of fish larvae to concentrate them in a confined space.

2.2 DESIGN AND USE OF LARVAL TABLE

The larval table was designed to have the water enter at the nose, flow horizontally through the flume area, and be pumped from the

back. The larval table uses vertical screens to separate the main flow of water and divert the organisms to a collection area. Two vertical screens were chosen over the inclined screen alternative because of a history of heavy debris and ctenophores in the sampling area. The combination of horizontal flow and vertical screens enabled the quick visual monitoring of the debris load and screen clogging. The vertical screens could also be removed easily to change the screen mesh size or to replace damaged screens.

The table was designed to divert the organisms via a diversion flow into collection baskets which could be sampled either in batch or continuous mode. The latter mode was used for FMS collection. This required two collection baskets (I and II) and the ability to "shut" one basket off during removal and to divert the flow into the second basket. A system of gates was designed to enable this switch in collection baskets.

The collection baskets were designed to hold the organisms in a relatively quiet zone while the diversion flow was filtered and continuously removed. In addition, the baskets were designed to hold the collected organisms in a 10-liter water bath while they were being transported to the laboratory.

The continuous mode of operating the larval table was used for this study and involved the collection of a number of samples. Samples were collected by rotating the basket collections: while one basket was used to collect, the other was being prepared for the next collection interval. The table was not raised and drained until the end of basket collections, at which time a "drain sample" and a "washdown sample" were collected. All organisms collected were held for FMS Impingement Flume studies.

2.3 DESIGN AND USE OF THE LARVAL TRAP

A larval trap was built to collect fish larvae by attracting them to a light source at night. It was constructed of PVC tubing, in a 3 ft square by 10 inch deep pattern; the joints were cemented with PVC cement using right angle corners. The frame was covered with 505 μm mesh on the sides and bottom. Extra mesh was used to create a shallow cone in the bottom, which came to just below the top plane of the apparatus. Hardware cloth was fixed over a six-inch opening at the top of the cone to prevent larger organisms from entering.

Deployment of the trap took place at night when planktonic densities were higher. The device was tied in place to the larval table dock and buoyancy maintained with styrofoam side floats. The collection began when a light was directed over the trap. An exterior cover of black plastic on the bottom attracted the organisms toward the cone opening. Organisms that swam into the trap could not escape. After several hours of collection, organisms were concentrated in a bucket and taken to the laboratory for processing.

CHAPTER 3.0

LABORATORY EQUIPMENT AND PROCEDURES

3.1 THE HOLDING FACILITY

3.1.1 Requirements

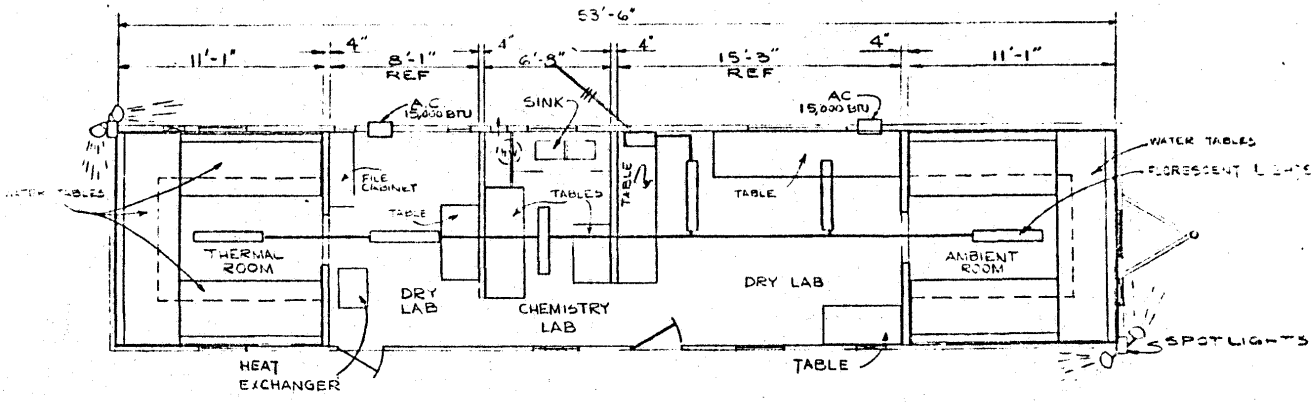
The holding facility provided sufficient space for experiments at ambient water temperatures to be conducted in flow-through systems with fish eggs and larvae, crab zoea, and other organisms as required. A small chemistry laboratory with sufficient equipment to measure ammonia-nitrogen, salinity, dissolved oxygen, temperature, and pH was also available. Organisms brought into the laboratory were to be sorted from detritus, initially into live and dead classifications, before being held in flow-through aquaria for a specified number of hours. A portion of the space in LMS' 55 x 12 ft house trailer (Figure 3.0-1), originally constructed for the Dilution Pump Viability Study, was used for Fine Mesh Screen (FMS) studies. An ambient temperature room with flowing seawater, an elevated temperature room with both flowing ambient and heated seawater (used only for the Dilution Pump Viability Study), a chemistry laboratory capable of measuring the above parameters, and areas for sample sorting, observation and storage were provided. These areas used for FMS investigations are described in the following sections.

3.1.2 The Ambient Room

The ambient temperature room was designed to provide space for sorting samples preparatory to placing organisms in various holding containers and for sufficient tank space to permit holding samples

FIGURE 3.0-1

INCUBATION
HOLDING FACILITY



FLOOR PLAN

at ambient water temperatures (±1°C). The ambient room was supplied with water from a dual seawater delivery system.

The dual seawater system was composed of identical pumps, deaeration containers, and filters feeding into a common inlet pipe which delivered water to the trailer. Water was drawn from behind the bar rack area of the dilution pump, and pumped into deaeration containers through sand filters. Before the water entered the deaeration containers it was forced through rayon or polyester bags which effectively filtered the water of particles larger than approximately 15 μm. Deaeration containers were necessary because preliminary experience showed that air could occur in the lines, thereby interrupting a sustained flow of water to the trailer. Water was delivered to each of the tanks in the upper and lower row of the ambient room's water tables via petcocks fitted with PVC tubing.

The maximum holding capacity for organisms in the ambient room was as follows:

Upper water table row	- 18 tanks x 14 cups/tank =	252 cups
Lower water table row	- 13 tanks x 15 cups/tank =	195 cups
Lower row	- egg cups, total	144

Therefore, 591 samples could be held at any one time in the ambient room.

3.1.3 Chemistry Laboratory

The chemistry laboratory (Figure 3.0-1) in the holding facility was designed and equipped for measurement of routine water quality parameters including temperature, dissolved oxygen, salinity, pH, and ammonia-nitrogen. For these purposes the laboratory was supplied with the following instruments:

1. Corning Model 130 specific ion meter fitted with a Corning® pH electrode, a Corning® reference electrode, and an automatic temperature compensator
2. American Optical hand-held refractometer equipped with a special scale for measurement of salinity
3. YSI Model 57 dissolved oxygen meter with a depth-compensated dissolved oxygen probe
4. Orion ammonia-nitrogen probe used in conjunction with the Corning Model 130 specific ion meter
5. Thermometers, including certified thermometers to calibrate those used routinely
6. Refrigerator, for storage of certain chemical supplies.

The chemistry laboratory stock also included all the equipment and supplies required for routine calibration of the instruments (such as pH buffers and supplies for modified Winkler titrations) as specified in the Quality Assurance Program and DPVS Workplans.

3.1.4 Sample Sorting/Observation Areas

To facilitate sample handling during the initial live sorting, observation, and analysis periods, the holding facility was equipped with laboratory benches, flowing seawater, water tables, microscopes, and various types of illuminators, including those with built-in magnifiers.

The sorting area for live samples was located in the ambient room (Figure 3.0-1) where flowing seawater at $\pm$1.0°C from ambient temperature was available to maintain the organisms at the conditions measured during collection. In addition to the ceiling lights, this area was equipped with fluorescent lighting directly over the lower level of the water tables to facilitate picking the live organisms from the samples. Sufficient space was available in the ambient

room for up to fou ians toany one time. In addition, this area went to dry laboratory of the holding facility (10-1) whicroscopes were housed. This was important it wascessary to check a live sample under the m, eithefy initial counts or to be certain that al requirems had been picked from the sample.

The main dry laborjacent bient room) and another small area adjacen thermaigure 3.0-1) were designated for perfor periodations during the viability studies and sortingtification of preserved samples. Having ate obsareas, one adjacent to each wet laborato:d miniitransportation of live organisms from one f the hility to another. This was especially hel experi being conducted simultaneously in both id ambie

The main dry lab ad thrte benches where technicians could worlwo werey used for picking and observations) and er areangle bench. Sufficient bench space was avi the lafor approximately eight technicians. The laborato the thermal room also contained a file ich wa: storage of data, data sheets, and sampl The of the holding facility exceeded the numbole thair assigned to a single shift.

The equipment assiese twcluded:

1 Wild M5A dinicroscostandard base and transmincidention

1 Wild M3 disicroscopwing arm stand and ts illum

2 Bausch and Lomb stereozoom microscopes with swing arm stands and Nicol illuminators

1 Olympus compound microscope

4 Illuminated magnifiers.

Other equipment and supplies used for picking preserved samples and performing periodic observations during viability studies, such as dissecting kits, pipettes, picking trays, culture bowls, petri dishes, and auxiliary lights were also available in these two areas. It should be noted here that all supplies used with the formalin preserved samples were so labeled and kept separated from the supplies used in conjunction with the live samples.

Additional storage areas for preserved samples and data were located just outside the ambient room above and below one of the three workbenches. Clipboards hanging on the walls just outside the ambient lab were provided to hold the data sheets being used for the experiments in progress. There were separate clipboards for each tank, making the data easily accessible for the routine observations.

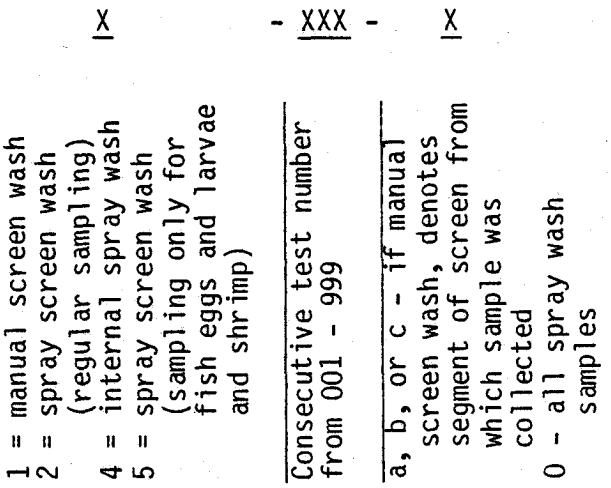
The main dry laboratory was also used for the culture of food organisms to feed the fish larvae and crustaceans. A small bench was set up next to the window for maintenance of Artemia cultures and, initially, for rotifer cultures (these were not needed because the fish larvae collected were large enough to eat Artemia nauplii and zooplankton collected in the field). Specific culture procedures are detailed in the DPVS Workplans.

3.2 LABORATORY PROCEDURES

3.2.1 Initial Sample Processing

3.2.1.1 Six-Panel Retrofit Studies. Samples for the six-panel retrofit studies were collected by, and delivered to the LMS holding

facility in plastic buckets by S&W. Sample code numbers were assigned by S&W as follows:



Generally, two series of samples were collected during each day when sampling occurred. A single series consisted of either two spray screen wash samples (sample code = 2) and one manual screen wash sample (a, b, and c portions were delivered in separate buckets) for a total of five buckets, or of three spray screen wash samples (two samples were code 5, one sample was code 2) for a total of three buckets. Occasionally, two manual screen wash samples (six buckets) were delivered when the spray wash apparatus was not operational. In one instance, three internal spray wash samples (sample code = 4) were delivered.

Samples were collected during one high and one low tide per day beginning with the week of 10 September 1979, both sets of samples were collected in the early morning since previous data indicated greater abundances of organisms during pre-dawn hours. The early morning schedule persisted for the duration of the study.

3.2.1.2 Impingement Flume Studies.

3.2.1.2.1 Sorting organisms for impingement flume studies. Organisms collected with the larval trap or larval table were sorted in a flowing water bath at ambient temperatures and were placed in appropriate containers as follows:

1. Fish larvae - up to 15 individuals in a 4-inch PVC holding container
2. Zoea - 50 individuals in an egg cup
3. Shrimp - up to 25 individuals in a 4-inch PVC holding container.

The organisms in the container were placed in upper level tanks in the ambient room until flume testing occurred. A tank log was prepared for each tank; the cup number, organism type and life stage, number of organisms held, and collection source were listed. Organisms were fed and a record was kept of any dead organisms removed to facilitate replacement and avoid unnecessary handling of specimens.

Inventory numbers were assigned by S&W at the time of testing. All inventory numbers began with a number "3" and were followed by three digits indicating the sample number. An "L" or an "F" following the sample number indicated whether the sample was a laboratory or flume control.

Organisms used for testing were removed from a tank in their original holding container and given to S&W, who was responsible for impinging the test organisms and returning those collected after impingement to the LMS holding facility for determination of initial and latent mortality. LMS then provided validated data sheets to S&W for subsequent analysis of impingement mortality.

3.2.2 Sample Sorting

3.2.2.1 Six-Panel Retrofit.

3.2.2.1.1 Sorting live samples. Samples were sorted soon after collection to determine the number of live and dead individuals of selected taxa and to obtain organisms for viability testing. The samples were sorted differently depending on their numerical designations. Manual wash samples beginning with the number "1" and spray wash samples beginning with the number "2" were sorted for live/dead determinations of zoea, fish eggs, and fish larvae. Shrimp were sorted for viability testing if they were abundant, and qualitative estimates of the number live and dead were made, but an actual live/dead count was not performed. Spray wash samples having a "5" designation were processed for live/dead determinations on fish eggs and fish larvae. If abundant, live shrimp were separated for viability testing, but no crab zoea were sorted from these samples. Samples with a "4" designation (internal wash) were not sorted for live organisms and the entire sample was preserved.

The specific procedures follow:

1. As soon as the samples were delivered, a field label containing the following information was placed in each bucket: sample number, date and time, location (TECO BIG BEND), sample type (manual or spray wash), temperature, and collectors.

2. The entire sample was quickly examined for fish larvae which were removed immediately to prevent them from becoming

entangled in the detritus. A maximum of ten larvae were placed in a 4-inch PVC container; up to three containers (30 larvae) were utilized per sample.

3. If a sample was a "1" or a "2" designation, it was split for live/dead determination of zoea and fish eggs using one of the two methods described below:

   - The sample volume was adjusted to a known amount (example: 5 liters), and a measured aliquot (i.e., 500 ml) was removed from a well mixed sample.
   - A measured aliquot was removed from the well mixed sample and the total sample volume was measured at the end of the sorting period.

   In either case, the percent of the sample analyzed was determined from the ratio of the volume analyzed to the total volume of the sample, and the results were recorded on the viability data sheets and on the preserved sample labels.

4. To maintain ambient temperature conditions, all sorting was done in a flowing water bath. The aliquot analyzed was placed in a culture bowl in the flowing water bath and a light was used to attract zoea which were then removed with a pipette. All fish eggs were removed. In some cases, newly hatched yolk-sac fish larvae were found when sorting for eggs. These organisms were believed to have hatched during the sorting period and were separated for viability analysis from the split portion of the sample only (the same aliquot analyzed for eggs and zoea). Three aliquots of ten organisms each for zoea, fish eggs, and yolk-sac larvae were placed in egg cups for viability testing and the remaining organisms were preserved as initial live. Shrimp were

sorted in the same manner, except that no effort was made to separate more live shrimp than those required for viability testing. In cases where the minimum number of 30 live individuals was not recovered from the initial split, additional aliquots were analyzed. Since live fish eggs are difficult to pick (they are clear and buoyant), a determination of the time to be spent on each sample was made. Biological factors (hatching of the eggs and mortality of both eggs and newly hatched larvae during the sorting period) and cost efficiency were considered in making these decisions.

5. The organisms which were sorted into containers for viability testing were placed in the designated test tank with flowing ambient water. A data sheet for each container was filled out with the following information: date and time of collection, sample type, sample number, organism type and life stage (if applicable), percent of sample analyzed, investigator, tank temperature, number of organisms in the container, tank and container number, and time container was placed in the test tank (see Tables 3.0-1 and 3.0-2). A tank log and a schedule for completing periodic observations were also filled out at this time.

6. After live sorting was completed, the samples were preserved in three separate containers labeled as follows:

   - Initial live - included all selected taxa from the analyzed portion of the sample which were alive at the time of collection, but were in excess of the 30 individuals used for viability testing.
   - Initial dead - contained dead organisms and detritus from the split portion of the sample.
   - Remaining portion of the sample not analyzed for live zoea or fish eggs.

TABLE 3.0-1

Page 1 of ___

TECO LARVAL DATA — FINE MESH SCREEN STUDY — 6-panel Screen — J.O. No. 12408.04

Date: _____
Time: _____
Test: _____
Sample No: _____

Ambient Temp: _____

Species group: _____
Size/Life stage: _____
% of sample analyzed: _____
Investigator(s): _____

Temp. (°C)	Technician	Time	Species / Life Stage	Total Spp. / All stages				Others	Comments
			Initial live						
			Number stunned						
			Initial dead						
			3-hr						
			6-hr						
			12-hr						
			24-hr						
			48-hr						
			72-hr						
			96 hr.						
			Total dead						
			Final live						
			Total Analyzed						
			Percent mortality						

Comments: _____

TABLE 3.0-2

TECO EGG DATA

FINE MESH SCREEN STUDY
6-panel Screen

J.O. No. 12408.04

Date: _____
Time: _____
Test: _____
Sample No: _____

Ambient Temp: _____

Species group: _____

% of sample analyzed: _____
Investigator(s): _____

Temp. (°C)	Technician	Time	Species	Total Spp.					Others
			Initial live						
			Initial dead						
			3-hr	*					
			6-hr						
			12-hr						
			24-hr						
			48-hr						
			72-hr						
			96-hr						
			Total dead						
			Total abnorm.						
			Total hatched						
			Final unhatched						
			Total analyzed						
			Percent mortality						

*Record as: No. dead / No. hatched normal / No. hatched abnormal

Comments: _____

Each vial or jar was labeled with the sample number, sample designation (i.e., initial live), percent of sample analyzed, and date. Preserved samples were logged by sample inventory number in the "preserved samples" notebook.

3.2.2.1.2 Sorting preserved (initial dead) samples.

3.2.2.1.2.1 General procedures. To facilitate sorting of selected taxa from the detritus and other matter, all samples (except initial live zoea which were picked while live) were stained with rose bengal stain. Use of this procedure has been shown to significantly increase recovery of organisms and to reduce sorting time (Mitterer and Pearson 1977).

Stained samples were poured from the Ball® jar or initial dead vial into a #60 standard sieve and rinsed gently with tap water to remove the formalin. The field label in the jar was also rinsed to remove any organisms that may have adhered. The rinsed sample was washed into a rectangular Pyrex® pan with tap water making sure that all organisms were removed from the sieve. With an unaided eye, all selected taxa were separated from the detritus and other organisms, and placed in appropriately labeled vials. After all readily visible organisms were removed, small aliquots were taken from the Pyrex® pan, placed in a small finger bowl, and examined under the microscope for additional organisms. During the entire procedure, an accurate record of the number of organisms picked was maintained; these data were recorded in the preserved sample log (Table 3.0-3). All vials were labeled, both inside and on top, with the sample number, taxon, number of individuals found, sample type (initial dead, initial live, or Quality Control-QC), and percent of original sample analyzed.

TABLE 3.0-3

FINE MESH SCREEN SAMPLES

SAMPLE No.	DATE OF SAMPLE	2 ORGANISM	3 No. FOUND	% OF SAMPLE PICKED	5 INITIALS	DATE COMPLETED	7 COMMENTS
1		ZOEA					
2		FISH LARVAE					
3		FISH EGGS					
4		FISH EGGS					
5		OTHERS					
6							
7		ZOEA					
8		FISH LARVAE					
9		FISH EGGS					
10		FISH EGGS					
11		OTHERS					
12							
13		ZOEA					
14		FISH LARVAE					
15		FISH EGGS					
16		FISH EGGS					
17		OTHERS					
18							
19		ZOEA					
20		FISH LARVAE					
21		FISH EGGS					
22		FISH EGGS					
23		OTHERS					
24							
25		ZOEA					
26		FISH LARVAE					
27		FISH EGGS					
28		FISH EGGS					
29		OTHERS					
30							
31							

a) L - INITIAL LIVE, D - INITIAL DEAD.

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3.2.2.1.2.2 Specific procedures used for sorting preserved six-panel retrofit samples. For each six-panel retrofit sample, there were two to three containers of preserved organisms to sort for selected taxa. The initial dead vial or jar was picked for zoea, fish eggs, and larvae. These organisms came from the split portion of the live sample initially picked for viability studies. The initial live vial contained zoea which were live, but in excess of the requirements of the viability studies. Since this vial was sorted during the live sorting period, no further picking was required. The Ball® jar which contained initially dead fish larvae and a mixture of initially live and dead fish eggs and zoea (in addition to other organisms caught on the screens) was sorted for fish larvae and eggs only. All organisms were counted and placed in appropriately labeled vials as described in Section 3.2.2.1.2.1 - General Procedures. The data were recorded as described.

In analyzing the data, initial dead fish larvae came from the entire sample (sum of larvae found in the initial dead from the split portion of the sample and from the Ball® jar). The initial live and dead zoea and fish eggs came from the split portion of the sample only. Fish eggs, picked from the Ball® jar portion of the sample, represented a mixture of live and dead eggs since this portion of the sample was not analyzed during the live sorting period. Total fish eggs (both live and dead) in the sample equaled the sum of those in the initial dead vial and in the Ball® jar. There were no initial live fish eggs preserved separately as there were for zoea; all live fish eggs picked from the samples were tested for viability. In the cases where QC vials were analyzed, these data were added to the results of the appropriate initial pick vial to obtain the total number of organisms.

The relative efficiency of picking fish eggs while live, as opposed to picking when the eggs are preserved and stained, and

the resulting effect on live/dead estimates must be noted. As mentioned previously, pelagic marine fish eggs are generally clear (some have oil droplets and pigment) and are buoyant while live. They are generally small (<1 mm) and are very difficult to pick from a sample with 100% accuracy. On the other hand, dead preserved eggs are generally opaque and much easier to find. When preserved samples are stained, as was done during these studies, the eggs are even easier to see than unstained specimens, and 100% recovery is readily achieved by a trained technician. Since it is nearly impossible for even the trained eye to pick live pelagic fish eggs efficiently, and much easier to pick preserved stained ones, live/dead estimates from unstained pelagic fish eggs are not reliable and would tend to overestimate mortality.

3.2.2.2 Impingement Flume. The organisms recovered were returned by S&W to the holding facility, where sorting took place to determine the number recovered and the initial mortality. Those initial live in excess of the number held for viability testing and the initial dead organisms from each flume sample were preserved separately in labeled vials; the labels noted sample number, organism type, designation (live or dead), date, and the number of organisms placed in the vial. These data were also recorded on the viability data sheets along with tank and cup number, number of organisms placed in the cup, time, water temperature at collection, and investigator's initials. The preserved organisms were counted and identified at a later date.

Immediately upon receipt of a sample, the Coordinator had technicians pick out live organisms and assigned a sample inventory number (given by S&W) to the sample. The inventory number was recorded on the following data sheets immediately if data sheets had not been labeled in advance:

- TECO Larval Data Sheets (Table 3.0-4)
- TECO Egg Data Sheets (Table 3.0-5)
- Tank Log (Table 3.0-6)

TABLE 3.0-4

TECO
LARVAL DATA

FINE MESH SCREEN STUDY
Impingement Flume

J.O. No. 12408.04

Date: _____
Time: _____
Test: _____
Sample No: _____

Ambient Temp: _____
Flume Temp: _____

Species group: _____
Size/Life stage: _____

Investigator(s): _____

No. introduced: _____
No. recovered: _____

Temp (°C)	Technician	Time	Species / Life Stage	Total Spp. All stages				Others	Comments
			Initial liv.						
			Number stunned						
			Initial dead						
			3-hr						
			6-hr						
			12-hr.						
			24-hr						
			48-hr.						
			72-hr.						
			96-hr.						
			Total dead						
			Final live						
			Total Analyzed						
			Percent mortality						

Comments: _____

TABLE 3.0-5

Page — of —

TECO
EGG DATA

FINE MESH SCREEN STUDY
Impingement Flume

J.O. No. 12408.04

Date: _____ Species group: _____

Time: _____

Test: _____

Sample No: _____ Investigator(s): _____

Ambient Temp: _____ No. introduced: _____

Flume Temp: _____ No. recovered: _____

Temp. (°C)	Technician	Time	Species	Total Spp.					Others
			Initial live						
			Initial dead						
			3-hr	*					
			6-hr						
			12-hr						
			24-hr						
			48-hr						
			72-hr						
			96-hr						
X	X	X	Total dead						
			Total abnormal						
			Total hatched						
			Final unhatched						
			Total analyzed						
			Percent mortality						X

Record as: No. dead / No. hatched normal / No. hatched abnormal

Comments: _____

TABLE 3.0-6

TANK LOG

Sample No._____
Tank No._____

CUP NUMBER		TYPE OF ORGANISM	NUMBER OF ORGANISMS	COMMENTS
CUP	POSITION*			

*Egg cups only.

All live fish larvae, zoea, and shrimp were held in the original containers for viability testing. A maximum of fifteen fish larvae and 30 shrimp were held in an individual cup. Crab zoea, in lots of ten, were held with a maximum of 30 organisms being observed.

3.2.3 Observations

Initially, all viability samples for both Six-Panel (sampling began 14 August) and Flume (sampling began 22 August) studies were held for 96 hours; observations were recorded at 6, 12, 24, 48, 72, and 96 hours. Beginning on 27 August, test samples were terminated after 48 hours with observations at 3, 6, 12, 18, 24, 36, and 48 hours (eggs were observed at three-hour intervals for the 48-hr duration or until hatching occurred). At every observation, each holding chamber was examined; live and dead organisms were counted, and all dead organisms were removed, placed in two-dram vials, and preserved with 5% formalin. Note, however, that only dead shrimp were counted since it was not possible to accurately count live shrimp in lots of 25 without removing them from the containers. In the case of fish eggs, all yolk-sac larvae were removed and preserved, as hatching success was the criterion for termination of viability testing on eggs.

All observations were recorded on the appropriate data sheets. Each vial contained a label on the lid and inside with the following information:

- sample inventory number (including digits for viability check time)
- tank and cup number.

Several problems were encountered in accounting for all the organisms tested in the viability studies. Initially the mesh on the egg cups used for zoea and fish eggs was attached using clear silicone cement. This material did not seal well; all egg cups were reglued with a 3M industrial adhesive which eliminated this problem.

Other problems in accounting for all the organisms tested in the viability studies included losses due to rapid disintegration of eggs and larvae in high temperatures; interspecific predation by crab larvae, megalops and juveniles, reproduction during the experimental period (mysids hatching during testing of adults); and miscounting due to difficulty of counting small live organisms. Occasional system failure caused tanks to flood washing organisms out of the cups or causing them to become stuck in the egg cup lids.

3.2.4 Laboratory Analysis of Animals Used in Viability Tests, Initial Live, and Initial Dead

Identification and enumeration of selected taxa were carried out for both the Six-Panel and Flume studies. All organisms tested in the Impingement Flume studies were analyzed; these included fish larvae, crab zoea, and shrimp. For the Six-Panel studies, all organisms used in viability testing were analyzed as well as crab zoea, fish eggs, and larvae from the initial dead and initial live preserved samples. Other taxa collected on the screens were preserved but not analyzed.

The procedures used to identify and count the fish and crustaceans are presented separately in Sections 3.2.4.1 and 3.2.4.2.

3.2.4.1 Identification - Egg and Larval Analysis - Fish

3.2.4.1.1 Taxonomy. Eggs and fish larvae were identified to the lowest practicable taxonomic level. Organisms taken to lower taxonomic status (e.g., genus and species) fit known literature descriptions, and those classified to family would be tentative if identified to a lower taxonomic level. Accuracy of identification in larvae is best attained with specimens that have developed adult characteristics, or exhibit characteristics found only for that species.

Of the larvae collected during the study period, four families appeared in largest numbers. These were: Sciaenidae, Engrauli-

dae, Soleidae, and Gobiidae. Six other families (Atherinidae, Blennidae, Carangidae, Cyprinodontidae, Syngnathidae, and Triglidae) had small numbers present in the study. The taxonomy was carried out with the aid of the literature cited in Appendix A, and a reference collection (see also Table 3.0-7).

A personal consultation was held with Dr. E. Houde, Rosensteil School of Marine Atmospheric Sciences, University of Miami, Florida, prior to undertaking identification. Included in the consultation was the identity of a reference collection of larval and juvenile fish collected in the study area and its proximity. Several types of eggs were also included. During the process of confirmation, the taxonomic level to which various families and their species could be identified was reviewed. Included in this review were the distribution, spawning data, and seasonality of both parameters for the species. Upon the recommendation of Dr. Houde, identification was made only to the family level for Soleidae, Gobiidae, and Blennidae. This is, in part, due to lack of available literature to carry out the separation of the lower taxonomic groupings and the small size of these larvae. At such a size, the presence of distinguishing characteristics was lacking. Those specimens damaged and without identifiable characteristics were labeled UID, or, unidentifiable.

Identification of sciaenid larvae can be taken to a lower level on the basis of spawning dates, seasonal distribution, and physical characteristics (primarily pigmentation) that are highly distinctive for a particular taxonomic level. Where pigmentation is lacking, the larvae were taken only to family. Cynoscion could be taken to species level (Cynoscion arenarius) if distinctive pigment and other meristic indications were present.

Engraulidae were established, during confirmation, as being indistinguishable within the family until the full complement of

TABLE 3.0-7 (Page 1 of 3)

KEY CHARACTERISTICS OF THE EGG AND LARVAL STAGES OF SELECTED PISCINE TAXA[a]

TAXON	SPAWNING PERIOD	DISTRIBUTION DURING SAMPLING	OIL PLACEMENT	HATCH SIZE	LARVAL BODY SHAPE	DISTINCTIVE PIGMENTATION	COMMENTS
Family Atherinidae	-	-	-	-	Extremely slender	-	Eggs usually have long adhesive filaments. Preanal length <1/4 TL.
Membras martinica	March-September	Shoreline-beaches	Scattered at one pole	3.0-5.0 mm TL	Slender	At 9 mm TL pigment spots at bases of anal rays - more lateral to fin.	
Menidia beryllina	Late spring-early summer and fall	Tidal river channels	1-3 major globules	3.5-4.0 mm TL	Slender	Prejuvenile to juvenile pigment lateral to anal fin. Undistinguishable from *M. martinica* until formed.	
Family Blennidae	Early spring-summer	Widespread	Many and scattered	2.6-3.8 mm TL	Short, thick	Heavy pigment over all of gut and on pectoral fins.	Eggs usually placed in empty oyster, clam, and scallop shells.
Family Clupeidae	Spring-fall	-	Varied	-	Slender and becoming heavier	-	Preanal length 70% SL or more.
Harengula jaguara	February-July	-	One	2.4 mm	-	Pigment along the dorsal tip of notochord, much like *Sardinella* sp.	Preanal length 83-90% SL.
Family Engraulidae	-	-	No oil present	-	Long and slender	-	Preanal length is about 75% SL.
Anchoa hepsetus	Winter and spring, possibly early summer	Nearshore	None	3.6-4.0 mm TL	Slender	None of major importance.	Elliptoid eggs. hatch at larger size than *A. mitchilli*, 18-24 anal rays at maturity.
Anchoa mitchilli	approximately year-round	Nearshore	None	1.8-2.7 mm	Slender	See above.	Less elliptical and more rounded eggs. 23-30 anal rays at maturity.

TABLE 3.0-7 (Page 2 of 3)

KEY CHARACTERISTICS OF THE EGG AND LARVAL STAGES OF SELECTED PISCINE TAXA[a]

TAXON	SPAWNING PERIOD	DISTRIBUTION DURING SAMPLING	OIL PLACEMENT	HATCH SIZE	LARVAL BODY SHAPE	DISTINCTIVE PIGMENTATION	COMMENTS
Family Gobiidae	Spring-fall	Widespread	None	1.2 mm and larger	Short heavy body	Ventral, postanal spots and later over air bladder.	Eggs are attached to shells, stones, coral, or side of burrows by threads. Preanal length between 40-60%
Family Sciaenidae	-	-	-	-	Robust head, tapered body	-	Eggs are small, pelagic, with one or more oil globules which coalesce with development. Lack of morphological features makes speciation difficult.
Bairdiella chrysura	May-September	Widespread	1-2 globules	1.5-1.9 mm	-	A reliable pigment band forms during the yolk-sac stage posterior to the head region. This band remains until late in the larval stage.	Spawning may occur more offshore in bays.
Cynoscion nebulosus	April-June, September peaks	Bays, over grassy areas	1 globule	1.7 mm	-	Palatine pigment at 2.1 mm NL, later no enlarged spot near middle of anal fin base.	Eggs are demersal after 12 hours. High salinity required.
C. arenarius	April-August	Bays, coves, estuaries	Variable in number	1.5-2.0 mm TL	-	Pigment pattern bandlike with development just above anal fin melanophore(s) in area may be greatly expanded.	Description of Cynoscion regalis was considered best available in use - Pers. comm. with Dr. E. Houde.
Pogonais cromis	February-November	Bays	1-2 and pigmented	1.9-2.4 mm	-	Oil globule heavily pigmented. Ventral pigmentation is early; later pigment is like that of C. arenarius above anal fin.	90% of spawning occurs in February-March.

TABLE 3.0-7 (Page 3 of 3)

KEY CHARACTERISTICS OF THE EGG AND LARVAL STAGES OF SELECTED PISCINE TAXA[a]

TAXON	SPAWNING PERIOD	DISTRIBUTION DURING SAMPLING	OIL PLACEMENT	HATCH SIZE	LARVAL BODY SHAPE	DISTINCTIVE PIGMENTATION	COMMENTS
Family Sciaenidae (Continued)							
Sciaenops ocellata	September-November	Coasts and channels	No information	No information	-	Internal pigment along notochord after 4.1 mm.	Peak spawn in October.
Family Soleidae	-	Widespread	Clustered oil droplets and higher number	1.6 mm SL	Short and thick	-	Distinguishing characteristic between *Achirus lineatus* and *Trinectes maculatus* is an appendage of the dorsal finfold at six days of age. This is retained until 4.0 mm SL.
Family Syngnathidae (*Syngnathus* sp.)	Varied according to species	Widespread	Many droplets	11.5	Long and slender	-	Several species' ranges overlap in area.

[a]Descriptions are from Hardy et al. 1978. Soleidae information is from Houde et al. (1970).

A personal consultation was held with Dr. E. Houde, Rosensteil School of Marine Atmospheric Sciences, University of Miami, Florida, prior to undertaking identification. Included in the consultation was the identity of a reference collection of larval and juvenile fish collected in the study area and its proximity. Several types of eggs were also included. During the process of confirmation, the taxonomic level to which various families and their species could be identified was reviewed. Included in this review were the distribution, spawning data, and seasonality of both parameters for the species. Upon the recommendation of Dr. Houde, identification was made only to the family level for Soleidae, Gobiidae, and Blennidae. This is, in part, due to lack of available literature to carry out the separation of the lower taxonomic groupings and the small size of these larvae. At such a size, the presence of distinguishing characteristics was lacking. Those specimens damaged and without identifiable characteristics were labeled UID, or, unidentifiable.

Identification of sciaenid larvae can be taken to a lower level on the basis of spawning dates, seasonal distribution, and physical characteristics (primarily pigmentation) that are highly distinctive for a particular taxonomic level. Where pigmentation is lacking, the larvae were taken only to family. Cynoscion could be taken to species level (Cynoscion arenarius) if distinctive pigment and other meristic indications were present.

Engraulidae were established, during confirmation, as being indistinguishable within the family until the full complement of rays is present in the anal fin. Since as many as four types of anchovy can occur in the study area, identification of Anchoa mitchilli can only be made when a minimum of 24 anal

rays is present in the anal fin. Since as many as four types of anchovy can occur in the study area, identification of Anchoa mitchilli can only be made when a minimum of 24 anal rays are present. It is believed that all Anchoa spp. collected may well prove to be Anchoa mitchilli upon further development of the anal fin.

Egg identification is difficult, because most characteristics are measurements of various parts of the egg and its membranes. This is a process that takes a great deal of time, and many descriptions are lacking in definitive information. Soleidae, Sciaenidae, and Engraulidae were the major families found, with others being classed as unidentified (UID). Oil globule structrue, or lack of oil, was a major characteristic used for identification of these three families. The one exception was Anchoa mitchilli eggs, which are highly distinctive, possessing an elliptical shape unlike any other egg.

3.2.4.1.2 Life stage. Stage intervals of development for Engraulid larvae were prolarval and postlarval. Presence of yolk, size, and meristic development were used in the separation of the two stages after hatching. The postlarval stage included early juvenile-like forms that had not completed full fin development.

Engraulidae were classified to life stage using information in the literature and experience of LMS taxonomists. Prolarvae were defined by size below 2.0-2.5 mm standard length (SL) and yolk presence. Postlarval development occurred between approximately 2.5 and 22.5-30.0 mm SL, with no yolk being present. Within this range the anal fin begins to develop and a full ray complement may be present between 15 and 22.5 mm. The pectoral and pelvic fins may not develop until later.

3.2.4.2 Crustacean Analysis

3.2.4.2.1 General procedures. The crustaceans were removed from individual vials and examined under a dissecting microscope for identification and enumeration. Any organisms which were damaged beyond recognition were listed as "UID" (unidentified); others which were damaged, but identifiable, were classified and a notation made indicating the condition of the organism. All data pertaining to organisms used in viability testing were recorded directly on the TECO viability data sheets (Tables 3.0-1 and 3.0-4). All data from initial live and dead samples were recorded on preliminary worksheets and later transcribed to the viability sheets. Data from the initial pick and QC vial (if applicable) were combined; in some cases these two vials were combined prior to analysis. Following identification and counting, all crustaceans were represerved in either 50% isopropanol or 70% ethanol.

3.2.4.2.2 Subsampling procedures. Due to the large number of zoea present in some of the initial live and initial dead samples from the six-panel retrofit study, it was necessary to analyze subsamples. The procedures used to accomplish this follow:

- If the total number of zoea was approximately 100 or less, the entire sample was analyzed.
- If the sample contained over 100 zoea, the sample was subsampled as follows:

  -- The QC vial and the initial pick vial were combined and placed in a 4-inch petri dish. The vials were rinsed to ensure that all organisms were removed.

  -- A grid was placed in the petri dish to subdivide the sample. Zoea were pipetted from randomly chosen quadrats which were analyzed, one at a time.

-- Sufficient quadrats were analyzed to count a minimum of 50 zoea. If there were 50 or more in one quadrat, at least two quadrats were analyzed.

3.2.4.2.3 Taxonomy.

- Crab Larvae

Identification of crab zoea was accomplished using published and unpublished literature sources and a reference collection verified by Dr. Patsy A. McLaughlin of Florida International University. As an aid to the investigators working on the zoea samples, the key characteristics observable without dissecting the organisms under the microscope (zoea are only several millimeters long) were summarized from the literature for selected taxa previously identified in the area (Tampa Electric Company 1977) and ones for which reference specimens were available. This summary is presented in Table 3.0-8 and the published references may be found in Appendix A - Part 2.

For the Six-Panel and Flume studies, only Menippe mercenaria was identified to species level; all other crab zoea were identified to the family (Xanthidae, Pinnotheridae, Grapsidae, Portunidae, Ocypodidae, or Porcellanidae) or, in some cases, the subfamily level (Sesarminae).

Megalopal stages occurred infrequently and were generally classified as "UID." In some cases, juvenile crabs occurred in the samples. These were classified as "UID juvenile crab" but are believed to be Pinnotheridae. Some genera of this family, for example, Pinnixa sp., do not have a megalopal stage and pass directly from the final zoeal stage to the juvenile crab (Hyman 1925). Absolute classification of these organisms as pinnotherids would require a further literature search.

Positive identification of crustacean larvae to species level (and often genus level) is not possible without close examination of appendages, particularly the antennae, antennules,

TABLE 3.0-8 (Page 1 of 4)

KEY CHARACTERISTICS OF THE ZOEAL STAGES OF SELECTED DECAPOD TAXA

TAXON	CARAPACE	ANTENNULES	ANTENNAE	ABDOMEN	TELSON	OTHER
Family Xanthidae	Possesses lateral rostral and dorsal spines.	Usually prominent.	Generally long and robust, usually 1/2 or equal length to rostrum.	Usually with lateral spines.	Forked usually w/ three interior spines, generally dorsal and/or lateral spines.	
Menippe mercenaria	Lateral spine 1/3-1/2 length of dorsal spines pointed slightly downward, dorsal and rostral spines approximately equal in length.	Conical with 5-6 distal sensory flagella (number of flagella changes depending on zoeal stage).	1/2 length of rostrum; biramous, rami appear equal in length (exopodite well developed).	5 segments (6th segment added at 3rd zoea) though only 4 may be clearly visible; 2nd segment (usually most clearly visible anterior segment) has one pair of mid-ventral, anteriorly pointing spines; 3rd segment-pair of mid-ventral, posteriorly pointing spines; 4th and 5th segment - each with a pair of posteriorly pointing spines on posterior dorsolateral surface (usually clear noticeable). In addition, each segment has two small setae on posterior dorsal surface (not easily seen).	Forked, rami usually 2/3 length of telson, 3 long tapering spines along inner surface of each ramus. Very small spine on mid-dorsal and/or mid-lateral surface.	The posterior margins of the 3rd, 4th, and 5th abdominal segments project into small spines on the lateral part of each segment. These two small spines, located laterally on each segment, point posteriorly and are more ventrally located than the larger more prominent spines outlined in the section describing the abdomen. The larger spines on the 3rd segment (as outlined in the abdomen section) appear to point more laterally outward (perpendicular to the body plane) than posterior downward as described. Source: Hyman 1925; Porter 1960.
Neopanope texana	Dorsal spine projects posteriorly and is nearly straight. Lateral spines are short, generally less than 1/3 or 1/2 the length of the dorsal spine. Lateral spines project perpendicularly outward from carapace. The rostral spine is	Conical with setae.	Protopodite is long, smooth and tapered, approximately the length of the rostrum. Small exopodite bears a small spine (very hard to see).	5 segments (6th segment added at 3rd zoea) though only 4 may be visible. The 2nd segment has a short mid-lateral spine on each side, projecting somewhat anteriorly and laterally. Another small spine projects posteriorly from the mid-lateral surfaces of the third segment	3 interior spines on each furcus. Setules are located on both inner and outer margins though they are not usually seen. Longer setules which can be seen, are located midway on the inner margin of the innermost pair of spines. A small dorsal spine is present at the me-	

KEY CHARACTERISTICS OF THE ZOEAL STAGES OF SELECTED DECAPOD TAXA

TAXON	CARAPACE	ANTENNULES	ANTENNAE	ABDOMEN	TELSON	OTHER
Neopanope texana (cont'd)	approximately the same length as the antennae. A small seta is located between the dorsal and lateral spines (not easily seen).			(one spine on each side of the 3rd segment). The three most posterior segments (3, 4, and 5) have spines on the posterior lateral margins which extend posteriorly over the adjacent segment.	dian part of each furcus of the telson. A fourth pair of small median spines develop on the innermost portion of inner margin in 2nd or 3rd stage zoeas.	Source: Hyman 1925; McMahon 1967
Neopanope packardii	Dorsal spine projects posteriorly with extreme distal portion forming a definite hook. Lateral spines similar to N. texana though slightly longer and more slender. The antennae and rosturm are equal in length.	Similar to N. texana.	Similar to N. texana except the most distal portion of the protopodite has short spines.	Similiar to N. texana.	Similar to N. texana except for the lack of a fourth pair of median spines in the innermost margin of the telson. This fourth pair of spines appears in the 2nd or 3rd zoeal stage of N. texana but not in N. packardii.	Very Similar to N. texana. The dorsal spine, protopodite, and possible use of telson are the more distinquishing characters to look for to separate these two species. Source: Costlow and Bookhout 1967; McMahan 1967
Panopeus herbstii	Dorsal spine basically straight becoming somewhat posteriorly curved in latter stages. The lateral spines are straight and short, less than 1/2 the length of the dorsal spine. The antennae are almost as long as the rostral spine.	Conical with several aesthetes and setae. In the early zoeal stages, 3 large aesthetes and two smaller setae.	Protopodite is long and tapering with a number of short spines on the distal portion. Antennae are almost as long as rostrum. Exopodite is very small and ends in a short spine.	5 segments (6th segment appears at stage 3). 2nd segment has a short spine that projects slightly anteriorly from the lateral surface. 3rd segment has a smaller hook on each lateral surface. The posterior lateral margins form long spines which overlap the adjacent segment on segments 3, 4, and 5	Small dorsal spine on each furcus of telson. Two lateral spines, one large and one small, on each furcus of telson. Three spines occur on each inner margin of each furcus. The small lateral spine is very hard to see.	Source: Costlow and Bookhout 1961
Rhithropanopeus harrisii	Very long rostrum. Equally long antennae. Very short lateral spines. Dorsal spine straight and long.	Conical with setae (approx. 4-5).	Smooth protopodite that is as long as the rostrum. Small dorsal seta at the proximal end (not easily seen); expodite minute.	5 segments (6th is added at 3rd zoea) 2nd segment bears a short mid-lateral projection which is directed laterally away from the segment. The three most	Each furcus has a median dorsal spine. 3 spines occur on the inside margin of each furcus.	

TABLE 3.0-8 (Page 3 of 4)

KEY CHARACTERISTICS OF THE ZOEAL STAGES OF SELECTED DECAPOD TAXA

TAXON	CARAPACE	ANTENNULES	ANTENNAE	ABDOMEN	TELSON	OTHER
Rhithropanopeus harrisii (cont'd)				posterior segments (3,4,5) have spines which increase in length as the segments go posteriorly. The spine on the 5th segment is the longest and projects dorsally overlapping the telson. This long spine is a distinguishing feature of this species.		
Eurypanopeus depressus	Dorsal spine pointed posteriorly and markedly hooked. Small lateral spines less than 1/2 length of dorsal spine. Antennae as long as rostrum.	Conical with very prominent pigment spot on distal end of antennule. This pigment spot distinguishes this species from other similiar species. Three to four setae present.	Long protopodite, equal in length to rostrum. Distal portion of antennae has a number of spines. Exopodite minute with a single seta.	Typical xanthid form, no distinguishing large spines on abdomen. 4 posterior segments - posteriolateral margin ends in short spines that slightly overlap adjacent segments.	Small dorsal spine on each furcus. 3 spines on inner margin of each furcus.	Source: Chamberlain 1962
Hexapanopeus angustifrons	Dorsal, lateral, and rostral spines; rostral spine approximately equal in length to antennae.	Short, conical with variable number of aesthetes (depending on stage).	Long, smooth, tapering protopodite; exopodite minute.	5 segments (6th is added at 3rd zoea) 2nd segment bears large spine on each lateral surface, small spine on lateral surfaces of 3rd segment.	Bifurcate, typical xanthid form, except that this is the only described species with neither dorsal or lateral spines on telson.	Source: Costlow and Bookhout 1961
Family Grapsidae Subfamily Sesarminae	Dorsal spine short and curved caudally. Antennae approximately equal in length to rostrum. No lateral spines.	Conical, having several terminal aesthetes setae.	Protopodite tapering from small knob of endopodite to distal portion with stiff hairs. Exopodite approx. 1/3 length of protopodite (exopodite a discrete segment). One row of spines on	5-6 segments (depends on stage). 2nd segment has short midlateral knob projecting laterally from each side. 3rd segment has small spine on each mid-lateral surface.	3 spines on inner margin of each furcus.	Source: Costlow and Bookhout 1966 Best distinguishing features - no lateral spines on carapace and antennae (protopodite) approximately equal in length to rostral spine. Both of these features must be present as

TABLE 3.0-8 (Page 4 of 4)

KEY CHARACTERISTICS OF THE ZOEAL STAGES OF SELECTED DECAPOD TAXA

TAXON	CARAPACE	ANTENNULES	ANTENNAE	ABDOMEN	TELSON	OTHER
Subfamily Sesarminae (cont'd)			distal portion of protopodite.			some Pinnotheridae lack lateral carapace spines and some Grapsids have them. Source: Hyman 1924, 1925a; Costlow and Bookhout 1960, 1962; Hart 1971.
Family Portunidae	Dorsal, lateral and rostral spines present.		Generally similar in length to rostrum, exopodite well developed - this serves to distinguish portunids from xanthids.	5-6 segments (depending on stage).	Bicornuate, three spines on interior margin of each furcus; lateral spines and often dorsal spines present.	Portunidae are similar to the xanthids and require close examination for differentiation. Source: Costlow and Bookhout 1959; Bookhout and Costlow 1974, 1977
Family Porcellanidae	Carapace elongate; no lateral spines; rostrum at least twice as long as carapace; posterior process as long as carapace				Flat and wide with long plumose setae posteriorly.	These are easily distinguished from all other crab zoea by the length of the spines. Source: Gore 1968, 1970; Hart 1971
Family Pinnotheridae						
Pinnixa sp.	Long dorsal spine, long rostrum, long lateral spines that curve distally and are deflected ventrally and posteriorly. All carapace spines are approximately equal in length.	Conical with 4-5 setae visible.	Minute, very difficult to see; this is a distinguishing feature of this family according to Hyman (1925).	5 segments, 5th segment is dorso-ventrally compressed forming lateral wings that extend posteriorly to overlap the most anterior portion of the telson. This is a distinguishing feature of *Pinnixa* sp.	Bicornuate with three spines along the interior margin of each cornu. The telson of one species, *P. chaetopterana*, has a median deltoid process	Pinnotherids are not a well-defined homogenous group. The minute antennae are the only feature common to a majority of them Source: Hyman 1925
Pinnotheres maculatus	Rostral, dorsal, and lateral spines present; lateral spines long and deflected ventrally.	Conical, bearing variable number of aesthetes (depending on stage).	Approximately 1/2 the length of the rostral spine; consists of tapering protopodite covered with small spines on distal surface.	5 rounded segments (6th added at 4th zoea), segments 2 & 3 bear small lateral spines.	Bifurcate with three pairs of spines on inner surface.	Source: Hyman 1925; Costlow and Bookhart 1966; Roberts 1975

mandibles, maxillules, maxillae, maxillipeds, and telson. Many of these are not readily observable without performing tedious dissections of the appendages from the larvae which must then be mounted for examination under a compound microscope. While this could have been accomplished by LMS personnel, the time required would have been substantial. In addition to the difficulties involved in identifying the species for which published descriptions are available, many species have not been described as yet, further complicating the issue. This is particularly true for the Pinnotheridae (McLaughlin, pers. comm.), a dominant family in the Big Bend area. Specific identification of Menippe mercenaria was possible because its larvae are distinctive and are readily discernible from the other xanthid larvae present in Hillsborough Bay. In addition, M. mercenaria is the only species of this genus known to be present in the Gulf of Mexico (Scotto 1979).

The preceding statements regarding zoeal taxonomy were substantiated during conversations with Dr. McLaughlin at Florida International University. She stated that specific identifications of the crab zoea were "highly questionable without detailed dissections of stained specimens" which, as discussed, are time consuming. She did believe, however, that specific identification of Menippe mercenaria was justified, particularly since one member of the LMS staff had conducted research on M. mercenaria involving extensive rearing through all the larval stages, and since the morphological characteristics of the zoea were sufficiently distinctive from the other xanthid zoea present in the area to allow positive identification.

- Shrimp

The shrimp present in the DPVS viability samples represented a mixture of larval, juvenile, and adult forms. Similar

techniques were used to identify these organisms as were used for the crab larvae; the published references are listed in Appendix A - Part 2.

All comments pertaining to the procedures involved in specific identification of crab larvae, such as dissection and mounting of appendages, also apply to the shrimp present in the six-panel retrofit and flume samples. The following levels of classification were used for the organisms found: Mysidacea, Stomatopoda, Palaemoninae, Ogyridae, Alpheidae, Penaeidae, Upogebiidae, Callianassidae, and Caridea. As discussed for the crab zoea, more specific identification is possible, but the time required to accomplish these identifications with a high degree of accuracy is substantial.

3.2.5 Water Quality Analyses

3.2.5.1 Introduction and Schedule. Temperature and dissolved oxygen were measured in each aquarium on a regular six-hour schedule for the duration of each test period. Initially, pH and salinity were measured on the same six-hour schedule; beginning on 15 August and continuing for the duration of the experiments, these two parameters were measured twice daily (once every 12 hours). Ammonia-nitrogen was monitored during the preliminary phase of the DPVS studies, but the observed levels were so low that it was decided to discontinue its measurement during the regular testing period (ammonia is not generally a problem in flow-through marine systems).

Data from each water quality check were recorded on a separate data sheet (on occasion, data from two or more water quality checks were recorded on the same data sheet) and placed on the water quality clipboard hung on the chemistry laboratory wall. Specific procedures used to collect and analyze the required water quality parameters are detailed in the following sections.

3.2.5.2 Instrument Calibration. Procedures used for calibration of chemical laboratory instrumentation and equipment are described below, as well as the frequency of calibration and quality control checks. All calibration and quality control data were recorded in a notebook kept in the chemistry laboratory.

3.2.5.2.1 pH meter. The pH meter was calibrated daily or with each use, whichever was less frequent, using standard pH reference solutions traceable to the National Bureau of Standards. Two different buffer solutions (pH 7 and 10), chosen to bracket the range of pH values expected in the samples, were used during each calibration period; appropriate adjustments to the instrument were made according to the manufacturer's instructions. All data were recorded on the pH calibration data sheet kept in the chemistry notebook. Copies of the manufacturer's instruction book and the data sheets were provided in the DPVS Workplans.

3.2.5.2.2 Thermometers. Once during the study, all thermometers were calibrated against a certified thermometer using a stirred glycerine bath technique.

Approximately 500 ml of glycerine (bp 760, 290.0°C [decomposed]) was put into a 1000 ml beaker with a magnetic stirrer. One certified thermometer and several working thermometers were suspended in the glycerine bath and the bath was slowly heated. The working thermometers were calibrated at two to three degree intervals from approximately 28° to 39°C (some thermometers were calibrated to 42°C). The certified thermometer reading was recorded as the calibration temperature, and the working thermometer reading was recorded as the observed temperature. These data were tabulated and deviations from calibration temperature were calculated.

3.2.5.2.3 Ammonia probe. The Orion ammonia probe (used with the Corning 130 specific ion meter) was calibrated daily or with each use, whichever was less frequent. Standard 0.1 M NH_4Cl solution supplied by the Orion Company was used for calibration following the specific procedures outlined in the Orion instruction manual, which was included in the DPVS Workplans. The data were plotted on semi-logarithmic graph paper. Recommended care and maintenance procedures for the ammonia probe are also included in the instruction manual.

3.2.5.2.4 Dissolved oxygen meter. The dissolved oxygen meter was calibrated daily or prior to each use, whichever was less frequent, using the modified Winkler titration (APHA 1976). Three BOD bottles and the probe calibration bottle were filled from the laboratory's flowing seawater supply, using appropriate techniques to prevent bubble formation. Winkler titrations were completed on aliquots from the three BOD bottles and were averaged. The DO meter was calibrated (to the mean value obtained from the Winkler titrations) using the probe calibration bottle and a magnetic stirrer. The DO meter readings, both before and after calibration, and the results of the Winkler titrations were recorded on the DO meter calibration sheet in the chemistry notebook. Detailed instructions for use of this meter and copies of the DO meter calibration data sheet were provided in the DPVS Workplans.

3.2.5.2.5 Refractometer (salinity). The American Optical refractometer was calibrated weekly, according to the manufacturer's instructions, using distilled water. Adjustments were made when necessary.

3.2.5.2.6 Analytical balance. Since reagents for chemical determinations were weighed in the Nyack Laboratory and sent to

the Tampa facility for final preparation, all calibration procedures were performed in the Nyack facility.

Daily, or with each use, whichever was less frequent, a single Class S weight, near the weighing range most often used, was weighed.

Monthly, a series of Class S weights, covering the weighing range normally used, were weighed. Data were recorded in a bound notebook and submitted monthly to the Quality Assurance Group.

3.2.5.3 Techniques Used to Collect Water Quality Data.

3.2.5.3.1 pH. Samples for pH were taken from the PVC cup at the front center of each aquarium using small Pyrex® beakers (50-100 ml). Sample pH values were read to the nearest two decimal places and all data were recorded on the TECO water quality data sheets (Table 3.0-9).

3.2.5.3.2 Temperature. Temperature was measured directly in the PVC cup at the front center of each aquarium. Values were recorded to the nearest 0.1°C on the TECO data sheets (Table 3.0-9), along with the thermometer identification number.

3.2.5.3.3 Ammonia. Samples for ammonia were collected from the PVC cups using 100 ml Pyrex® beakers. To each 100 ml sample, 1 ml of 10 M NaOH was added. Ammonia concentration was read as relative millivolts which were converted to mg/l using the calibration curve. Specific procedures for preparing the calibration curve and determining ammonia concentration can be found in the Workplans.

TABLE 3.0-9

ROUTINE WATER QUALITY

Investigator _____
Start Time _____
Date _____

TANK No./ CUP No.	TEMPERATURE (°C) MIXING CHAMBER	CUP	THERM. No.	D.O. (ppm) TANK	D.O. (ppm) CUP	pH TANK	pH CUP	SALINITY (o/oo)	AMMONIA (mg/l)	COMMENTS

3.2.5.3.4 Dissolved oxygen. Dissolved oxygen concentrations were determined in the PVC cup at the front center of each aquarium. During the equilibration period the probe was continuously moved in a circular manner to prevent oxygen depletion in the vicinity of the membrane. Data were recorded on the TECO water quality data sheets (Table 3.0-9).

3.2.5.3.5 Salinity. Salinity was measured with a refractometer by taking several drops of water from the aquarium with a Pasteur pipette and placing the water on the viewing area of the refractometer. Measurements were made to the nearest 1.0 ppt salinity and recorded on the TECO water quality data sheets (Table 3.0-9).

3.2.6 Data Control

3.2.6.1 General Procedures. Procedures relating to sample coding, labeling of data sheets and sample logs, and maintenance of sample integrity were reviewed in Section 3.2.2-Sample Sorting; labeling of sample vials was reviewed in Section 3.2.2-Sample Sorting and Section 3.2.3-Observations. Section 3.2.5 describes data procedures for water quality measurements.

At the end of each particular experiment, all pertinent data were removed from the clipboards, reviewed by the Coordinator, and filed in the designated area. Data were removed from the designated area only with permission of the Project Manager or Coordinator for reproduction, analysis of viability organisms, or examination by S&W. LMS provided the original validated data sheets to S&W for subsequent analysis of impingement mortality. A copy of the data sheets was retained by LMS for its records.

All records concerning instrument calibration (see Section 3.2.5) were kept only in the chemistry laboratory on standard data sheets provided in the calibration notebook. Accurate records contained

name of analyzer, time, results, and notes of any unusual occurrences, including equipment malfunctions.

Data records were kept in the holding facility in those areas assigned by the Supervisor. Other data and quality control procedures have been outlined in detail in the Workplans and Quality Assurance Manual submitted to S&W.

3.2.6.2 Quality Control Procedures for Sample Sorting. A 10% reanalysis was performed on all preserved (initial dead) samples for the Six-Panel study. These samples were randomly chosen for reworking by the quality control analyzer. If a sample was found to be different from the QC value by >10%, additional samples were reworked by the QC analyzer until the results were $\geq$90% of the QC value. Records for this procedure were kept in the preserved sample log.

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APPENDIX A

PART 1: ICHTHYOPLANKTON

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APPENDIX 4

FINE-MESH SCREEN PROTOTYPE STUDY
SPRING 1980

FINE MESH SCREEN PROTOTYPE STUDY

SPRING 1980

BIG BEND STATION - UNIT 4

TAMPA ELECTRIC COMPANY

JUNE 30, 1980

STONE & WEBSTER ENGINEERING CORPORATION
BOSTON, MASSACHUSETTS

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SECTION 1

INTRODUCTION

Tampa Electric Company (TECO) is presently planning the addition of a fourth generating unit at the Big Bend Station. The site is located on the eastern shore of Tampa Bay in North Ruskin, Florida (Figure 1-1). Region 4 of the U.S. Environmental Protection Agency (EPA) has expressed concern for losses of organisms due to the operation of the Unit No. 4 cooling water intake. Accordingly, early in 1979, TECO requested Stone & Webster Engineering Corporation (S&W) to conduct an evaluation of various larval exclusion technologies which could be utilized in lieu of closed-cycle cooling at Unit No. 4.

Specific tasks involved in the evaluation included:

1. The review of available intake technologies which might be applied to Big Bend Station to minimize losses;

2. The selection of organism protection systems which have the potential for biological effectiveness and engineering reliability, and more detailed, site-specific evaluations of these systems;

3. The evaluation of the need for additional studies to verify the effectiveness and reliability of the selected system;

4. The performance of studies, if warranted.

Results of Tasks 1 through 3 evaluations indicated that fine-mesh screening had a definite potential for effective application at Big Bend. Accordingly, preliminary studies were conducted at the site in the summer of 1979. Two separate study efforts were involved:

1. A partial fine-mesh backfit of an existing traveling screen at Big Bend - Unit 1.

2. A flume study in which various test organisms were impinged on a fine-mesh screen panel over a range of impingement velocities and durations.

The objectives of these studies were:

1. To determine whether available Representative Important Species (RIS) are capable of surviving impingement on a fine-mesh screen under conditions of existing screen design.

2. To determine the relationship between specific velocity/impingement duration conditions and survival rate.

The decision to conduct two separate studies was based on the fact that the use of one of the existing screens at Big Bend for a partial backfit evaluation would not permit changes in screen rotation speed or impingement velocity. With fine-mesh panels incorporated, velocities could be in

excess of 3 fps which would far exceed values that would be selected for a fine-screening installation. Therefore, it was believed that mortality estimates from the 1979 study would be higher than would be observed if a dual-flow screen were specifically designed to collect planktonic organisms.

To obtain a clearer understanding of the effects of impingement on organism survival, the flume study was conceived to permit testing under controlled conditions. Velocity and impingement duration were selected as the primary variables of interest in the flume since, at a given power plant water flow requirement, the design velocity determines the number and size of traveling screens needed, and the acceptable upper impingement duration limit determines the slowest speed at which the screen can rotate. Since fine-mesh screens must rotate continuously, it is desirable from a maintenance and cost standpoint to minimize the size and number of screens and to operate them at the slowest speed possible. Therefore, test parameters were selected to cover a range of values which would have a good potential for protecting organisms and would also be practical to achieve at Big Bend Station Unit No. 4.

The partial backfit and flume studies were designed to supply information which would serve as a basis for deciding whether to continue with additional fine screening studies at Big Bend in 1980. The rationale for making this decision was as follows:

1. If positive results (in the form of acceptable survival values) are obtained from both the partial backfit and flume studies, proceed with additional studies in 1980.

2. If the partial backfit study yields negative results, but flume survival rates are good, proceed with 1980 studies since backfit conditions are very conservative.

3. If both backfit and flume studies yield negative results, cancel plans for further studies.

The results of the 1979 studies are presented in detail in a separate report (Stone & Webster 1980). In summary, acceptable survival rates were observed in both test facilities for several of the RIS that were available for testing, as well as for a number of other species. Therefore, the decision was made to proceed with additional, large-scale investigations in 1980. In order to ensure the validity of the data to be obtained, it was further decided that the 1980 test facility would be a full-scale, prototype traveling screen which would be identical in every way to the screen which would be incorporated into an actual fine-mesh screening installation at Big Bend - Unit No. 4. Design efforts began in late summer along with model studies which were conducted to optimize the screen's hydraulic characteristics and organism collection system. Construction continued through the winter and was completed in time to initiate biological testing at the beginning of the entrainment season in early March.

This report presents a description of the test and laboratory facilities being utilized, all methodologies employed and a summary of results obtained between March 3 and April 17. These data represent roughly two-thirds of those collected during the first two phases of the study program, which

ended on May 8. The third phase will begin in June and will involve a less intensive screen sampling schedule of one week per month through September, as compared to continuous sampling (five days per week) during Phases 1 and 2.

A detailed description of the entire study program and the data gathered will be given in a confirmatory report scheduled for publication in November 1980.

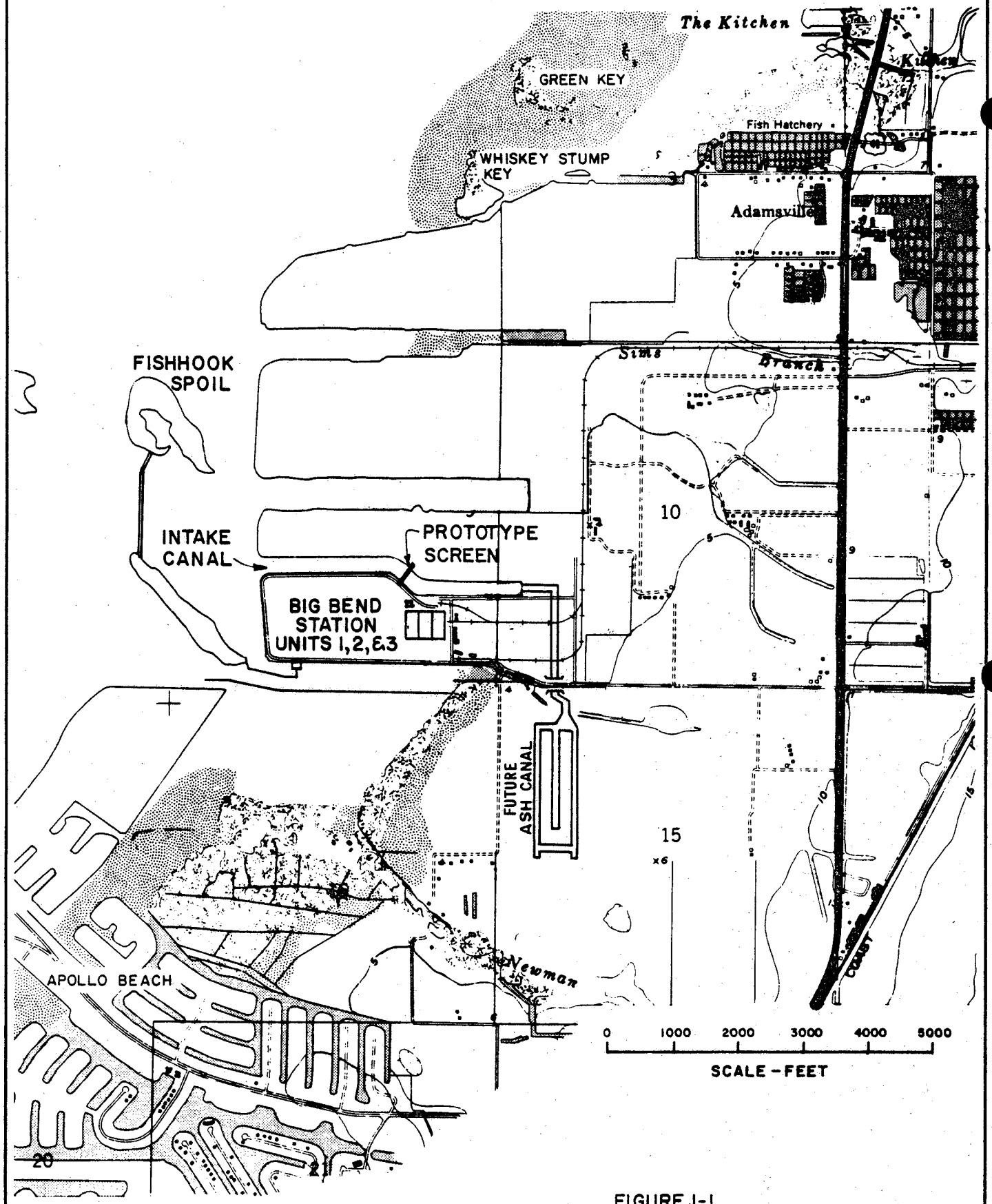

FIGURE 1-1
GENERAL SITE LOCATION
FINE-MESH SCREEN PROTOTYPE
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

SECTION 2

DESCRIPTION OF TEST FACILITY

The general site plan for the test facility is shown on Figure 2-1. The test screen is situated on a platform located in the intake channel immediately upstream of the existing pipe bridge. Stairs from the pipe bridge provide access to the screen. As shown on Figure 2-1, laboratory facilities are located on the north side of the intake channel, approximately 150 ft from the screen facility.

Figure 2-2 shows a more detailed plan of the screen operating deck. The prototype screen is of the dual-flow type and incorporates all of the features required for fine screening. Seals are incorporated between screen baskets and between the baskets and the side frame to prevent the passage of organisms through these areas. The screening medium is 0.5-mm square mesh made of woven-monofilament polyester.

The screen is capable of operation at speeds up to 28 fpm. On automatic control, the screen runs continuously at 7 fpm; as the head differential across the screen reaches 4 and then 6 in., the speed increases to 14 and 28 fpm, respectively. On manual control, the screen can be operated at speeds between 0 and 28 fpm. Three speeds of 7, 14, and 28 fpm were selected for study. These speeds correspond to maximum impingement durations of approximately 7, 4, and 2 minutes, respectively.

Flow through the screen is supplied by an in-line pump (an adapted ship bow thruster pump) located under the test platform and connected directly to the screen via a transition section (Figure 2-3). The pump is belt-driven by a 250-hp motor located on the deck. Assorted pulleys allow for flow adjustments. Given the size of the pump and motor, flows ranging from 8,270 to 50,000 gpm can be achieved. Since the test screen is 2 ft wide, these flows correspond to screen face velocities ranging from approximately 0.25 to 1.5 fps. During the present study, pulleys were selected to achieve velocities of 0.5 and 1.0 fps.

The discharge flow from the pump, composed of fine-screened water, is conveyed by a pipe to a location far enough downstream in the intake channel to prevent recirculation (Figure 2-1). At the point where the pipe passes under the pipe bridge, two taps are installed in the pipe to allow for the insertion of a flow-measuring device (for verification of pump flow rate and an organism sampler which can be used to determine the collection efficiency of the fine-mesh screen (Figure 2-4). A work platform is provided directly above this location to allow for the recording of pitometer measurements and the collection of biological samples.

A floating platform is installed directly in front of the upstream (ascending) side of the test screen and is accessible by ladder. This platform is used for observing the location and movement of organisms as individual screen baskets clear the water surface. It also serves as a sampling location and work station from which the need for additional spray systems is being evaluated.

The test screen incorporates shallow lifting buckets on each 2-ft wide screen basket which retain approximately a 1-in water depth. A low-pressure (10 psi) spray header, located on the ascending side of the screen, acts to remove organisms from the screen mesh surface and lifting buckets (Figure 2-4). A high-pressure (55 psi) spray header is located on the descending side of screen to remove any remaining debris into a separate trough. A screenwash pump with a strainer is located on the operating deck and takes suction from the filtered water (bow thruster pump discharge). As each screen basket passes the spraywash, organisms on the mesh or in the lifting bucket are gently rinsed into a collection trough (Figure 2-4). Once in the trough, the organisms flow by gravity into a primary collection tank from which they are drained into a secondary collection chamber, which also serves as the container in which the organisms are transported to the laboratory.

As shown on Figure 2-1, a land-based laboratory is available for processing of all screen samples. Screen sampling is conducted by Stone & Webster Engineering Corporation personnel. Following collection, the samples are delivered to personnel from Mote Marine Laboratory (the contracted lab operator) for processing. The laboratory facility is designed to:

1. Permit sorting, counting, identification, and determination of initial mortality of planktonic organisms.

2. Hold selected organisms for up to 96 hours to determine latent mortality.

Ambient, filtered intake water is supplied to the laboratory via a system of pumps, filters, and piping. A redundant water supply system was installed as a backup in the event of a system failure. This water serves as a water bath for maintaining ambient temperatures in a system of closed holding containers. However, the system is designed to allow for modification to a once-through mode of operation in which screened containers could be utilized to permit continuous flushing.

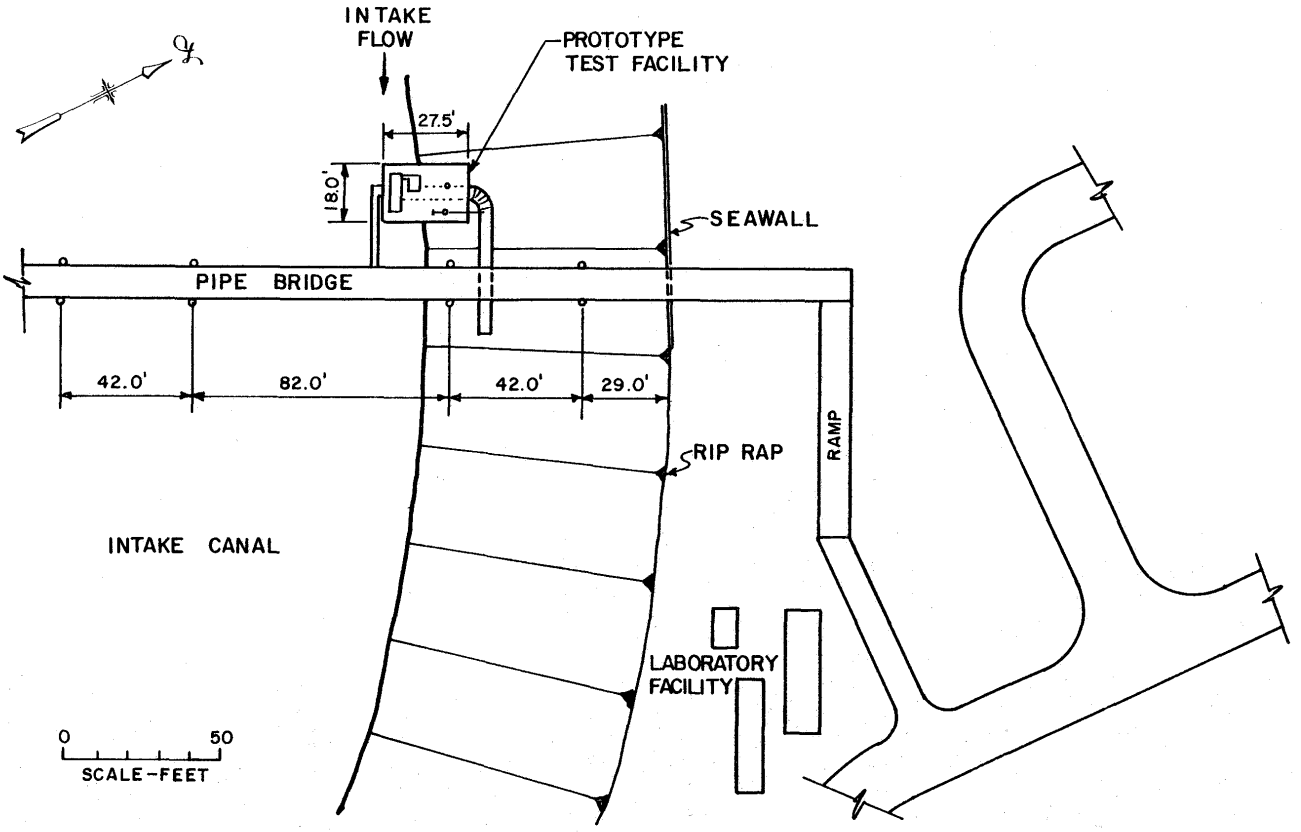

FIGURE 2-1
SITE PLAN
FINE-MESH SCREEN PROTOTYPE
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

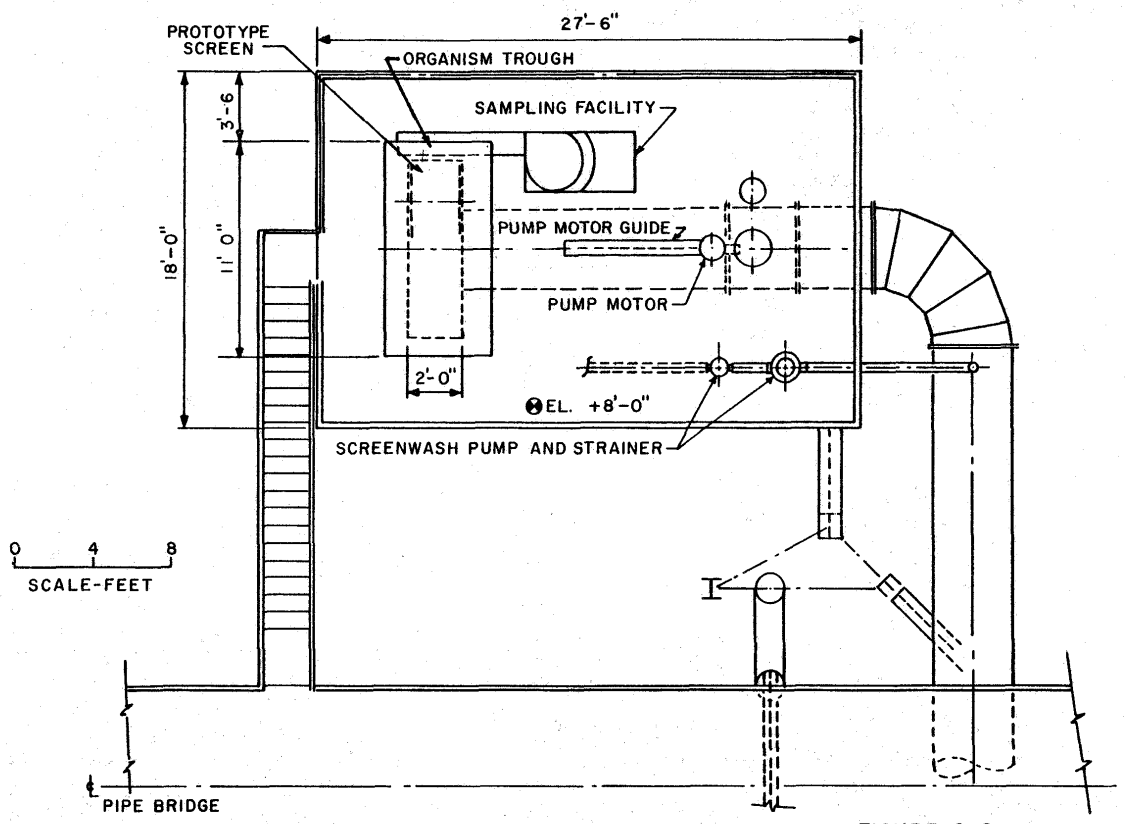

FIGURE 2-2
DECK ARRANGEMENT
FINE-MESH SCREEN PROTOTYPE
BIG BEND STATION- UNIT 4
TAMPA ELECTRIC COMPANY

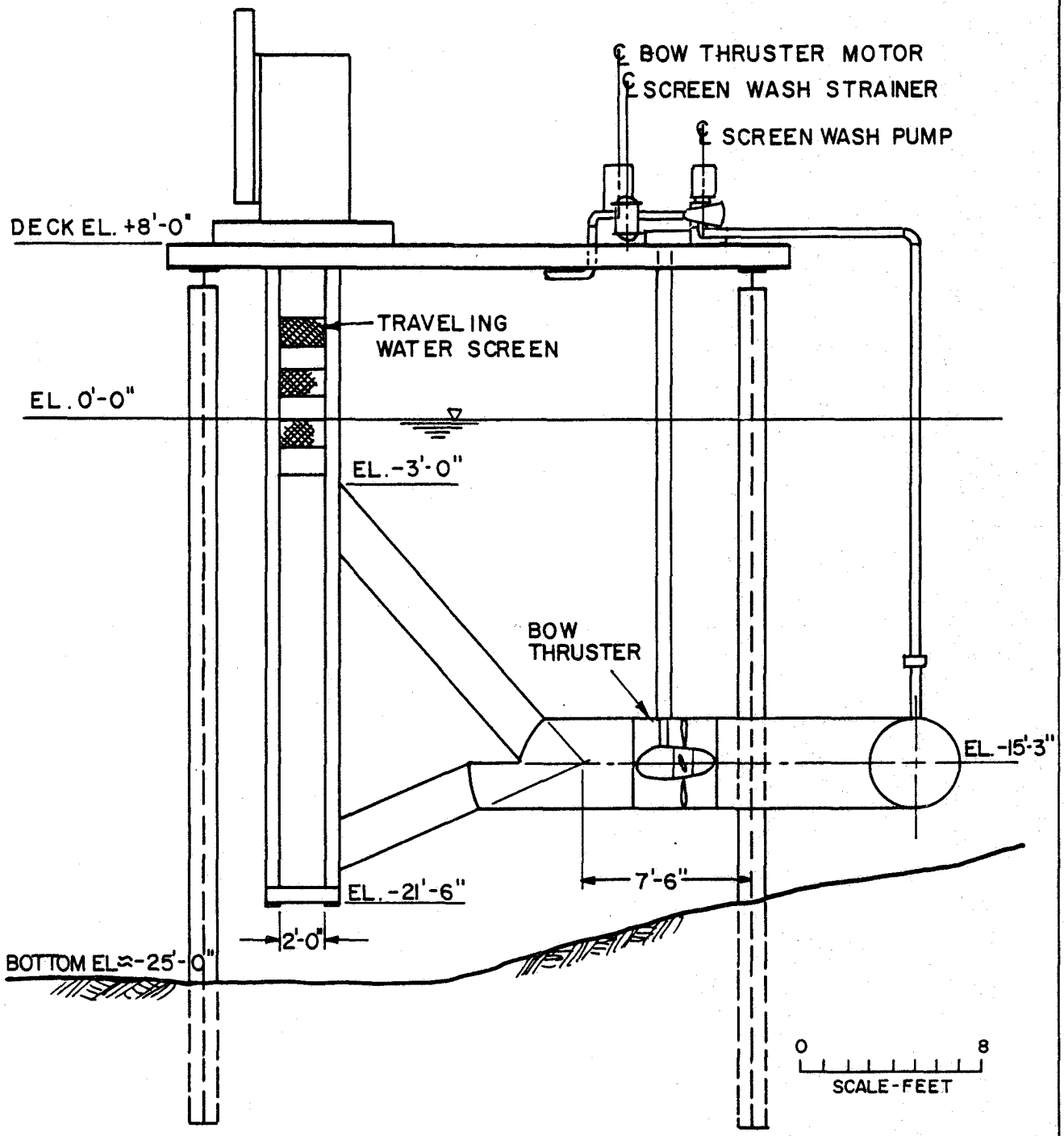

FIGURE 2-3
PROFILE ARRANGEMENT
FINE-MESH SCREEN PROTOTYPE
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

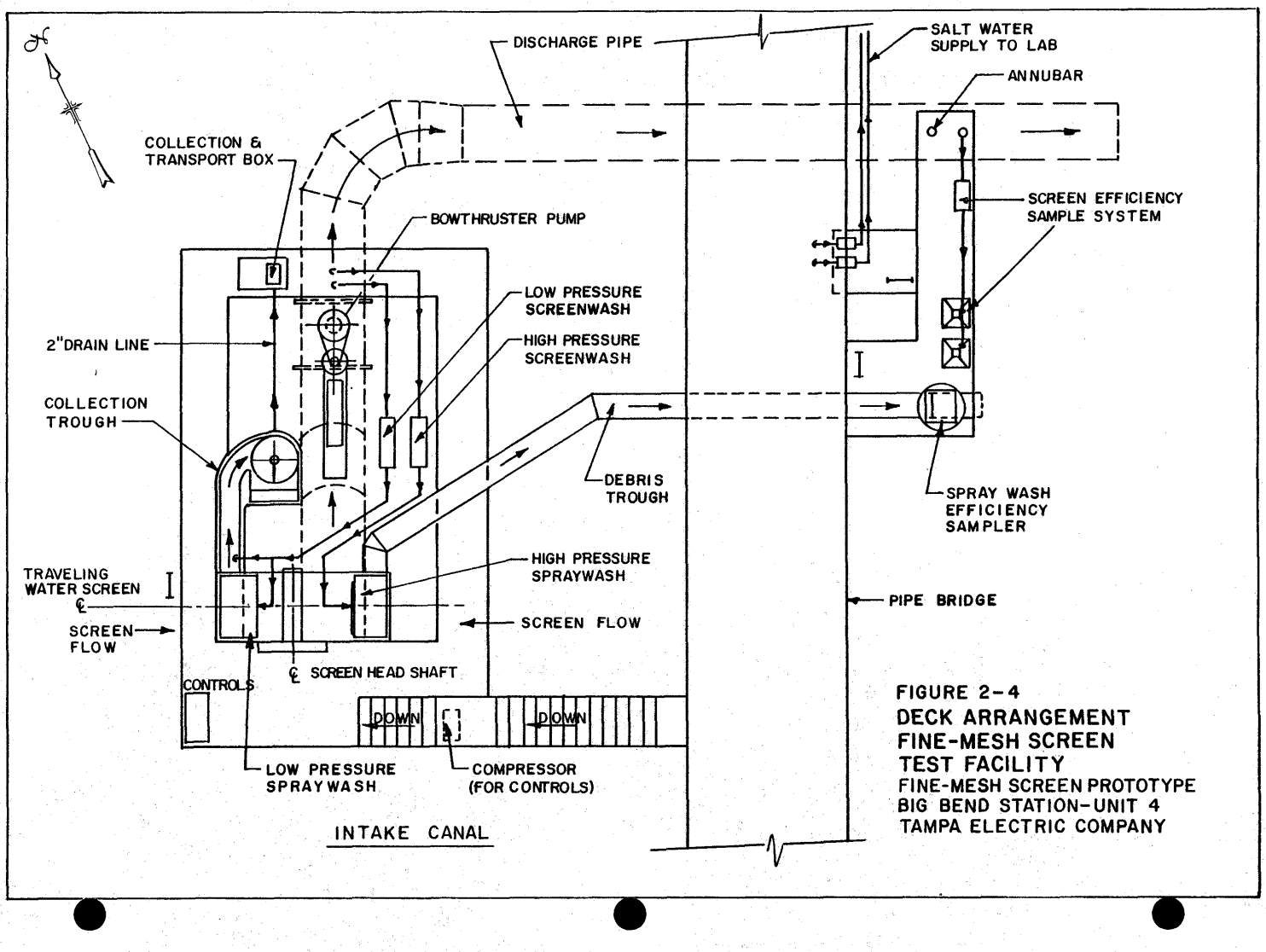

FIGURE 2-4
DECK ARRANGEMENT
FINE-MESH SCREEN
TEST FACILITY
FINE-MESH SCREEN PROTOTYPE
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

SECTION 3

SAMPLING PROCEDURES

3.1 INTRODUCTION

Sampling with the prototype screen began on March 3, 1980. In addition to routine screen sampling, a number of supplemental studies were included in the original program design or have since been added. Procedures for all studies are presented in this section whether or not they have been utilized to date. However, those procedures utilized to date are described in greater detail. Supplemental study data will be analyzed in the near future and will be presented in the final report. Therefore, the procedures used in the supplemental studies are presented briefly here but will be discussed in detail in the final report.

3.2 REPRESENTATIVE IMPORTANT SPECIES

During the study program, emphasis has been placed on obtaining survival data for the RIS life stages listed below:

Species	Life Stage
Bay anchovy	Egg, yolk-sac larvae, post-larvae, juveniles
Black drum	Egg, yolk-sac larvae, post-larvae, juveniles
Silver perch	Egg, yolk-sac larvae, post-larvae, juveniles
Spotted seatrout	Egg, yolk-sac larvae, post-larvae, juveniles
Scaled sardine	Egg, yolk-sac larvae, post-larvae, juveniles
Tidewater silverside	Egg, yolk-sac larvae, post-larvae, juveniles
Stone crab (Xanthids)	Zoeal stages, megalops
Pink shrimp	Post-larval stages
American oyster	Larvae
Blue crab	All life stages

The rationale for the selection of the RIS at Big Bend Station is presented in a separate report (S&W 1980). Life stage selections were based on the probable occurrence of each RIS in screen samples given the proposed operating conditions.

Due to the difficulty in identifying live crab zoea, no attempt was made to sort and hold zoea by species. Rather, zoea were held as groups and identified at the completion of the survival studies. It was hoped that stone crab zoea would be in great enough abundance to yield meaningful survival data when sorted from other xanthid species.

Other species were held as well when space and time permitted. However, the RIS life stages always took priority over others. The decision to include or exclude in the study any species not listed above was made each day on the basis of abundance and available time.

3.3 PROTOTYPE SCREEN SAMPLING PROCEDURES

Essentially the same sampling procedures were utilized during the first two phases of the study. As discussed previously, tests were conducted at screen travel speeds of 7, 14, and 28 fpm and approach flow velocities of 0.5 and 1.0 fps. Therefore, a complete series of tests involved screen-wash collections at each of the six velocity/screen speed combinations in the following matrix:

		Screen Travel Speed (fpm)		
		7	14	28
Approach Velocity (fps)	0.5			
	1.0			

Within a given day, the timing of the sampling procedures was such that six samples could be collected and processed in the laboratory. Since the process of changing pulleys to achieve test velocities required several hours, it was not feasible to conduct tests at both velocities within a single day. Therefore, the pulleys were changed at the end of every second day of testing at a given velocity. Within a day, two replicates of a one-velocity/three-screen speed portion of the matrix were obtained.

During Phase 1, tests were conducted five days per week (up to six tests per day) during the daytime hours (approximately between the hours of 0900 and 1500). At the beginning of Phase 2, the sampling strategy was modified to include night collection. The intent of night sampling was to determine whether species/life stage occurrence, abundance and/or mortality differ between day and night. Under this mode, sampling was conducted Monday through Thursday during the daytime and Thursday night between approximately 1900 and 2400 hrs.

Regardless of phase or sampling strategy, the same procedures have been utilized in all tests to date and will be used during Phase 3. Prior to sampling, the bow thruster pump and screen (Figure 2-3) are set at the desired operating point for the specific test being conducted. The low- pressure spraywash is preset at 10 psi and then shut off until the sample is taken. Once the screen is in full operation and the movement of water and organisms through the test facility is in steady-state, sampling is initiated by turning on the low-pressure spray, allowing the contents of a predetermined number of screen baskets to be rinsed into the collection trough, and then shutting off the spray. The number of baskets washed differs for each water velocity/screen travel speed condition such that

at each condition, the total volume of water sampled by the prototype screen is equivalent.

Organisms washed into the collection trough are carried into a primary collection area (Figure 2-2) which contains a screened overflow (0.25 mm mesh). In this area, large debris (leaves, shells, ctenophores) can be removed as the area drains. Once the water level reaches the bottom of the overflow screen, the sample is concentrated to the point where it can be drawn down into the secondary collection and transport chamber where the sample is further concentrated. The drawdown is slow and gentle to avoid stress due to high velocities and turbulence in the drain line and container.

Once the sample has been completely transferred, the container is sealed and transported to the land-based laboratory for sorting and latent effects studies.

At the time of each sample, the following information (as a minimum) is recorded: date; time; air temperature; water temperature of the intake and collection area; tidal stage and measured height; wind direction and velocity; screen travel speed; screen flow velocity (nominal); spraywash pressure; any unusual sampling problems which occurred; and any other information which is deemed important.

In addition to screenwash samples, control organisms have been collected and held for comparison to 96-hr mortality values experienced among organisms collected by the screen. During Phase 1, control organisms were collected one day per week, generally Monday, while in Phase 2, controls were collected twice weekly.

Control organisms are collected from the intake canal by suspending a stationary plankton net in the canal flow (velocity $\leq$0.4 fps) for approximately five minutes. The net is then gently washed and the contents are transported to the laboratory where the sample is sorted for RIS life stages. Up to 60 of each life stage are then held in lots of five individuals for 96-hr. As discussed in Section 3.4, 60 organisms represents two replicate control groups, since a normal test group consists of 30 individuals.

As mentioned above, all samples collected from the prototype screen are transferred to the land-based laboratory where they are sorted and held. The procedures for processing a screen sample from time of entry into the laboratory to the end of the latent-effects holding period are presented in the following section.

3.4 LABORATORY PROCEDURES

Once the transport container is delivered to the laboratory, the following procedures are carried out:

1. The transport container is placed in a water bath and temperature is recorded immediately.

2. When RIS are abundant, the sample is gently stirred or agitated to obtain a homogeneous distribution of organisms and a volumetric subsample is drawn off.

3. The primary sample is maintained in a water bath and held for later processing.

4. The subsample (in a water bath) is sorted immediately into species/life stages, concentrating on RIS species first.

5. Up to five individuals of each species/life stage are placed in a separate container for transfer to the holding area; organisms are sorted to the lowest taxonomic level possible without delaying initiation of holding or adding incremental stress to the test organisms; crab zoea are held in lots of 48.

6. A species/life stage sample consists of 30 organisms (48 zoea); therefore, once six lots of a species/life stage are counted and recorded, they are transferred immediately to the holding area for the latent effects study.

7. When "stunned" organisms occur in the subsample, they are treated in the same manner as the live organisms, but are held as a separate, additional, latent-effects sample.

8. Sorting continues until samples of all RIS life stages have been placed in holding containers; the location of all organisms is carefully documented.

9. The remainder of the subsample is sorted by species, recording numbers of live, stunned, and dead organisms on data sheets. (These data will be used to determine "initial survival.")

10. If the primary sample is no longer needed, it is preserved for later analysis.

11. If organism densities are low, several additional subsamples are taken in order to obtain 30 live organisms of available RIS for holding; in this case, only the first subsample is completely sorted for live, stunned and dead organisms; the remaining subsamples are drawn only to bring the total of each RIS life stage to 30 (48 zoea), if possible. All organisms now in the holding facility are checked at 3, 6, 12, 18, 24, 36, 48, 60, 72, 84, and 96 hr; the number live and dead at each check is recorded, as well as any abnormal occurrences (e.g., missing organisms).

12. All organisms which die during the holding period are preserved in labeled vials.

13. At the completion of the holding period, the final number of live and dead organisms is recorded and each group is preserved in a labeled vial.

14. Water quality parameters are recorded frequently during all holding experiments; parameters recorded include salinity, temperature, dissolved oxygen, pH, and ammonia.

15. At the end of each latent-effects test, all vials are rechecked and all organisms are identified (to species, if possible), categorized to life stage and counted.

These procedures have functioned very effectively in permitting an accurate accounting of most organisms from collection through final identification. Data gathered during each stage of the latent-effects studies are recorded on various data sheets which are subjected to frequent quality assurance checks. A detailed description of the data handling procedures employed is given in the appendix to this report.

3.5 SUPPLEMENTAL STUDIES

In addition to the prototype screen sampling efforts, several supplemental studies are being, or will be, conducted to gather information which will be used in the overall evaluation of the potential effectiveness of fine-mesh screens at Big Bend Station. Each study is described individually below.

3.5.1 Spraywash Efficiency Study

Since the spraywash system being incorporated into the prototype screen represents a new design, the efficiency of the system in washing organisms into the collection trough is being investigated. Samples are collected by screening the water exiting the debris trough on the high-pressure spraywash side of the screen while the low-pressure spraywash is in operation (refer to Figure 2-2). In this way, the number of organisms removed by the low-pressure spray can be directly compared to the number carried over to the high-pressure spray and the low-pressure spraywash efficiency can be calculated. If the low-pressure spray is effectively cleaning the screen mesh and lifting buckets, relatively few organisms should be recovered in the high-pressure spraywash water. Naturally, the speed of the screen will influence cleaning efficiency, with efficiency expected to decrease as speed increases. Therefore, samples are taken at all three travel speeds (7, 14, and 28 fpm).

Each sample is concentrated by washing down the screened collection box and is then preserved for later analysis by laboratory personnel. Laboratory analysis consists of enumeration, identification to species or lowest feasible taxonomic level, determination of life stage and size measurements (fish larvae only).

3.5.2 Plankton Net Sampling

Plankton net samples collected adjacent to the prototype screen structure will be used to compare the relative meroplankton impingement rates at the various screen test conditions with the abundance of meroplanktonic

organisms measured in the immediate vicinity of the prototype structure. Samples are collected using the same techniques employed in the 1979 meroplankton study (Mote Marine Laboratory, 1980). Four replicate samples are collected on one day during each week of screen sampling at the time that screen samples are collected. Samples are preserved for later processing. Laboratory analysis for RIS will consist of enumeration, identification to species or lowest feasible taxonomic level, determination of life stage, and size measurement (fish larvae only).

3.5.3 Prototype Screening Efficiency

To determine the efficiency of the prototype screen in preventing the passage of organisms either through the 0.5-mm mesh or the various sealed areas in the screen assembly, samples of the screened water will be taken during Phase 3. Samples will be preserved and processed in the laboratory. Laboratory analysis will consist of enumeration, identification to species or lowest feasible taxonomic level, determination of life stage, and size measurements.

Samples will be collected from the sample pump discharge (refer to Figure 2-4) in two conical plankton nets submerged in tanks. Results obtained will be used to establish the need for additional sampling or, possibly, modifications to the screen. The Phase 3 samples will be processed immediately after collection and the data will be examined to determine whether major "leaks" exist in the screening assembly which must be found and sealed prior to use on a full-scale basis at a power plant intake.

3.5.4 Air Exposure Studies

Past studies have shown that some organisms, particularly in their early life stages, are very sensitive to air exposure. Since the prototype screen has the potential for exposing impinged organisms to the air for short periods of time (several minutes), it is desirable to determine how this additional stress factor might influence overall mortality resulting from collection and removal from the fine-mesh screening. Accordingly, provisions were made to conduct on-site studies on species showing low survival. During such studies, individuals would be exposed to the air for up to three minutes, followed by 96-hr mortality determinations. Past research at Big Bend indicates that Anchoa mitchilli may be particularly sensitive to air exposure. Since the anchovy is abundant at Big Bend, it was planned that emphasis would be placed on testing this species.

To date, very high initial mortality observed among anchovy larvae collected by the prototype screen is not believed to be a function of air exposure, but rather the impingement and removal process. This conclusion is based on careful observation of the position and condition of these organisms as they clear the water surface during screen rotation. Under the conditions tested, anchovy larvae have been observed to be dead or dying as the screen panels enter the air. Therefore, it was not deemed necessary to conduct air exposure studies during Phases 1 and 2.

Should survival of anchovy larvae improve during Phase 3, such that air exposure appears to be affecting mortality, studies will be conducted. Testing will consist of placing small lots of organisms in holding containers with screened bottoms, lifting the containers out of the water for different periods of time (from ten seconds to three minutes), returning them to the water, and monitoring mortality for 96 hr.

The data obtained from this study effort would be used to determine the need for an additional low-pressure spraywash. To minimize air exposure, the wash would be located at a point just above mean high water and would be designed to rinse impinged (exposed) organisms from the screen mesh into the water-filled lifting bucket. In this way, the organisms would now remain in water while traveling upward to the spraywash located at operating deck elevation.

3.5.5 Organism Return System Investigations

3.5.5.1 Introduction

A critical component of an organism protection device is the design, operation, and discharge location of the organism return system. Should fine-mesh screens be employed at Big Bend Station, a trough will be utilized to transport collected organisms for discharge at one of two possible locations: (1) the presently unused canal just north of, and parallel to, the intake canal, and (2) off of the breakwater south of Fish Hook Spoil (Figure 3-1). At either location, two concerns exist: can the RIS organisms of concern at Big Bend be transported in a trough without undue stress, and will differences in water quality between the intake and the discharge location adversely affect the survival potential of returned organisms.

To address these concerns, S&W initiated a number of additional studies in May 1980. These studies will continue until September and will be discussed in detail in the final study report. Therefore, the following discussions present a brief summary of each task associated with the organisms return system studies.

3.5.5.2 Flume Study

In order to evaluate the effect of travel through a return trough on organism survival, studies will be conducted in a circular flume. The flume will measure 12 in. deep by 9 in. wide and will have an outer diameter of 8.3 ft. A central motor drive unit will propel paddles around the flume thereby moving the water contained therein. The paddles will seal tightly with the flume walls and bottom to prevent leakage.

Tests will be conducted by placing individual groups of RIS life stages into the flume and allowing them to circulate at velocities of 2 fps for 1 hr. This velocity is considered sufficiently high to move organisms rapidly to the release site and low enough to minimize damage due to turbulence and abrasion. Test organisms will be obtained from the prototype

screen. Thus, they will have experienced the entire process of impingement, removal and transport. The results can then be compared to the results obtained from the prototype screen to determine the incremental stresses of transport. Control organisms collected from the prototype screen will also be placed in the flume and collected to determine whether the flume testing procedure contributes substantially to any mortality observed.

Following each test run, the organisms will be removed from the flume by draining the water into a screened collection box. The organisms will then be enumerated as live, stunned, and dead and held for 96 hr to determine latent mortality. Holding procedures will be identical to those used in the prototype screen evaluation (Section 3.4).

3.5.5.3 Water Quality Measurements

Assuming that the organisms of interest at Big Bend can survive passage through relatively a long trough, a final question remains relative to the effects of water quality on ultimate survival. Of the two proposed discharge locations, the preferred location has been identified as the canal (Figure 3-1) which is parallel to, and immediately north of, the power plant intake canal (PIC). This location would have a much shorter travel distance and would therefore return the organisms quickly with less potential for transport stresses. Due to differences in flushing rates, it is possible that this proposed organism return canal (ORC) could differ in water quality from the PIC to the extent that organism survival would be affected. In order to identify any important differences in water quality between the ORC and the PIC, a series of water quality, hydrographic and plankton samples will be collected during Phase 3 (May through September). The other possible discharge location off of the breakwater south of Fish Hook Spoil is an area of ambient bay conditions and is deemed to have acceptable water quality should it be used. Three sampling stations have been established: one in the PIC and two in the ORC (Figure 3-1). The frequency of sampling is determined by the tasks, as outlined below:

a. Water Quality Sampling: DO, pH, salinity and temperature will be recorded at three depths (surface, mid-depth, bottom) at each station using a YSI DO meter, a YSI S-C-T meter and an Orion pH meter. Sampling will occur on a weekly basis in the first week of May and terminate in the third week of September.

b. Other Water Quality Parameters: NO_3, NO_2, NH_3-N, Organic N, Ortho-P, Organic P, chlorophyll "a" and phaeophytin "a", BOD_5, TSS, oil and grease, metals (Cd, Ni, Zn, Hg, Mn, Cr, Cu, Fe, Pb), organochlorine pesticides and fecal coliforms will be sampled at each station at two depths (surface and bottom). Samples will be taken once per month and one time 24 hr after a heavy rainfall.

3.5.5.4 Plankton Sampling

To aid in the determination of the suitability of ORC water for sustaining the RIS returned from a fine screening installation, phytoplankton, zooplankton, and meroplankton samples will be collected at each water quality station once per month from May through September. Four replicates will be collected at each station for each sample.

Phytoplankton samples will be collected with a 1 gal water sampler from about 0.5 ft below the water surface at each station (four samples per station). The samples will be preserved in the field, returned to the laboratory and processed in the following manner:

A minimum of two subsamples will be analyzed from each sample, the subsample will be pipetted into a 0.12 m Palmer nannoplankton counting chamber where cells will be allowed to settle before examination under a microscope. Large phytoplankton will be enumerated and identified at 200X magnification and small diatoms and phytoflagellates at 400X magnification. One or two diameters of the counting chamber will be scanned until approximately 150 to 200 cells are counted (filamentous blue-green algae, however, are counted as trichomes and not cells). Identification will be carried to the species level for large cells and to the lowest practical level for small diatoms and phytoflagellates.

The total concentrations of cells in the subsample will be calculated by:

$$C = \frac{N}{V}$$

where

C = total cell numbers (cells ml^{-1})
N = number of cells counted
V = volume examined (ml)

The total concentration of cells in the sample will be estimated from the average of the subsample concentrations.

Zooplankton samples (four at each station) will be collected with a 0.5 m diameter, 80 micron mesh net. At each station, the net will be allowed to sink approximately 2 m and will then be towed to near the surface. A General Oceanic 2030 flowmeter will be mounted on the mouth of the net to provide an estimate of the water volume sampled. Upon retrieval, the net will be washed down and the samples in the cod-end will be preserved in 10 percent buffered formalin.

Laboratory analysis of the zooplankton samples will be conducted in the following manner. A 5 or 10 ml aliquot (depending on the apparent abundance of zooplankton in the sample) will be withdrawn from each replicate sample and placed in a gridded petri dish. All animals contained in the aliquot will be enumerated and identified to the lowest practical taxonomic level under a dissecting microscope. If less than 200 animals are found in the initial aliquot, additional aliquots will be withdrawn and sorted

until at least 200 organisms are found. In some cases, due to low numbers of organisms, the entire sample will be sorted.

The number of organisms per m^3 at each station will be calculated from the mean number of organisms of each species from the four replicates.

Meroplankton samples will follow the methods of the 1979 Aquatic Ecology Program (Mote Marine Laboratory 1980).

3.5.5.5 Organism Survival Studies

Organism survival studies using ORC water in holding containers will be conducted during one week each per month from June through September. Organisms collected from the prototype screen will be sorted into batches of 30 (lots of five) and held in ORC water for 96 hr. Procedures will be as outlined in Section 3.4; however, all samples will be collected in one day. In addition, control organisms collected from the prototype screen will be held in intake canal water for comparison of latent survival.

3.5.5.6 Hydrodynamic Evaluation

Organisms which have been returned to the water body are once again subjected to the processes of ambient dispersion. A prediction and assessment of probable movement, especially the likelihood of reentrainment in the intake flow, is being sought in order to contribute to the evaluation of candidate release points.

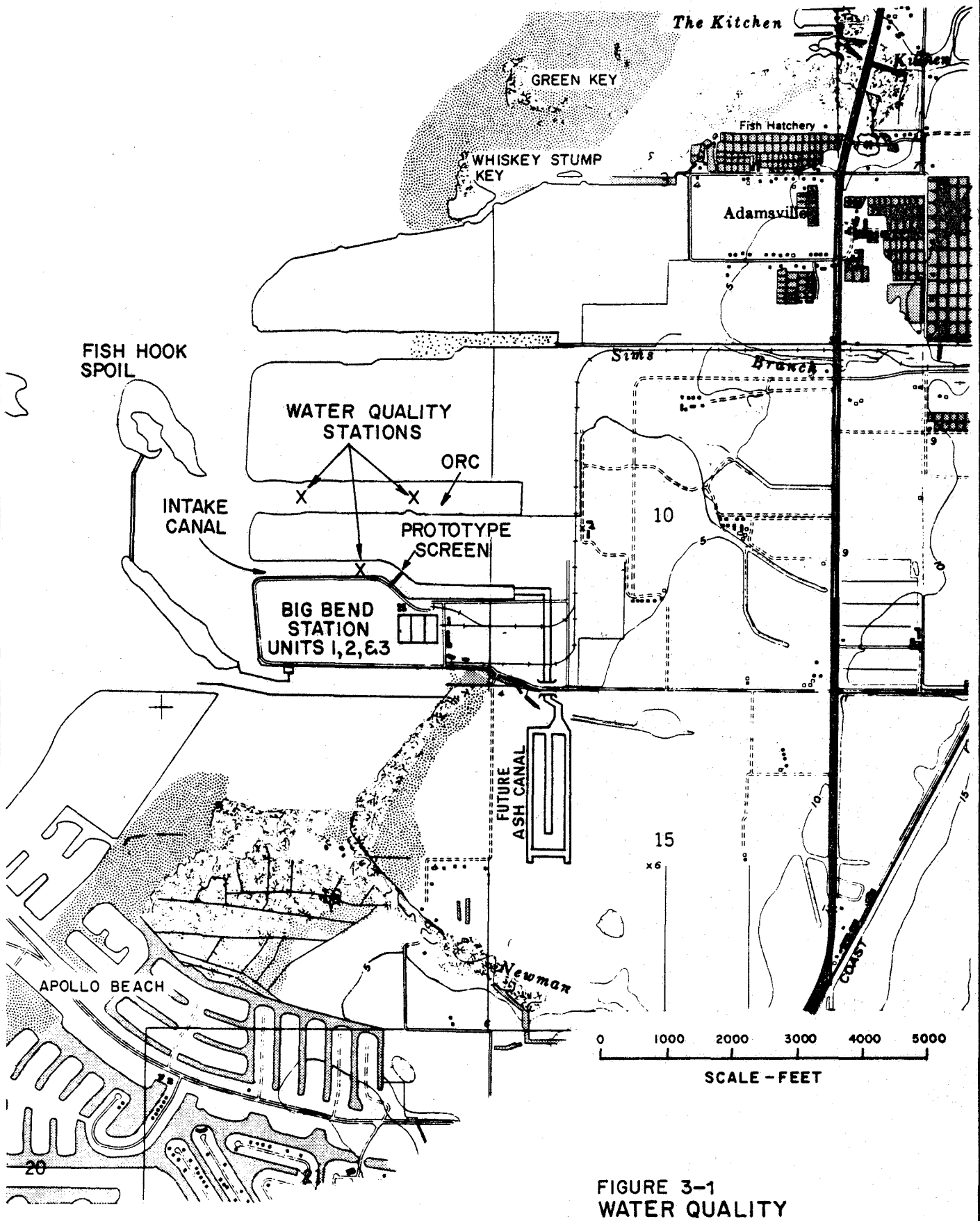

FIGURE 3-1
WATER QUALITY
SAMPLING STATIONS
FINE-MESH SCREEN PROTOTYPE
BIG BEND STATION- UNIT 4
TAMPA ELECTRIC COMPANY

SECTION 4

RESULTS TO DATE

This section presents the results of an analysis of available data collected during Phase 1 and part of Phase 2. The data represent initial and latent survivorship of organisms which have been collected by the fine-mesh prototype screen and control organisms not subjected to impingement stress. The results of initial survival studies include tests conducted up to May 7, 1980 and the latent survival data include results of tests conducted up to April 17, 1980.

The proportion of organisms which were alive when the sample was brought into the laboratory was determined from data on the species/life stages presented in Table 4-1. In order to have sufficient observations for analysis, less abundant species were combined to form the following groups: sciaenids, clupeids, gobies, decapods (minus the stone crab). The bay anchovy and stone crab were analyzed separately.

Table 4-2 presents the mean initial survivorship and the standard deviation for the organism groups. These data indicate that the invertebrates had the highest survival, most often in excess of 90 percent. The fragile fish, such as the bay anchovy (Anchoa mitchilli), had low survivorship, as expected for larvae and post-larvae.

To provide an indication of the source of variability in these survivorship estimate, an analysis of variance was conducted according to the experimental design discussed in Section 3.3. All analyses of variance were conducted by life stage on the taxanomic groupings identified in Table 4.2.

Table 4-3 presents the results of the analyses of variance. In general, few of the analyses revealed significant ($p \leq 0.05$) effects for screen speed, approach velocity or their interactions. An inspection of the means which are significantly different suggests that the results between species are confused. For example, the bay anchovy egg interaction between screen speed and approach velocity reveals higher survivorship at 1.0 fps than 0.5 fps for screen speeds of 7 fpm and 28 fpm, and the reverse pattern for 14 fpm. Since this pattern is contrary to expectation and not confirmed by the other species, the result is probably a function of the samples analyzed to date and not a general trend.

Therefore, in view of the few analyses which revealed significant screen speed or approach velocity effects and the unexpected nature of some of the differences, it appears that, in general, the initial survivability is not greatly affected by screen speeds from 7 to 28 fpm or approach velocities from 0.5 to 1.0 fps.

The latent survivorship of those organisms which were initially alive was studied in the holding experiments in the laboratory. The proportion of organisms which were alive at 48 hr and 96 hr was used as an index of latent survival.

Species/life stages which were used as a basis to determine 48 and 96 hr latent survivorship are presented in Table 4-4 and 4-5, respectively. As with the initial survivorship estimates, these data were collapsed into similar taxonomic groups for analysis. The mean and standard deviation for the 48 and 96 hr survivorship values are presented in Tables 4-6 and 4-7, respectively. The results indicate that survivorship is taxa-and life stage-specific, as is the relationship between 48 and 96 hr values. These values should be viewed in connection with control survivorship presented later in the results.

The hatchability of eggs during the holding experiment is an index of the viability of the eggs. Since the development time of eggs for many of the species tested is quite rapid, nearly all eggs should hatch prior to 96 hr. Therefore, the proportion of eggs which hatched during the holding period is presented in Table 4-8.

An analysis of variance procedure, of the same design as the initial survival analysis, was employed to investigate the sources of variation in latent survivorship. The results of analyses of variance using 48 hr survivorship as the dependent variable are presented in Table 4-9, while the results using 96 hr survivorship as the dependent variable are presented in Table 4-10.

The results of the analyses of variance for latent survivorship were similar to that of the initial survivorships. Few independent variables for a few of the groups were found to be significant ($p \leq 0.05$). However, the fact that for most analyses these variables did not consistently explain a significant amount of variability, suggests that these variables within the range of values tested do not significantly alter the survivorship of organisms.

To date, the results of three control samples were available and the survivorship of control organisms which had not experienced the fine-mesh screen system are presented in Table 4-11. These survivorship values indicate that natural mortality, not associated with stresses resulting from the collection and holding procedures, is a contributing factor to the mortalities observed among organisms collected by the fine-mesh screen.

TABLE 4-1

TAXA/LIFE STAGES USED IN INITIAL SURVIVORSHIP ANALYSIS

Taxa	Common Name	Life Stage
Anchoa mitchilli	bay anchovy	eggs
		larvae
		postlarvae
Bairdiella chrysura	silver perch	postlarvae
Cynoscion arenarius	sand seatrout	postlarvae
Pogonias cromis	black drum	postlarvae
Sciaenidae	unidentified drums	eggs
		larvae
		postlarvae
Gobiosoma robustum	code goby	postlarvae
Microgobius gulosus	clown goby	postlarvae
Microgobius sp.	unidentified goby	postlarvae
Clupeidae	unidentified herrings	eggs
Harengula jaguana	scaled sardine	eggs
Menippe mercenaria	stone crab	zoea (stage 1)
Caridea	unidentified caridean shrimp	zoea (unstaged)

TABLE 4-1 (Cont'd)

Taxa	Common Name	Life Stage
Upogebia affinis	mud shrimp	zoea (unstaged)
Brachyuran	unidentified true crab	zoea (unstaged)
		megalops
Decapoda	unidentified decapods	zoea (unstaged)
"Shrimp"	unidentified shrimp-like decapods	zoea (unstaged)
Paguridae	unidentified hermit crabs	zoea (unstaged)

TABLE 4-2

Prototype Mean Initial Survival, by Grouping as Per Analysis of Variance (Table 4-3)

Species	Life Stage	No. Observations	Proportion Alive	
			Mean	Standard Deviation
Bay anchovy	eggs	174	0.391	0.238
	larvae	107	0.006	0.050
	postlarvae	126	0.015	0.097
Sciaenidae	eggs	171	0.712	0.240
	larvae	25	0.432	0.470
	postlarvae	107	0.179	0.366
Clupeidae	eggs	42	0.438	0.476
Gobiidae	postlarvae	49	0.022	0.091
Decapods (all)	zoea (unstaged)	373	0.908	0.255
	megalops	36	0.972	0.167
Stone crab	zoea (stage 1)	51	0.988	0.071

TABLE 4-3

Analysis of Variance for the Effect of Screen Speed and Approach Velocity on Initial Survival

Species	Life Stage	No. Observations	F Ratio		
			Screen Speed	Approach Velocity	Interaction
Bay anchovy	eggs	174	0.29	0.06	4.12*
	larvae	107	1.11	1.10	1.11
	postlarvae	126	1.21	0.86	0.37
Sciaenidae	eggs	171	0.90	2.17	3.47*
	larvae	25	0.13	0.25	0.03
	postlarvae	107	0.02	5.85**	1.62
Clupeidae	eggs	42	1.25	2.55	0.05
Gobiidae	postlarvae	49	2.20	0.23	0.25
Decapods (all)	zoea (unstaged)	373	7.80**	8.90**	0.42
	megalops	36	0.44	0.37	0.44
Stone crab	zoea (stage 1)	51	0.35	0.55	0.35

* $p \leq 0.05$
** $p \leq 0.01$

TABLE 4-4

Taxa/Life Stages Used In 48 Hour Latent Survivorship Analysis

Taxa	Common Name	Life Stage
Anchoa mitchilli	bay anchovy	larvae
		postlarvae
		hatched larvae
Bairdiella chrysura	silver perch	postlarvae
Cynoscion arenarius	sand seatrout	postlarvae
Pogonias cromis	black drum	postlarvae
Sciaenidae	unidentified drums	larvae
		postlarvae
		hatched larvae
Gobiosoma robustum	code goby	postlarvae
Microgobius gulosus	clown goby	postlarvae
Clupeidae	unidentified herrings	hatched larvae
Menippe mercenaria	stone crab	zoea (stage 1)
Caridea	unidentified caridean shrimp	zoea (unstaged)
Upogebia affinis	mudshrimp	zoea (unstaged)
Brachyura	unidentified true crabs	zoea (unstaged)
		megalops
Decapoda	unidentified decapods	zoea (unstaged)
"Shrimp"	unidentified shrimp-like decapods	zoea (unstaged)
Paguridae	unidentified hermit crabs	zoea (unstaged)

TABLE 4-5

Taxa/Life Stages Used In 96 Hour Latent Survivorship Analysis

Taxa	Common Name	Life Stage
Anchoa mitchilli	bay anchovy	larvae
		postlarvae
		hatched larvae
Bairdiella chrysura	silver perch	postlarvae
Cynoscion arenarius	sand seatrout	postlarvae
Pogonias cromis	black drum	postlarvae
Sciaenidae	unidentified drums	larvae
		postlarvae
		hatched larvae
Gobiosoma robustum	code goby	postlarvae
Microgobius gulosus	clown goby	postlarvae
Clupeidae	unidentified herrings	hatched larvae
Menippe mercenaria	stone crab	zoea (stage 1)
Caridea	unidentified caridean shrimp	zoea (unstaged)
Upogebia affinis	mud shrimp	zoea (unstaged)
Brachyura	unidentified true crabs	zoea (unstaged)
		megalops
Decapoda	unidentified decapods	zoea (unstaged)
"Shrimp"	unidentified shrimp-like decapods	zoea (unstaged)
Paguridae	unidentified hermit crabs	zoea (unstaged)

TABLE 4-6

48 HOUR LATENT SURVIVORSHIP

Species	Life Stage	N	Proportion Alive	
			Mean	Standard Deviation
Sciaenidae	hatched larvae	850	0.844	0.325
	larvae	31	0.228	0.399
	postlarvae	133	0.890	0.282
	adult	12	1	0
Clupeidae	hatched larvae	74	0.951	0.209
	postlarvae	10	1	0
Bay anchovy	hatched larvae	945	0.612	0.244
	larvae	8	0.125	0.354
	postlarvae	10	0.700	0.483
Stone crab	zoea (stage 1)	63	0.965	0.148
	(stage 2)	11	1	0
Decapods (all)	zoea (combined)	433	0.955	0.192
	megalops	88	0.985	0.112

TABLE 4-7

96 HOUR LATENT SURVIVORSHIP

Species	Life Stage	N	Proportion Alive	
			Mean	Standard Deviation
Sciaenidae	hatched larvae	850	0.788	0.372
	larvae	31	0.183	0.376
	postlarvae	133	0.798	0.342
Clupeidae	hatched larvae	74	0.851	0.323
	postlarvae	10	0.900	0.316
Bay anchovy	hatched larvae	945	0.432	0.225
	larvae	8	0.125	0.354
	postlarvae	10	0.433	0.410
Stone crab	zoea (stage 1)	63	0.894	0.248
	zoea (stage 2)	11	0.727	0.467
Decapods (all)	zoea (unstaged)	433	0.736	0.415
	megalops	88	0.908	0.272

TABLE 4-8

Hatchability of Eggs During Holding Experiments

Species	Proportion of Eggs Hatched
Bay anchovy	0.865
Clupeidae unidentified	0.588
Sciaenidae unidentified	0.842

TABLE 4-9

Analysis of Variance for 48 Hour Latent Survival

Species	Life Stage	F Value: Screen Speed	F Value: Approach Velocity	F Value: Interaction	No. Observations
Sciaenidae	hatched larvae	0.33	4.69*	0.07	849
	larvae	0.28	1.10	0.36	31
	postlarvae	1.38	3.79	2.64	133
Clupeidae	hatched larvae	0	0.53	0	74
Bay anchovy	hatched larvae	0.52	86.71**	0.60	945
Stone crab	zoea (stage 1)	0.30	1.66	1.01	63
Decapods (all)	zoea (combined)	2.93	3.71	2.38	433
	megalops	1.44	2.92	1.44	88

*$p \leq .05$
**$p \leq .01$

TABLE 4-10

Analysis of Variance for 96 Hour Latent Survival

Species	Life Stage	F Value: Screen Speed	F Value: Approach Velocity	F Value: Interaction	No. Observations
Sciaenidae	hatched larvae	1.08	1.60	0.19	849
	postlarvae	2.45	1.82	0.91	133
Clupeidae	hatched larvae	0.88	0.38	0.02	74
Bay anchovy	hatched larvae	4.07*	49.82**	0.17	945
Stone crab	zoea (stage 1)	0.03	0.04	0.29	63
Decapods (all)	zoea (combined)	3.66*	13.51**	2.96	433
	megalops	0.71	0.06	1.79	88

*$p \leq 0.05$
**$p \leq 0.01$

TABLE 4-11

Latent Survival for Control Samples

Species	Life Stage	No. Observations	Proportion Alive		Hours Held
			Mean	Standard Error of the mean	
Bay anchovy	hatched larvae[1]	40	0.558	0.025	48
			0.367	0.020	96
	postlarvae	13	1	0	48
			0.600	0.047	96
Cynoscion arenarius	hatched larvae[2]	28	1	0	48
			1	0	96
Unidentified fish species	hatched larvae[3]	15	1	0	48
			0.889	0.051	96
Menticirrhus sp.	hatched larvae[2]	11	1	0	48
			1	0	96
Sciaenidae unidentified	hatched larvae[4]	11	0.430	0.036	48
			0.125	0.039	96

[1]Hatchability after 96 hours = 0.873
[2]All eggs hatched
[3]All eggs hatch or included in Sciaenidae unidentified
[4]Hatchability after 96 hours = 0.994

SECTION 5

CONCLUSIONS

The results presented in Section 4 indicate that fine-mesh screening is a viable alternative for removing organisms from the circulating water flow at Big Bend Station and returning them safely to their natural environment. The 0.5-mm mesh used on the prototype screen has demonstrated its capacity for effectively retaining the RIS life stages under study; therefore, such a fine-mesh system would ensure the protection of the RIS at Big Bend.

Results of testing to date indicate that initial and latent survival are species- and life stage-dependent, with invertebrates showing the highest survival and bay anchovy larvae showing the lowest survival. Such low survival rates for anchovy larvae were anticipated given the very fragile nature of this species.

Initial and latent survival of fish eggs was relatively high, particularly among Sciaenids. No attempt was made to adjust latent survival values for control mortality (Table 4-11); however, by comparing test and control mortalities, it is evident that much of the mortality observed among test organisms is a reflection of natural mortality and handling stress. The process of collecting, concentrating and sorting organisms removed from the prototype screen is certainly a contributing factor in mortality that would not be as severe in a full-scale, fine-mesh screen facility. This fact, and consideration of control mortalities, leads to the conclusion that survival values at Big Bend could be higher than those observed in studies to date. Overall survival values for invertebrates, specifically the stone crab, should approach 100 percent.

Although few fish and invertebrate juveniles and adults are impinged at the existing Big Bend Station, a fine-mesh screen intake system should greatly alleviate impingement and would reduce the mortality of those organisms which would become impinged since they are presently all killed after being collected from the screen. Observations in 1979 and 1980 of the survival of the few juvenile and adult organisms collected by the fine-mesh screen suggest that they are not affected by the impingement and removal process. These organisms can be returned to Tampa Bay without significant effect on the overall biological integrity of the bay system.

On the basis of existing data, it would appear that installation of fine-mesh screening on Big Bend Units 3 and 4 would result in entrainment losses less than those presently experienced with Units 1 to 3 without dilution pumping. Further studies throughout the summer months will provide additional data to refine these preliminary results. Additional species/life stages of the RIS will be studied in the summer months; additional control data will be collected; verification of filtration and spray wash efficiencies will be made; and return flume survival will be estimated. In addition, the remainder of the study data gathered this spring but not included in this report will be added to the data base and subjected to further analyses.

REFERENCES

Mote Marine Laboratory, 1980. 1979 Aquatic Ecology Program, Big Bend Power Station, Tampa, Florida. Final Report (April 21, 1980).

Stone & Webster Engineering Corporation, 1980. Studies To Develop An Intake Design For Reducing Entrainment Losses, Unit No. 4-Big Bend Station. Prepared For Tampa Electric Company (February 1980).

APPENDIX

PROTOTYPE FINE-MESH SCREEN EVALUATION
BIOLOGICAL STUDIES
PROGRESS REPORT
BY
MOTE MARINE LABORATORY

PROTOTYPE FINE MESH SCREEN
EVALUATION
BIOLOGICAL STUDIES

PROGRESS REPORT

Reference : ESSOW No. 12408.04-W003V
J.O. No. 12408.04

Submitted to: Stone and Webster Engineering Corporation
P.O. Box 2325
Boston, Massachusetts 02107
Attn: Mr. Curtis R. Young

Submitted by:

Selvakumaran Mahadevan, Ph.D.
Staff Scientist/Project Manager

Mote Marine Laboratory
1600 City Island Park
Sarasota, Florida 33577

March 15, 1980

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APENDIX - EXAMPLES OF PROJECT DOCUMENTATION AND RECORDS

I. INTRODUCTION

The Prototype Fine Mesh Screen Evaluation Biological studies were begun on February 1, 1980. The preliminary phase (February 1-29, 1980) addressed some of the potential problems that may arise in the regular testing program and conducted short-term studies on feeding requirements, best methods for observation and sorting, and the suitability of a closed system for holding organisms. The phase also physically set up the holding facility and its once-through seawater system, and conducted tests to debug the seawater system. Phase 1 (March 1-31, 1980) was designated as a shakedown phase. This phase requires intensive sampling as part of a preliminary screen evaluation. Data obtained will serve as a basis for finalizing test parameters and procedures to be used in phases 2 and 3 (Regular Testing Program; Phase 2: April 1 to May 15, 1980; phase 3: June 1 to September 15, 1980). This report provides a summary of progress to date on the preliminary phase and part of phase 1. It provides a description of the Standard Operating Procedures (SOP) to be used in the Regular Testing Program, discusses findings of the preliminary phase and provides a summary of the recommendations of our expert consultants to date on the sorting and holding procedures. Based on our findings and the recommendations of the consultants, we request approvals for certain methods and procedures that are not specifically addressed in the ESSOW for the study.

II. PROGRESS TO DATE

a) Facilities

As specified in the ESSOW, a laboratory facility has been set-up at the site (Big Bend). The laboratory is located in two trailers:

Trailer 1 (Holding Facility): This 60' x 12' trailer is outfitted with a once-through seawater system. The seawater is distributed to 23 tables. Nineteen of these tables are "holding" tables with a capability of holding approximately 8000 organisms at one time. Holding containers are 500 ml. jars and tackle box trays. Four of these tables are "sorting" tables (space for a total of eight sorters) with glass windows and

underneath-the-table lighting. Seawater is withdrawn from the intake canal and piped to a tank via two filters (a dual system exists from intake to the tank for purposes of a back-up system). From the tank, the seawater is piped to the tables through three lines. Each table has an individual valve for water flow control. The holding facility also has two worktables where microscopes are available. Four carts in the facility serve as observation aids (carts lighted from underneath with glass windows on top) and as water quality monitors tray.

Trailer 2 (office): This 48' x 12' trailer serves as the office trailer. It contains office space for the section supervisors (Comp and Phillips), work-space for the technicians (including microscope area, a copier, files and a culture room where algae and rotifers are grown).

The laboratory facilities have been inspected by the following Stone and Webster personnel: Messrs. E.P. Taft, C.R. Young and R. Felts. The seawater system has been continuously operating since February 29, 1980 and no problems have been encountered. The laboratory design was as outlined in the proposal; no variations were made. To date, samples to about 1/3 capacity of the holding facility are being processed. Approximately 4-5 spaces in the sorting area are being utilized.

b) Preliminary Studies

All reports culminating from the preliminary studies have been forwarded to Stone and Webster personnel, C.R. Young and E.P. Taft (please see letter of transmittal dated 2/29/80 and accompanying enclosures). Since those reports, we have held organisms (collected by a plankton net and from the screen) at the site (holding facility). Data sheets have been transmitted to Mr. E.P. Taft. These combined studies re-inforced our earlier findings that organisms could be held in closed containers.

Summarizing the findings to date:

1. Feeding is required for larvae beyond the eye pigmentation stage.
2. High survival rates were evident even in closed containers.
3. Mortality stains are too species-specific and are difficult to be retained in the preservation stage.
4. Various methods of observation of live/dead organisms were tested and guidelines for best methods in sorting and observing were drawn.
5. Control organisms can be successfully collected with plankton nets.

c) External Expertise

Dr. Sheldon Dobkin and Mr. Keith Taniguichi visited the holding facility and provided input in the sorting and holding of organisms. Letters summarizing their suggestions were sent to Messrs. E.P. Taft and C.R. Young (dated 2/29/80 and 3/11/80). Both felt that closed systems (500 ml containers or tackle box trays) would be adequate if the organisms densities are low and if water change is accomplished at least once during the 96 hour period (preferably at the 48-hour observation check). Both felt that feeding is necessary if the organisms are held for 96 hours. Both speculated that 48 hours would be a sufficiently long period for estimating latent mortality. Both experts provided various suggestions to our staff for efficient sorting and holding techniques.

III. STANDARD OPERATING PROCEDURES

The Standard Operating Procedures (SOP) for the program are discussed below.

FIELD PROCEDURES

Procedures have been established for the conduct and documentation of activities which take place in the field. Implementation of the procedures is the direct responsibility of the Section Supervisor who will be in the field during most if not all sampling trips. In addition to periodic observation of sampling activities, the program manager will review field documentation to assure that all required information has been provided, that all procedures were followed and that proper signatures have been obtained.

Procedures for the collection of meroplankton RIS in the intake canal were described in the Scope of Work of this project.

Tows are taken as described in the Scope of Work for this project. A 4.8 m beam is mounted across the boat to allow the nets to fish

outside the prop wash as much as possible. The nets are released simultaneously, allowed to sink to near the bottom, and pulled from that position so as to travel obliquely through the water column. The nets are then recovered simultaneously over the same side of the boat. Flowmeter readings are taken, checked, and entered in the log-book. The nets are rinsed into the cod end, the cod jar is removed, and an internal label and formaldehyde are added. The jar is capped, shaken, another jar is screwed onto the net, and the procedure repeated.

Physical data are taken upon arrival at the station. Station depth is taken by a marked line at the Hydrolab which is lowered vertically and the depth read directly. The line is marked in 0.5 m intervals. From the depth data, mid and bottom depths are found for measurement of hydrographic data. Data are taken by one person, with any questionable data retaken by another person after all readings for all depths have been completed.

Plankton nets are thoroughly rinsed after each tow to minimize cumulative net clogging. Nets are checked for tears after every sampling trip, and machine washed in cold water whenever microscopic examination shows any change in pore size due to clogging. If necessary, minor repairs to the nets are performed in the field.

All samples are preserved in the field and are doubly labeled, i.e., both internal and external labels for sample containers. The labels identify the sample by date, station, gear, time of sampling, and tow number, and are initialed by the Section Supervisor. Samples are returned to the laboratory immediately after completion of a sampling trip.

All data are recorded by one person of the field crew and checked and signed by another member of the field crew.

Spraywash and screen efficiency samples are collected by Stone and Webster personnel and given to a section supervisor at the holding facility. The section supervisor records collection data on internal and external labels of a quart jar. The sample is preserved with buffered formaldehyde in the quart jar and transported to MML-Sarasota laboratory.

LABORATORY PROCEDURES

A. Net and Spraywash/Screen Efficiency Samples:

Plankton net samples and spraywash/screen efficiency samples are processed in the laboratory in a manner that each sample or subsample is traceable to its collection and that all data reported for these portions of the study are both valid and documented. Procedures are as follows:

Each aliquot is examined twice, with agitation between examinations. To check for sorting and identification efficiency, at least 5 percent of the samples are re-sorted and verified by a qualified individual other than the person who did the initial sorting and identification. Sorting efficiency is maintained above 95 percent for all RIS.

Identification of larval specimens is made through use of standard literature sources for each RIS. Voucher specimens are referred to appropriate External Consultants for identification/confirmation, as necessary. A reference collection of taxonomically confirmed species is maintained.

Bench data sheets (Data Sheet No. 4 - Appendix) contain all field data for a sample including the volume sampled, as well as sorting data and individual measurements. Three copies of the bench sheets are made. One copy is transmitted to Stone and Webster, the original is retained by the Project Coordinator, one copy is placed in the Archives at MML, and one copy is placed in the Section Supervisor's (Blanchet) files.

Subsampling is accomplished by use of a 10 ml capacity Tipet dispenser or 5 ml pipet for numerous eggs. The sample is placed in an appropriately sized Erlenmeyer flask after the volume is adjusted to allow efficient sorting. The sample is agitated thoroughly, and aliquots are drawn off into a gridded petri dish. Depending on the density of plankton, up to four aliquots may be sorted at one time. Subsamples are sorted consistently, that is, they are completely sorted for any RIS for which less than 100 specimens have been picked from the sample. The density/$100m^3$ of any species is then calculable by comparing the volume of sample examined (VE) to pick out any number of specimens (NS), to the total volume of the sample (TV) and the volume of water filtered (VF), to give the density of the species (SD):

$$\left(\frac{NS \cdot TV}{VE}\right)\left(\frac{VF}{100}\right) = SD$$

All samples are stored until the project is completed. All sorted specimens will be catalogued and similarly maintained, except for

voucher specimens which will be placed in the permanent MML reference collection. Catalog numbers of sorted specimens are carried on the data bench sheets and in a bound notebook in which entries are logged as the samples are sorted.

B. Regular Testing Program:

Procedures for the sorting of live meroplankton RIS and holding them for 96 hours (includes Regular Testing Program, Controls and Air Exposure Tests) are as follows:

1. Live meroplankton sorting: Samples obtained from the screen or other control methods (net, light trap, etc.)are subsampled by the section supervisor and sorting by technicians commenced. Live or stunned organisms for holding are pulled out in lots of five or less (fish eggs and larvae) and single individuals (zoea) in an attempt to total 30 organisms of each species/life stage. Once the organisms for holding are drawn off the first subsample, the rest of the RIS is sorted as live, dead or stunned (only for screen samples) and preserved in three seperate containers (no counts or final identification is made). If a total of 30 organisms of each species/life stage for holding is not available from the first subsample a second subsample is drawn and sorted only for the live/stunned organisms necessary. The procedure is repeated once more if necessary. A maximum of only 3 subsamples per sample are processed. For controls, two lots of 30 organisms per available RIS species/life stage is sorted per week for holding. Once the organisms for holding and the initial mortality estimation are withdrawn from the sample, the remains are preserved. Organisms for Air Exposure Testing are also provided from the sorting of control samples. Stringent QA procedure is enforced during the live sorting process. The section supervisor (Duane Phillips) or alternate (Donna Famiglietti) draws the subsamples and supervises the sorting and data recording (Data Sheet No. 1 - Appendix). He/She then transfers the position-marked containers (500 ml glass jars for fish eggs and larvae; 2" cube tackle box trays for zoea) to the holding facility supervisor (Gary Comp) or designated alternate shift supervisor/technician (K. McCarthy or E. Myers or R. Dennis or K. Caraccia). Data Sheet No. 1 is copied (4 copies): one copy is provided to the holding facility supervisor (Comp); one copy is retained in the section supervisor's (Phillips) files; one copy is transmitted to Stone and Webster's field representative; one copy is filed in the project coordinator's files and the original is

transmitted to the 'preserved material' section supervisor (Blanchet).

2. Holding: On receiving the position marked-containers, the holding facility supervisor or alternate records the sorting data (Data Sheet No. 2 - Appendix) and places the container in the appropriate water table and position (Tables are marked alaphabetically and positions within a table sequentially marked. Charts over each table identify the exact position of each container). Checks (observation of dead/ live organisms) are thenceforth made on a regular schedule (3,6,12,18, 24,36,48,60,72,84, and 96 hours) and appropriate information recorded on data sheets (Data Sheet No.2 - Appendix). Dead organisms during each check are pulled out, preserved in a labeled vial and placed on the transport rack with appropriate entry made on to the transport control sheet (Appendix). The labels (external stick-on) contain sample number (two digits e.g. 1A), subsample number (1 digit e.g. 1), table identification (1 digit e.g. K), position within the table (1-2 digits e.g. 29) and check hour (1-2 digits e.g. 18). An example label is: 1A1K29-18. At the end of the 96 hour period all animals are preserved with live and dead seperated and identified with a 'D' or 100 (live) respectively in the labels. e.g. 1A1K29-100. Transport racks are individually labeled before use and one rack is used to transport all vials within one sample only (e.g. a transport rack specifically marked for sample 1A). When a complete day's sample vials are accumulated (e.g. 1A through 1F-6 samples in that day), samples are transported to MML-Sarasota. Samples preserved from the initial mortality sorting are labeled with sample No. (e.g. 1A), subsample No. (e.g. 1) and condition of organism (e.g., L=live, D=dead, S-stunned). An example label would contain: 1A1-L. These samples are transported the same day with accompanying transport control sheets. Control samples and air exposure test samples are treated similarly. Completed Data Sheets No. 2 are copied (5 copies); one copy is retained in the holding facility supervisor's files; two copies are transmitted to Stone and Webster; one copy is filed in the MML archives; one copy is filed in Preserved Material section supervisor's (Blanchet) files and the original is filed in the project coordinator's file.

3. Preserved Material Handling: All samples transported from the holding facility are received at MML-Sarasota by the section supervisor (Harry Blanchet) or alternate (Tom Long) and checked to ensure accuracy of vials transported. The samples are then processed

(identification, enumeration, length measurement) and data entered on Data Sheet No. 3 (Appendix). Four copies of this data sheet are made after all quality control checks are made. One copy is retained by the section supervisor, one copy is transmitted to Stone and Webster field representative, one copy is filed in the MML archives, one copy is placed in the holding facility section supervisor's (Comp) files and the original is placed in the project coordinator's files. Samples from initial mortality are processed similarly and data entered on to the appropriate Data Sheet No. 1 (that is, the original that was transmitted by D. Phillips to H. Blanchet, see (a) above). Four copies of this data sheet are made. One copy is transmitted to Stone and Webster field representative, one copy is filed in the holding facility supervisor's (Comp) files, one copy is placed in the MML archives, one copy is retained in the section supervisor's (Blanchet) files, and the original filed in the project coordinator's files. All preserved material from the holding facility (after processing and quality control checks) are lumped into primary samples (e.g. 1A-one Screen Test sample; AE1-one Air Exposure Test; CT1-one Control Group; etc.) and stored until completion of project.

C. Computer Data Entry: Utilizing Data Sheets 1,2,3 and 4, the section supervisor (Blanchet) or a technician transfers data to appropriate computer data sheets (examples in Appendix). Checks are made to ensure accuracy of data transfer. Two copies of the computer data sheets are made. The original is transmitted to the Stone and Webster (Boston office), one copy is placed in the holding facility supervisor's (Comp) files, one copy is placed in the project coordinator's files and one copy is filed in MML archives.

IV. RECOMMENDATIONS

Based on our preliminary studies' findings and the suggestions of our expert consultants, we recommend:

1. Feeding the organisms (with a mixture of algae and rotifer culture) that are held for latent mortality.
2. Holding the organisms for 96 hours as planned in the ESSOW.
3. Holding the fish eggs and larvae in 500 ml glass jars (5 individuals to a container) and zoea in 2" cube tackle box trays (single organism to a container). 3" PVC pipes with screen bottom should be kept as back-up in the event of excessive mortality in closed system.
4. Collecting control organisms with a plankton net (with back-up of a light trap, if necessary).
5. Eggs that hatch during holding be kept until the normal duration of the experiment (96 hours) but record kept of the hatch time.
6. Partially changing water in the container (during 48 hour check)
7. Holding 48 zoea instead of 30 zoea per sample as specified in the ESSOW (tackle box trays are in compartment units of 24).

V. REQUEST FOR APPROVALS

We request that the following items be approved by the Engineers:

1. Collection of control organisms by primarily plankton nets with the use of a light trap, if necessary.
2. Holding of all organisms in closed systems, (with a back-up of open-system containers if a need arose to change).
3. Feeding the organisms (post-larvae only) with a mixture of algae and rotifer at the 24 hr, 48 hr and 72 hr checks.
4. Changing water partially (larvae only) at the 48 hour check.
5. Holding 48 zoea instead of 30 zoea per screen or control sample.

APPENDIX

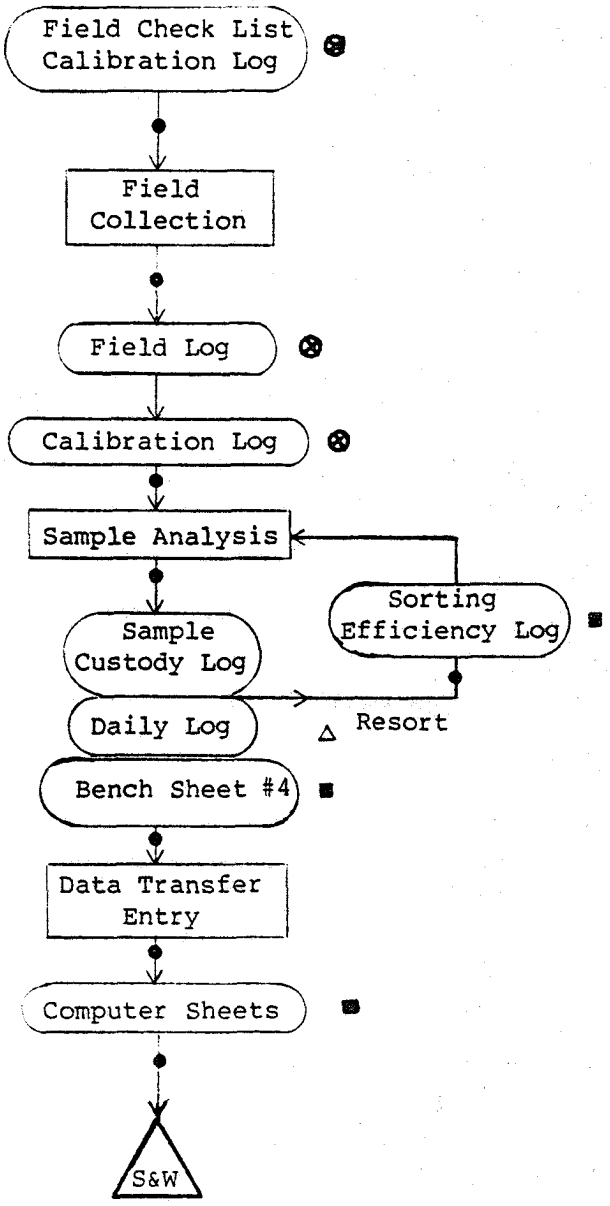
EXAMPLES OF PROJECT

DOCUMENTATION

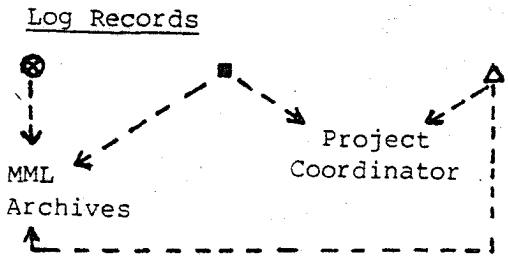
AND

RECORDS

Data-Flow for Plankton net samples, Spray Wash and Screen Efficiency Samples.



- Checks by supervisor
- Task
- Documentation
- Project Coordinator is custodian of these logs
- Section Supervisor is custodian of these logs or data sheets
- Personal log
- Copies to
- Original to



WEIGHT TRACEABILITY CERTIFICATE

TO: Mote Marine Lab
1600 City Island Park
Sarasota, Florida, 33581

The Mettler balances listed below have been serviced by our representative on Nov. 15 1979

This is to certify that the test weights used are traceable to the National Bureau of Standards.

Mettler identification number of test weights used: #64

Mettler calibration date of test weights used: Aug. 6 1979

National Bureau of Standards test number: 732/CEDC-30

National Bureau of Standards test date: June 6 1979

Type and serial number of balances serviced:

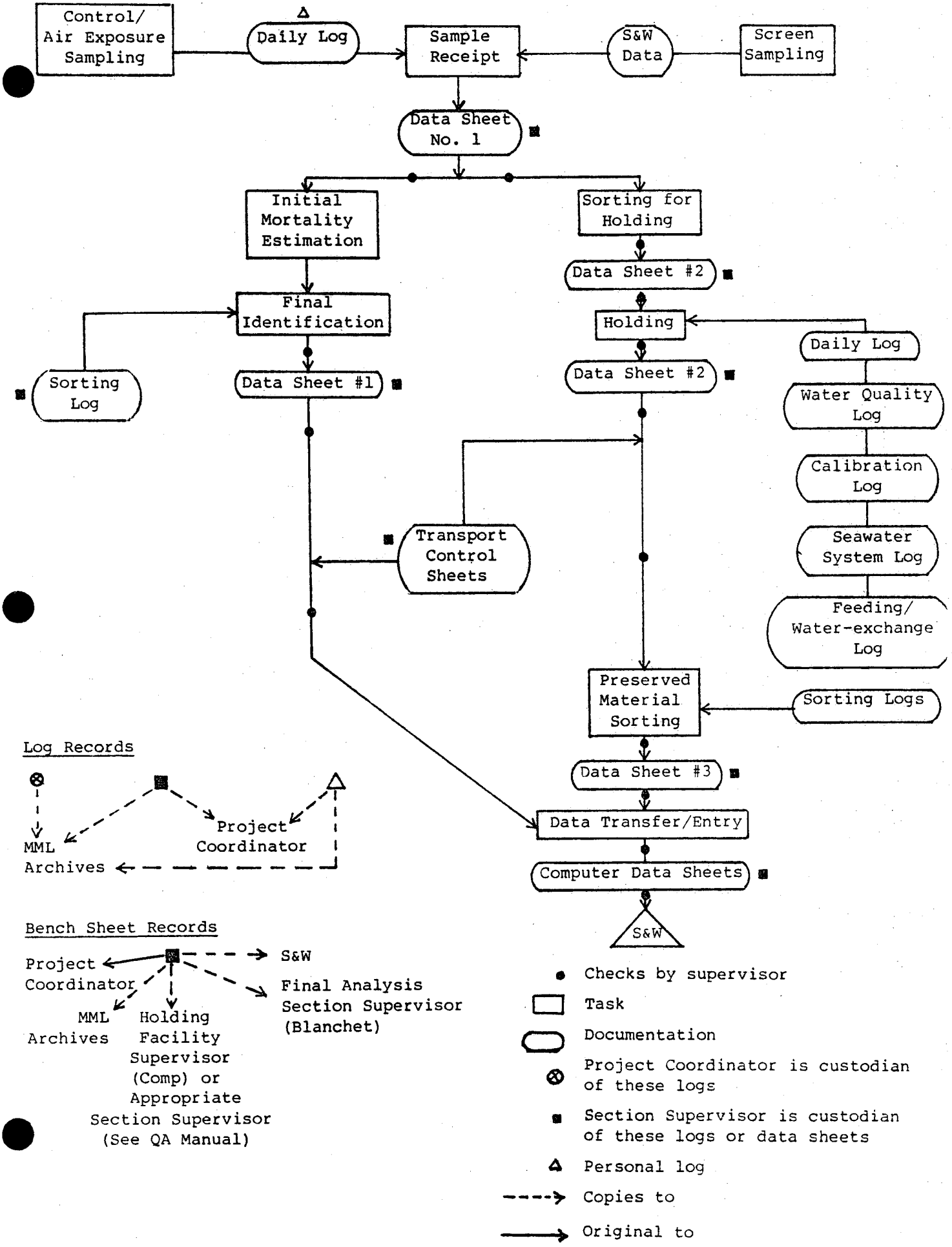
B5 #406055

L E Brooks
Mettler Service Representative

11-4-79
Date of Issue

Mettler Instrument Corporation
Box 71, Hightstown, NJ 08520
(609) 448-3000

Data-Flow for regular testing program, controls and air- exposure tests.



SANGAMO WESTON SARASOTA
~~XXXX~~ SCHLUMBERGER

STANDARDS LABORATORY REPORT REPORT NO. 1

SECTION A

1. CALIBRATING ACTIVITY: S.W.S.
2. SUBMITTING ACTIVITY: SARSOTA COUNTY POLUTION CONTROL
3. TEST INSTRUMENT: -2°C. to +68°C THERMOMETER
4. MANUFACTURER: FISHER
5. MODEL NUMBER: ASTM 36C
6. SERIAL NUMBER: EAD 101
7. REASON FOR SUBMISSION
   - CERTIFICATION [x] 1
   - CALIBRATION [ ] 2
   - FAILURE FROM DAMAGE [ ] 3
   - OPERATIONAL FAILURE [ ] 4
8. DATE OF LAST SERVICING: FIRST TIME
9. SERVICING CYCLE (MONTHS)
   - CERTIFICATION: 6
   - CALIBRATION:
10. CALIBRATION PROCEDURE: LAB.

SECTION B

1. CALIBRATION TECHNICIAN: A.J.LAWTON
2. TEST DATE: 4-2-80
3. CONDITION RECEIVED
   - WITHIN TOLERANCE [x] 1
   - OUTSIDE TOLERANCE [ ] 2
4. CONDITION RETURNED
   - WITHIN TOLERANCE [x] 1
   - OUTSIDE TOLERANCE [ ] 2
5. CERTIFICATED OR REPORTED VALUE, IF FIXED STANDARD:
6. MAN-HOURS TO CALIBRATE: 2.0
7. MAN-HOURS TO REPAIR: N/A
8. SERVICING LABEL AFFIXED
   - CERTIFICATION [x] 1
   - CALIBRATION [ ] 2
   - LIMITED USE LABEL [ ] 3
   - LIMITED USE TAG [ ] 4
9. NEXT SERVICING DATE
   - CERTIFICATION: 10-6-80
   - CALIBRATION:

SECTION C

METROLOGICAL CONDITIONS

TEMPERATURE 72 °F
RELATIVE HUMIDITY 55 %

REMARKS

READING OF STD.	READING OF EAD101
0	+.2
12.0	12.0
28.0	28.1
30.0	30.1
50.0	50.4
52.0	52.4
55.0	55.2
60.0	60.3

REFERENCE STANDARDS USED SER. NO. 63C 1910, 64C 2598, 65C 1003.

[ ] REPLY TO REMARKS REQUESTED

APPROVED [signature]
LABORATORY SUPERVISOR

NOTE: GENERAL INSTRUCTIONS FOR COMPLETING THIS FORM ARE PROVIDED IN STANDARDS LAB. MANUAL

QAL FORM A40

SAMPLE LABEL

MOTE MARINE LABORATORY SARASOTA, FL

Proj. #:	Samp. gear:
Stat. #:	Samp. day/hr: /
Repl. #:	Samp. time:
Tide Ph:	Samp. vol/area:
Coll. by:	Anal. by:
Comment:	Chkd. by:

MOTE MARINE LABORATORY, 1600 CITY ISLAND PARK, SARASOTA, FLORIDA 33577

(1)

PROJECT NUMBER: 310.85 Fine Mesh Screen Biological Evaluation

MEROPLANKTON SORTING DATA SHEET

Date: Sample Number/ID: Page __ of

SAMPLE VOLUME: Sorting Team:

Subsample Volumes

1	2	3

SUBSAMPLE ID NUMBER:

A. INITIAL MORTALITY ESTIMATION

a. Rough Sorting by: _____

b. Final ID by _____ Date _____

Vial No.	Species Code	Life Stage	Live		Dead		Stunned	
			#	Length	#	Length	#	Length

QA Checks:

Rough Sorting:

_____

Initials/Date

Final ID:

_____

Initials/Date

NOTE: Lengths are in millimeter

Comments: Preliminary sorting for Initial Mortality Estimation done: YES NO By:

B. HOLDING SAMPLES/SEPARATION

Position	Species	Life Stage	*L/S	#/Lot	Time	Separated

* L = Live; S = Stunned

MOTE MARINE LABORATORY, 1600 CITY ISLAND PARK, SARASOTA, FLORIDA 33577

LATENT SURVIVAL MONITORING DATA SHEET
Sample # Date:

Project #310.85
Fine Mesh Screen Biological Evaluation

Page ___ of ___

S.S. #	Set by	Posi-tion	Species Code	Life Stage	0 hrs.		3 hrs.		6 hrs.		12 hrs		18 hrs		24 hrs		36 hrs		48 hrs		60 hrs		72 hrs		84 hrs		96 hrs		Total D	Unaccounted
					Time	L/S	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	L	D	

Sample Checks

L = Live S = Stunned D = Dead S.S.# = Subsample number . Note: Eggs that hatch are recorded in parentheses.

	Start Time	Sample	Stop Time	Sample	By /Date		Start Time	Sample	Stop Time	Sample	By /Date
1.						10.					
2.						11.					
3.						12.					
4.						13.					
5.						14.					
6.						15.					
7.						16.					
8.						17.					
9.						18.					

Comments:

Q.A. Checks

	Time /Date	Sample	By	Comments
1.				
2.				
3.				
4.				
5.				
6.				
7.				

Comments:

③

MOTE MARINE LABORATORY
1600 CITY ISLAND PARK
SARASOTA, FLORIDA 33577

Project #310.85

FMS BIOLOGICAL EVALUATION

LATENT SURVIVAL MONITORING ID DATA SHEET

Sample # Subsample # Date Collected:

Vial No.	Position	Hours	Species	Life Stage	# Organisms	Lengths (mm)	ID by	Date

Quality Control Checks (ID)

1. Vial Numbers: by Date:

2. Vial Numbers: by Date:

Comments:

4

MOTE MARINE LABORATORY
Sarasota, Florida 33577

Page _____ of _____

Station: _____ Collection Date: _____day/nite

PROJECT No. 310.85
FMS Biological Evaluation

Replicate #: _____ Sample vol.: _____

Meroplankton Data Sheet

VIAL #	Aliquot															
	Volume															
	Crassostrea															
	Penaeus P.L.															
	Callinectes Zoea															
	Menippe Zoea															
	Anchoa larvae															
	Harengula larvae															
	Menidia larvae															
	Bairdiella larvae															
	Cynoscion larvae															
	Pogonias larvae															
	Anchoa prolarvae															
	Anchoa eggs															
	Harengula eggs															
	Menidia eggs															
	Bairdiella eggs															
	Cynoscion eggs															
	Pogonias eggs															

QUALITY CONTROL INFORMATION

Sorted by: Date: Comments:
Checked by: Title: P.I. Date:

Data Transfer by: Date:
Checked by: Title: P.I. Date:

Revised 3/19/80

MOTE MARINE LABORATORY

1600 CITY ISLAND PARK
SARASOTA, FLORIDA 33577

PHONE: (813) 388-4441

WILLIAM R. MOTE
CHAIRMAN OF THE BOARD

WILLIAM H. TAFT, Ph.D.
PRESIDENT

Project: 310.85
Reference: FMS Biological Evaluations

INSTRUCTIONS FOR SAMPLE TRANSPORT CONTROL SHEET

This form is designed to assure accurate traceability of samples from the field laboratory to the base lab in Sarasota. A separate sheet must be completed for each tray of vials sent to Sarasota. It is strongly urged that different types of samples (vials) be separated by empty taped rows.

PACKER:

1. Complete the top half of the form.
2. Either at the time of packing or (better) immediately before loading for transport, check the total number of vials listed on the sheet.
3. Count the number of vials in the tray.
4. Spot-check at least three vial numbers on the sheet to make sure those vials are in the tray. Circle numbers on sheet.
5. Complete the Packer Check column.
6. Sign and date the Packer Check column.
7. Lock the container with the transport control sheet.

TRANSPORTER (Driver):

Open the container

1. Verify the number of vials listed on the control sheet.
2. Verify (count) the number of vials in the tray.
3. Locate, in the tray, the three vials double-checked by the packer.
4. Spot-check three additional vial numbers on the sheet to make sure those vials are in the tray.
5. Complete the Transporter Check column.
6. Sign and date the Transporter Check column.
7. Make sure there is a sheet for each tray.
8. Lock the container with the transport control sheet.

RECEIVER (Harry or his designee):

Open the container

1. Verify that the Control Sheet vial numbers and the vials received match one-to-one.
2. Complete the Receiver Check column.
3. Sign and date the Receiver Check column.
4. Give the Control Sheet to Jeff for filing.
5. Remove the vials and store it in the lab sample container. Lock it.

TRANSPORTER AND RECEIVER:

If you find any discrepancies, whatsoever, refuse to accept the delivery. As soon as practical, notify Jeff Patton and the shift supervisor on duty to have the shipment returned to the field laboratory for corrective action. The sooner the problem can be traced, the easier it will be to correct. Delay will only compound the problem.

Revised 3/19/80

MOTE MARINE LABORATORY
1600 City Island Park
Sarasota, Florida 33577

Tray No. _____
Project # 310.85
FMS Biological Evaluation

Page ___ of ___
(1 page for each tray)

SAMPLE TRANSPORT CONTROL SHEET

ACCURACY ASSURANCE CHECKS

	Packer Check	Transporter Check	Receiver Check
Total No. of vials listed	_____	_____	_____
Total No. of vials counted in tray	_____	_____	_____
Vial numbers checked (✓)	_____	_____	_____ all
Signed:	_____	_____	_____
Date:	_____	_____	_____

MOTE MARINE LABORATORY

EQUIPMENT CALIBRATION LOG FORMAT

EQUIPMENT: MODEL NUMBER:

MANUFACTURER: SERIAL NUMBER:

STANDARD USED:

PRE-CALIBRATION		POST-CALIBRATION	
READING OF STANDARD	READING OF TEST INST.	READING OF STANDARD	READING OF TEST INST.

BY: DATE: TIME: BY: DATE: TIME:

APPROVED
(SUPERVISOR)

▲5045 B

J.O. No. Presented by: Date: Page___

Checked by: Date: of ___

	STUDY	CARD TYPE	SAMPLE ID	SUB SAMPLE ID	SAMPLE VOL.	SUB SAMPLE VOL.	SPECIES	LIFE STAGE	LIVE SORT	STUNNED	DEAD SORT	TOTAL NO. HELD	
	1	2	3 4	5 6	7 8	9 10	11	12 13	14 15	16 17 18	19 20	21	22 23	24 25	26 27 28 29	30	31 32 33
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STONE & WEBSTER

PROTOTYPE FINE MESH SCREEN EVALUATION

J.O. No. 12408.04

Presented by

Checked by

Date

Date

Page

STUDY	CARD TYPE	SAMPLE ID	SUBSAMPLE ID	SPECIES	LIFE STAGE	LIVE-DEAD	LENGTHS 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
1	2	3 4	5 6	7 8	9 10	11	12 13	14 15	16 17 18	19 20 21	22 23	24 25	26 27	28 29 30	31 32	33 34	35 36	37 38	39 40	41 42	43 44	45 46	47 48	49 50	51 52	53 54	55 56	57 58	59 60	61 62	63 64	65 66	67 68	69 70	71 72	73 74	75 76 77	78 79 80
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APPENDIX 5

HYDRODYNAMIC ANALYSIS PROCEDURES

APPENDIX 5

HYDRODYNAMIC MODELING

A5.0 INTRODUCTION

This appendix describes the two types of models (near-field and far-field) used for the hydrothermal and meroplankton entrainment studies for Big Bend Station.

The near-field model (Section A5.1) was used to predict detailed temperature distributions near the Station where the hydrodynamic characteristics of the discharge plume are more important than those of the receiving water body.

The far-field model (Section A5.2) determined the effects of the Station on meroplankton concentrations and on temperatures at distances from the Station where the near-field model was not applicable. This model was also used to determine the long-term buildup of heat in the vicinity of the Station.

A5.1 NEAR-FIELD MODELING

A5.1.1 General

A semi-empirical, near-field, hydrothermal model was specifically developed for Big Bend Station because available surface discharge models are applicable only to cases of relatively high densimetric Froude Number. (The densimetric Froude Number is defined as the ratio of inertia force to buoyancy force per unit mass of water). Big Bend's discharge has a relatively low velocity and a moderate temperature rise which results in a relatively low densimetric Froude Number.

The model simulates (1) a channel flow region, in which the flow is analyzed while it is within the discharge channel, and (2) a radial flow region, in which the flow is analyzed as it spreads laterally upon leaving the discharge channel. The plume is initially well mixed but becomes detached from the bottom and forms a surface layer flowing over the cooler ambient water at the point the densimetric Froude Number falls below some critical value. The plume then entrains a portion of the cooler bottom water at the interface, resulting in a reduction of the temperature rise of the plume. An empirical relation (Lean & Willock 1965) is employed to calculate the amount of entrainment. Conservation of momentum and surface heat transfer are also considered in calculating the temperature of the plume.

The model used in this report is a slightly modified version of the one used for the Units 1-3 316 Demonstration (TECO 1977). The only modification is a small change in the coefficient that

describes the amount of entrainment of ambient water. This modification is the result of a model calibration effort which used data from a dye survey performed in October 1979 (Aquatec 1979). Section A5.1.2 presents mathematical details of the model. Section A5.1.3 describes the calibration process and the final model parameters that were used.

A5.1.2 Details of the Mathematical Model

The mathematical model considers buoyancy effects, energy losses, entrainment of underlying cold water into the surface flow, and heat loss to the atmosphere. The model consists of two distinct parts: one for the discharge channel, which assumes a two-layer flow through a rectangular cross-section; and one for the bay, which assumes a two-layer radial flow.

In the calculation the following assumptions are made:

1. Slack tide condition;
2. Rectangular, open channel, two-layer flow in the discharge channel;
3. Radial flow into Hillsborough Bay;
4. Steady state source flow;
5. Constant shearing stress factor;
6. Constant heat loss rate.

The basic equations for rectangular channel flow are:

Hydrostatic pressure (A5.1-1)

$$\frac{1}{\rho}\frac{\partial p}{\partial y} = g$$

Momentum in the X-direction (A5.1-2)

$$U_x \frac{\partial U_x}{\partial x} + v \frac{\partial U_x}{\partial y} = -\frac{1}{\rho}\frac{\partial p}{\partial x} + \frac{1}{\rho}\frac{d\tau_{xy}}{\partial y}$$

Mass conservation (A5.1-3)

$$\frac{\partial U_x}{\partial x} + \frac{\partial v}{\partial y} = 0$$

Heat conservation (A5.1-4)

$$U_x \frac{\partial T}{\partial x} + v \frac{\partial T}{\partial y} = 0$$

The equations for radial flow are essentially the same as those for the rectangular channel, except that the notations x, U_x, and τ_{xy} are transformed to r, U_r, and τ_{ry}, respectively

where

ρ = density of the surface water,

P = hydrostatic pressure,

x,y = longitudinal and vertical coordinates for rectangular channel flow,

r,y = radial and vertical coordinates for radial flow,

g = gravitational constant,

U_x, U_r = velocity of the surface flow in x and r direction, respectively,

v = velocity of the surface flow in y-direction, or the rate of entrained flow,

τ_{xy}, τ_{ry} = shearing stress between two-layer flow,

T = temperature of the surface water.

Equations A5.1-1 through A5.1-4 for both layers are integrated and transformed to the solvable forms which only depend on the first order partial derivative of x in the rectangular channel flow and r in the radial flow.

For rectangular channel flow:

$$\frac{\partial U_1^2 h_1}{\partial x} = \frac{h_1^2}{2}\frac{\partial g'}{\partial x} - h_1 g \frac{\partial H}{\partial x} - \frac{\tau_i}{\rho} \qquad \text{(A5.1-5)}$$

$$\frac{\partial U_2^2 h_2}{\partial x} = h_1 h_2 \frac{\partial g'}{\partial x} - h_2 g \frac{\partial H}{\partial x} + \frac{\tau_i}{\rho} - \frac{\tau_o}{\rho} \qquad \text{(A5.1-6)}$$

$$\frac{\partial U_1 h_1}{\partial x} = -\frac{\partial U_2 h_2}{\partial x} = U_e \qquad \text{(A5.1-7)}$$

$$h_1 + h_2 = H \qquad \text{(A5.1-8)}$$

$$\rho C_p \frac{\partial (\Delta T\, U_1\, h_1)}{\partial x} = -K\Delta T \qquad \text{(A5.1-9)}$$

and for radial flow:

$$\frac{1}{r}\frac{\partial U_1^2 h_1 r}{\partial r} = \frac{h_1^2}{2}\frac{\partial g'}{\partial r} - h_1 g \frac{\partial H}{\partial r} - \frac{\tau_i}{\rho} \qquad \text{(A5.1-5)'}$$

$$\frac{1}{r}\frac{\partial U_2^2 h_2 r}{\partial r} = h_1 h_2 \frac{\partial g'}{\partial r} - h_2 g \frac{\partial H}{\partial r} + \frac{\tau_i}{\rho} - \frac{\tau_o}{\rho} \qquad \text{(A5.1-6)'}$$

$$\frac{1}{r}\frac{\partial U_1 h_1 r}{\partial r} = -\frac{1}{r}\frac{\partial U_2 h_2 r}{\partial r} = U_e \qquad \text{(A5.1-7)'}$$

$$h_1 + h_2 = H \qquad \text{(A5.1-8)'}$$

$$\rho C_p \frac{1}{r} \frac{\partial (\Delta T\, U_1 h_1 r)}{\partial r} = - K \Delta T \qquad \text{(A5.1-9)}$$

where subscripts 1 and 2, respectively, refer to the upper and lower layers:

$H = h_1 + h_2$ = total depth,

τ_i = interfacial shearing stress,

τ_o = bottom shearing stress,

U_e = rate of entrainment from colder layer to warmer layer,

K = rate of heat transfer to atmosphere,

$g' = g \frac{\Delta \rho}{\rho}$ = densimetric gravitational acceleration.

Equations A5.1-5 to A5.1-9 are solved simultaneously for u_1, h_1, ΔT, ρ, u_2, and h_2 by the method of finite difference.

In the discharge channel, the above parameters are solved for points between the initial critical flow section and the outlet to the bay. This then defines initial conditions for determining the flow pattern into Hillsborough Bay.

The rate of entrainment, U_e, is determined from the curve of Lean and Willock, which has the form of:

$$U_e = 0.0025\, F^4\, u \qquad \text{(A5.1-10)}$$

where

U_e = rate of entrainment, fps,

u = relative velocity between the two layers,

F = densimetric Froude Number,

$$= \frac{V}{\sqrt{\frac{\Delta \rho}{\rho} gh}}$$

where

V = velocity of flow in the upper layer,

$\Delta \rho = \rho_c - \rho$,

ρ_c = density of cold water,

ρ = density of warm water,

g = acceleration due to gravity,

h = depth of the upper layer.

Equation A5.1-10 is valid when the densimetric Froude Number, F, ranges between 1.3 and 0.32. Laboratory testing has shown that densimetric Froude Numbers less than or equal to 0.75, allow a two layer flow to exist and, therefore, cooling by entrainment is possible.

Equation A5.1-9 is solved independently after the parameters U_1, h_1, and T are known at finite intervals. This can be expressed as:

$$T_x - E = (T_o - E) \cdot \exp\left(-\frac{K\,\Delta X}{\rho C_p\, U_1\, h_1}\right) \qquad \text{(A5.1-11)}$$

for rectangular channel and

$$T_r - E = (T_o - E) \cdot \exp\left(-\frac{K\,\Delta A}{\rho C_p\, Q}\right) \qquad \text{(A5.1-11)'}$$

for radial flow

where

T_o = Temperature of water entering increment,

E = Equilibrium temperature,

T_x, T_r = Temperature of water at end of increment,

ΔX = Length of the increment,

ρ = Density of the upper warm layer,

u_1 = Velocity in the upper warm layer,

C_p = Specific heat of water at constant pressure,

h_1 = Thickness of the upper warm layer,

ΔA = Surface area of the increment,

Q = Accumulated flow rate.

The solution of Equations A5.1-5 to A5.1-9 and A5.1-5' to A5.1-9' yield input to Equations A5.1-11 and A5.1-11', which finally yield the decay of temperature in the discharge channel and in Hillsborough Bay.

A5.1.3 Model Calibration

Calibration of the model involved matching the results of a near-field dye survey performed by Aquatec, Inc. in October 1979 (Aquatec 1979). The areas enclosed by various dilution values from field survey results were compared to model-predicted areas enclosed by corresponding dilution values. The distances from the point of discharge to various dilution values were also compared. The model input parameters corresponded to plant operating conditions and meteorological conditions which existed at the time of the survey.

Two parameters were varied in the attempt to match the field data. One was the coefficient of entrainment in Equation A5.1-10. The other parameter was the radial angle encompassed by the discharge flow after the flow has left the discharge channel and entered Hillsborough Bay.

The value of the entrainment coefficient in Equation A5.1-10 was varied over the range of 0.0010 to 0.0200. The value which yielded the best comparison was 0.0032, which is slightly larger than the original value of 0.0025.

The radial angle encompassed by the discharge flow was varied over the range of 35 to 90°. Changes in this angle did not substantially improve the agreement with field data. Thus, the final angle determined for use in the production runs was 61°, the same angle used in the modeling studies for the 316 Demonstration for Units 1-3, and which is based on the geometry of the discharge area.

Comparisons of the results of the field study and the model run using the final parameter values are shown on Figures A5.1-1 and A5.1-2. Figure A5.1-1 shows the comparison of areas measured from dye survey results and those predicted by the model. Dilution is represented on the Figure by dye concentration for field survey results and by ΔT for the model results. Similarly, Figure A5.1-2 shows the comparison of distances from the discharge structure to various values of dilution. These figures indicate that the model results are accurate at higher ΔT values but the plume size is overestimated at lower values of ΔT.

References

Aquatec, Inc. 1979. Hydrothermal field study report. Big Bend Power Station, Tampa Bay, Florida.

Lean, G.H. and A.F. Willock. 1965. The behavior of a warm water layer flowing over still water. Int. Ass. for Hydr. Res., Hydr. Res. Sta., Wallingford, England.

TECO (Tampa Electric Company). 1977. Big Bend Station 316 Demonstration. TECO, Tampa, Florida.

A5.2 FAR-FIELD MODELS

The far-field modeling effort for Big Bend Station was conducted with a pair of mathematical models, CAFE-1 and DISPER-1 (Wang & Connor 1975; Leimkuhler et al 1975). Both are two-dimensional finite-element models which were developed at the Massachusetts Institute of Technology (MIT). CAFE-1 is a hydrodynamic model which predicts current velocities and water levels for use in DISPER-1. DISPER-1 is a dispersion model and is described in detail in Section A5.2.2. Both models have been verified extensively by their originators (Wang & Connor 1975; Wang 1978; Leimkuhler et al 1975) and others in the engineering community (MIT 1977).

A5.2.1 Hydrodynamic Model: CAFE-1

A5.2.1.1 General

CAFE-1 treats a coastal water body as two dimensional and homogeneous in density. From input parameters such as boundary geometry, bottom topography and roughness, tidal fluctuation, and wind, the model produces current velocities and surface elevations varying in time and space. The model formulation is based on the vertically integrated conservation of mass and momentum equations established for shallow water bodies. The basic notion of the finite-element method is that of subdividing the water body into an assemblage of discrete subregions, or finite elements. Each element is represented by a set of the mass and momentum equations, identical to all other elements. The model solves all the equations simultaneously so that an approximation to a continuous solution is obtained (for example, the tidal elevation and velocity varies gradually from one element to surrounding elements).

The finite-difference method may also be used to simulate hydrodynamic activity. Both finite-difference and finite-element methods numerically solve the basic hydrodynamic conservation equations. However, finite-element models possess several advantages over finite-difference models. One is the flexilibity of varying grid sizes. Another is that a series of straight lines more accurately represents a curved boundary than does a series of horizontal and vertical lines (or "stair steps") as in the finite-difference method. Often the desired accuracy can be achieved in the finite-element models with fewer grid points.

A5.2.1.2 Model Formulation

This section presents a basic overview of the model formulation of CAFE-1. More details on each aspect of the model formulation are provided by Wang and Conner (1975).

The fundamental equations are the vertically integrated equations of conservation of mass and dynamic equilibrium, as follows:

Conservation of Mass

(A5.2-1)

$$H_{,t} + q_{x,x} + q_{y,y} = q_I$$

x equilibrium

(A5.2-2)

$$q_{x,t} + (\bar{U}q_x)_{,x} + (\bar{U}q_y)_{,y} - fq_y + (F_P - F_{xx})_{,x} - F_{yx,y}$$
$$+ \frac{1}{\rho_o}(\tau_x^s - \tau_x^b) - \bar{M}_x - \frac{1}{\rho_o}(P^s H_{,x} + \Delta\rho g H h_{,x}) - g\eta h_{,x} = 0$$

y equilibrium

(A5.2-3)

$$q_{y,t} + (\bar{V}q_x)_{,x} + (\bar{V}q_y)_{,y} + fq_x - F_{xy,x} + (F_p - F_{yy})_{,y}$$
$$+ \frac{1}{\rho_o}(\tau_y^s - \tau_y^b) - \bar{M}_y - \frac{1}{\rho_o}(P^s H_{,y} + \Delta\rho g H h_{,y}) - g\eta h_{,y} = 0$$

where

(A5.2-4)

$$F_P = gh\eta + \frac{1}{2}g\eta^2 + \frac{1}{2}\frac{\Delta\rho}{\rho_o} g H^2 + \frac{P^s}{\rho_o} H$$

(A5.2-5)

$$F_{x_i\, x_j} = E_{ij}\left(\frac{\partial q_i}{\partial x_i} + \frac{\partial q_i}{\partial x_j}\right) \quad i,j = 1,2 \text{ no summing over } i,j$$

(A5.2-6)

$$\tau_x^b = C_f \rho \left(q_x^2 + q_y^2\right)^{\frac{1}{2}} \frac{q_x}{H}$$

$$\tau_y^b = C_f \rho \left(q_x^2 + q_y^2\right)^{\frac{1}{2}} \frac{q_y}{H} \qquad \text{(A7.2-7)}$$

τ_x^s, τ_y^s = x, y components respectively of wind stress, $\rho_{air} C_D U_{10}^2$

h = depth of water with respect to datum,

η = height of water surface with respect to datum,

$H = h + \eta$

q_x, q_y = x, y components of flux,

$\bar{U}$, $\bar{V}$ = x, y components of vertically averaged velocity,

q_I = source flux,

ρ_o, $\Delta\rho$, ρ_{air} = respectively, average density of water, change in density of water, density of air,

E_{ij} = eddy viscosity coefficient matrix,

C_f = bottom friction factor,

C_D = wind drag coefficient.

In Equations A5.2-1, A5.2-2, and A5.2-3, partial differentiation is written as a subscript comma followed by the independent variable.

The boundary conditions used in the model formulation are separated into two categories: discharge boundaries and force boundaries.

For discharge boundaries

$$q_\eta = \alpha_{\eta x} q_x + \alpha_{\eta y} q_y$$

$$q_s = -\alpha_{\eta y} q_x + \alpha_{\eta x} q_y$$

where

q_η, q_s = fluxes normal and tangential, respectively, to the boundary

q_x, q_x = x, y components of flux,

$\alpha_{\eta x} = \cos(n, x)$,

$\alpha_{\eta y} = \cos(n, y)$.

For force boundaries, the external forces are specified as:

$$F_{\eta\eta} = F_p + \alpha_{\eta x}^2 F_{xx} + \alpha_{\eta y}^2 F_{yy} + 2 \alpha_{\eta x} \alpha_{\eta y} F_{xy}$$

$$F_{\eta s} = (\alpha_{\eta x}^2 - \alpha_{\eta y}^2) F_{xy} + \alpha_{\eta x} \alpha_{\eta y} (F_{yy} - F_{xx})$$

where

$F_{\eta\eta}$, $F_{\eta s}$ = normal and tangential specific force measures (a specific force measure is equal to a force per unit width and density)

F_p, F_{xx}, F_{xy}, F_{yy}, $\alpha_{\eta x}$, $\alpha_{\eta y}$ are specified as above.

The solution to the equations given above is generally too complex to be obtained by analytical means. Thus, a numerical technique must be used to complete the solution. CAFE-1 employs the finite-element method to perform this task. In the finite-element method, the spatial domain of interest is divided into subregion called elements. In each element a function is approximated by a simple polynominal called a trial function. The functional relationship for a typical element is then developed and the contributions from all elements are summed to obtain the system equations. Details of the finite-element method are given by Connor (1973) and Wang and Connor (1975).

A5.2.1.3 Application of the Model

Schematization of a finite-element model of a water body depends on the specific objectives of the simulation. Once the objectives have been clearly defined, the structure of elements, or the grid pattern, may be designed to reflect the simulation's objectives. This is achieved quite simply with a finite-element model.

There were three objectives for the present study:

1. Illustrate gross, bay-wide patterns of meroplankton concentration for several specified source locations to determine appropriate sampling locations for field studies as described previously,

2. Determine station effects on far-field larval concentrations,

3. Determine the far-field thermal plume configuration.

The element grid was developed so as to provide resolution sufficient for meaningful and distinguishable variability in the results of the study objectives. Thus, the element sizes were

chosen to be smaller than the scale of these phenomena, but not so small as to provide unnecessary detail. In particular, the smallest grid elements were concentrated near the Station, larger elements were assigned in more remote locations, and the largest elements were assigned at the extremities of the model, such as in Old Tampa Bay, where only volumetric similarity was required. Furthermore, the guidelines provided by Wang and Connor (1975) were followed to ensure proper hydrodynamic schematization of these models. The element sizes near Big Bend Station were comparable to those used for the simulation of Biscayne Bay by Wang (1978); the shortest leg of an element in the present study was approximately 1,400 meters whereas that used by Wang was approximately 1,000 meters. The Biscayne Bay study was given no preferential region of interest and the size of elements was not intentionally varied throughout the model area. The resulting finite-element grid used in the Big Bend study is shown on Figure A5.2-1.

Bathymetric features in the model were represented using current National Ocean Survey nautical charts (1978). An average water depth was assigned to each node by considering the chart readings in the vicinity of the node.

Two types of boundary conditions were used in the model. At the open ocean boundary, tide data were prescribed in terms of a table of tide heights and times of occurrence throughout a tidal cycle. For fixed land boundaries, a no-flux condition, which assumes that the land is impermeable, was employed. The effects of river inflow were ignored for the final production runs. Previously the effects of river inflow were shown to be insignificant to the model results (S&W 1979).

A5.2.1.4 Model Calibration

The calibration of the CAFE-1 model generally consists of varying the bottom friction coefficient to obtain model results which match field data. In performing this task, tidal, wind, and river inflow conditions existing during the survey are simulated in the model input. The eddy viscosity coefficient is generally not varied because it has little effect other than providing a stabilizing influence to model computation.

The calibration effort for Big Bend Station used two different sets of field data. The first consisted of USGS data reported by Goodwin (1976). The second set consisted of current measurements taken during a dye survey performed by Aquatec, Inc., in October 1979 (Aquatec 1979). The comparison between the field and model results for current for both surveys is presented on Table A5.2-1. The comparison with the USGS data is excellent. However, the comparison with the Aquatec data is less satisfactory. This is because large freshwater inflow during and directly before the Aquatec survey resulted in less than ideal

conditions for the measurement of current. The final values of the bottom friction coefficient vary from approximately 0.006 in the deep channel areas in lower Tampa Bay to 0.025 in the shallow areas in the upper section of the Bay.

A5.2.2 Dispersion Model: DISPER-1

A5.2.2.1 General

The dispersion model DISPER-1 completes the set of two-dimensional finite-element models used for the far-field modeling of Tampa Bay. CAFE-1 provided current velocities and water levels for input to DISPER-1. DISPER-1, with the appropriate input parameters, was used to determine the effect of Station operation on temperature and meroplankton concentrations in Tampa Bay.

A5.2.2.2 Model Formulation

This section presents a basic overview of the model formulation of DISPER-1. The fundamental equation used in DISPER-1 is that for the mass balance of a constituent. This is expressed by the convection-diffusion equation (Leimkuhler et al 1975):

$$\frac{\partial C}{\partial t} + \frac{\partial}{\partial x}(\bar{U}C) + \frac{\partial}{\partial y}(\bar{V}C) = -\frac{\partial}{\partial x}Q_x - \frac{\partial}{\partial y}Q_y + P \qquad \text{(A5.2-8)}$$

where

$$Q_x = -\rho H E_{xx}\frac{\partial \bar{c}}{\partial x} - \rho H E_{xy}\frac{\partial \bar{c}}{\partial y} \qquad \text{(A5.2-9)}$$

$$Q_y = -\rho H E_{yx}\frac{\partial \bar{c}}{\partial x} - \rho H E_{yy}\frac{\partial \bar{c}}{\partial y} \qquad \text{(A5.2-10)}$$

$C = \rho \bar{c} H$ = vertically integrated concentration (mass per unit area),

ρ = mass density of water,

$\bar{c}$ = vertically averaged concentration (mass of constituent per mass of fluid),

H = total depth,

$\overline{U}$, $\overline{V}$ = vertically averaged values of horizontal velocity,

E_{xx}, E_{yy}, $E_{xy} = E_{yy}$ = dispersion coefficients,

P = mass contribution due to sources and sinks.

Two types of boundary conditions are used in DISPER-1: one in which the concentration is specified and one in which the dispersive flux is specified.

As with CAFE-1 (discussed in Section A5.2.1.2) the solution of Equations A5.2-8, A5.2-9, and A5.2-10 is obtained by the finite element method. Details on the application of the finite element method to DISPER-1 and other detailed information on the model formulation of DISPER-1 have been presented by Leimkuhler et al (1975) and Christodoulou et al (1976).

A5.2.2.3 Calibration

Calibration of DISPER-1 involves specification of the dispersion coefficients E_{xx}, E_{yy} and E_{xy} in Equations A5.2-9 and A5.2-10. Generally, the data available for calibration limit the calibration process to the specification of a single isometric ($E_{xx} = E_{yy}$; $E_{xy} = 0$) dispersion coefficient. An isometric dispersion coefficient is sufficient for most applications.

Calibration of the DISPER-1 model to Tampa Bay consisted of a two-step process, each of which involved the use of the results of a dye study performed by Aquatec, Inc. in October 1979 (Aquatec 1979).

In the first step, the dye survey results were analyzed statistically to obtain an isometric dispersion coefficient. Contour plots of dye concentration at various times during the survey were used to obtain the covariance (σ^2) of dye concentration and plume width by the relationship:

$$\sigma^2 = \int_{xi}^{x_f} (x - \overline{x})^2 \frac{C}{A} dx$$

)

(Rochester Gas & Electric Corp 1974.)

where

x_i, x_f = initial, final points of plume crossing,

A = area under the C(x) curve,

$\bar{x}$ determined by $\int_{x_i}^{\bar{x}} C\,dx = A/2$

Values for σ^2 were determined at various times (t) and the isotropic dispersion coefficient (E) was determined from:

$$\sigma^2 = 2\,Et$$

The value of E obtained by this method was 8 sq m/sec. Following this analytical procedure, an attempt was made to match the results of the survey using DISPER-1. Current velocities and water levels predicted by CAFE-1 for the survey period, as well as a source term which simulated the dye release, were input to DISPER-1.

Two cases with different dispersion coefficients were run. For one case, the dispersion coefficient had the value of 8 sq m/sec, as obtained by the analysis of dye data. For the other case, a value of 30 sq m/sec was used. Both computer runs yielded results that were somewhat less than satisfactory, due to the inability of the model grid to adequately resolve the relatively small dye plume. However, the dispersion coefficient of 8 sq m/sec resulted in a plume that was much more similar to the plume that was measured during the dye survey. Thus, 8 sq m/sec was accepted as the calibrated dispersion coefficient for Tampa Bay.

A5.2.2.4 Application of the Model

The grid used for the application of the DISPER-1 model to Tampa Bay was the same one used for the CAFE-1 model. Development of this grid is discussed in Section A5.2.1.3.

A5.2.2.4.1 Thermal Discharge

The boundary condition used for the thermal discharge runs consisted of zero temperature rise at the open boundary. The Station thermal input was simulated by specifying source terms representative of various rates of thermal loading. DISPER-1 was modified to allow heat transfer from the water surface to the atmosphere to be included in the model. An average heat transfer coefficient value of 130 Btu/day°F sq ft was used, based on water temperature and meteorological measurements for Tampa Bay (TECO 1977 and 1979). The calibrated value of 8 sq m/sec was used for the dispersion coefficient. Current velocities and water levels predicted by CAFE-1 for a typical tidal cycle were input.

A5.2.2.4.2 Meroplankton Entrainment

The impact of the plant on ambient patterns of meroplankton was determined by the use of DISPER-1. In order to simulate the Station properly as a sink term, the model was modified to allow the option of the use of a concentration dependent sink term. With this modification, the number of meroplankters removed from the system at each time step in the computation equaled the concentration of meroplankton times the station flow rate.

The model was run for several different cases. These cases involved different values of initial and boundary conditions which were used to duplicate the ambient patterns of meroplankton distribution observed in the field studies. In running the cases, the model was first used without the sink term to simulate the ambient patterns observed. The sink term was then imposed and the reduction of meroplankton concentration in each element was observed.

To alleviate model stability problems that arose during the meroplankton entrainment runs, a dispersion coefficient of 30 sq m/sec was used, rather than the calibrated value of 8 sq m/sec. The 30 sq m/sec value provided conservative results for these studies, since a larger dispersion coefficient results in a greater amount of entrainment. Current velocities and water levels predicted by CAFE-1 for a typical tidal cycle were input.

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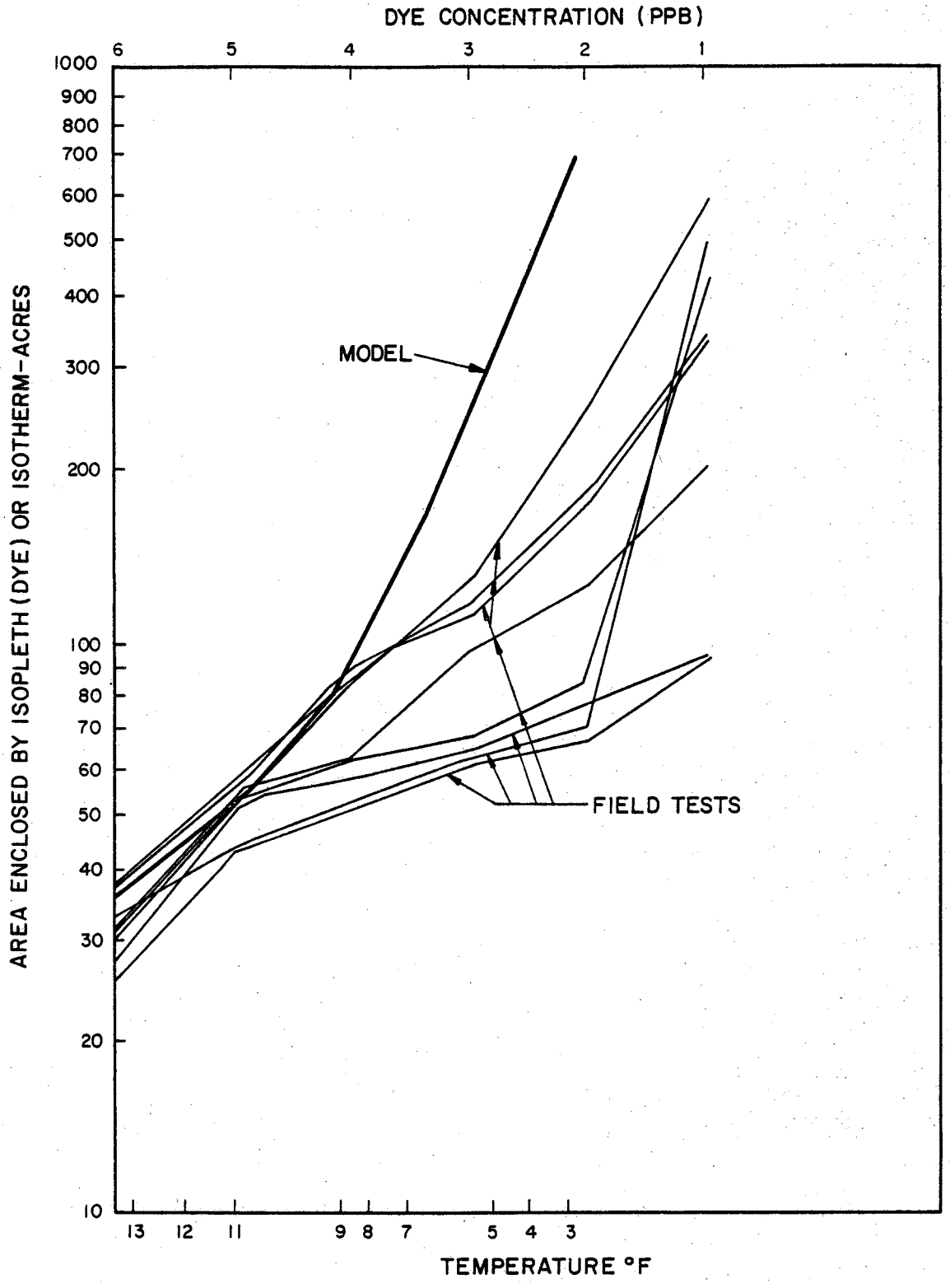
TABLE A5.2-1

COMPARISON OF FIELD AND MODEL CURRENT RESULTS

Survey	Station Location	Current Amplitude (m/sec) Field	Model
USGS	Center Lower Tampa Bay - off Lewis Island	0.84	0.87
	Near Weedon Island	0.80	0.79
	Near Big Bend	0.36	0.39
Aquatec	Center Lower Tampa Bay - off Snell Isle	0.53	0.33
	Near Big Bend	0.34	0.19



NOTE:
AREA ENCLOSED BY DYE ISOPLETH VS. DYE CONCENTRATION, AND AREA ENCLOSED BY HEATED PLUME VS. WATER TEMPERATURE ABOVE AMBIENT.

FIGURE A5.1-1
DYE SURVEY AREA COMPARISON
MODEL PREDICTION VS. FIELD STUDY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

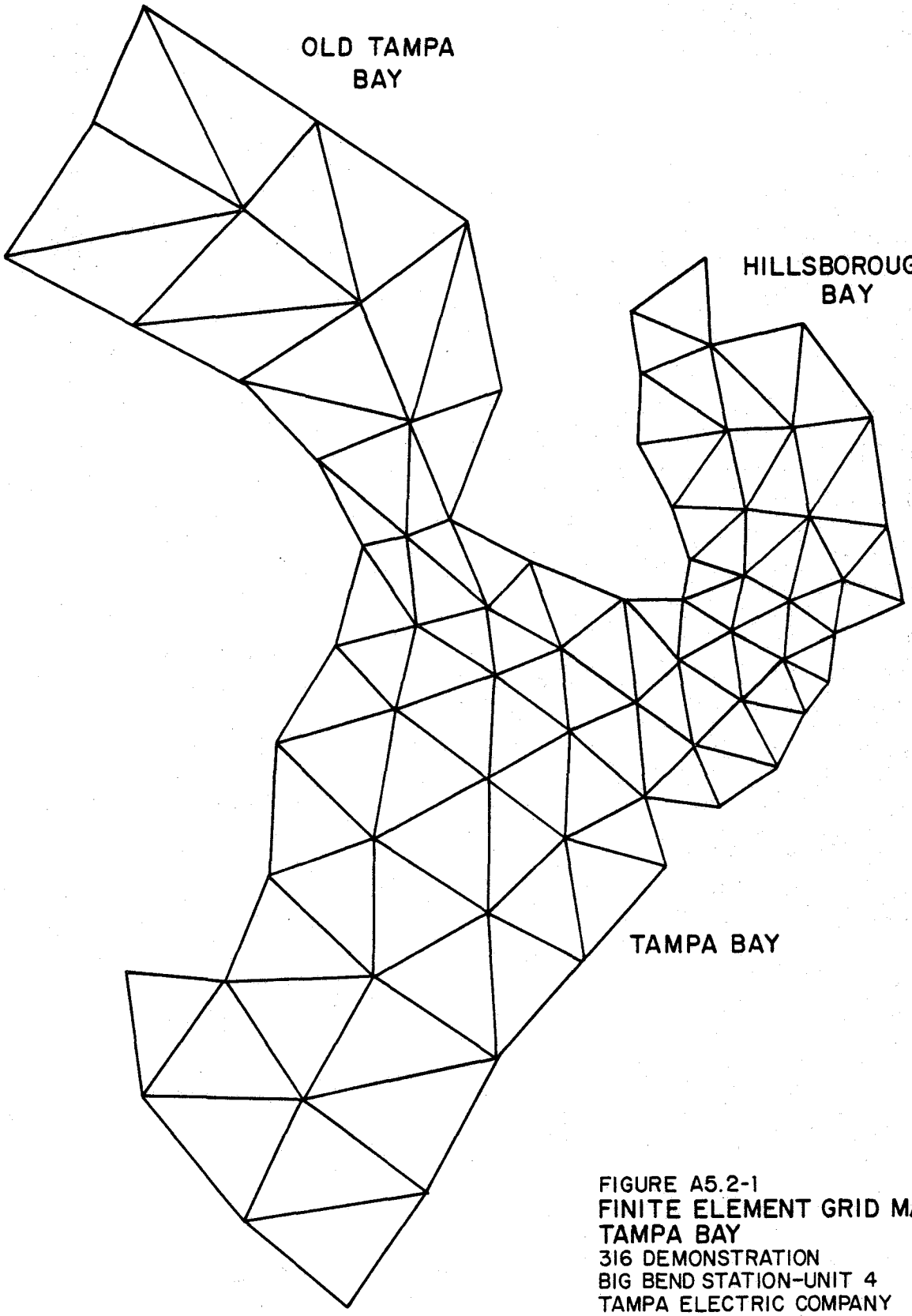


FIGURE A5.2-1
FINITE ELEMENT GRID MAP
TAMPA BAY
316 DEMONSTRATION
BIG BEND STATION-UNIT 4
TAMPA ELECTRIC COMPANY

APPENDIX 6

RIS THERMAL TOLERANCE TABLES

APPENDIX 6

TEMPERATURE TOLERANCES
RIS INVERTEBRATES AND FISHES

TEMPERATURE TOLERANCES: EXPLANATION OF TERMS

All aquatic organisms (with the exception of aquatic mammals and a few large, fast-swimming fish) have body temperatures that conform to the temperature of their environment. Variations in water temperature create conditions that are optimum at times, but are generally above or below optima for particular physiological, behavioral, and competitive functions of the species/life stage (Coutant 1972:2).

An explanation of terms used in Tables A6-1 through A6-10 to describe the responses of fishes and invertebrates to temperature are provided below.

Acclimation Temperature: The thermal level to which an organism is physiologically adjusted (Mihursky & Kennedy 1967:22). The term acclimation is used to indicate experimentally induced, relatively rapid, thermal adaptation, while a similar term, acclimatization, is reserved for slow, naturally occurring adaptation (Coutant 1970:351). Temperature effects are greatly modified by the past thermal history of an individual; most organisms acclimate upward to raised temperatures faster than they acclimate downward to lowered temperatures (Mihursky & Kennedy 1967:23). Acclimation to a temperature proceeds at different rates and efficiencies under the influence of different levels of other simultaneous acclimations (e.g., salinity) (Kinne 1964:330).

Preferred Temperature: When organisms are placed in a temperature gradient, they select a certain temperature as measured by the frequency of their occurrence (Fry 1964, cited in Gift & Westman 1971:3). The temperature of maximum frequency of occurrence in the experimental gradient is the preferred temperature (or preferendum). In nature, many things affect the physiological state of the organism (e.g., season, salinity, and diet), and many additional behavioral activities (e.g., feeding and reproductive condition) may override a pure behavioral response to select a preferred temperature. Thus the determination of a preferred temperature does not necessarily indicate a temperature which is available to an organism in its natural environment (Gift & Westman 1971:4).

Final Preferendum: Studies have shown that increasing acclimation temperatures result in higher preferred temperatures (Pitt et al 1956, Ferguson 1958, and Alabaster 1963, cited in Gift & Westman 1971:4). If an organism remains in a thermal gradient for a

sufficient length of time, it will eventually gravitate and become acclimated to its final preferendum (Reynolds 1977:735); the final preferendum is reached when a preferred temperature equals the acclimation temperature (Fry 1964, cited in Gift & Westman 1971:3).

Tolerance Limit (TL): Each species (and often each distinct life stage) has a characteristic range of temperature it will tolerate or survive that is established by internal biochemical adjustments made while at an acclimation temperature (Coutant 1972:4). At temperatures above and below the tolerance range, survival is a function of two factors - temperature and duration of exposure - with mortality occurring more rapidly the further the temperature is from the threshold (Coutant 1972:5). The upper or lower TL is defined as the temperature at which the organism under consideration can survive a designated period of time (Doudoroff 1942:222,223). Ordinarily this is expressed as the survival of 50 percent of a sample of individuals,i.e., the median tolerance limit (TLm).

Lethal Temperature (LT): The temperature at which the organism under consideration dies after a designated period of time. Ordinarily, this is expressed as the mortality of a stated fraction of the sample. For example, an LT50 indicates the mortality of 50 percent of a sample and is equivalent to the TLm.

Incipient Lethal Temperature (ILT): The temperature which, when a sample of organisms is brought rapidly to it from a different temperature, will kill a stated fraction of the sample (generally 50 percent) within an indefinitely prolonged exposure (Coutant 1970:349). The acclimation temperature directly affects the ILT (Coutant 1970:351).

Ultimate Incipient Lethal Temperature (UILT): Although the tolerance range is shifted upward by acclimation to warmer water and downward by acclimation to cooler water, there is a limit to such accommodations (Coutant 1972:5). Elevation of the ILT is not directly proportional to elevation of the acclimation temperature but rather some fraction of it (Coutant 1970:349). The result is that acclimation temperature and upper ILT tend to converge upon the ultimate incipient lethal temperature (UILT), at which both the acclimation temperature and the ILT are the same (Coutant 1970:351; 1972:4,5).

Avoidance Temperature: Avoidance reactions to temperature are characterized by escape or evasive reactions elicited by non-preferred temperature extremes, often called upper and lower turnaround or avoidance temperatures (Neill & Magnuson 1974 and Beitinger 1974, cited in Reynolds 1977:736). An organism's ability to discriminate slight temperature differences near the upper and lower avoidance temperatures enables it to avoid temperatures sufficient to create stress (Gift & Westman 1971:6).

It is necessary, however, to know whether avoidance temperatures refer to temperatures never voluntarily occupied or to temperatures seldom occupied (Meldrim & Gift 1971:18; Reynolds 1977:736).

Critical Thermal Maximum (CTM): The temperature that causes a breakdown in avoidance behavior (Gift & Westman 1971:6). The CTM is the thermal point at which the locomotor activity becomes disorganized and the animal loses its ability to escape conditions that will soon cause its death (Mihursky & Kennedy 1967:23; Liden & Burton 1978:3). Even if this temperature is not lethal to the organism, it would quite possibly cause the organism to become vulnerable to predation by another more temperature-tolerant species (Coutant 1969:269).

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TABLE A6-1

TEMPERATURE TOLERANCE - AMERICAN OYSTER

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
Adult	45	22	25-minute exposure TLm	Fingerman & Fairbanks 1957:61
	42	22	117-minute exposure TLm	Fingerman & Fairbanks 1957:62
	41	24	0.74°C/hr TLm	Fingerman & Fairbanks 1957:58
	46.5	24	4.5°C/hr TLm	Fingerman & Fairbanks 1957:58
	47.5	24	13.2°C/hr TLm	Fingerman & Fairbanks 1957:58
	48.5	-	Critical thermal maximum	Henderson 1929
	20-25	-	Optimal pumping rate	Collier 1951
	25-30	-	Optimal pumping rate	Galtsoff 1927
	>32	-	Decreasing pumping rate	Loosanoff 1958:61
	>34	-	Severe pumping stress	Loosanoff 1958:61
	30	-	Maximum heart beat	Federighi 1929
	42	-	Pumping ceases	Galtsoff 1964:407
	>38	-	Pumping ceases	Fingerman 1959
	2	-	Minimal pumping rate	Loosanoff 1958:59
	8-16	-	Increased pumping rate	Loosanoff 1958:61
	16-28	-	No fluctuation in pumping rate	Loosanoff 1958:61
	28-32	-	Increased pumping rate	Loosanoff 1958:61
	20	3-5	Direct exposure, increased pumping rate to that of controls	Loosanoff 1958:67

TABLE A6-1 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
			at 20°C	
	15-25	-	Physiological optimum (growth)	Collier 1953:20
	13-22	-	Optimum growth	Loosanoff & Nomejko 1949
	15-20	-	Most rapid growth	Loosanoff & Nomejko 1949
	25	-	Significant decrease in growth rate	Loosanoff & Nomejko 1949
	5-15	-	Decreased index of condition	Medcof & Needler 1941:253
	>20	-	Decreased index of condition if spawning	Medcof & Needler 1941:253
	<5	-	Stable index of condition	Medcof & Needler 1941:253
	15-20	-	Stable index of condition (<20 ppt)	Medcof & Needler 1941:253
	>15	-	Increased index of condition except if spawning	Medcof & Needler 1941:253
	-2 to 30	-	Range of occurrence	Butler 1954:484
	25-30	-	No decrease in growth (or relative to gametogenesis or spawning) as compared to lower temperatures (Apalachicola Bay, FL)	Ingle & Dawson 1952:401
	1-36	-	Range of occurrence	Galtsoff 1964:407
	<8	-	Hibernation (feeding ceases)	Galtsoff 1964:407
	25-26	-	Maximum pumping rate	Galtsoff 1964:407

TABLE A6-1 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
	>32	-	Rapid decline in pumping rate (feeding ceases)	Galtsoff 1964:407
	>22	-	Pronounced increased mortality with Apr. temperature rise (Crystal River, FL)	Dawson 1955:300
	5	-	Cessation of pumping	Galtsoff 1926
	5.6	-	Initiation of pumping	Nelson 1928b:221
	10-20	-	Major increases in growth	Butler 1954:483
	5	-	Survived >5 weeks when buried	Dunnington 1968:102
	10-15	-	Survived >3 weeks when buried	Dunnington 1968:102
	15-20	-	Survived >1 week when buried	Dunnington 1968:102
	32	7-19	Excised mantle and adductor muscle respiration maxima (28-30 ppt)	Percy et al 1971:355
	40	7-19	Excised gill respiration maximum; rate declines >28°C (28-30 ppt)	Percy et al 1971:355
	35	-	Initial compensation, but mortality increased greatly after a few days (35 ppt)	Quick 1971:172
	35	-	Abnormal cytoplasmic degeneration and retardation of gametogenesis but compensation and	Quick 1971:172

TABLE A6-1 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
			repair also evident (15 ppt)	
	20.0	-	Minimum mass spawning temperature (Canada)	Medcof 1939
	16.4	-	Minimum mass spawning temperature (Long Island, NY)	Loosanoff & Engle 1940
	25.0	-	Minimum mass spawning temperature (Delaware Bay)	Stauber 1950
	22-23	-	Minimum mass spawning temperature (Upper Chesapeake Bay)	Engle 1950
	25.0	-	Minimum mass spawning temperature (Eastern Chesapeake Bay)	Engle 1950
	25.0	-	Minimum mass spawning temperature (Texas)	Hopkins 1931
	22.5	-	Isolated spawning (Apalachicola Bay, FL)	Ingle 1951:132
	26.0	-	Initial mass spawning (Apalachicola Bay, FL)	Ingle 1951:132
	28.0	-	Simultaneous mass spawning (Apalachicola Bay, FL)	Ingle 1951:133
	35	-	Retardation of spawning	Galtsoff 1964:308
	15-32 or 34	-	Spawning range	Galtsoff 1964:308, 309
	>22 or 23	-	Mass spawning	Galtsoff 1964:309
	20	-	2°C increment for additional spawning (minimum critical temperature)	Nelson 1928a:154

TABLE A6-1 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
	18-27	-	Initiation of spawning based on initial spatfall (observations over 7-yr period) (Pensacola, FL)	Butler 1955:75
	15	-	26.5 days for gametogenesis (Long Island)	Loosanoff & Davis 1952
	20	-	7.9 days for gametogenesis	Loosanoff & Davis 1952
	25	-	5.4 days for gametogenesis	Loosanoff & Davis 1952
	15	-	150 days for gametogenesis (Delaware Bay)	Price & Maurer 1971:33
	20	-	56 days for gametogenesis	Price & Maurer 1971:33
	25	-	35 days for gametogenesis	Price & Maurer 1971:33
	18	8	No gonadal development after 71 days (Apalachicola Bay, FL)	Loosanoff 1969:160
Egg	17.5-32.5	-	Hatching success >50 percent at 17.5-27.0 ppt; except ≤17.5 or ≥32.5°C	Davis & Calabrese 1964:647, 648
	30-34	-	Embryo impaired by 1-16 hr exposure	Roosenburg et al 1970

TABLE A6-1 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
	40	24 (48 hr)	10-sec - TLm value	Hidu et al 1974:108
	36	24 (48 hr)	1-min - TLm value	Hidu et al 1974:108
	34	24 (48 hr)	10-min - TLm value	Hidu et al 1974:108
	31	24 (48 hr)	1-hr TLm	Hidu et al 1974:108
Ciliated gastrula	35	24 (48 hr)	1-hr TLm	Hidu et al 1974:108
Veliger	42	24 (48 hr)	1-hr TLm	Hidu et al 1974:108
Larva	19-30.5	-	Maximum survival (80-percent survival contour) 2-day-old larvae (19-30 ppt)	Lough 1975:87, 88
	>21	24 (2 days at 27.5ppt)	Maximum survival (60-percent survival contour) 10-day-old larvae (8-30.5 ppt)	Lough 1975:87, 88
	>19	24 (2 days at 27.5ppt)	Maximum growth (100-percent response contour) 10-day-old larvae (>33 ppt)	Lough 1975:87, 88
	>30	24 (2 days at 27.5 ppt)	Optimum growth and survival (80-percent contour) 10-day old larvae (18-35 ppt)	Lough 1975:87, 88
	29	24	4-hr exposure increased percent set	Lutz et al 1970:69
	>35	25	5-sec exposure; 30-day survival decreased with temp. increases	Diaz 1973:993
	45	25	5-sec exposure; permanent impairment	Diaz 1973:993

TABLE A6-1 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Remarks	Source
	35	25	5-sec exposure increased percent set	Diaz 1973:993
	40, 45	25	5-sec exposure significantly decreased percent set	Diaz 1973:993
	33	24 (48 hr)	2-16 hr TLm	Hidu et al 1974:106
	20	24 (48 hr)	2-16 hr TLm	Hidu et al 1974:106
	≤15	-	No apparent growth	Davis & Calabrese 1964:645
	17.5-33	-	Growth rate increases from minimum rate to maximum rate of increase	Davis & Calabrese 1964:645
	22.5-32.5	-	>50 percent survival to 8-day straight-hinge stage at 10-27.0 ppt	Davis & Calabrese 1964:648
	27.5-32.5	-	Optimal growth; 10.0-27.5 ppt except 7.5 ppt at 27.5°C	Davis & Calabrese 1964:655
	30.0-32.5	-	Set 10-12 days	Davis & Calabrese 1964:655
	20.0	-	Set 36-40 days	Davis & Calabrese 1964:655

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TABLE A6-1 (Cont)

SOURCES: (Cont)

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TABLE A6-1 (Cont)

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TABLE A6-2

TEMPERATURE TOLERANCES - PINK SHRIMP

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Salinity (ppt)	Remarks	Source
Adult/Juv.	35.5	Tampa Bay, FL	-	-	Eldred et al 1961:87
	15.8 - 33.0	Tampa Bay, FL	20.4 - 35.2	-	Dragovich & Kelly 1964:79
	13.0 - 31.0	Tampa Bay, FL	19.6 - 35.2	-	Saloman 1968:1,2,5
	16.1 - 30.1	Florida waters	-	Spawning (range)	Eldred et al 1965:14
	19.6 - 30.6	Dry Tortugas area, FL	-	Spawning (range)	Jones et al 1964:87
	21.7 - 30.4	Dry Tortugas area, FL	36.2 - 37.7	-	Iversen & Idyll 1960:2
	19.8 - 21.9	-	-	Spawning (min. range)	Jones et al 1970:649
	28.7 - 29.7	-	-	Spawning (max. range)	Jones et al 1970:649
	10.1 - 33.0	Anclote area, FL	11.0 - 32.0	Peak abundance at 25 - 33°C	FPC 1977b:VII.129
	16.6 - 32.2	Florida Bay, FL	27.8 - 49.6	-	Hudson et al 1970:8
	7.6 - 34.7	Northeastern FL coast	0.6 - 40.4	Size range 15-145 mm TL	Joyce 1965, cited in Copeland & Bechtel 1974:183
	<10	North Carolina	-	Cessation of body functions	Williams 1955:137
	23.9	North Carolina	-	Post-larval recruitment (min. temp.)	Eldred et al 1961:88
	≤35	North Carolina	-	-	Williams 1955:122,123
	4	North Carolina	-	Deeply buried in substrate	Williams 1955:138
	6.0 - 32.2	Pamlico Sound, NC	6.3 - 18.8	Size range 7-212 mm TL	Williams 1955:123, 134-138
	10.5 - 28.8	Lake Pontchartrain, LA	3.9 - 10.3	-	Darnell & Williams

TABLE A6-2 (Cont)

Life Stage	Temperature (°C)	Location	Salinity (ppt)	Remarks	Source
					1956:844
	20.0 - 21.5	Chandeleur Sound, LA	30.6 - 35.3	-	Darnell & Williams 1956:845
	8.0 - 26.9	Lake Borgne - Breton Sound, LA	3.0 - 21.9	Size range 40-110 mm	El-Sayed 1961, cited in Copeland & Bechtel 1974:183
Postlarva	≥23.9	North Carolina	-	Recruitment	Eldred et al 1961:88
	12.6 - 30.6	Port Aransas, TX	29.7 - 37.4	Size range 6.5-9 mm	Copeland & Truitt 1966:68,72
	>26	Buttonwood Canal, FL	-	-	Roessler & Rehrer 1971:801
	24-31	Anclote area, FL	-	Peak abundance 31°C	FPC 1977a:V.173
Larva	19.8 - 29.7	Dry Tortugas area, FL	-	-	Jones et al 1970:649
Egg/Larva	≥16.1	-	-	-	Eldred et al 1965:2

TABLE A6-2 (Cont)

Life Stage	Temperature (°C)	Remarks	Source
Laboratory Observations:			
Adult/Juv.	>33	Burrowing does not occur	Fuss & Ogren 1966, cited in Perez-Farfante 1969:519
	≤8.8	Osmoregulatory abilities impaired	Williams 1960:570
	27 & 29	Spawning initiated	Ewald 1965:439
	37.2	Lethal with prolonged exposure	Marble & Nowell 1971
	12	Lethal (concrete or wood bottom tanks)	Eldred et al 1961:86
	14 - 16	Lower TL	Fuss & Ogren 1966, cited in Perez-Farfante 1969:519
	<10	Complete cessation of functions	Williams 1955:137 Fuss & Ogren 1966, cited in Perez-Farfante 1969:519 Eldred et al 1961:86
Egg	27 - 29	Hatch (13-14 hr)	Hudinaga 1942, cited in Dobkin 1961:325
Nauplius	27 - 29	Optimal Development	Thorhaug et al 1971b:131
	27 - 28	Optimal Development	Idyll et al 1970, cited in Thorhaug et al 1971b:127
	<24 - 25	No metamorphosis to protozoea	Thorhaug et al 1971b:126-7
	>30.5	No metamorphosis to protozoea	Thorhaug et al 1971b:126-7; 1972:IX.1
	33 - 34	Survival severely decreased 10 hr after hatch	Thorhaug et al 1971b:127
	30.5 - 31.5	Upper LT (22 hrs)	Thorhaug et al 1972: IX.2
	<15	Lower LT (12 hrs)	Thorhaug et al 1971a:X1.16
	>37	Upper LT (12 hrs)	Thorhaug et al 1971a:X1.16
	33.0	Lower Lt >50 (18 hrs)	Thorhaug et al 1971a:X1.16
	<15	Upper LT >50 (18 hrs)	Thorhaug et al 1971a:X1.16

TABLE A6-2 (Cont)

Life Stage	Temperature (°C)	Remarks	Source
	35	Abnormally vigorous swimming activity (<12 hrs)	Thorhaug et al 1971a:X1.16
	<24	Individual resting; required prodding to elicit movement	Thorhaug et al 1971a:X1.16
	<25.0	No metamorphosis to protozoea	Thorhaug et al 1971a:X1.16
	>31.5	No metamorphosis to protozoea	Thorhaug et al 1971a:X1.16
	<23.0	Attainment of 5th nauplial stage negligible	Thorhaug et al 1971a:X1.16
	>32.6	Attainment of 5th nauplial stage negligible	Thorhaug et al 1971a:X1.16
Protozoea -1st	36.0 - 37.6	Upper LT (18 hrs)	Thorhaug et al 1972:IX.2
	>37.0 - 37.8	LT 18 hrs after hatch	Thorhaug et al 1971b:127
	>37.6	Upper LT (18 hrs)	Thorhaug et al 1971a:x1.16
	<37.0	Upper TL (18 hrs)	Thorhaug et al 1971a:x1.16
Protozoea -3rd	>36.8 - 37.8	Upper LT (17 hrs)	Thorhaug et al 1972:IX.2
	>35.7 - 36.7	Upper LT 22 hr after hatch	Thorhaug et al 1971b:128
	>37.7	Upper LT (17 hrs)	Thorhaug et al 1971a:X1.16
	>36.7	Upper LT (22 hrs)	Thorhaug et al 1971a:X1.16
	<35.7	Upper TL (22 hrs)	Thorhaug et al 1971a:X1.16
Mysis	>36.9 - 37.4	Upper LT	Thorhaug et al 1971b:128
	<14.6	Lower LT	Thorhaug et al 1971b:128
Mysis-3rd	36.8 - 37.8	Upper tolerance limit (72 hrs)	Thorhaug et al 1972:IX.2
	>36.9	Upper LT (>20 hrs)	Thorhaug et al 1971a:X1.16
	<35.9	Upper TL (>20 hrs)	Thorhaug et al 1971a:X1.16
	<34.9	Upper TL (>34 hrs)	Thorhaug et al 1971a:X1.16

TABLE A6-2 (Cont)

Life Stage	Temperature (°C)	Remarks	Source
	>36.9	Upper LT (>34 hrs)	Thorhaug et al 1971a:X1.16
Larva	27 - 30	Optimal	Thorhaug et al 1971b:131
	<24	No development	Cook & Murphy 1969:753
	24 - 32	Rate of development increases with temperature	Cook & Murphy 1969:753
	31	High mortality (probably due to bacteria)	Ewald 1965:442
	26	Metamorphosis after 15 days	Ewald 1965:442
	21	Metamorphosis after 25 days	Ewald 1965:442
	36 - 37	Upper TL for most larval life stages	Thorhaug et al 1972:IX.1
Postlarva -1st	>36.8 - 37.8	Upper LT	Thorhaug et al 1971b:128
	<33.5	"Safe" limit	Thorhaug et al 1971b:128
	37.9 - 40.7	Upper LT (1 hr)	Thorhaug et al 1972:IX.2
	>37.8	Upper LT (25 hrs)	Thorhaug et al 1971a:X1.16
	<33.5	Upper TL (25 hrs)	Thorhaug et al 1971a:X1.16
	34.9 - 36.3	Upper LT (30-40 hrs)	Thorhaug et al 1971a:X1.16
Postlarva -2nd	>39.1	Upper LT (>45 min)	Thorhaug et al 1971a:X1.16
	38.5	Upper TL (>45 min)	Thorhaug et al 1971a:X1.16
	38.5*	Upper LT (30 min)	Thorhaug et al 1971a:X1.16
	>38.5	Upper LT (128 min)	Thorhaug et al 1971a:X1.16
	38.0*	Upper LT (2.5 hrs)	Thorhaug et al 1971a:X1.16
	<37.9	Upper TL (128 min)	Thorhaug et al 1971a:X1.16
	37.9 - 39.6	Upper LT (2 hrs)	Thorhaug et al 1971a:X1.16

TABLE A6-2 (Cont)

Life Stage	Temperature (°C)	Remarks	Source
	36.0-37.9	Upper LT (16.5-24 hrs)	Thorhaug et al 1971a:X1.16
	40.7	Upper LT (<5 min)	Thorhaug et al 1971a:X1.16
	12.8	Lower LT (<5 min)	Thorhaug et al 1971a:X1.16
Juvenile - late	36.3 - 38.5	Upper tolerance limit (40 hrs)	Thorhaug et al 1972:IX.2

NOTE:

* Author's data corrected for apparent typographical errors.

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TABLE A6-3

TEMPERATURE TOLERANCES - BLUE CRAB

Range of Occurrence:

Life Stage	Temperature (°C)	Remarks	Source
Adult	20, 30	Recirculating culture - 60 days with no significant differential in growth. Molt frequency 30°C > 20°C - % mortality 30°C < 20°C (Delaware Bay)	Winget et al 1976: 31,32
	14.1-33.9	Salinity 5.6-35.9 ppt (Tampa Bay, FL)	Dragovich & Kelly 1964:83
	45	Short periods of exposure (Texas)	Powers 1977:78
Juvenile	13-34	Growth rate increases with temperature	Leffler 1972:105
	13-27	Molting rate increases with temperature	Leffler 1972:105
	27-34	Molting rate continuing to increase with temperature but at a lesser increase than 13-27°C	Leffler 1972:105
	13-34	Mortality rate increases with temperature	Leffler 1972: 107
	13-34	Metabolic rate increases with temperature (but acclimation apparent)	Leffler 1972:108
	3.8-31.5	Freshwater confinement; observation range (St. Johns River, FL)	Tagatz 1968:283-285
	8.3-32.1	Seawater confinement; observation range 6-25.8 ppt (St. Johns River,FL)	Tagatz 1968:283-285

TABLE A6-3 (Cont)

Life Stage	Temperature (°C)	Remarks	Source
	29-30	Maximum growth	Holland et al 1971; cited in Liden & Burton 1978:35-37
Larva	25	Development to 1st crab (at least) 20.1, 26.7, 31.1, 32.0 ppt, not 10.5, 15.6 ppt	Costlow & Bookhout 1959:390
	20 & 30	No development to 1st crab (North Carolina) 5-40 ppt	Costlow & Bookhout 1959:390
	15-30	No development 15 & 20°C in 5 ppt-15°C in 10 ppt	Costlow & Bookhout 1969:254
	30	Development time shorter than at 20°C	Costlow & Bookhout 1969:254
Zoea	20	No development beyond 1st zoeal stage (North Carolina)	Costlow & Bookhout 1959:390
Egg	19-29	Optimum hatch 11-14 days (23-30 ppt) Chesapeake Bay	Sandoz & Rogers 1944:219

Laboratory Observations:

Life Stage	Temperature (°C)	Acclimation (°C)	Location	Salinity (ppt)	Remarks	Source
Adult	34	26	Delaware River	4	Avoidance (6.7-9.2 cm)	Meldrim & Gift 1971:36
	31.5	6	North Carolina	6.8	48-hr TLm	Tagatz 1969:714
	34.5	14	North Carolina	6.8	48-hr TLm	Tagatz 1969:174
	36.9	22	North Carolina	6.8	48-hr TLm	Tagatz 1969:174
	37.0	30	North Carolina	6.8	48-hr TLm	Tagatz 1969:714

TABLE A6-3 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Location	Salinity (ppt)	Remarks	Source
	33.1	6	North Carolina	34	48-hr TLm	Tagatz 1969:714
	34.7	14	North Carolina	34	48-hr TLm	Tagatz 1969:714
	36.9	22	North Carolina	34	48-hr TLm	Tagatz 1969:714
	38.7	30	North Carolina	34	48-hr TLm	Tagatz 1969:714
	37	-	-	-	Avoidance	Aldrich personal communication cited in Gallaway & Strawn 1975:199
	40	-	-	-	Will enter gradient for short-term feeding	Aldrich personal communication cited in Gallaway & Strawn 1975:199
	34	26	-	4	Avoidance mean (67-92 mm/CW)	Meldrim et al 1974:43
	35.5	25	-	5	Avoidance mean (102-123 mm/CW)	Meldrim et al 1974:43
	34.5	25	-	7	Avoidance mean (47-80 mm/CW)	Meldrim et al 1974:43
	34.3	20	Delaware River	21-29	Upper avoidance (10.9 cm/CW)	Gift & Westman 1971:51
	39.2	20	Delaware River	21-29	Avoidance breakdown (10.9 cm/CW)	Gift & Westman 1971:51
	34.4	26.1	-	-	Avoidance (6.7-9.2 cm/CW)	Meldrim & Gift 1971:36
	20 (10 days)	1 (4 days)	-	-	14 of 16 good condition	Tagatz 1969:715
	19	15	Patuxent River	-	Spawning induced	Sulkin et al 1976:103

TABLE A6-3 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Location	Salinity (ppt)	Remarks	Source
Ovigerous individual	10	-	-	-	Osmoregulation of ovigerous individuals markedly impaired at 5% seawater	Tagatz 1971:17
Juvenile	39.0	30	North Carolina	34	48-hr TLm	Tagatz 1969:714
	39.4	30	Galveston Bay, TX		1000 min. upper tolerance limit	Holland et al 1971; cited in Gallaway & Strawn 1975:198
	31.4	6	North Carolina	6.8	48-hr TLm	Tagatz 1969:714
	35.0	14	North Carolina	6.8	48-hr TLm	Tagatz 1969:714
	37.0	22	North Carolina	6.8	48-hr TLm	Tagatz 1969:174
	37.2	30	North Carolina	6.8	48-hr TLm	Tagatz 1969:174
	33.0	6	North Carolina	34	48-hr TLm	Tagatz 1969:714
	35.3	14	North Carolina	34	48-hr TLm	Tagatz 1969:714
	39.0	22	North Carolina	34	48-hr TLm	Tagatz 1969:714
	39.0	30	North Carolina	34	48-hr TLm	Tagatz 1969:714
	37-38	20	-	-	96-hr TL50	ANSP 1970, cited in Linden & Burton 1978:35-37
	37.1	20	-	-	1000-min TLm	Holland et al 1971, cited in Linden & Burton 1978:35-37

TABLE A6-3 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Location	Salinity (ppt)	Remarks	Source
	38.6	25	-	-	1000-min TLm	Holland et al 1971, cited in Linden & Burton 1978:35-37
	39.4	30	-	-	1000-min TLm	Holland et al 1971, cited in Linden & Burton 1978:35-37
	37.5	20	Delaware River	21-29	Upper avoidance (5.4 cm/CW)	Gift & Westman 1971:51
	40.0	20	Delaware River	21-29	Avoidance breakdown (5.4 cm/CW)	Gift & Westman 1971:51
	25	13.9	Delaware River	4.5	Preference (3.3-5.6 cm/CW)	Meldrim & Gift 1971:29
Larva	19-29	-	Chesapeake Bay	18-29	Survival; < 15°C or > 29°C marginal at 18-29 ppt, 14 ppt marginal	Sandoz & Rogers 1944:223-224
	19-23	-	Chesapeake Bay	-	Most active feeding	Sandoz & Rogers 1944:224
	20-29	-	Chesapeake Bay	21-28	Favorable molting temperature; 28 ppt marginal	Sandoz & Rogers 1944:224
	14-19	-	Chesapeake Bay	17-30	Ecdysis not successful	Sandoz & Rogers 1944 & 224, 225
	20	-	-	-	Never developed beyond first zoeal stage	Van Engle 1958, cited in Williams 1965:170
	30	-	-	-	Never developed beyond third zoeal stage	Van Engle 1958, cited in Williams 1965:170
	15	-	-	-	<50% survival regardless of salinity	Costlow 1967:95

TABLE A6-3 (Cont)

Life Stage	Temperature (°C)	Acclimation (°C)	Location	Salinity (ppt)	Remarks	Source
Zoeal	24	-	-	25	Maximum survival 12-24 days	Rust & Carlson 1960:196
	15	-	-	20-40	Metamorphosis delayed with increasing salinity	Costlow 1967:95
Egg	19-29	-	-	-	Hatch 9-33 ppt but 23-30 ppt optimum	Sandoz & Rogers 1944:219
	26.1	-	-	-	14-17 days to hatch	Churchill 1919:97
	29.4	-	-	-	12-15 days to hatch	Churchill 1919:97

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TABLE A6-4

TEMPERATURE TOLERANCES - STONE CRAB

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Salinity (ppt)	Remarks	Source
Adult	15.4 - 29.7	Tampa Bay, FL	Jan-Dec[1]	23.6 - 33.2	-	Dragovich & Kelly 1964:83
	>37	Biscayne Bay, FL	-	-	Killed in discharge canal	Hagan & Purkerson 1970, cited in USAEC 1973:5.25
Megalopa	18 - 31	Anclote area, FL	May-Nov	28 - 35	Peak abundance 29-31°C at 33-34 ppt	FPC 1977: V.169-V.170
Zoea	16 - 31	Anclote area, FL	Mar-Nov	27 - 35	Peak abundance 29-31°C at 31-34 ppt	FPC 1977: V.169-V.170

Laboratory Observations:

Life Stage	Temperature (°C)	Exposure (hrs)	Remarks	Source
	Mortality			
Egg	>36.3		upper LT;30 ppt (40 hrs)	Thorhaug et al 1971:X1.17
	>36.3		upper LT (70-90 hrs)	Thorhaug et al 1971:X1.17
	36.3-38.5		upper LT (40 hrs)	Thorhaug et al 1972:1X.2
Zoea-1st	>42.8		upper LT (20 min)	Thorhaug et al 1971:X1.17
	<40.3		upper TL (20 min)	Thorhaug et al 1971:X1.17
	>40.3		upper LT (2 hrs)	Thorhaug et al 1971:X1.17
	39.1		upper TL (2 hrs)	Thorhaug et al 1971:X1.17
	>38.0		upper LT (3.5 hrs)	Thorhaug et al 1971:X1.17
	<34.5		upper TL (3.5 hrs)	Thorhaug et al 1971:X1.17
	>36.7		upper LT (36 hrs)	Thorhaug et al 1971:X1.17
	>37.8		upper LT (9 hrs)	Thorhaug et al 1971:X1.17
	34.4-36.0		upper LT (24 hrs)	Thorhaug et al 1972:1X.2
	34.8		TLm (9 hrs)	Thorhaug et al 1971:X1.17
	33.0		upper TL (9 hrs)	Thorhaug et al 1971:X1.17
Zoea-2nd	>43.8		upper LT (4 min)	Thorhaug et al 1971:X1.17
	<42.8		upper TL (4 min)	Thorhaug et al 1971:X1.17
	>38.5		upper LT (3.25 hrs)	Thorhaug et al 1971:X1.17
	37.5		upper TL (3.25 hrs)	Thorhaug et al 1971:X1.17
	>37.5		upper LT (13 hrs)	Thorhaug et al 1971:X1.17
	36.5		upper TL (13 hrs)	Thorhaug et al 1971:X1.17
	33.1-34.2		upper LT (91 hrs)	Thorhaug et al 1972:1X.2
	36.1-37.3		TLm (22 hrs)	Thorhaug et al 1971:X1.17
Zoea-3rd	>37.6		upper LT (5 hrs)	Thorhaug et al 1971:X1.17
	32.9		upper TL (5 hrs)	Thorhaug et al 1971:X1.17
	36.9		LT 80 (5 hrs)	Thorhaug et al 1971:X1.17
	>36.7		upper LT (23 hrs)	Thorhaug et al 1971:X1.17

TABLE A6-4 (Cont)

Life Stage	Temperature (°C)	Exposure (hrs)	Remarks	Source
Zoea-5th	34.7-35.5		upper LT (44 hrs)	Thorhaug et al 1972 :1X.2
Zoea/Meg.	30.5-31.5		upper LT; molting (24 hours)	Thorhaug et al 1972:1X.2
Megalopa	>30.5		upper LT (23 hours)	Thorhaug et al 1971:X1.19
	36.0-37.0		upper LT (16 hrs)	Thorhaug et al 1972:1X.2
	33.6-36.3		TLm (96 hrs)	Thorhaug et al 1972:1X.25
Meg./Juv.	28.9-30.5		upper LT; molting (24 hrs)	Thorhaug et al 1972:1X.2
Juvenile	42.7		upper LT (<15 min)	Thorhaug et al 1971:X1.19
	41.3		upper LT (<29 min)	Thorhaug et al 1971:X1.19
	40.3		upper LT (<44 min)	Thorhaug et al 1971:X1.19
	38.0		upper LT (>4 hrs)	Thorhaug et al 1971:X1.19
	>36.9		upper LT (96 hrs)	Thorhaug et al 1972:1X.25
	37.0		upper TL (42 hrs)	Thorhaug et al 1971:X1.19
	12.6		lower TL (42 hrs)	Thorhaug et al 1971:X1.19
	Development			
Egg	<29.1		No hatching, but alive (40 hrs)	Thorhaug et al 1971:X1.17
	<23.4		No hatching, but alive (70-90 hrs)	Thorhaug et al 1971:X1.17
	<12.6		No hatching, but alive (280 hrs)	Thorhaug et al 1971:X1.17
Zoea/Meg.	16.7-30.5		Metamorphosis completed	Thorhaug et al 1971:X1.19
Larva	20		No development beyond megalops at 20-40 ppt (no survival at 10 ppt)	Ong & Costlow 1970:27, 28
	20-30		Survival increases with temperature at 20-40 ppt	Ong & Costlow 1970:27, 28
	30		Optimal survival at 30-35 ppt	Ong & Costlow 1970:29
	23-30		Survival increases with temperature and salinity	Porter 1960:169
	23-25		Development may not be completed at <27 ppt	Porter 1960:170, 176
	27-30		Develop through at least 5th or 6th zoeal stage	Porter 1960:170, 176
Juvenile	>20		Survival enhanced with temperature and salinity (>23 ppt)	Bender 1971:32
	Molting			
Juv./Adult	15		Inhibition threshold to molting	Cheung 1969:343
	Spawning			
Adult	27-31		Successful range for spawning	Porter 1960:169

NOTE:

1. Period represents duration of investigation which does not necessarily encompass species occurrence except in the case of those investigations continuing over a period of at least 12 months (i.e., Jan-Dec).

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TABLE A6-5

TEMPERATURE TOLERANCES - BAY ANCHOVY

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Remarks	Source
Adult/Juv.	9-31	Chesapeake Bay	Spawning (peak >20°C)	Dovel 1971:44
	0-31	Chesapeake Bay	-	Dovel 1971:47
	≥17.2	Long Island Sound	Spawning	Austin 1974:22
	≤37	Galveston Bay, TX	Thermal discharge (one specimen)	Gallaway & Strawn 1974:95
	24.5-32.5	Galveston Bay, TX	Preference (based on abundance)	Gallaway & Strawn 1974:95
	33-36	Galveston Bay, TX	Substantially reduced abundance	Gallaway & Strawn 1974:95
	5.0-34.9	Louisiana coast	-	Perret et al 1971: 44, cited in FPC 1977:VII.125
	22-32.9	Anclote area, FL	-	Baird et al 1972: 186, cited in FPC 1977:VII.125
	16-34	Buttonwood Canal, FL	Collected Jan-Dec (15.5-45.2 ppt)	Roessler 1970:864
	10.8-32.5	Tampa Bay, FL	Collected Jan-Dec (5-35 ppt)	Springer & Woodburn 1960:21
	23.5	Matecumbe Key, FL	Collected Nov (34.5 ppt)	Springer & McErlean 1962:42, 43
	3.8-31.2	North Carolina	Collected Jan-Dec (0-35.9 ppt); Absent Offshore Dec-Mar only	Tagatz & Dudley 1961:8
	7.9-32.0	Georgia coast	Collected Jan-Dec	Dahlberg 1972:336
Juvenile	<11	Chesapeake Bay	Movement out of surface waters	Dovel 1971:8
Juv./Larva	≤31	Chesapeake Bay	Maximum temperature	Dovel 1971:7
	23-27	Chesapeake Bay	Peak abundances (3-7 ppt)	Dovel 1971:7

TABLE A6-5 (Cont)

Life Stage	Temperature (°C)	Location	Remarks	Source
Larva	>11	Chesapeake Bay	Predominantly in surface waters	Wang 1974:274, cited in Jones et al 1978:160
Egg	≥9.7	Chesapeake Bay	Minimum temperature (single observation)	Dovel 1971:8
	>20	Chesapeake Bay	Peak abundances (13-15 ppt)	Dovel 1971:6
	13-30	Chesapeake Bay	-	Dovel & Wiley 1973, cited in Liden & Burton 1978:23
	≥10.6	Long Island Sound		Austin 1974:22

Laboratory Observations:

Life Stage	Temperature (°C)	Remarks	Source
Egg	28±0.8	Hatch 24 hrs	Kuntz 1914:3
	20	Hatch <24 hrs	Hildebrand 1963:178, cited in FPC 1977:VII.125
Larva	28	Absorption of yolk sac 25 hr after hatching	Houde 1974:271
	≤15.1	Minimum tolerance limit	Rebel 1973:22
	≥35.8	Maximum tolerance limit	
	18.6-32-5	No significant difference between temperature and survival	

TABLE A6-5 (Cont)

Avoidance Testing:

Temperature (°C)	Acclimation (°C)	Salinity (ppt)	Length (mmTL)	Source
27.0	18.0	4.0	63-74	Meldrim & Gift 1971:34
24.0	16.0	4.5	48-68	Meldrim & Gift 1971:34
27.5*	15.0	7.0	52-96	Meldrim et al 1974:41
27.0	18.0	6.5	53-65	Meldrim et al 1974:41
30.5*	20.0	6.5	53-71	Meldrim et al 1974:41
32.0	24.0	6.5	57-70	Meldrim et al 1974:41
30.0	27.0	7.0	60-65	Meldrim et al 1974:41
27.1*	15.0	29.0	60-88	Terpin et al 1977:37
31.3*	21.0	29.0	50-90	Terpin et al 1977:37
32.1	22.0	29.3	58-85	Terpin et al 1977:37

Preference Testing:

Temperature (°C)	Acclimation (°C)	Salinity (ppt)	Length (mmTL)	Source
Horizontal				
15.6	15.0	4.0	63-74	Meldrim & Gift 1971:27
19.2*	16.1	4.0	55-86	Meldrim & Gift 1971:27
30.0	22.2	4.5	71-77	Meldrim & Gift 1971:27
17.0	10.0	27.0	61-80	Terpin et al 1977:10, 26
20.7*	15.0	28.5	63-86	Terpin et al 1977:10, 26
22.7*	18.0	27.5	62-82	Terpin et al 1977:10, 26
23.2*	21.0	29.0	71-81	Terpin et al 1977:10, 26
24.7	22.0	29.0	68-75	Terpin et al 1977:10, 26
Vertical				
20.0	15.0	29.0	70-71	Terpin et al 1977:11, 33

TABLE A6-5 (Cont)

Heat Shock Testing:

Temperature (°C)	Acclimation (°C)	Exposure (hr)	Percent Mortality	Source
20	10	4.8	100	Terpin et al 1977:14, 15, 43, 44
25	10	0.8	100	
15	15	48.0	0	
18	15	48.0	0	
22	15	48.0	0	
25	15	48.0	14.3	
28	15	1.3	100	
32	15	0.2	100	
17	17	48.0	0	
21.5	17	48.0	40	
25	17	48.0	60	
28.5	17	42.0	100	
21	21	48.0	0	
24.5	21	48.0	28.6	
28	21	48.0	40	
29	21	38.0	80	
32	21	0.1	100	

Cold Shock Testing:

Temperature (°C)	Acclimation (°C)	Exposure (hr)	Percent Mortality	Source
22	22	48	0	Terpin et al 1977:16, 47
18	22	48	0	Terpin et al 1977:16, 47
15	22	48	0	Terpin et al 1977:16, 47
10	22	29	100	Terpin et al 1977:16, 47

NOTE:

* Calculated from author's data.

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TABLE A6-6

TEMPERATURE TOLERANCES - SCALED SARDINE

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Salinity (ppt)	Remarks	Source
Adult/Juv.	15.5 - 34.0	Buttonwood Canal, FL	Jan-Dec[1]	15.5 - 45.2	Reduced abundance <25 ppt	Roessler 1970:883
	19.9 - 33.6	Matecumbe Key, FL	Jan-Dec[1]	35.9 - 37.9	Surface water temperature and salinity during collection	Springer & McErlean 1962:42,47
	20.5 - 30.5	Texas coast	Apr-Nov	4.8 - 36.9	Rarely collected <24°C or <25 ppt	Gunter 1945:26
	21.0 - 32.4	Tampa Bay, FL	May-Dec	12.8 - 35.1	Rarely collected <25 ppt (one specimen at 16.8°C)	Springer & Woodburn 1960:19
	14	Hillsborough Bay, FL	Feb		Two specimens collected	TECO 1977:5.63
Larva	18.4 - 30.5	Eastern Gulf of Mexico	-	27.2 - 36.9	Age less than 6 days	Houde 1977:615
Egg	19.2 - 27.0	Southern Brazil	Sep-Apr	34.8 - 35.8	Offshore surface temperature in spawning area	Matsuura 1972:135
	>28	Southeastern Florida	May-Jun[1]	-	Offshore surface temperature in spawning area	Houde et al 1974:1107
	20.8 - 30.7	Eastern Gulf of Mexico	Jan-Sep	29.9 - 36.9	Relatively few collected <24°C or <35 ppt	Houde 1977:615

Laboratory Observations:

Life Stage	Temperature (°C)	Remarks	Source
Larva	26 - 32	Optimal growth	Saksena et al 1972:693
	28.2	Highest % survival	Rebel 1973:17
	≤19.7 & ≥35.0	Minimum and maximum LT	Rebel 1973:17
	24.6 & 31.4	TLm (standard deviation = 1.8°C)	Rebel 1973:19
Egg	21 - 23	Hatching success high (latent larval survival low)	Saksena et al 1972:693
	14.9 - 36.5	Hatching success	Rebel 1973:17

TABLE A6-6 (Cont)

Life Stage	Temperature (°C)	Remarks	Source
	20 & 35	Minimum and maximum LT	Saksena et al 1972:693
	>24	Hatch <24 hrs	Houde 1977:619

NOTE:

1. Period represents duration of investigation which does not necessarily encompass species occurrence except in the case of those investigations continuing over a period of at least 12 months (i.e., Jan-Dec).

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TABLE A6-7

TEMPERATURE TOLERANCES - TIDEWATER SILVERSIDE

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Remarks	Source
Adult/Juv.	8.4 - 39	Galveston Bay, TX	Jan-Dec[1]	Thermal discharge & adjacent areas.	Gallaway & Strawn 1974:107
	34	Galveston Bay, TX	-	Avoidance temperature (upper)	Coutant 1977:742
	7.9 - 32	Georgia coast	Dec-Jan	Salinity - 0 - 7.9 ppt	Dahlberg 1972:339
	18.0 - 34.0	Buttonwood Canal, FL	Jan-Dec[1]	Salinity - 15.5 - 44.5 ppt	Roessler 1970:885
	2.9 - 32	North Carolina coast	Jan-Dec	Salinity - 0 - 22.3 ppt	Tagatz & Dudley 1961:10
	≤32.5	Mid-Atlantic bight	-	-	Smith 1971
	≤34.0	Gulf of Mexico	-	-	Rasin 1976
	≥8.0	Gulf of Mexico	-	-	Swingle 1971
	5.0 - 9.9	Gulf of Mexico	-	Range of minima	Christmas & Waller 1973
	30.0 - 34.9	Gulf of Mexico	-	Range of maxima	Christmas & Waller 1973 Tarver & Savoie 1976 Perret et al 1971
	18 - 30	Delaware River	-	Spawning	Smith 1971
	26	Gulf of Mexico	Apr	Spawning	Robbins 1969:65
	22.5-24.8	Gulf of Mexico	Feb-Mar	Ripe females collected	Gunter 1950
	14.4-31.7	Cedar Key, FL	Mar & Jul	Ripe adults collected (20.4-31.8 ppt)	Reid 1954:7, 30
Juvenile	1.8 - 32	North Carolina coast	-	-	Tagatz & Dudley 1961:16-18
	21 - 29	Chesapeake Bay	Jan-Dec[1]	Peak abundance	Dovel 1971:52

TABLE A6-7 (Cont)

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Remarks	Source
	≤33.5	Gulf of Mexico	-	-	Franks 1970
	>5	Gulf of Mexico	-	-	Christmas & Waller 1973
Larva	12 - 30	Chesapeake Bay	Jan-Dec[1]	Peak abundance 21-29°C	Dovel 1971:10

Laboratory Observations:

Life Stage	Temperature (°C)	Acclimation (°C)	Salinity (ppt)	Length (mmTL)	Remarks	Source
Adult/Juv.	14.3[2]	4.4	6	60 - 78	Preference temperature	Meldrim & Gift 1971:28
	19.2[2]	15.0	6	58 - 71	Preference temperature	Meldrim & Gift 1971:28
	32.8	20.0	6	48 - 71	Avoidance temperature	Meldrim & Gift 1971:35
	25.8[2]	3.9	9	47 - 71	Avoidance temperature	Meldrim & Gift 1971:35
	25.8[2]	3.9	6	45 - 74	Avoidance temperature	Meldrim & Gift 1971:35
	22.5[2]	5.0	6	53 - 78	Avoidance temperature	Meldrim & Gift 1971:35
Larva	22	NA	-	NA	Yolk-sac depletion 3-4 day... starvation	Martin & Drewry 1978:101
Egg	21 - 22	NA	-	NA	Hatch 10-12 days (Chesapeake Bay)	Martin & Drewry 1978:101
	22 - 29	NA	-	NA	Hatch 12 days (Maryland)	Rubinoff 1961: 242-244
	25.6 - 27.8	NA	-	NA	Hatch 8-10 days (North Carolina)	Hildebrand 1922: 120

TABLE A6-7 (Cont)

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Remarks	Source
	29	NA	NA	Hatch 5-6 days (Texas)	Hubbs & Drewry 1959
	26.5 - 27.5	NA	NA	Hatch 6 days (Texas)	Hubbs 1967

NOTES:

1. Period represents duration of investigation which does not necessarily encompass species occurrence except in the case of those investigations continuing over a period of at least 12 months (i.e., Jan-Dec).

2. Calculation of preference and avoidance temperatures is from author's data.

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TABLE A6-8

TEMPERATURE TOLERANCES - SILVER PERCH

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Salinity (ppt)	Remarks	Source
Adult/Juv.	19.4	-	-	-	Spawning as indicated by gonadal condition of adult or presence of eggs in water	Miller 1965:91
	≤28	North Carolina coast	Jun-Jul	-	-	Kuntz 1914:3
	18.0 - 34.0	Buttonwood Canal, FL	Jan-Dec[a]	15.9 - 44.1	-	Roessler 1970:884
	7.5 - 32	Georgia coast	Jan-Dec[a]	1.3 - 34.1	-	Dahlberg 1972:341
	13.7 - 30.5	Texas coast	Jan-Dec	2.1 - 33.7	Scarce or absent Nov-Mar	Gunter 1945:66
	10.0 - 32.5	Tampa Bay, FL	Jan-Dec	3.7 - 35	Most collected >20.0 ppt	Springer & Woodburn 1960:50
	13	Tampa Bay, FL	Dec	-	Cold kill	Springer & Woodburn 1960:50
	9.9 - 33.0	Anclote area, FL	Jan-Dec[a]	12 - 31	-	FPC 1977:VII.95
	16.7 - 31.2	North Carolina coast	Mar-Oct	0 - 27.5	-	Tagatz & Dudley 1961:9
	≤4.5	Port Aransas area, TX	Jan	-	Cold kill (massive)	Moore 1976:462
Juvenile	≥4.8	-	-	-	-	Thomas 1971:44
	≤32.5	Tampa Bay, FL	May-Dec	-	-	Springer & Woodburn 1960:50
Larva	16.4 - 31.8	Little Shark River, FL	Jan-Dec	23.5 - 37.4	-	Jannke 1971:71

TABLE A6-8 (Cont)

Laboratory Observations:

Life Stage	Temperature (°C)	Acclimation (°C)	Length (mm TL)	Remarks	Source
Adult	29.7	20.0	142 (ave.)	Avoidance temperature (upper)	Gift & Westman 1971:47
	34.4	20.0	142 (ave.)	Critical thermal maximum	Gift & Westman 1971:47
Juvenile	35.5	20.0	64 (ave.)	Critical thermal maximum	Gift & Westman 1971:47
Egg	18.9 - 21.1	NA	NA	Hatch 40-50 hrs	Welsh & Breder 1923:171
	27	NA	NA	Hatch 18 hrs	Kuntz 1914:3

NOTE:

1. Period represents duration of investigation which does not necessarily encompass species occurrence except in the case of those investigations continuing over a period of at least 12 months (i.e., Jan-Dec)

SOURCES:

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TABLE A6-9

TEMPERATURE TOLERANCES - SPOTTED SEATROUT

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Salinity (ppt)	Remarks	Source
Adult/Juv.	7	Port Aransas area, TX	-	-	Restricted swimming	Moore 1976:462
	<7	Port Aransas area, TX	-	-	Moribund or torpid	Moore 1976:462
	19.7-28.3	Texas coast	-	-	Abundance increased with temperature	Simmons 1951, cited in Jannke 1971:72
	8.1 - 34.9	Texas coast	Jan-Dec	2.3 - 34.9	-	Gunter 1945:76
	>23.3	Texas coast	-	-	Spawning migration into estuary	Simmons 1951, cited in Jannke 1971:72
	4 - 33	Upper Laguna Madre, TX	Jan-Dec	25 - 75	No spawning >45 ppt; juveniles limited by high temperature & salinity	Simmons 1957:185
	≤13.5	Cedar Key, FL	-	-	Movement to deeper channel	Moody 1950:156, 157
	16.7 - 31.1	Buttonwood Canal, FL	Jan-Dec[a]	16.9 - 44.1	-	Roessler 1970:884
	9.6	Old Tampa Bay, FL	Dec	14.4	Cold kill	Rinckey & Saloman 1964:9
	14.0 - 33.0	Tampa Bay, FL	May-Jan	7.2 - 35.1	-	Springer & Woodburn 1960:52
	7.2	Indian River area, FL	-	-	Cold kill (12-hr duration)	Tabb 1958:398
	15 - 26	Indian River area, FL	-	-	"Preferred" temperature	Tabb 1958:399
	12.1 - 32	Anclote area, FL	Jun-Feb	17.9 - 28.9	Also absent October	FPC 1977:VII.99
	25.5 - 28.5	East-central FL	-	-	Spawning	Tabb 1966:63
	<7.2 - 10.0	East-central FL	-	<5	Tolerance limit (minimum)	Tabb 1966:61
	24.8 - 31.2	North Carolina coast	Jul-Aug	0 - 15	-	Tagatz & Dudley 1961:9
	<10	North Carolina coast	-	-	Fall migration out of estuaries	Tabb 1966:65

TABLE A6-9 (Cont)

Life Stage	Temperature (°C)	Location	Period	Salinity (ppt)	Remarks	Source
	10 - 12	North Carolina coast	-	-	Spring migration into estuaries	Tabb 1966:65
	5 - 34.9	-	-	-	-	Christmas & Waller 1973, cited in Johnson 1978:181
	24 - 30	Little Shark River, FL	Mar-Sep	-	Peak spawning	Jannke 1971:71,72
	≥24	Everglades National Park, FL	-	-	Peak spawning	Stewart 1961:77
	16 - 27	-	-	-	Probable optima	Johnson 1978:181
	<16 & >25	Georgia coast	-	-	Migration out of shallow-water areas	Mahood 1974, cited in Johnson 1978:181
Larva	16.4 - 31.8	Little Shark River, FL	Jan-Dec	23.5 - 37.4	-	Jannke 1971:71, 72

Laboratory Observations:

Life Stage	Temperature (°C)	Remarks	Source
Adult/Juv.	≤4.5	No recovery by warming	Moore 1976:462
	4.5 - 7	Recovery in 8 hrs by warming at 10°C	Moore 1976:462
	7.2	No survival (24-hr exposure)	Tabb 1958:398
	8.9	Some survival (12-hr exposure)	Tabb 1958:398
	24 - 26	Induced spawning	Fable et al 1978:65
Egg	25.0	Hatch 40 hrs	Smith 1907, cited in FPC 1977:VII.100
	27	Hatch 15 hrs	Fable et al 1978:67
	25	Hatch 18 hrs	Fable et al 1978:67
	23	Hatch 21 hrs	Fable et al 1978:67

TABLE A6-9 (Cont)

NOTE:

1. Period represents duration of investigation which does not necessarily encompass species occurrence except in the case of those investigations continuing over a period of at least 12 months (i.e., Jan-Dec).

SOURCES:

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TABLE A6-10

TEMPERATURE TOLERANCES - BLACK DRUM

Range of Occurrence:

Life Stage	Temperature (°C)	Location	Period	Salinity (ppt)	Remarks	Source
Adult/Juv.	3 - 35	Laguna Madre area, TX	Jan-Dec[1]	10 - 80	More abundant 25-50 ppt	Simmons & Breuer 1962:200
	6	Port Aransas area, TX	Jan	-	Torpid and floating	Moore 1976:462
	14.9 - 30.7	Texas coast	Jan-Dec[1]	2.6 - 34.9	More abundant 10-15 ppt	Gunter 1945:74
	15.8 - 26.1	Buttonwood Canal, FL	Dec-May[1]	29.7 - 33.1	Not common; few observations	Roessler 1970:884
	9.0	North Carolina coast	Jan	28.6	-	Tagatz & Dudley 1961:10
	17.4 - 31.5	Tampa Bay, FL	Jan-Dec[1]	16.1 - 32.3	Only 4 specimens collected	Springer & Woodburn 1960:63
	1	York River, VA	Jan	15	Only 1 specimen collected	Richards 1973:590
	9.6 - 21.1	Chesapeake Bay	Apr-Jun	-	Spawning migration	Richards 1973:589, 590
	17.5	Chesapeake Bay	Apr	-	Spawning (standard deviation = 2.7°C)	Richards 1973:590
Juvenile	8.3 - 35.2	Delaware River	-	-	-	Thomas 1971:61
	25.0 - 31.7	Chesapeake Bay	-	-	Found in marsh waters	Richards & Castagna 1970:245
	3.3	Chesapeake Bay	-	-	Torpid and floating... died in captivity	Frisbie 1961:99

TABLE A6-10 (Cont)

Laboratory Observations:

Life Stage	Temperature (°C)	Acclimation (°C)	Salinity (ppt)	Length (mmTL)	Remarks	Source
Adult	36.0	28.9	4.0	110 - 113	Preference temperature	Meldrim & Gift 1971:29
	29.4	25.0	4.0	79 - 120	Avoidance temperature	Meldrim & Gift 1971:36
	26.1	18.3	4.5	110 - 135	Avoidance temperature	Meldrim & Gift 1971:36
Egg	20	NA	-	NA	Hatch 24 hrs	Joseph et al 1964:427

NOTE:

1. Period represents duration of investigation which does not necessarily encompass species occurrence except in the case of those investigations continuing over a period of at least 12 months (i.e., Jan-Dec).

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TABLE A6-10 (Cont)

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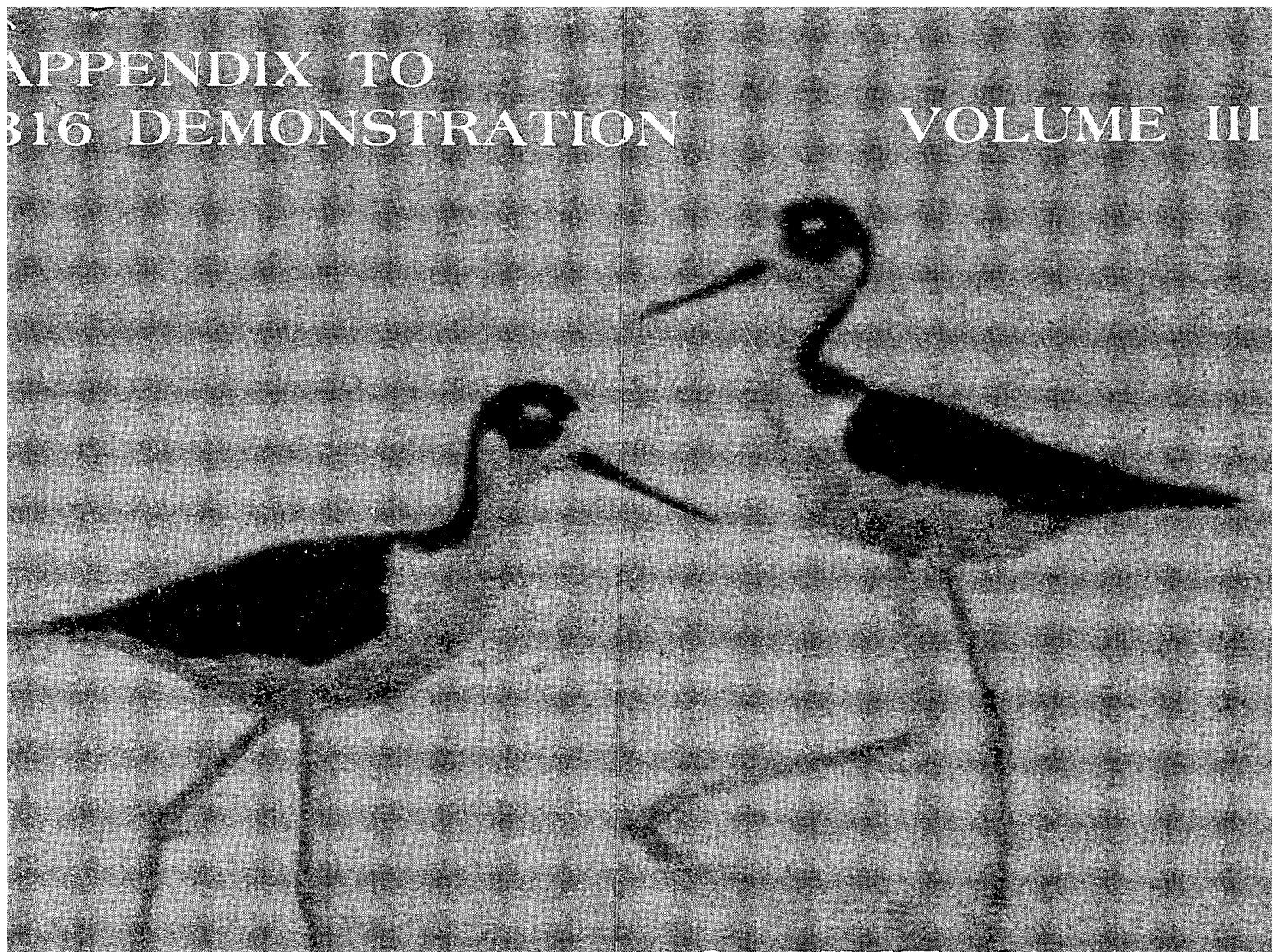
APPENDIX TO
316 DEMONSTRATION VOLUME III



VOLUME 3
OF
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ECOLOGICAL SURVEYS
OF THE
BIG BEND AREA

SEPTEMBER 1977

TECO
TAMPA ELECTRIC COMPANY

ECOLOGICAL STUDIES AT BIG BEND STEAM ELECTRIC STATION (TAMPA ELECTRIC COMPANY)

AN ANALYSIS AND SUMMARY OF STUDIES ON THE EFFECTS OF THE COOLING WATER SYSTEM ON AQUATIC FAUNA

A 316 DEMONSTRATION
BIOLOGICAL STUDY

Edited By

Richard D. Garrity
William J. Tiffany III
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CHAPTER FIVE

Part I

A STUDY OF ICHTHYOPLANKTON SEASONALITY AND ENTRAINMENT BY THE BIG BEND POWER PLANT, TAMPA BAY, FLORIDA

BY

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INTRODUCTION

A large number of fish species, many of commercial importance, are planktonic during their egg and larval stages. Their relative immobility and small size make them susceptible to entrainment through power plants which use seawater for once-through condenser cooling. Entrained organisms are subjected to many stresses during plant passage including thermal shock, rapid pressure changes, mechanical damage, and exposure to chemicals used to control the growth of fouling organisms (Clark and Brownell, 1973; Coutant, 1974; Marcy, 1974). These eggs and larvae are also exposed to elevated temperatures during passage through plant discharge canals. The importance of power plant mortality is unknown, but is related to the quantity of organisms withdrawn at plant intakes and the species affected (Marcy, 1974).

Estuarine areas, such as those near the Big Bend plant, are known to be important nursery areas for many species of sport and commercial fishes (Pearse and Gunter, 1957; Skud and Wilson, 1960; Sykes and Finucane, 1966; Gallaway and Strawn, 1974; Carr and Giesel, 1975). Young fishes which live in these environments are sensitive to a variety of

fluctuations in the environment, including temperature (deSylva, 1969; Austin, 1973). Fishes living in water in the 25-30°C temperature range, the range normally experienced in the source water of the Big Bend plant during summertime (TECO, 1975a), are already living at temperatures close to their thermal death point (Mayer, 1914; Voss et al, 1969). Rapid increase in water temperature above this level may have detrimental effects upon individual organisms. Losses of ichthyoplankton caused by plant entrainment and temperature increase represent a larger impact on the ultimate adult populations over a larger geographical area than do similar losses of phytoplankton or zooplankton because of the longer regeneration time and life cycle of fishes (Morgan and Stross, 1969; Mihursky, 1969; Marcy, 1974).

Power plant induced mortality is not restricted to rapid temperature increases. Marcy (1973) reported 100% mortality of larval fish passing through the Connecticut Yankee Plant, but he attributed only 20% to thermal effects. He ascribed the remainder of the mortality to mechanical abrasion caused by passage through the condenser tubes.

Studies at other power plants (Marcy, 1971; Edsall and Yocum, 1972; Atomic Energy Commission, 1973; Florida Power Corporation, 1975) have estimated entrainment mortalities ranging from 100 million individuals per year to as high

as 164.5 million individuals per day. It is difficult to determine the significance of these numbers without knowledge of the abundance, rate of production, and natural mortality rates of the populations from which these individuals came.

Literature Review

There has been little work done concerning the abundance and distribution of fishes of the Tampa Bay area. The most comprehensive work to date is Springer and Woodburn's (1960) study of the adult fishes in the vicinity of St. Petersburg. Their study dealt almost entirely with juveniles and adults of the area, although some information concerning spawning seasons, based on the collection of ripe or nearly-ripe adults, was given. Some information concerning food habits of various species was also provided. They did provide a systematic listing of the fish species found in the area. Additions to the list have been reported by Springer (1961) and Moe and Martin (1965).

Kelly and Dragovich (1967) studied the zooplankton of the Bay system, but they provided little information on the ichthyoplankton. Fish eggs were not identified and larvae were identified only to family. Sykes and Finucane (1966) outlined the distribution of immature forms of commercially important fish species in the Bay area. They did not, however, provide information dealing with the distribution of either eggs or smaller larvae.

Some of the most useful information elucidating the seasonal distribution and relative abundance of juvenile and adult fishes

in the vicinity of the Big Bend plant was gained from compiling five and one half years worth of data gathered during the continuing studies at Big Bend. This information has been summarized in the ichthyoplankton section of a previous report (Phillips, 1976b).

Study Objectives

Ichthyoplankton sampling in the vicinity of the Big Bend plant began in August, 1975. The specific objectives of the program as outlined in the Prospectus for Studies (Conservation Consultants, Inc., 1975) were to "determine the number and kinds of fish eggs and larvae entrained by the plant and their viability after plant passage." This portion of the report will deal primarily with the first part of the objectives (i.e. numbers and kinds of eggs and larvae entrained). Comparisons between estimated numbers of eggs entrained and the number of eggs present within the study area will be attempted for selected species. Viability of entrained eggs and larvae will be discussed in Ichthyoplankton Studies, Part II, Rearing Studies.

Although not specifically requested by the regulatory agencies, much information concerning species composition, seasonal distribution, and abundance of fish eggs and larvae within the study area has been obtained as part of this program. Some of this information has been presented in previous reports (Phillips, 1976a; 1976b; 1976c; 1977a; 1977b). Additional discussion of these factors will be presented in this report.

Study Limitations

Sampling Efficiency

In any biological sampling program, quantitative estimates of species abundance are biased by the efficiency of the collecting gear. The efficiency of plankton nets used for ichthyoplankton sampling depends on several factors, including initial filtering rate of the net, clogging of the mesh, extrusion of eggs and larvae through the mesh, and avoidance of the net by larger individuals. A discussion of these factors can be found in Tranter and Heron (1967), Mahnken and Jossi (1967), Tranter and Smith (1968), Vannucci (1968), Clutter and Auraka (1968) and Barkley (1972). A brief discussion of sampling inefficiency during the study, due to clogging, extrusion and avoidance, is presented in the following paragraphs.

During the course of sampling at Big Bend, the problem of net clogging was probably one of the most important factors affecting the efficiency of the gear used. During winter sampling periods, large numbers of ctenophores were encountered at sampling stations. They rapidly filled the cod-end container and clogged the net mesh, preventing long tows. Spring and summer sampling periods were plagued by net clogging caused by the presence of large numbers of chain diatoms. No attempts have been made to quantify the reduced efficiency of the sampling gear, but it is assumed that ichthyoplankton abundance estimates are biased on the low side.

Extrusion of eggs and larvae through the net mesh was probably not a significant problem, since a 363 μm mesh net was used rather than a 505 μm mesh net, as recommended for ichthyoplankton sampling by UNESCO (1975). The eggs and larvae of most species common in the Big Bend area range upward in size from 0.5 mm. Many samples contained larvae that were smaller than previously reported hatching lengths.

Avoidance of plankton nets by fish larvae is another problem encountered in ichthyoplankton surveys. Several explanations for net avoidance have been suggested. These include vertical migration by the larvae, patchiness, detection of pressure waves in front of the net by the larvae and visual observation of the net by the larvae (Scotten et al., 1973). Additional factors affecting catch size, and possibly related to net avoidance, include differences observed when sampling occurs during different moon phases, during different tidal phases and between daytime and nighttime collections (Bridger, 1956; deSylva, 1970; Fore and Baxter, 1972). In an attempt to minimize some of these avoidance factors, sampling at Big Bend was designed to occur during both day and night, always within the same 24-hour period, and on the same tide phase within that period whenever possible. Again, no attempt was made to quantify net avoidance, but it is assumed that these factors caused the estimates of the populations to be on the low side.

Plankton Patchiness

A well known phenomenon affecting the accuracy of plankton surveys is that of patchiness. Cushing (1962) suggested that predators aggregate near their prey, thus creating areas of greater abundance, or patches. Patches have been shown to range in size from only a few meters diameter to as large as 60 km in diameter (Cushing, 1962). The size of ichthyoplankton patches in the vicinity of the Big Bend plant is unknown; however, it is probably safe to assume that they are on the order of meters or hundreds of meters in diameter rather than kilometers. This assumption is based upon the known schooling behavior of most of the fishes with pelagic eggs that are common near the plant. Spawning would tend to occur in a relatively small, localized area within and near the school of spawners, and with the poor flushing characteristics of Tampa Bay (Ross, 1973), patches of eggs and larvae would be less likely to be dispersed by currents.

Wiebe and Holland (1968) showed that a net of 100 cm mouth diameter sampled more accurately than one of only 25 cm diameter. In a computer simulation of zooplankton patchiness and its effect on sampling error, Wiebe (1971) demonstrated that precision in sampling small patches (7.5 to 42.5 m/side) was not directly related to increases in the volume of water filtered, but rather to sampling the "right" number of patches. He found that increased accuracy could be gained by making longer tows. Sampling error associated with smaller plankton patches should have been lessened

during studies at Big Bend by the combined use of a large net (100 cm diameter) with relatively long tows (up to 100 m^3 filtered).

Sorting Efficiency

Fifty samples were randomly selected to be re-sorted to check the efficiency of initial sorting. Procedures used to re-sort samples followed those outlined by Clark, et al. (1969, 1970). For samples which initially contained large numbers of larvae, or for samples containing large volumes of zooplankton, three 10 ml aliquots were withdrawn at random and sorted for additional larvae. If the number of non-anchovy larvae in the three aliquots exceeded ten percent of the total number originally found in the sample (on an extrapolated volume basis), the entire sample was sorted a second time. In the case of samples which contained only low numbers of larvae initially, the entire sample was resorted. To eliminate bias, no sample was resorted by the same person who sorted it initially. The number of larvae found when samples were resorted was used to calculate a "percentage missed" on initial sorting. Due to the limitations of time and manpower, it was not possible to resort all samples.

Mean sorting efficiency, for non-anchovy larvae as determined from the fifty resorted samples, was 92.9% (i.e. 7.1% missed on initial sorting). Spring and summer samples contained a larger number of 'missed' larvae than samples collected during the fall and winter months.

Lack of a Water Current Study

As previously stated, many species of fish are planktonic during their egg and early larval stages. Due to their small size and relative immobility, they drift more or less passively with the water currents. The present ichthyoplankton survey provides information on the number of eggs and larvae in a given area at the time they are collected. However, a knowledge of circulation patterns in the study area could also provide information on the location of eggs and larvae during the past and at future times, as well as on the length of time that eggs and larvae remain in a given area. This information is useful in determining both population size and the proportion of a population entrained by the power plant.

Only one study of the currents in the vicinity of the plant is extant (Stone and Webster, 1970). This study was conducted during an eight-hour period on October 9, 1969, previous to the start-up of the first unit at Big Bend. Results of this study provide little information concerning the currents near the plant since the study area was small (nine square miles), the duration of the study short, and it was concluded that wind effects during the time of the survey were significant.

A computer simulation of the currents within Tampa Bay was attempted by Ross (1973). Although a counterclockwise gyre was reported offshore from the power plant, this area was not studied in sufficient detail to determine either the source of plant cool-

ing water or the source and fate of water present at open bay ichthyoplankton stations (E-5, B/C-5, A-5, O-17).

Identifications

Two hundred and eighty-seven species, representing eighty families of fish (excluding sharks, skates and rays), have been reported from the Tampa Bay area (Springer and Woodburn, 1960; Springer, 1961; Moe and Martin, 1965; Powell, Dwinell and Dwinell, 1972). Of these, only 30% (86 species) have been described during their egg and larval stages (many of these descriptions are not of species present at Big Bend, but of closely related species within the same genera). During ichthyoplankton studies at Big Bend, eggs and larvae representing forty one species from twenty-two families have been collected. Many of the identifications made as part of this program are only tentative and have been so noted in previous reports. Specific problems of identification are mentioned in the discussion of seasonality and entrainment.

Attempts were made to identify all eggs and larvae to the species level; however, this was not possible in many cases. Egg identifications are accurate to at least the family level, with some of the more common forms accurate to the genus or species level. Larval identifications are somewhat easier to make, and in most cases, are accurate to at least the genus level. Many of the more common larvae were identified accurately to the species level. Identifications of most species were verified by experts

in other parts of the southeast U. S. (see Acknowledgements). Identifications of several species, previously undescribed, were made from size series of larvae assembled from plankton collections. Larvae smaller than 2.5 mm SL presented difficulties and, in many cases, were not identified below genus.

METHODS

Sample Collection and Sorting

Methods utilized during the ichthyoplankton program have been discussed in previous reports (TECO, 1975b; Phillips, 1976b) but will be reviewed herein.

Ten stations in the vicinity of the plant (Figure 5.1) were sampled at two week intervals from January, 1976 through March, 1977. Samples were collected during both the daytime and at night on the same tide phases. Inclement weather and boat breakdown forced the postponement of sampling on several occasions. Plankton samples were collected with a 363 μm mesh, one meter mouth diameter, metered plankton net towed at a speed of approximately 2 knots behind a 24-foot outboard boat. The net was weighted and allowed to sink at the start of each tow. This technique resulted in the net fishing an oblique trajectory, starting near the bottom and ending at the surface. Efforts were made to filter as much water as possible and to try to approach 100 m^3 as recommended by UNESCO (1975). The volume of water filtered was limited on numerous occasions, due to extreme net clogging, caused either by dense phytoplankton and zooplankton blooms or by large numbers of ctenophores.

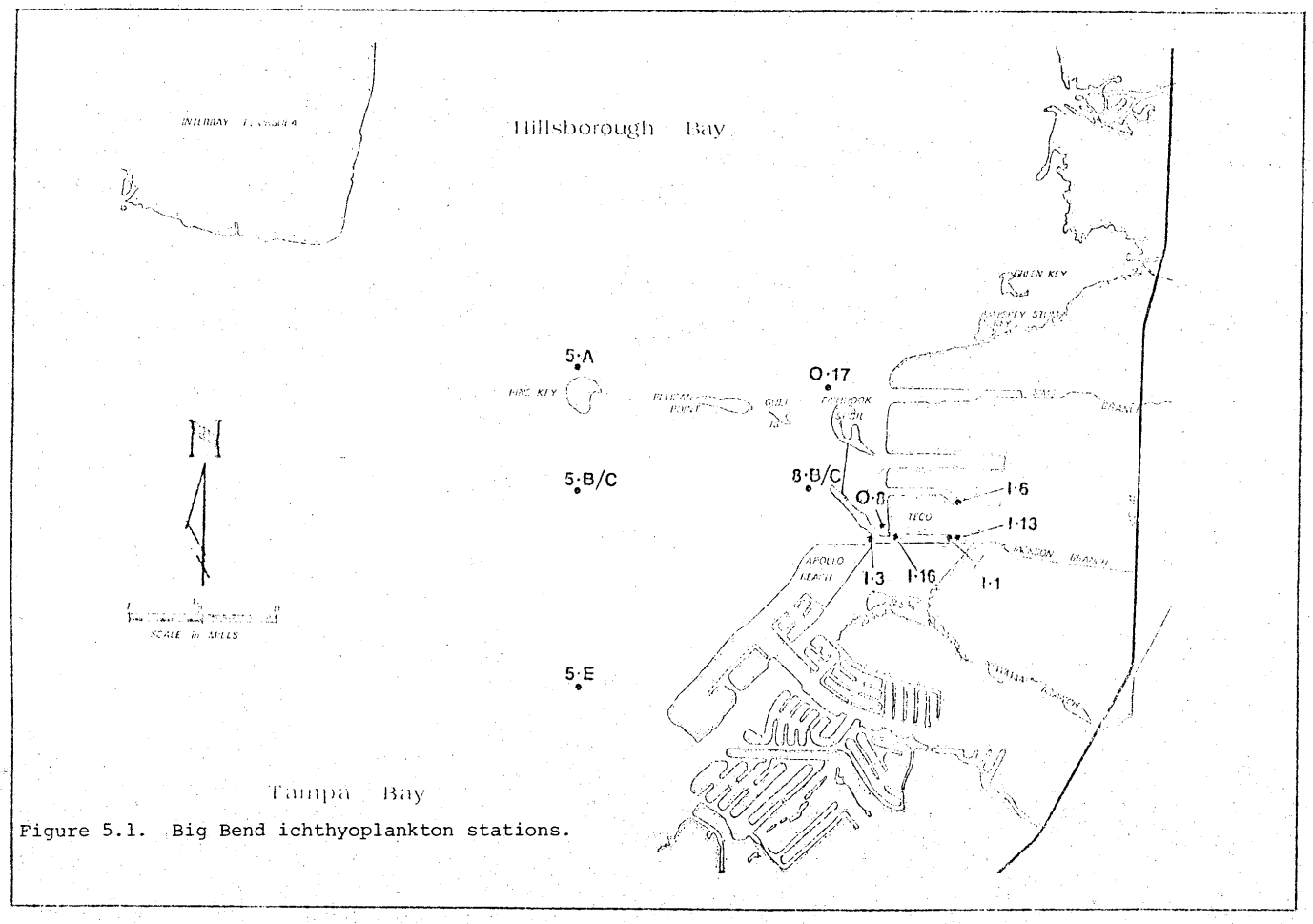

Figure 5.1. Big Bend ichthyoplankton stations.

Poor Original

One liter glass bottles were used as cod end containers for each sample collected. A measured amount of buffered formalin was added to each sample immediately after collection to give a final concentration of 5%. The plankton net was washed immediately after each tow to insure that there would be no cumulative net clogging or contamination.

Physical data, consisting of station depth, air temperature, surface, mid-depth and bottom water temperature, salinity and dissolved oxygen, was taken at each station prior to sample collection. Surface, mid-depth, and bottom water samples were collected with a PVC Van Dorn bottle and returned to the laboratory for analysis of water turbidity. Instruments used to collect physical data have been listed in a previous report (TECO, 1975b).

All samples were sorted with the aid of binocular dissecting microscopes using 10-15X magnification. Each microscope was fitted with an ocular micrometer. The standard length (SL), i.e. the straight-line distance from the most anterior part of the head to the tip of the notochord (Mansueti and Hardy, 1967) measured to the nearest one-tenth millimeter, was recorded for the first fifty individuals of each species. If there were fewer than fifty individuals of a species in a sample, all individuals of that species were measured. All larvae, except those of the bay anchovy, Anchoa mitchilli,

were removed from each sample and placed in numbered vials. Anchovy larvae were not removed from samples because they were so numerous. They were counted, and the total number of anchovy larvae in each sample was recorded. The contents of each vial were later reexamined under an Olympus dark-field dissecting microscope at 20-25X magnification for verification of the initial identifications.

Three random 10 ml aliquots were withdrawn from each sample and sorted for eggs. If there were 100 or more eggs of a particular species in each aliquot, the number of eggs contained in the aliquots was used to extrapolate the number of eggs in the entire sample on a volume basis. The entire sample was sorted for eggs of any species with fewer than 100 eggs in the first aliquot. Representative numbers of eggs of each species were placed in numbered vials for later verification of identifications.

All eggs and larvae were identified to the lowest taxon possible, based upon descriptions given in current literature. In addition, confirmation of our identifications were obtained from scientists at the Florida Department of Natural Resources; the University of Miami, Rosenstiel School of Marine and Atmospheric Science; the Southeast Fisheries Center, National Marine Fisheries Service, Miami; and the University of Southwestern Louisiana. In most cases, larval identifications are accurate to the genus level. Egg identifications are accurate at least to the family level. A complete listing of literature used to aid in egg and larval identifications is given in Appendix 5.A.

Replicate Samples

In order to estimate the possible variability that might be expected for ichthyoplankton samples in the Big Bend area, a series of replicate tows were collected on one date (April 14, 1977). Six consecutive plankton tows were made at each of two stations (A-5, an open bay station; I-1, the plant discharge). Replicate samples were collected and sorted as described for routine ichthyoplankton samples.

RESULTS AND DISCUSSION

Replicate Samples

The results of the six consecutive tows taken at station I-1 and A-5 on April 14, 1977 are presented in Tables 5.1-5.4. For each species, the number of individuals per $100m^3$ reported represents the mean value of all six tows at one station. Coefficients of variation were calculated with the following equation from Eberhardt and Gilbert (1975):

$$C.V. = \frac{\text{standard deviation}}{\text{mean}} = \frac{s}{\bar{x}}$$

The coefficients of variation for individual larval species range from 0.21 - 2.46 at I-1 and from 0.70 - 2.86 at A-5. The lowest coefficient of variation at station I-1, and second lowest at station A-5 was obtained for Anchoa mitchilli. This is not surprising since this species is by far the most abundant species collected, representing 82.4% of the larvae collected at

Table 5.1. Mean number per $100m^3$ and calculated coefficients of variation for fish eggs collected in six consecutive tows at station I-1 (plant discharge).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
Anchoa mitchilli (bay anchovy)	83.33	0.22
?Sciaenidae	6.33	1.11
TOTAL	89.67	0.17

Table 5.2. Mean number per $100m^3$ and calculated coefficients of variation for fish eggs collected in six consecutive tows at station A-5 (open bay).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
?Engraulidae	55.67	0.35
Anchoa hepsetus (striped anchovy)	3.67	1.39
Anchoa mitchilli (bay anchovy)	2915.67	0.13
?Sciaenidae	226.00	0.32
?Prionotus	0.67	2.45
Achirus lineatus (lined sole)	1.33	1.62
TOTAL	3203.00	0.14

Table 5.3. Mean number per $100m^3$ and calculated coefficients of variation for fish larvae collected in six consecutive tows at station I-1 (plant discharge).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
Anchoa mitchilli (bay anchovy)	376.50	0.21
Syngnathus sp. (pipefish)	0.83	2.46
Cynoscion (?*arenarius*) (sand seatrout)	1.00	2.45
Menticirrhus saxatilis (Northern kingfish)	1.67	1.54
Sciaenidae?	3.17	2.45
Hypsoblennius hentzi (feather blenny)	1.83	2.45
Gobiosoma robustum (code goby)	21.67	0.64
?*Microgobius*	2.67	1.10
Microgobius gulosus (clown goby)	43.50	0.58
Unidentified goby	0.67	2.43
Achirus lineatus (lined sole)	2.50	1.12
Too Damaged to ID	0.83	2.46
TOTAL	456.83	0.22

Table 5.4. Mean number per $100m^3$ and calculated coefficients of variation for fish larvae collected in six consecutive tows at station A-5 (open bay).

Species	Mean Number Per $100m^3$ Filtered	Coefficient of Variation
Brevoortia sp.	1.17	2.86
Anchoa mitchilli (bay anchovy)	7053.50	0.73
Strongylura timucu (timucu)	0.50	2.44
Membras martinica (rough silverside)	11.33	0.70
Orthopristis chrysoptera (pigfish)	0.67	2.43
Cynoscion arenarius (sand seatrout)	65.33	1.49
Cynoscion (?*arenarius*)	61.67	1.56
Menticirrhus saxatilis (Northern kingfish)	51.00	0.95
Pogonias cromis (black drum)	0.83	2.46
?Sciaenidae	5.17	1.56
Hypsoblennius hentzi (feather blenny)	4.17	1.68
Microgobius gulosus (clown goby)	2.17	1.11
Achirus lineatus (lined sole)	1.33	1.56
Unidentified	2.83	1.85
Too damaged to ID	0.67	2.43
TOTAL	7262.33	0.73

station I-1 and 97.1% of the larvae collected at station A-5. This dominance by anchovy larvae is reflected in the total coefficient of variation, which is equal (station A-5) or virtually equal (station I-1) to the A. mitchilli coefficient of variation. Much higher coefficients of variation were found for almost all of the other, less numerous, larval species collected.

The coefficients of variation for the egg taxa also show much variation. Again, the lowest values at each station were found for Anchoa mitchilli.

Species Composition & Seasonal Patterns

The results of the ichthyoplankton sampling between January, 1976 to March, 1977 have been presented in past quarterly reports (Phillips, 1976b; 1976c; 1977a; 1977b; 1977c).

Larvae from twenty-two families of fish were collected during the fifteen months of ichthyoplankton sampling (January, 1976 to March, 1977). Forty one species were represented by these larvae, although this number could be slightly higher or lower because of some uncertain identifications at the species level. Engraulid (anchovy) larvae were the dominant type, constituting 87.4% of all larvae collected. Two, or possibly three species of engraulids were represented in the collections, although Anchoa mitchilli (bay anchovy) larvae were by far

the most numerous. Larval sciaenids (drums) were second in abundance, accounting for 3.9% of all larvae taken. The family with the most species was the Sciaenidae, with seven species from five genera. Larvae of six of the twenty-two families recorded constituted 98.3% of all larvae collected. This information is summarized in Table 5.5.

Eggs from twelve families were collected. Of these, engraulid and sciaenid eggs accounted for 73.1% and 26.2% respectively of all eggs collected, and together these two families represented 99.3% of the eggs taken during the fifteen months. This information is also summarized in Table 5.5.

Seasonality of the Big Bend ichthyoplankton was discussed in a previous report (Phillips, 1977b), but will be briefly reviewed here. Although some spawning occurred during each month of 1976, peak densities of both eggs and larvae were noted between the months of March and October. The total number of eggs and larvae collected each month is presented in Figure 5.2. A. mitchilli eggs and larvae dominated on most sampling dates during this period. Other species which reached their greatest abundance during spring and summer include several species of sciaenids, (drums), a clupeid, Harengula jaguana (scaled sardine), two species of carangids (jacks), a sparid, Archosargus probatocephalus (sheepshead), and the lined sole, Achirus lineatus.

Table 5.5. Percent of total eggs and larvae taken during ichthyoplankton sampling at Big Bend, by family.

LARVAE		EGGS	
Family	% of Total	Family	% of Total
Engraulidae	87.4	Engraulidae	73.1
Sciaenidae	3.9	Sciaenidae	26.2
			99.3%
Gobiidae	2.7	Carangidae	0.4
Pomadasyidae	2.1	Clupeidae	0.2
Carangidae	1.1		
Sparidae	1.1		
	98.3%		
Clupeidae	0.5	Soleidae	
Blenniidae	0.4	Triglidae	
Soleidae	0.2	Pomadasyidae	
Triglidae	0.2	Cyprinodontidae	0.1%
Atherinidae	0.1	Ephippidae	(total)
		Belonidae	
		Atherinidae	
Gobiesocidae		Gobiidae	
Syngnathidae			
Cynoglossidae			
Ephippidae			
Ophichthidae			
Tetraodontidae	0.3%		
Mugilidae	(total)		
Belonidae			
Bothidae			
Cyprinodontidae			
Gerreidae			

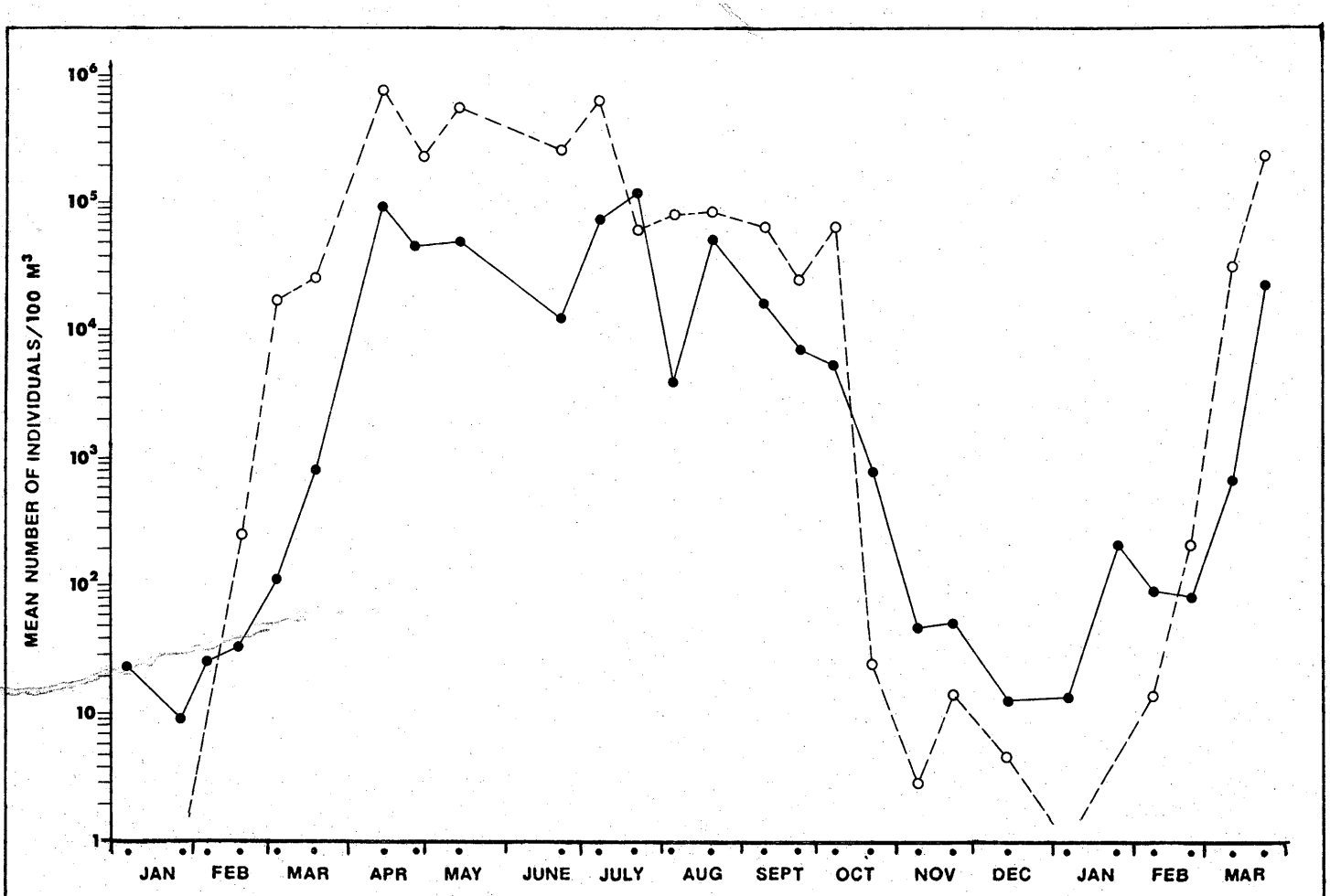

Figure 5.2. Seasonal abundance of total eggs (o---o) and total larvae (●——●), January, 1976 - March, 1977.

The initiation of spawning in the spring by most species can probably be attributed to a variety of factors, including seasonal increases in water temperatures caused by solar heating, the abundance of planktonic food organisms, and favorable day lengths at this time of year. Gunter (1945) found that spawning along the Texas coast was related to water temperatures, and he provided a list of species which begin breeding when specified temperatures are reached.

Spawning at Big Bend continued throughout the summer months when water temperatures were as high as 32° to 35°C.

Fall represented the time of year when spawning tapered off and, for many species, ceased altogether. This decline was most noticeable because of the absence of both anchovy and drum eggs and larvae after about mid-October. Several species including two atherinids (silversides), the skilletfish, Gobiesox strumosus and the gobies and blennys continued to spawn at low levels throughout the fall and even into the winter months.

Little spawning occurred during winter months (December through February, 1976 and 1977) and most collections contained no eggs and only a few larvae. Recently hatched feather blenny larvae (Hypsoblennius hentzi) were taken on all sampling dates. Menhaden (Brevoortia spp.), pinfish (Lagodon rhomboides), and

spot (Leiostomus xanthurus) larvae and juveniles were taken in January and February of both 1976 and 1977. These three species spawn somewhere south of the study area (possibly in the Gulf) and migrate into the area at a size usually exceeding 12mm SL. Leptocephalus larvae of the speckled worm eel, Myrophis punctatus, absent in samples from 1976, were taken in January and February, 1977.

A graph summarizing the months of occurrence of all species collected during the ichthyoplankton program is presented in Appendix 7.B.

Seasonal Distribution of Selected Species

CLUPEIDAE - herrings

At least two species of clupeids have been collected during routine ichthyoplankton sampling at Big Bend. These include menhaden eggs and larvae identified only as Brevoortia sp. (because of the confusion generated by the presence in the area of three members of this genus, B. patronus, B. smithi and their hybrid B. patronus x smithi [Dahlberg, 1970]) and eggs and larvae of the scaled sardine, Harengula jaguana Poey.

Brevoortia larvae are apparently spawned in the Gulf of Mexico and migrate into the Big Bend area during January and February after having reached a size of 10-15mm SL. Larval menhadens were usually taken in greater numbers at open bay

stations rather than near plant intakes and discharges. Although larvae were collected in January and February of both 1976 and 1977, numbers were usually low. Adults have rarely been taken in the vicinity of the plant (see Chapter 8). It is probable that plant impact on this species is relatively insignificant.

Eggs and larvae of the scaled sardine, H. jaguana, were present within the study area from late April through August, 1976. This species has a slight commercial value as a baitfish, but stocks in the Big Bend area are not fully exploited for this purpose. Mean numbers per $100m^3$ for both eggs and larvae are presented graphically in Figure 5.3. Eggs were always more numerous than larvae except on July 20, 1976, but densities of both were always low, indicating that the waters in the vicinity of the plant may not be a major spawning area for the species. H. jaguana eggs were most numerous on May 13, 1976 and declined in number through August. The late spring and summer spawning season observed in Tampa Bay coincides with the spawning season for the species in other parts of its range (Gunter, 1945; Martinez and Houde, 1975).

ENGRAULIDAE - anchovies

Engraulid eggs and larvae were more abundant in Big Bend ichthyoplankton samples than those of any other family, accounting for 87.4% of all larvae and 73.1% of all eggs taken during the

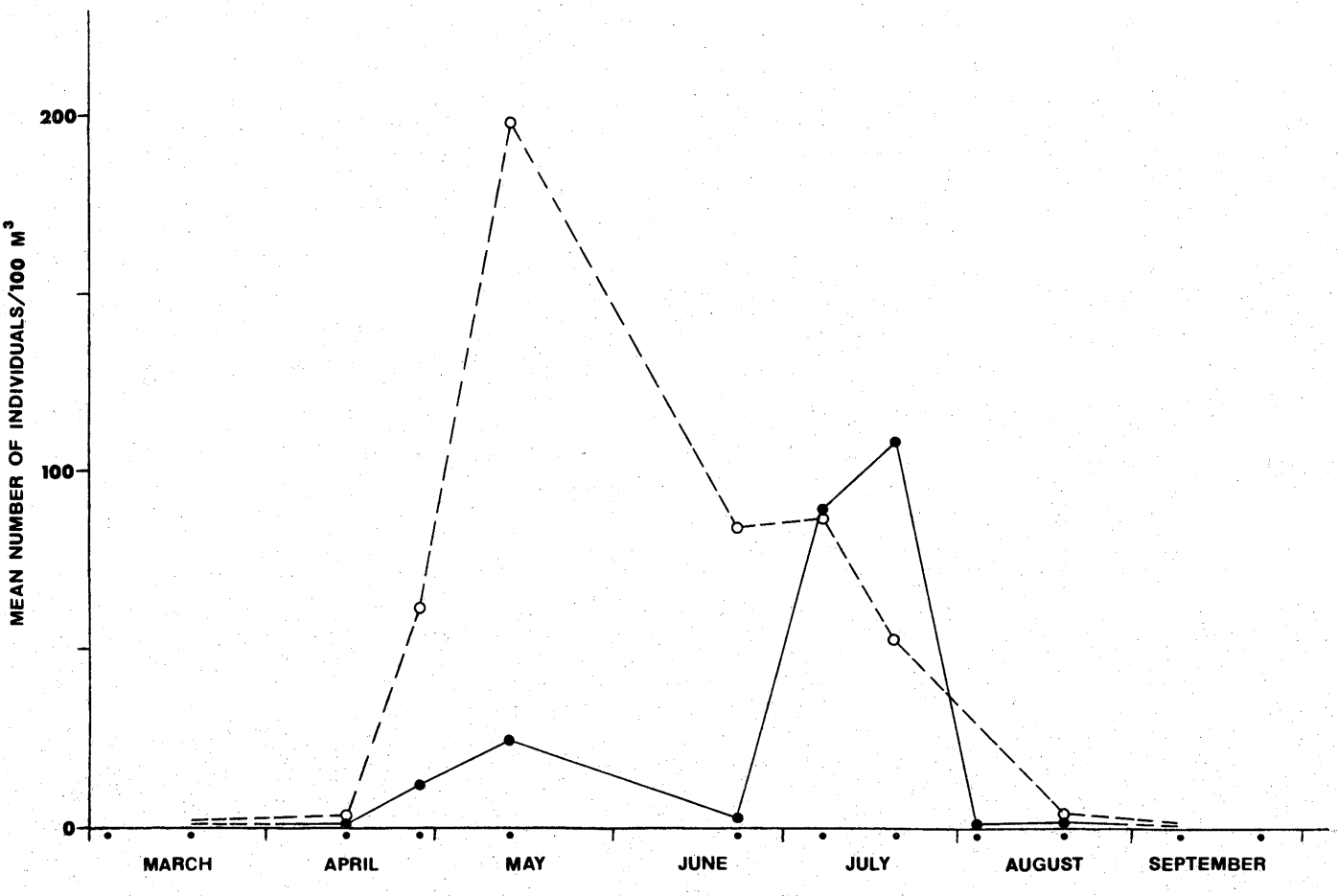

Figure 5.3. Seasonal abundance of Harengula jaguana (scaled sardine) eggs (o---o) and larvae (●——●) during, 1976.

fifteen months of sampling. Eggs and larvae of both the striped anchovy, Anchoa hepsetus (Linnaeus) and the bay anchovy, A. mitchilli (Valenciennes) were common in spring and summer samples. A third type of anchovy egg, tentatively considered as unidentified engraulid? and, possibly belonging to the Cuban anchovy, A. cubana (Poey), was present in samples collected between March and early October, 1976. A. mitchilli eggs and larvae were the most commonly collected engraulid, and frequently, were more numerous than the eggs and larvae of any other species.

A. hepsetus eggs were taken from early March through late June, 1976, but were most numerous in late April and early May. Striped anchovy larvae were collected from April through July and reached peak densities in June and early July. The spawning season observed at Big Bend during 1976 corresponds to the April-July breeding season reported by Hildebrand and Cable (1930) at Beaufort, North Carolina.

Seasonal distribution of A. mitchilli eggs and larvae is illustrated in Figure 5.4. Eggs were first taken in early March, 1976 and were collected regularly through late October, 1976. Peak densities occurred from April through July. The lower numbers taken after July may represent a second spawning by the same individuals or may reflect initial spawning by a smaller number of late maturing females. Lack of detailed fecundity information, particularly data concerning the stages

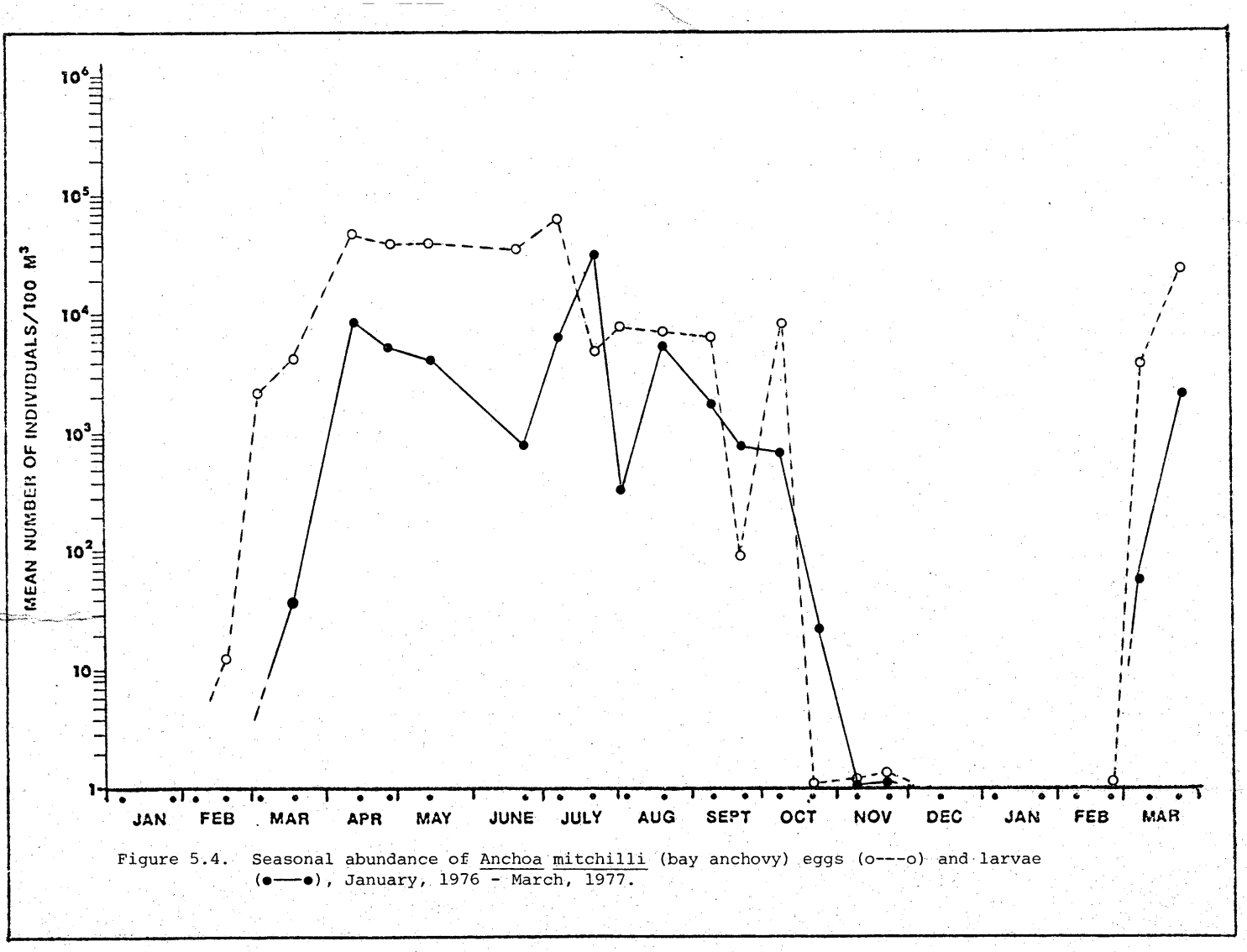

Figure 5.4. Seasonal abundance of Anchoa mitchilli (bay anchovy) eggs (o---o) and larvae (●——●), January, 1976 - March, 1977.

of developing oocytes within the ovaries of maturing females, makes further determination impossible. Larvae were collected from late March through early November. Peak densities occurred from April through October. Low numbers of larvae in samples from June 22, 1976 and August 3, 1976 probably reflect sampling variability since the number of eggs taken on these dates remained high. A. mitchilli eggs and larvae were usually more numerous at open bay stations than near the plant.

GOBIESOCIDAE - clingfishes

The clingfishes were represented in Big Bend ichthyoplankton collections by larvae of one species, Gobiesox strumosus Cope, the skilletfish. Eggs of this species are demersal and are normally attached to shell fragments or other substrate (Runyan, 1961) and were never taken in plankton collections. Larvae were taken during most months, indicating that this species has a protracted spawning season in the Big Bend area. Seasonal distribution in the vicinity of the plant is illustrated in Figure 5.5. Although mean numbers per $100m^3$ were very low, it appears that two spawning peaks occurred during 1976, the first, larger peak from March through May, and the second much smaller peak from late August through December. Data from early 1977 indicates that spawning again increased during March.

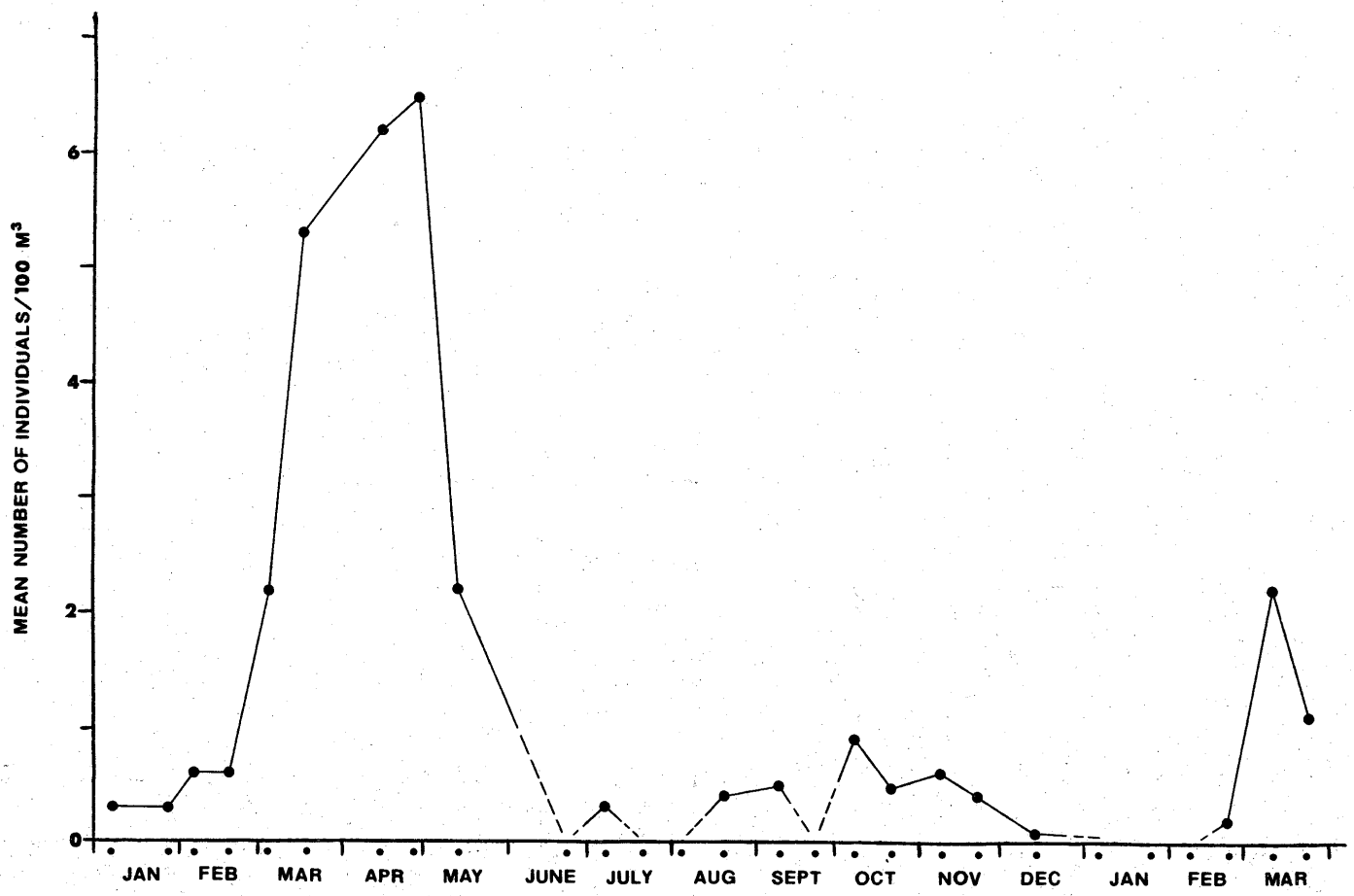

Figure 5.5. Seasonal abundance of Gobiesox strumosus larvae, January, 1976 - March, 1977.

It is obvious that any plant impact upon this species would be greatest during the spring.

CARANGIDAE - jacks and pompanos

Carangid eggs were taken on all sampling dates between April and early September. Three species of carangid eggs were identified, although only one of these was verified to species: Oligoplites saurus (Bloch and Schneider), leatherjacket. Three species of carangid larvae were also present in samples collected between April and October including O. saurus, Chloroscombrus chrysura (Linnaeus), and an unidentified member of the family. Figure 5.6 illustrates the seasonal distribution of eggs and larvae of the carangids grouped as a family. Eggs were most numerous on May 13, 1976, and there appears to be a second, smaller peak during July. Inexplicably low numbers of both eggs and larvae occurred on June 22 and August 3, 1976. It is unknown whether these low numbers indicate a cessation of spawning on these dates or whether they reflect sampling variability.

POMADASYIDAE - grunts

This family was represented in Big Bend ichthyoplankton by only one species, Orthopristis chrysoptera (Linnaeus), the pigfish. Eggs of this species were not common, but were most abundant in early April, 1976. It is possible that the eggs

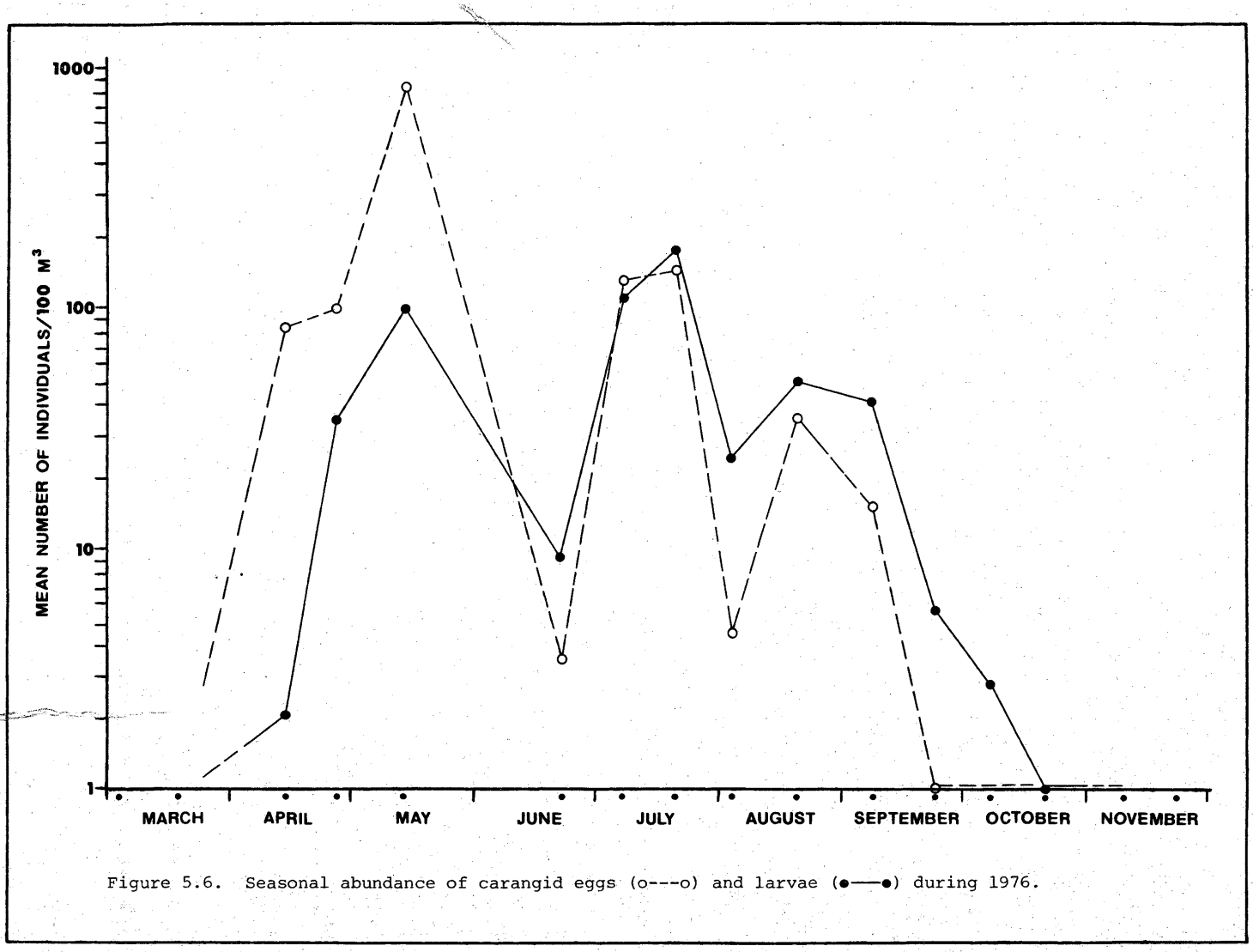

Figure 5.6. Seasonal abundance of carangid eggs (o---o) and larvae (●——●) during 1976.

of this species, at least in the early stages of development, were confused with sciaenid eggs. Larval pigfish were collected on all sampling dates between early April and early October, 1976. Peak densities occurred in early July, following a small peak in late April and low numbers during May. Hildebrand and Cable (1930) found that pigfish spawn between March and June at Beaufort, with peak spawning occurring in May. Springer and Woodburn (1960) did not capture ripe individuals during their study, but suggested that the spawning season in Tampa Bay parallels that at Beaufort, North Carolina. Because of the similarity between O. chrysoptera and Bairdiella chrysura larvae, it is possible that some of our smaller specimens may have been misidentified, which may partially explain this discrepancy.

A majority of the pigfish larvae taken at Big Bend were from stations near the plant rather than from open bay stations.

SPARIDAE - porgies

Larvae of two members of this family, Archosargus probatocephalus (Walbaum) the sheepshead and Lagodon rhomboides (Linnaeus), the pinfish, were present in ichthyoplankton collections. Eggs, if taken, were not recognized.

Sheepshead larvae were initially identified from a size series assembled from plankton catches. Our identification

was confirmed by William Richards and Thomas Potthoff of the Southeast Fisheries Center, NMFS, Miami. No descriptions of this species were available at the time; however, larval stages have recently been described by Mook (1977).

A. probatocephalus larvae were collected from early April through early September. Peak densities occurred in late April and early May. Mean number of individuals per $100m^3$ by sampling date is illustrated in Figure 5.7. Springer and Woodburn (1960) attributed a spring spawning season to the species. No growth progression has been obtained from our data; however, small individuals (less than 2.5mm SL) were taken through the middle of August, indicating that, spawning was still occurring at that time.

Larval and early juvenile pinfish were collected only during January and February in both 1976 and 1977. Springer and Woodburn (1960) stated that this species spawns offshore in the Gulf during late fall and early winter, and the young move into Tampa Bay during the winter. Both Reid (1954) and Kilby (1955) found this was also true at Cedar Key. Most of the larvae taken at Big Bend were larger than 12.0mm SL confirming that they were spawned several weeks earlier. Pinfish were more numerous during 1977 than in 1976.

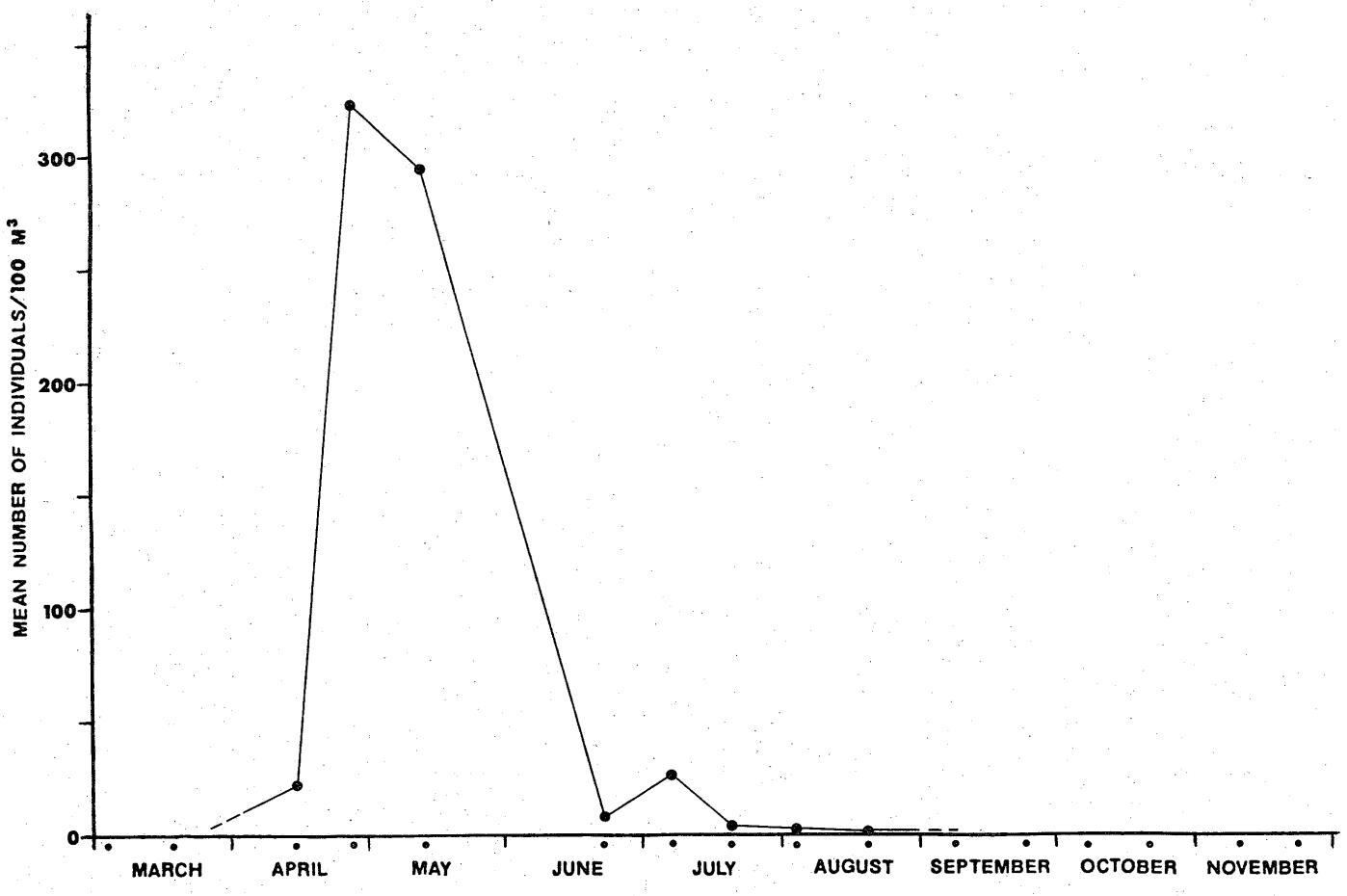

Figure 5.7. Seasonal abundance of Archosargus probatocephalus (sheepshead) larvae during, 1976.

SCIAENIDAE - drums

Sciaenid eggs and larvae, as a family, were the second most abundant of all families collected during 1976. Only anchovies comprised a larger portion of the total number of eggs and larvae collected. Sciaenid eggs and larvae accounted for 26.2% and 3.9%, respectively, of all eggs and larvae taken.

Sciaenids were represented by a larger number of species (seven) than any other family. The seven species caught were: Bairdiella chrysura (Lacepede), silver perch; Cynoscion arenarius Ginsburg, sand seatrout; C. nebulosus (Cuvier), spotted seatrout; Leiostomus xanthurus Lacepede, spot; Menticirrhus americanus (Linnaeus), southern kingfish; M. saxatilis (Bloch and Schneider), northern kingfish; and Pogonias cromis (Linnaeus), black drum. Larval red drum, Sciaenops ocellata (Linnaeus) (locally called redfish) were not taken, or not recognized if taken.

The smaller eggs and larvae (smaller than 2.5mm SL) of sciaenids presented special problems in identification. Due to the similarity between many of the sciaenid species present in the area during these early stages, identifications below the family level may not always be accurate. In this report, neither seasonality nor entrainment will be discussed in terms of individual species. Instead, all species will be grouped and discussed as a family.

Several species of sciaenids, including the kingfishes, spotted seatrout and black drum are important commercial and sport fishes in the Tampa Bay area. Recreational fishermen frequently catch drums in the vicinity of the power plant, particularly during the late summer and in the fall.

Figure 5.8. shows the seasonal distribution of sciaenid eggs and larvae during 1976 and early 1977. Both eggs and larvae were present in relatively large numbers between early March and early November, 1976. Eggs were always more numerous than larvae, indicating a large amount of spawning was occurring within the study area. Neither eggs nor larvae were collected from late November, 1976 through January, 1977. Low numbers of eggs and larvae were taken during February, and numbers increased steadily through the final sampling date in March, 1977.

BLENNIIDAE - combtooth blennies

Most of the blenny larvae collected were identified as those of the feather blenny, Hypsoblennius hentzi (Lesueur). Some of these larvae may be misidentified due to the similarity of larval H. hentzi and another species common in Tampa Bay, Chasmodes saburrae Jordan and Gilbert, the Florida blenny, whose larvae are undescribed. Another species, H. ionthas (Jordan and Gilbert), the freckled blenny, may also occur in Tampa Bay. Because of this confusion, blennies will be discussed as a family.

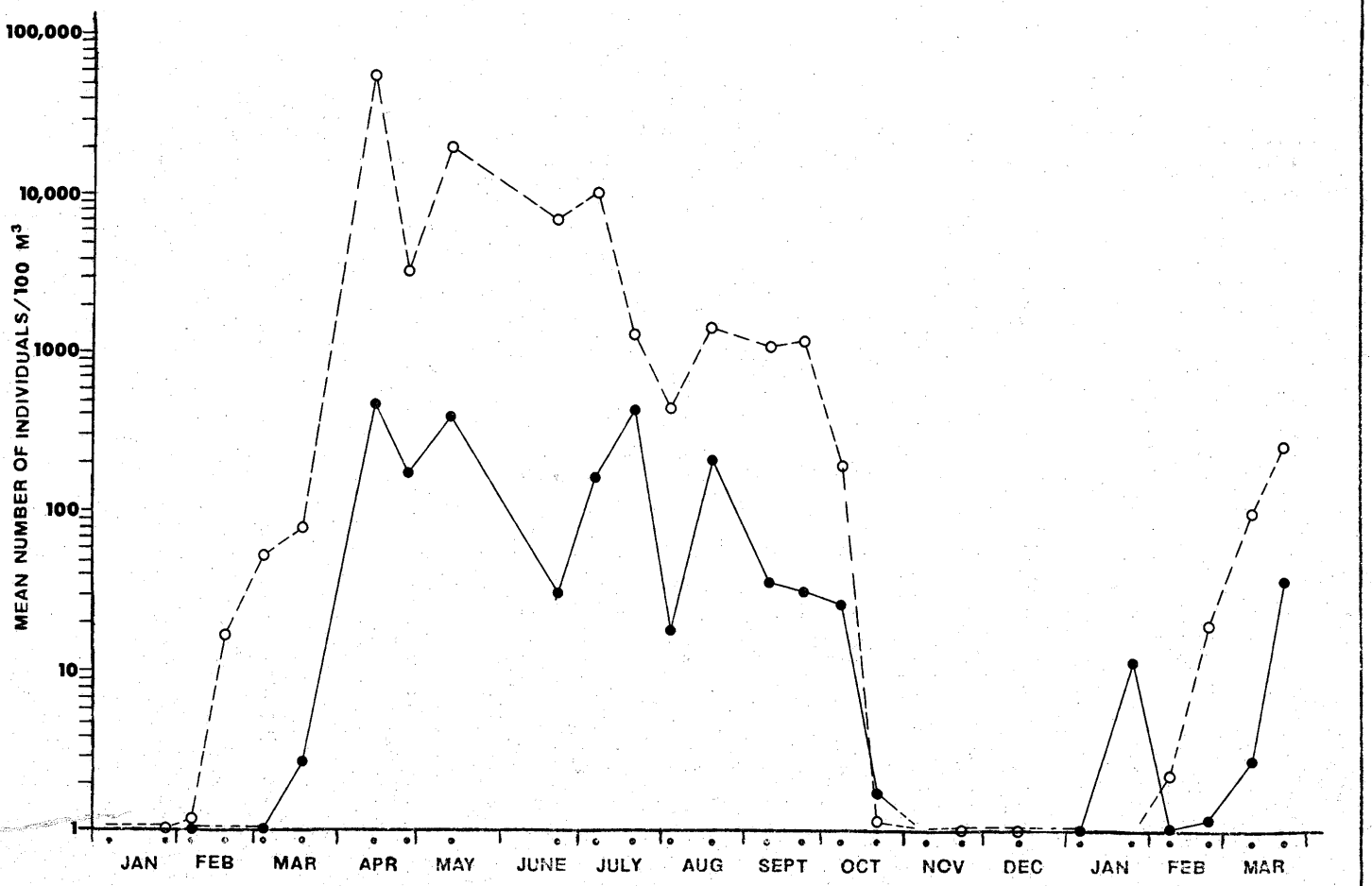

Figure 5.8. Seasonal abundance of sciaenid eggs (o---o) and larvae (●——●), January, 1976 - March, 1976.

Mean numbers of larvae per $100m^3$ by date are shown in Figure 5.9. Eggs, which are demersal, were never taken. Larval blennies were taken on all sampling dates except late February, 1977. Peak densities occurred from late April through early June, 1976. A second, smaller peak was evident from September through November, 1976. The number of larvae collected remained low throughout the winter months (December, 1976 to February, 1977) but the spring increase was again apparent in samples from March, 1977.

GOBIIDAE - gobies

Larval gobies are distinctive as a family and are easily identified at this level. The larvae of the two species of gobies which are common as adults in the Big Bend area, Gobiosoma robustum Ginsburg, the code goby, and Microgobius gulosus (Girard), the clown goby are undescribed. Other larvae of species of these two genera have been described by Hildebrand and Cable (1938); however, smaller larvae (less than 10mm SL) remain difficult to identify. Size series of larvae obtained from Big Bend ichthyoplankton collections verified the presence of both G. robustum and M. gulosus in the samples, but each genus is also represented by at least two other species in the Tampa Bay area (Springer and Woodburn, 1960; Springer, 1961). It is therefore possible that some of the smaller goby larvae

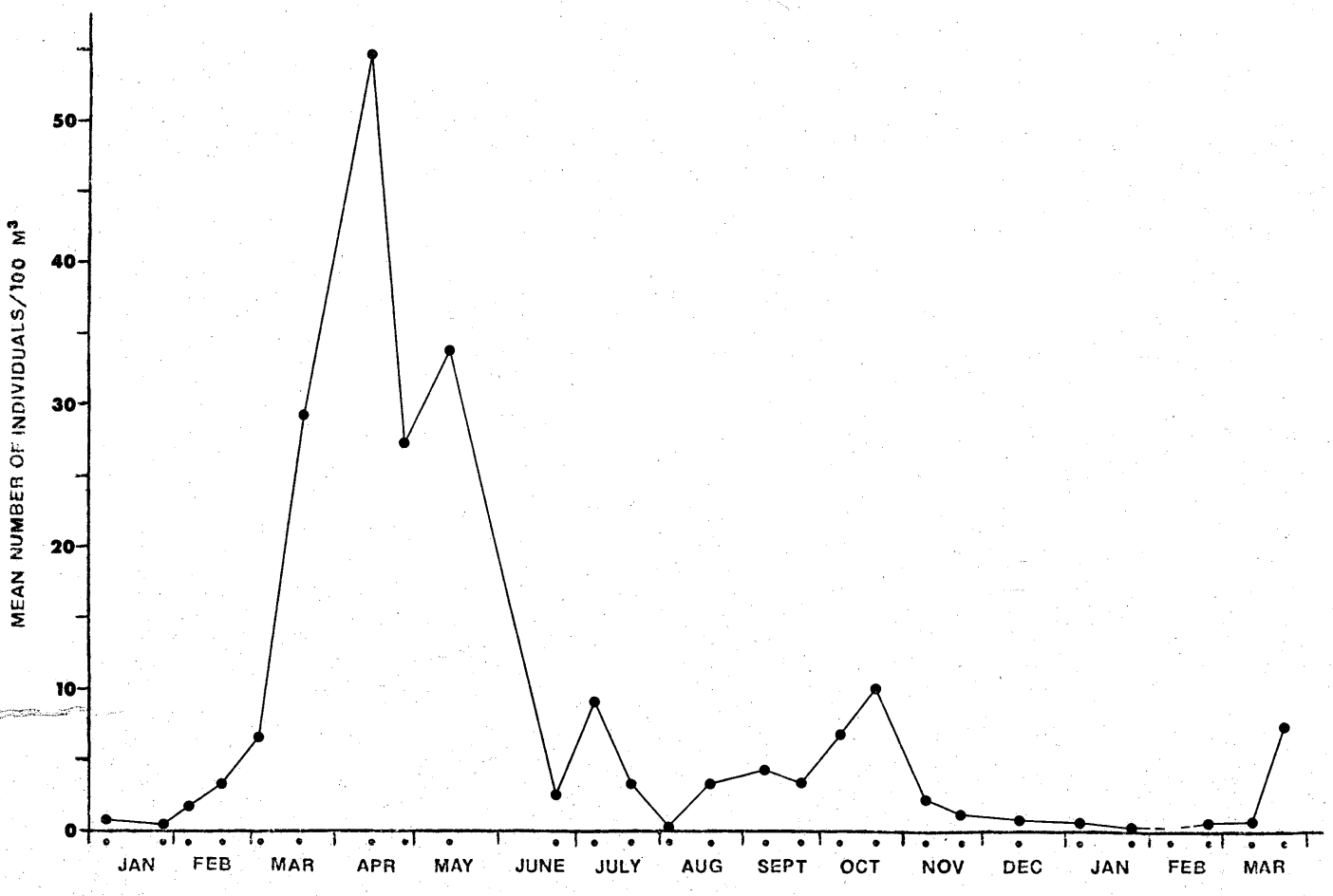

Figure 5.9. Seasonal abundance of blenny larvae, January, 1976 - March, 1977.

obtained at Big Bend were incorrectly identified. Between late February and the end of October, 1976, numerous specimens identified as ?Gobiosoma and ?Microgobius, both of which were described in a previous report (Phillips, 1976c), were obtained in plankton samples. It was not possible to assemble a size series for these larvae, because the largest individual collected was only 5.2mm SL. Goby eggs, which are demersal, were taken on only one occasion (March 3, 1976; plant discharge).

Seasonal data is presented in Figure 5.10. Gobies are treated as a family because of the identification problems discussed above. It appears that three peaks of abundance occurred during 1976, the first and largest in April. The second and third peaks, approximately equal in intensity but lower than the spring peak, occurred in late June through July, and from September through October. These two peaks may not actually be distinct, because the low number of larvae collected on August 3 may reflect either an actual decline in the amount of spawning or may reflect sampling variability.

SOLEIDAE - soles

Two species of soles were taken during routine ichthyoplankton sampling at Big Bend, viz., the lined sole Achirus lineatus (Linnaeus), and the hogchoker, Trinectes maculatus (Bloch and Schneider).

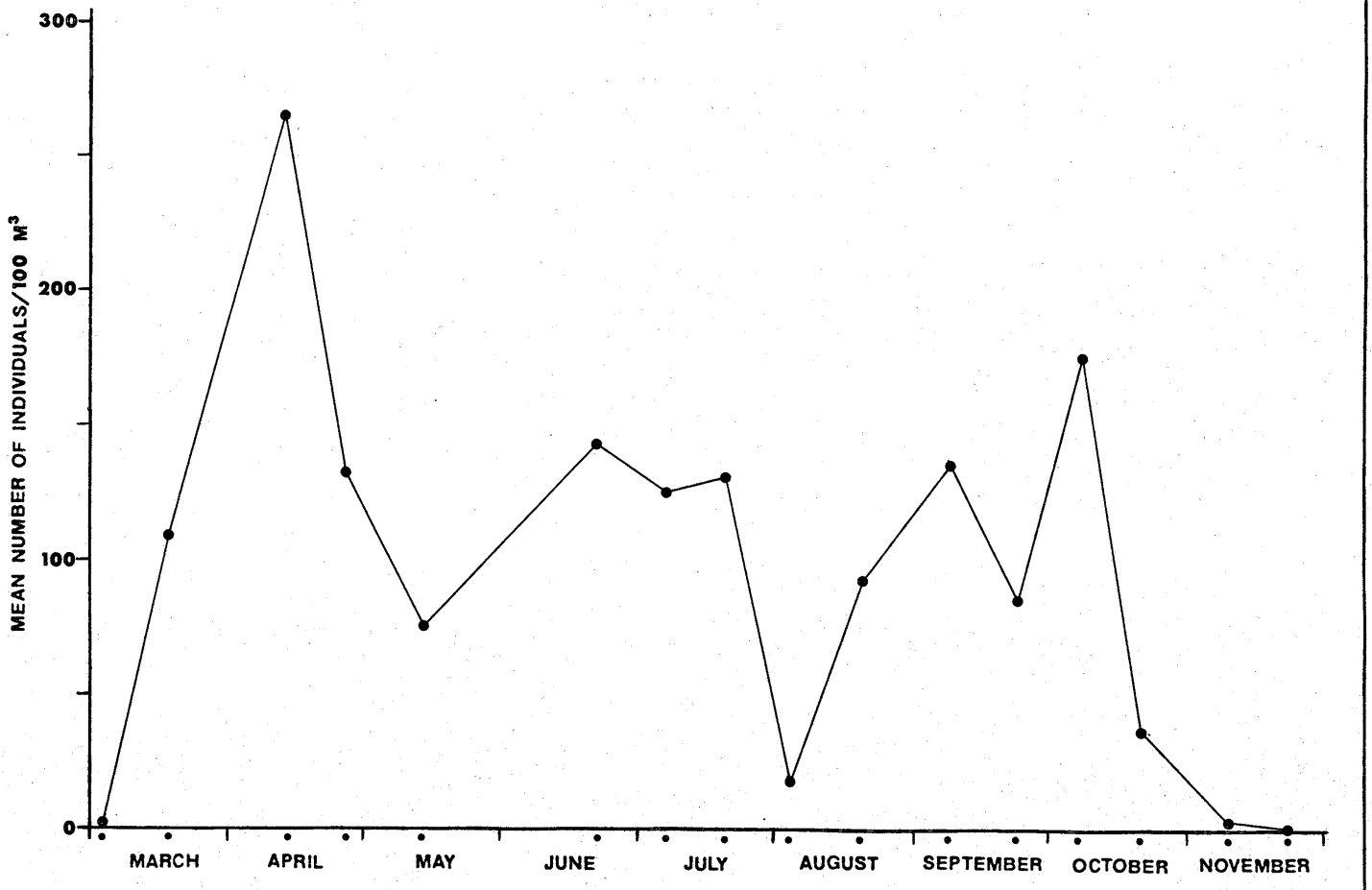

Figure 5.10. Seasonal abundance of goby larvae during 1976.

Hogchoker larvae were never common, but were collected in late April, during May, and again in July. A. lineatus larvae were present in low numbers from late April through early September, 1976, but no peaks in abundance were evident. As with many other species, samples from June 22 and August 3 contained the fewest larvae during this period although the reasons for this are not known. Houde, Futch, and Detwyler (1970) used Tampa Bay larvae collected between May and November 1962 and 1963 to describe development in this species.

Entrainment

Plant Operation

In order to calculate the numbers of eggs and larvae entrained by the plant during each month of the study, it is necessary to know the volume of water which passed through the plant during each month. Table 5.6 provides the number of days per month that each unit was in operation (circulating pump operation days). A constant volume of $15.21 m^3 sec^{-1}$ ($537 ft^3 sec^{-1}$) was assumed for each of the three units, based upon specifications outlined by Johnson (1977). A constant volume of $25.2 m^3 sec^{-1}$ ($83 ft^3 sec^{-1}$) was assumed for the dilution pump. Operational data for the plant circulating pumps and for the dilution pump was provided by Tampa Electric Company.

Calculations of Numbers Entrained

Estimated numbers of eggs and larvae entrained through the plant were calculated from data collected at the plant discharge (station I-1). Data collected at the plant intake (station I-6) was not used because of differences in sampling methodology. Samples were collected at station I-1 directly within the discharge flume. At station I-6, samples were collected in the normal fashion, by an oblique tow in the vicinity of the intake structure. Due to the nature of the two sampling methods,

Table 5.6. Plant and thermal pump operational data between January, 1976, and March, 1977 indicating the number of days each units were in operation.

Month	PLANT Unit 1	Unit 2	Unit 3	Total of All 3 Units	Dilution Pump
1976					
January	2.00	29.16	*	31.16	6.83
February	0.00	27.58	*	27.58	0.00
March	0.44	30.51	*	30.95	15.33
April	12.28	29.75	*	42.03	27.00
May	30.11	5.00	22.54	57.65	28.50
June	28.70	0.00	28.12	56.82	23.00
July	30.24	21.95	26.83	79.05	31.00
August	27.62	29.47	18.57	75.66	28.00
September	25.26	27.51	28.69	81.46	20.83
October	29.89	30.88	25.45	86.22	31.00
November	24.45	24.25	18.33	67.03	15.33
December	28.62	30.87	28.98	88.47	31.00
Total	239.61	286.93	197.51	724.05	257.82
1977					
January	29.41	25.95	27.73	83.09	27.83
February	27.69	25.93	15.04	68.66	22.83
March	30.20	30.67	0.00	60.87	26.83

* Not in Service

it appears that the samples taken at the discharge (station I-1) more accurately measure the ichthyoplankton entrainment through the plant. Entrainment of the eggs and larvae of each species collected was calculated according to the following formula:

$$E_x = P\ O_x\ \frac{A_d + A_n}{n}$$

E_x = estimated number of eggs or larvae entrained by the plant during period x

P = amount of water pumped through one unit per day (a constant equal to $1.314 \times 10^6 m^3$)

O_x = sum of the number of days each unit operated during period x

A_d = the number of individuals per m^3 collected at the plant discharge during the day during period x

A_n = the number of individuals per m^3 collected at the plant discharge during the night during period x

n = the number of sampling trips during period x (equal to 2, 1 day + 1 night)

Each sampling date is used to represent the period of time including one-half the number of days since the previous sampling date and one-half the number of days until the next sampling trip. For example, samples were collected on March 18, April 14 and April 27. The April 14 sampling date represents the period of time extending from April 1 through April 20.

After E_x was calculated for all of the time periods represented by sampling dates, the entrainment figures were summed to yield monthly entrainment figures. For example, the entrainment for the month of March, 1976, is equal to $\frac{23.5}{49}$ (entrainment for February 3.5 - March 23.5) + $\frac{7.5}{27.5}$ (entrainment for March 23.5 - April 20).

Estimated numbers of eggs and larvae entrained through the dilution pump were calculated from data collected at the pump intake (station 0-8) and the pump discharge (1-16). Since the collection methods at these two points were similar, an average of the numbers of each species collected at the two stations was used. Entrainment of the eggs and larvae of each species collected was calculated according to the following formula:

$$E_x = R\, D_x\, \frac{B_d + B_n}{n}$$

R = amount of water pumped through the dilution pump per day (a constant equal to $2.177 \times 10^6 m^3$)

D_x = the number of days the dilution pump operated during period x

B_d = an average of the number of individuals per m^3 collected at the dilution pump intake and discharge during the day during period x

B_n = an average of the number of individuals per m^3 collected at the dilution pump intake and discharge during the night during period x

n = the number of sampling trips during period x (equal to 2, 1 day + 1 night)

The dilution pumps stations (0-8 and 1-16) were not sampled on several occasions due to construction or because the pumps were not operating. The period of time represented by certain sampling dates is, therefore, longer than was the case with the plant discharge, (station 1-1). The estimates of dilution pump entrainment of eggs and larvae are, therefore, less accurate than the estimates of plant entrainment. The period of time from January 16 - March 15, 1976 is not represented by a sampling date. However, since the dilution pumps were not operating during this period, entrainment of eggs and larvae was equal to zero. To obtain the monthly entrainment figures, the entrainment for the various periods of time represented by each sampling date was summed as described for plant entrainment.

Estimated Entrainment

The estimated numbers of eggs and larvae of each species entrained monthly by both the dilution pump and the plant are presented in Appendices 5C 1-30. Entrainment figures were calculated

for each species entrained. These figures must be used with caution. They represent the best estimates possible from the data collected, but are affected by sampling variability and species identification problems. The high coefficients of variation obtained for many species from the replicate tows taken during April, 1977 provide an indication of the possible sampling variability present throughout the study.

Discussion of entrainment will be limited to the eggs and larvae of a species of potential commercial importance, Harengula jaguana, the scaled sardine; a species important as a forage fish for other species in the area and which is also the most abundant species collected, Anchoa mitchilli, the bay anchovy; a family of importance as a sport fishery resource, the sciaenidae; and monthly totals of all species.

(i) Assessment of Entrainment of Harengula jaguana (scaled sardine)

The estimated numbers of scaled sardine eggs and larvae entrained by the dilution pumps and by the Big Bend plant between January, 1976 and March, 1977 are presented in Tables 5.7 and 5.8.

Eggs and larvae of H. jaguana were present in the vicinity of the plant and dilution pumps and susceptible to entrainment only between April and July, 1976. The greatest number of eggs

Table 5.7. Estimated number of Harengula jaguana eggs entrained by the Big Bend Plant and by the dilution pumps per month between January, 1976, and March, 1977.

Month	Number Entrained by Plant	Number Entrained by Dilution Pump	Total Number Entrained
1976			
January	0	0	0
February	0	0	0
March	0	0	0
April	1.719×10^7	3.983×10^6	2.117×10^7
May	5.113×10^8	8.232×10^7	5.936×10^8
June	2.980×10^7	8.958×10^6	3.876×10^7
July	4.186×10^7	4.923×10^7	9.109×10^7
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
TOTAL	6.002×10^8	1.445×10^8	7.446×10^8
1977			
January	0	0	0
Februrary	0	0	0
March	0	0	0

Table 5.8. Estimated number of Harengula jaguana larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	0	0	0
April	3.948×10^6	1.945×10^5	4.142×10^6
May	3.352×10^6	4.019×10^6	7.371×10^6
June	1.342×10^6	7.575×10^6	8.917×10^6
July	1.629×10^7	3.524×10^7	5.153×10^7
August	0	0	0
September	0	0	0
October	0	0	0
November	0	0	0
December	0	0	0
Total	2.493×10^7	4.703×10^7	7.196×10^7
1977			
January	0	0	0
February	0	0	0
March	0	0	0

were entrained by both the plant and the dilution pumps during the month of May. Larvae were entrained in greatest numbers at both locations during the month of July. The number of eggs entrained by both the plant and the dilution pump was greater than the number of larvae entrained each month. Approximately four times as many eggs were entrained by the plant than by the dilution pumps. However, approximately twice as many larvae were entrained by the dilution pumps than by the plant. During 1976, a total of 7.466×10^8 eggs were estimated to be entrained by both the dilution pump and the plant. A total of 7.196×10^7 larvae were estimated to be entrained through the dilution pumps and the plant.

To assess the significance of the above entrainment estimates, it is necessary to estimate the number of eggs produced in the study area. This aspect is discussed in the following sections.

Size of Study Area and Number of Scaled Sardine Eggs Spawned

Each open bay station was used to represent a portion of the study area as shown in Figure 5.11. The area represented by each station is given in Table 5.9.

Determinations of the areas represented by each station were based upon known distances (in meters) between stations. Areas presented in Table 5.9 were used in Equation (1) to

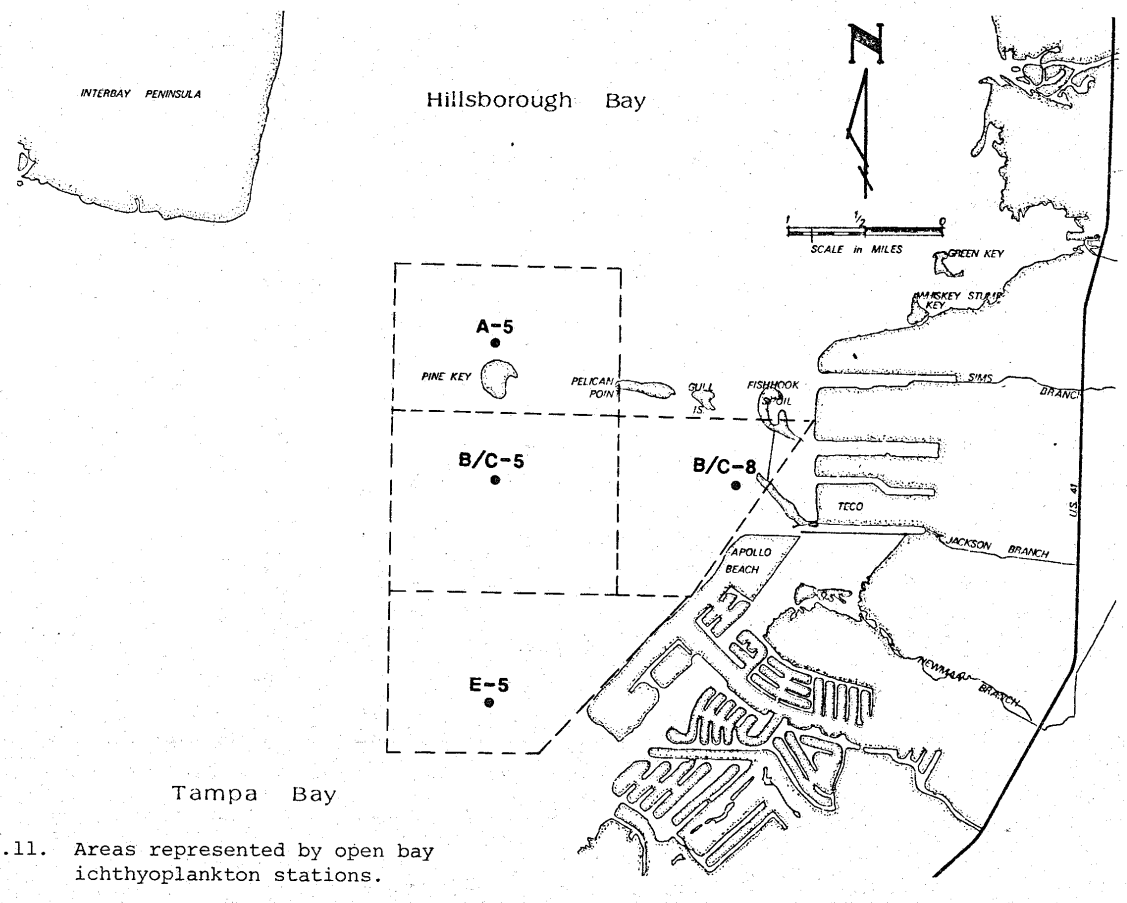

Figure 5.11. Areas represented by open bay ichthyoplankton stations.

Table 5.9. Area represented by each open bay ichthyoplankton station.

Station	Area Represented by Each Station ($m^2 \times 10^6$)
A-5	3.399
B/C-5	3.885
E-5	3.885
B/C-8	2.266

estimate the number of scaled sardine eggs spawned within the study area on each sampling date.

Number of Scaled Sardine Eggs in Study Area

The total number of Harengula jaguana eggs spawned within the study area during 1976 was calculated using techniques similar to those outlined by Sette and Ahlstrom (1948), Ahlstrom (1954, 1959) and Houde (1977).

The number of eggs collected at each station was used to estimate the total number of eggs in the area represented by each station. Areas represented by each station were calculated in square meters and were determined by the perpendicular bisectors of lines from each station to the adjacent station (except for station E-5 and B/C-8 where trapezoids were formed by the shoreline). The number of eggs within each area was determined from:

$$T_a = \frac{c_a d_a}{v_a} \cdot A_a \qquad (1)$$

Where T_a = the estimated total number of eggs in the area represented by station a.

c_a = catch at station a.

d_a = depth, in meters, at station a.

v_a = volume of water filtered at station a (cubic meters).

A_a = Area in square meters represented by station a.

The estimated number of eggs for the total study area represented by each biweekly sampling is:

$$T_k = \sum_{a=1}^{n} T_a \qquad (2)$$

Where T_k = the estimated number of eggs spawned within the study area on sampling date k.

n = the number of stations sampled on date k.

T_a = defined in Equation (1).

Estimated abundance of anchovy eggs within the study area during 1976 is calculated from:

$$T_y = \sum_{i=1}^{s} \frac{T_k D_k}{d_k} \qquad (3)$$

Where T_y = total estimated number of eggs spawned during the year.

s = the number of sampling days on which the estimate is based.

T_k = defined in Equation (2).

D_k = the number of days represented by sampling date k, equal to one half the days since the previous sampling and one half the days until the next sampling.

d_k = the duration (in days) of the egg stage from spawning until hatching.

Variance estimates on the abundance of eggs for each sampling date and for estimated total annual production were not calculated.

Impact Assessment

To estimate the impact of entrainment of eggs of Harengula jaguana by the plant and by the dilution pump, the number of eggs estimated to have been entrained is compared to the number of eggs estimated to have been produced within the study area. This method yields a percentage of eggs destroyed during the year as a result of the operation of the power plant (assuming 100% mortality of eggs passing through the plant).

This method does not address the possible impact of larval entrainment. Larval entrainment is more serious than a comparable amount of egg entrainment, due to the extremely high natural mortality rates between egg and early larval stages. There is no suitable method to estimate the impact of larval entrainment with the data available from the present study.

Estimates of the total number of Harengula jaguana eggs spawned in the study area on each sampling date are presented in Table 5.10. A total of 3.320×10^{11} eggs was estimated to have been produced during 1976 (April - July, 1976). The total number of eggs entrained by the combined action of the plant and the dilution pump was 7.446×10^{8}. The calculation:

Table 5.10. Annual spawning estimate for Harengula jaguana within the open day portion of the study area (based on stations B/C-8, A-5, B/C-5, and E-5) during 1976. Includes dates on which eggs were collected.

Date	Daily Spawning Estimate	# Days Represented By Each Sampling	Eggs Spawned During Each Sampling Period
April 14	4.707×10^{7}	20	9.414×10^{8}
April 27	2.850×10^{8}	14.5	4.133×10^{9}
May 13	8.173×10^{8}	28	2.288×10^{10}
June 22	8.301×10^{9}	27.5	2.283×10^{11}
July 7	6.378×10^{8}	14	8.929×10^{9}
July	4.948×10^{9}	13.5	6.680×10^{10}
		Total	3.320×10^{11}

$\frac{\text{\# eggs entrained}}{\text{\# eggs produced}} \times 100\% = \%$ of eggs produced destroyed by entrainment.

This calculation yields an estimate that 0.22% of the scaled sardine eggs in the study area were destroyed as a result of entrainment resulting from plant operation during 1976.

(ii) Assessment of Entrainment of Anchoa mitchilli (bay anchovy)

The estimated number of A. mitchilli eggs and larvae entrained by the dilution pumps and by the plant between January, 1976 and March, 1977 are presented in Tables 5.11 and 5.12.

Eggs or larvae were entrained by the dilution pumps and/or the plant during all months except January and December, 1976 and January, 1977. The highest number of eggs were entrained by both the dilution pump and by the plant during the month of May. Entrainment of eggs during 1976 at both locations increased steadily to a maximum point during May, then decreased steadily until eggs were no longer present. Entrainment of eggs during 1976 was approximately equal at the dilution pumps and the plant, resulting in a total of 5.795×10^{10} eggs estimated to have been entrained during the year. The highest number of larvae were entrained by the plant during the month of August, and by the dilution pump during the month of May.

Table 5.11. Estimated number of Anchoa mitchilli eggs entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	2.582×10^{7}	0	2.582×10^{7}
March	2.398×10^{8}	3.757×10^{9}	3.997×10^{9}
April	9.579×10^{9}	7.245×10^{9}	1.682×10^{10}
May	1.350×10^{10}	1.141×10^{10}	2.491×10^{10}
June	3.429×10^{9}	3.168×10^{9}	6.597×10^{9}
July	1.673×10^{9}	3.414×10^{9}	5.087×10^{9}
August	1.613×10^{8}	1.960×10^{8}	3.573×10^{8}
September	9.298×10^{7}	3.338×10^{7}	1.264×10^{8}
October	2.672×10^{7}	0	2.672×10^{7}
November	0	0	0
December	0	0	0
Total	2.873×10^{10}	2.922×10^{10}	5.795×10^{10}
1977			
January	0	0	0
February	0	1.306×10^{5}	1.306×10^{5}
March	1.362×10^{10}	6.885×10^{9}	2.050×10^{10}

Table 5.12. Estimated number of Anchoa mitchilli larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	1.949×10^{6}	1.659×10^{9}	1.661×10^{9}
April	4.614×10^{9}	3.044×10^{9}	7.658×10^{9}
May	3.950×10^{9}	1.828×10^{9}	5.778×10^{9}
June	9.439×10^{8}	4.089×10^{8}	1.353×10^{9}
July	4.197×10^{9}	2.901×10^{9}	7.098×10^{9}
August	5.934×10^{9}	5.426×10^{8}	6.477×10^{9}
September	2.902×10^{9}	2.103×10^{8}	3.112×10^{9}
October	3.689×10^{8}	1.487×10^{7}	3.837×10^{8}
November	8.343×10^{5}	1.447×10^{6}	2.281×10^{6}
December	0	0	0
Total	2.291×10^{10}	1.061×10^{10}	3.352×10^{10}
1977			
January	0	0	0
February	0	0	0
March	1.036×10^{9}	2.578×10^{8}	1.294×10^{9}

A total of 3.352×10^{10} larvae were estimated to have been entrained by both the plant and the dilution pump during 1976.

Impact Assessment

The total number of Anchoa mitchilli eggs spawned within the study area was calculated using the method described for Harengula jaguana eggs.

Estimates of the total number of A. mitchilli eggs spawned on each sampling date and the number of days represented by each date are presented in Table 5.13. Months during which no anchovy eggs were collected (January, February and December, 1976) were omitted from the table. Daily spawning estimates were derived from Equations (1) and (2).

The total number of anchovy eggs spawned during 1976 was derived with Equation (3). A value of one was used for the duration in days of the egg stage [denominator of Equation (3)] based upon information given by Mansueti and Hardy (1967).

Based upon Big Bend ichthyoplankton catches, it is estimated that 2.688×10^{12} A. mitchilli eggs were spawned in the open bay portion of the study area during 1976.

A total of 5.795×10^{10} A. mitchilli eggs were estimated to have been entrained during 1976 by the combined operation of the dilution pump and the plant. The eggs entrained represent only 2.16% of the total eggs estimated to occur in the open bay

Table 5.13. Annual spawning estimate for *A. mitchilli* within open bay portion of study area (based on stations B/C-8, A-5, B/C-5, and E-5) during 1976. Includes only dates on which eggs were collected.

Date	Daily Spawning Estimate ($\times 10^8$ eggs)	Days Represented By Each Sampling	Eggs Spawned During each Sampling Period ($\times 10^{10}$)
Feb. 18	0.0795	13	0.0103
Mar. 3	20.7327	14.5	3.0062
Mar. 18	48.0539	21	10.0913
Apr. 14	350.0635	20	70.1269
Apr. 27	162.9718	14.5	23.6309
May 13	38.7373	28	10.8465
June 22	190.0147	27.5	52.2540
July 7	359.7119	14	50.3597
July 20	50.9364	13.5	6.8764
Aug. 3	74.1741	14.5	10.7553
Aug. 18-19	37.5937	18	6.7669
Sept. 8	61.2089	18	11.0176
Sept. 22	12.1789	14.5	1.7659
Oct. 7	80.8753	14	11.3225
Nov. 9	0.0051	16	0.0008
Nov. 22	0.0071	18.5	0.0013
		Total	268.8327

portion of the study area. It does not appear that this level of entrainment of anchovy eggs would have a significant effect on the adult anchovy population in the study area.

Even though a considerable amount of data has been gathered on this species as part of the ichthyoplankton program at Big Bend, the population dynamics of Tampa Bay anchovies remain relatively unknown. Gunter (1945), Reid (1954) and Kilby (1955) suggested that this species primarily inhabited open bays in Taxas and at Cedar Key. Past trawling studies at Big Bend neither confirm nor deny this pattern in Tampa Bay; however, large schools have been observed near open bay stations during the spring and summer months. Ichthyoplankton collections indicate that the majority of the spawning in this species does occur at open bay stations, which limits the potential entrainment of eggs. Data gathered as part of the adult fish surveys at Big Bend suggest that juvenile anchovies move inshore (where they are taken in seine hauls and on the travelling screens) during the late fall, and remain there throughout the winter months.

(iii) Entrainment of Sciaenidae - drums

Seven species of sciaenid larvae were recognized from samples collected during the course of this study. Eggs were less recognizable and were separated into three genera, plus

a large number that could not be identified. Because of these identification problems with the eggs and smaller larvae, discussion of sciaenid eggs and larvae will be limited to a treatment of the family as a whole. Entrainment of individual species is listed for each month in Appendix 5C, but these estimates are less reliable than those of other more readily identifiable species.

The estimated numbers of sciaenid eggs and larvae entrained by the dilution pumps and the plant between January, 1976 and March, 1977 are presented in Tables 5.14 and 5.15.

Sciaenid eggs were entrained during all months except January, 1976. Larvae were entrained during all months except January, February, November and December, 1976. The highest numbers of sciaenid eggs were entrained during the month of April at both the dilution pump and the plant. The number of eggs entrained during 1976 increased to a peak during the month of April, then steadily decreased to a minimum during the month of December. The highest number of larvae were entrained by the plant during the month of April and by the dilution pump during the month of May. A total of 1.255×10^{11} eggs and 1.269×10^{9} larvae were entrained during 1976 by both the dilution pump and the plant.

Table 5.14. Estimated number of Sciaenidae eggs entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	4.471×10^{6}	0	4.471×10^{6}
March	3.062×10^{7}	1.438×10^{10}	1.441×10^{10}
April	3.024×10^{6}	2.661×10^{10}	5.685×10^{10}
May	1.863×10^{10}	2.028×10^{10}	3.891×10^{10}
June	3.490×10^{9}	4.582×10^{9}	8.072×10^{9}
July	2.681×10^{9}	3.468×10^{9}	6.149×10^{9}
August	4.316×10^{8}	1.601×10^{8}	5.917×10^{8}
September	1.854×10^{8}	3.272×10^{7}	2.181×10^{8}
October	1.779×10^{7}	0	1.779×10^{7}
November	9.646×10^{5}	8.172×10^{4}	1.046×10^{6}
December	2.994×10^{5}	1.532×10^{4}	3.147×10^{5}
Total	5.571×10^{10}	6.951×10^{10}	1.252×10^{11}
1977			
January	0	3.581×10^{4}	3.581×10^{4}
February	1.648×10^{6}	3.979×10^{6}	5.627×10^{6}
March	5.587×10^{7}	3.856×10^{7}	9.443×10^{7}

Table 5.15. Estimated number of Sciaenidae larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	2.784×10^5	8.110×10^7	8.137×10^7
April	1.837×10^8	1.530×10^8	3.367×10^8
May	1.339×10^8	1.758×10^8	3.097×10^8
June	3.508×10^7	3.733×10^7	7.241×10^7
July	1.083×10^8	1.538×10^8	2.621×10^8
August	1.138×10^8	3.164×10^7	1.454×10^8
September	4.094×10^7	1.262×10^7	5.356×10^7
October	5.852×10^6	1.792×10^6	7.644×10^6
November	0	0	0
December	0	0	0
Total	6.219×10^8	6.471×10^8	1.269×10^9
1977			
January	2.437×10^6	3.581×10^4	2.473×10^6
February	1.171×10^6	1.909×10^5	1.362×10^6
March	7.511×10^6	4.546×10^6	1.206×10^7

Impact Assessment

The number of sciaenid eggs produced within the study area was not calculated for individual species. It was not possible to identify sciaenid eggs accurately enough to utilize this method of estimating the number of eggs produced within the study area during 1976. As a result, the impact of the entrainment of sciaenid eggs can not be accurately assessed.

The assessment of the entrainment of sciaenid eggs as a group would not be biologically valid due to possible differences in spawning habits and population levels of the various species in the study area.

(iv) Total Eggs and Larvae

The estimated total number of eggs and larvae of all species entrained by the dilution pumps and the plant between January, 1976 and March, 1977 are presented in Tables 5.16 and 5.17.

Eggs were entrained during every month except January, 1976. Larvae were entrained during every month. The highest number of eggs were entrained by both the dilution pump and by the plant during the month of April. Entrainment of eggs during 1976 increased to a peak value during the month of April, then declined monthly throughout the remainder of the year. Egg entrainment remained at a high level from March - July. The highest number

Table 5.16. Estimated number of total eggs entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Operating Days By Plant	# Entrained By Dilution Pump	# Operating Days By Dilution Pump	Total # Entrained
1967					
January	0	31.16	0	6.83	0
February	3.069×10^{7}	27.58	0	0	3.069×10^{7}
March	2.709×10^{8}	30.95	1.817×10^{10}	15.33	1.845×10^{10}
April	3.996×10^{10}	42.03	3.395×10^{10}	27	7.391×10^{10}
May	3.295×10^{10}	57.65	3.246×10^{10}	28.5	6.541×10^{10}
June	7.092×10^{9}	56.82	8.126×10^{9}	23	1.522×10^{10}
July	4.442×10^{9}	79.05	7.029×10^{9}	31	1.147×10^{10}
August	6.052×10^{8}	75.66	3.599×10^{8}	28	9.652×10^{8}
September	2.803×10^{8}	81.46	6.689×10^{7}	20.83	3.472×10^{8}
October	4.592×10^{7}	86.22	0	31	4.592×10^{7}
November	9.646×10^{5}	67.03	8.172×10^{4}	15.33	1.046×10^{6}
December	2.994×10^{5}	88.47	1.532×10^{4}	31	3.147×10^{5}
Total	8.568×10^{10}	724.05	1.002×10^{11}	257.82	1.858×10^{11}
1977					
January	0	83.09	3.581×10^{4}	27.83	3.581×10^{4}
February	1.648×10^{6}	68.66	4.110×10^{6}	22.83	5.758×10^{6}
March	1.368×10^{10}	60.87	6.925×10^{9}	26.83	2.060×10^{10}

Table 5.17. Estimated number of total larvae entrained by the Big Bend plant and by the dilution pumps per month between January, 1976 and March, 1977.

Month	# Entrained By Plant	# Operating Days By Plant	# Entrained By Dilution Pump	# Operating Days By Dilution Pump	Total # Entrained
1976					
January	2.217×10^{6}	31.16	5.940×10^{5}	6.83	2.811×10^{6}
February	3.022×10^{6}	27.58	0	0	3.022×10^{6}
March	5.342×10^{7}	30.95	1.873×10^{9}	15.33	1.926×10^{9}
April	5.234×10^{9}	42.03	3.458×10^{9}	27	8.692×10^{9}
May	4.476×10^{9}	57.65	2.502×10^{9}	28.5	6.949×10^{9}
June	1.161×10^{9}	56.82	5.926×10^{8}	23	1.754×10^{9}
July	4.764×10^{9}	79.05	3.197×10^{9}	31	7.961×10^{9}
August	6.290×10^{9}	75.66	6.325×10^{8}	28	6.923×10^{9}
September	3.434×10^{9}	81.46	2.939×10^{8}	20.83	3.728×10^{9}
October	6.191×10^{8}	86.22	3.266×10^{7}	31	6.517×10^{8}
November	1.312×10^{7}	67.03	6.136×10^{6}	15.33	1.926×10^{7}
December	1.871×10^{6}	88.47	2.007×10^{6}	31	3.878×10^{6}
Total	2.596×10^{10}	724.05	1.259×10^{10}	257.82	3.855×10^{10}
1977					
January	2.437×10^{6}	83.09	2.937×10^{6}	27.83	5.374×10^{6}
February	6.914×10^{6}	68.66	4.829×10^{6}	22.83	1.174×10^{7}
March	1.087×10^{9}	60.87	2.756×10^{8}	26.83	3.843×10^{8}

of larvae were entrained by the plant during the month of August, and by the dilution pump during the month of April. Larval entrainment remained at a high level between March and October. A total of 1.858×10^{11} eggs and 3.855×10^{10} larvae were entrained during 1976 by the combined operation of the plant and the dilution pump.

SUMMARY AND CONCLUSIONS

1. Larvae of forty-one species representing twenty-two families were collected during Big Bend ichthyoplankton studies. Eggs from twelve families were also collected.
2. Spawning occurred during all months between January, 1976 and March, 1977. Peak densities of both eggs and larvae occurred during spring and summer months. The least amount of spawning activity occurred during winter months of both 1976 and 1977.
3. Eggs and larvae of the bay anchovy, Anchoa mitchilli, were more abundant than any other species during the spring and summer. Engraulids accounted for 73.1% of all eggs and 87.4% of all larvae collected during the fifteen months. The spawning season at Big Bend began in early March, 1976 and continued through late October, 1976.
4. Sciaenids, represented by seven species of larvae, were second in abundance after the engraulids, making up 26.2% of all eggs and 3.9% of all larvae collected during the study. Sciaenid eggs and larvae were present within the study area between early March and early November, 1976.

5. Larval clupeids, carangids, pomadasyids, sparids and gobiids were also common in spring and summer samples, although each family made up less than 3% of all larvae collected.

6. Winter samples were dominated by blenny and goby larvae, but numbers were usually low. Pinfish, menhaden, and spot larvae migrated into the study area from spawning grounds offshore during January and February of both 1976 and 1977.

7. It is estimated that a total of 1.858×10^{11} eggs and 3.855×10^{10} larvae were entrained by the plant during 1976. Egg entrainment occurred during all months except January, 1976. Larvae were entrained during every month of the study. The greatest amount of both egg and larval entrainment occurred in April, 1976.

8. Total sciaenid entrainment (seven species) during 1976 was estimated to be 1.252×10^{11} and 1.269×10^{9} for eggs and larvae, respectively. The significance of this amount of entrainment could not be evaluated due to the problems encountered in identifying the individual species.

9. H. jaguana entrainment occurred during the months of April through July, 1976. The estimated number of entrained eggs was 7.446×10^{8}. Larval entrainment was

estimated to be 7.196×10^7 individuals.

10. The number of H. jaguana eggs entrained was estimated to represent 0.22% of the eggs produced in the open bay portion of the study area.

11. Entrainment of A. mitchilli eggs occurred from February - October, 1976 and in March, 1977. Larvae were entrained from March - December, 1976 and in March, 1977. Estimated numbers entrained during 1976 were 5.795×10^{10} eggs and 3.352×10^{10} larvae.

12. The number of A. mitchilli eggs entrained was estimated to represent 2.16% of the eggs produced in the open bay portion of the study area.

13. The impact of entrainment of larvae was not assessed due to the absence of a suitable method.

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APPENDIX 5.A

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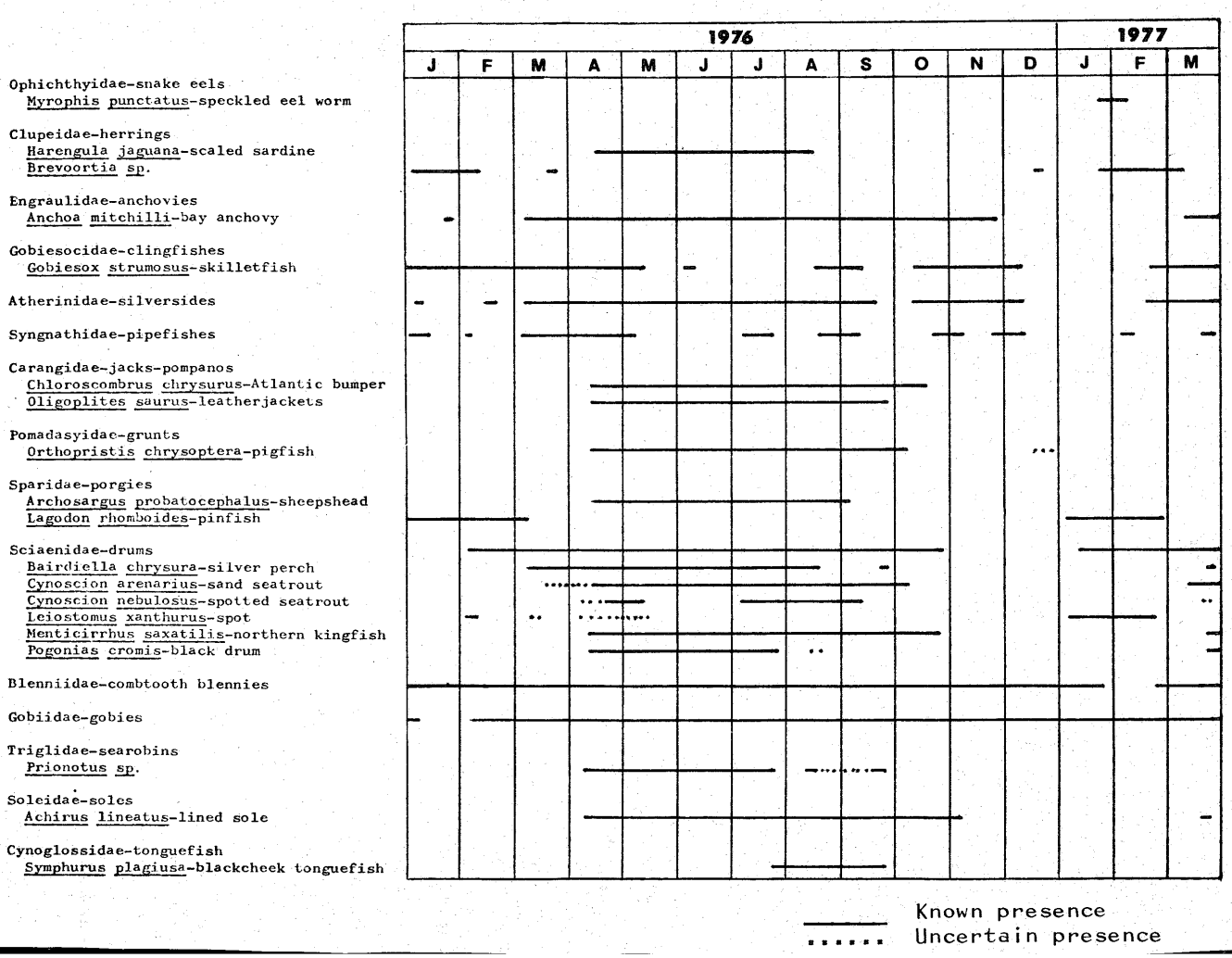
APPENDIX 5.B

Seasonal Occurrence of Tampa Bay Fish Larvae

Appendix 5B. Seasonal occurrence of Tampa Bay fish larvae.



APPENDIX 5.C

Estimated Entrainment of Eggs and Larvae by the Big Bend Plant and by the Dilution Pump

Appendix 5C-1. Estimated Number of Larvae Entrained During January, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia patronus	0	7.434×10^4	7.434×10^4
Gobiesocidae			
Gobiesox strumosus	5.254×10^5	0	5.254×10^5
Atherinidae			
Menidia beryllina	0	2.230×10^5	2.230×10^5
Syngnathidae			
Hippocampus erectus	0	3.717×10^4	3.717×10^4
Syngnathus floridae	4.358×10^5	0	4.358×10^5
Sparidae			
Lagodon rhomboides	0	3.717×10^4	3.717×10^4
Blenniidae			
Hypsoblennius hentzi	1.256×10^6	7.434×10^4	1.330×10^6
Gobiidae			
Microgobius gulosus	0	1.487×10^5	1.487×10^5
TOTAL	2.217×10^6	5.940×10^5	2.811×10^6

Appendix 5C-2. Estimated Number of Eggs Entrained During January, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
TOTAL	0	0	0

Appendix 5C-3. Estimated Number of Larvae Entrained During February, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Gobiesocidae			
Gobiesox strumosus	4.340×10^5	0	4.340×10^5
Syngnathidae			
Syngnathus floridae	2.988×10^3	0	2.988×10^3
Syngnathus louisianae	5.816×10^4	0	5.816×10^4
Blenniidae			
Hypsoblennius hentzi	1.626×10^6	0	1.626×10^6
Gobiidae			
Gobiosoma robustum	9.012×10^5	0	9.012×10^5
TOTAL	3.022×10^6	0	3.022×10^6

Appendix 5C-4. Estimated Number of Eggs Entrained During February, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa hepsetus	5.816×10^4	0	5.816×10^4
Anchoa mitchilli	2.582×10^7	0	2.582×10^7
Sciaenidae			
Unidentified	4.471×10^6	0	4.471×10^6
Gobiidae			
Gobiosoma robustum	8.724×10^4	0	8.724×10^4
Soleidae			
Achirus lineatus	2.908×10^4	0	2.908×10^4
Unidentified	2.282×10^5	0	2.282×10^5
TOTAL	3.069×10^7	0	3.069×10^7

Appendix 5C-5. Estimated Number of Larvae Entrained During March, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia sp.	8.353×10^5	0	8.353×10^5
Engraulidae			
Anchoa hepsetus	0	5.275×10^6	5.275×10^6
Anchoa mitchilli	1.949×10^6	1.659×10^9	1.661×10^9
Gobiesocidae			
Gobiesox strumosus	2.123×10^6	1.358×10^6	3.481×10^6
Atherinidae			
Menidia beryllina	8.353×10^5	1.478×10^7	1.562×10^7
Syngnathidae			
Hippocampus erectus	2.784×10^5	0	2.784×10^5
Syngnathus louisianae	1.292×10^5	0	1.292×10^5
Carangidae			
Oligoplites saurus	0	1.119×10^6	1.119×10^6
Pomadasyidae			
Orthopristis chrysoptera	0	4.171×10^7	4.161×10^7
Sparidae			
Archosargus probatocephalus	0	1.518×10^7	1.518×10^7
Sciaenidae			
Bairdiella chrysura	2.784×10^5	7.015×10^7	7.043×10^7
Cynoscion arenarius	0	9.427×10^6	9.427×10^6
Menticirrhus saxatilis	0	1.518×10^6	1.581×10^6
Blenniidae			
Chasmodes sp.?	0	3.916×10^6	3.916×10^6
Hypsoblennius hentzi	1.408×10^7	1.302×10^7	2.710×10^7

Appendix 5C-5. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Gobiidae			
Gobiosoma robustum	3.263×10^7	2.333×10^7	5.596×10^7
Gobiosoma sp.?	0	3.116×10^6	3.116×10^6
Microgobius gulosus	2.784×10^5	3.995×10^4	3.184×10^5
Microgobius sp.?	0	5.275×10^6	5.275×10^6
Triglidae			
Prionotus sp.	0	1.358×10^6	1.358×10^6
Soleidae			
Achirus lineatus	0	2.477×10^6	2.477×10^6
Unidentified	0	8.787×10^5	8.787×10^5
TOTAL	5.342×10^7	1.873×10^9	1.926×10^9

Appendix 5C-6. Estimated Number of Eggs Entrained During March, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa hepsetus	1.292×10^5	5.433×10^6	5.562×10^6
Anchoa mitchilli	2.398×10^8	3.757×10^9	3.997×10^9
Unidentified	0	5.595×10^5	5.595×10^5
Cyprinodontidae			
Unidentified	0	5.674×10^6	5.674×10^6
Carangidae			
Oligoplites saurus	0	9.988×10^6	9.988×10^6
Unidentified sp. A	0	8.629×10^6	8.629×10^6
Pomadasyidae			
Orthopristis chrysoptera	0	6.393×10^5	6.393×10^5
Sciaenidae			
Bairdiella chrysura	0	1.157×10^{10}	1.157×10^{10}
Cynoscion sp.	2.227×10^7	7.090×10^8	7.313×10^8
Menticirrhus sp.	2.784×10^5	1.039×10^6	1.317×10^6
Unidentified	8.076×10^6	2.103×10^9	2.111×10^9
Gobiidae			
Gobiosoma robustum	2.811×10^5	0	2.811×10^5
Triglidae			
Prionotus sp.	0	1.758×10^6	1.758×10^6
Soleidae			
Achirus lineatus	6.461×10^4	1.758×10^6	1.822×10^6
TOTAL	2.709×10^8	1.817×10^{10}	1.845×10^{10}

Appendix 5C-7. Estimated Number of Larvae Entrained During April, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	3.948×10^6	1.945×10^5	4.142×10^6
Unidentified	0	4.322×10^4	4.322×10^4
Engraulidae			
Anchoa hepsetus	0	9.395×10^6	9.395×10^6
Anchoa mitchilli	4.614×10^9	3.044×10^9	7.658×10^9
Gobiesocidae			
Gobiesox strumosus	4.137×10^6	2.420×10^6	6.557×10^6
Atherinidae			
Menidia beryllina	3.397×10^6	2.652×10^7	2.991×10^7
Carangidae			
Chloroscombrus chrysurus	1.610×10^7	2.427×10^6	1.853×10^7
Oligoplites saurus	6.117×10^6	2.425×10^6	8.542×10^6
Pomadasyidae			
Orthopristis chrysoptera	2.918×10^7	7.844×10^7	1.076×10^8
Sparidae			
Archosargus probatocephalus	1.106×10^8	3.984×10^7	1.504×10^8
Sciaenidae			
Bairdiella chrysura	1.155×10^8	1.275×10^8	2.430×10^8
Cynoscion arenarius	5.107×10^7	1.896×10^7	7.003×10^7
Cynoscion nebulosus	1.046×10^6	2.233×10^5	1.269×10^6
Menticirrhus americanus	2.323×10^5	0	2.323×10^5
Menticirrhus saxatilis	8.366×10^6	4.209×10^6	1.258×10^7
Pogonias chromis	7.510×10^6	6.481×10^4	7.575×10^6
Unidentified	0	2.039×10^6	2.039×10^6

Appendix 5C-7. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	0	7.039×10^{6}	7.039×10^{6}
Hypsoblennius hentzi	1.007×10^{7}	2.410×10^{7}	3.417×10^{7}
Gobiidae			
Gobiosoma robustum	1.687×10^{8}	4.250×10^{7}	2.112×10^{8}
Gobiosoma sp.?	1.046×10^{6}	5.550×10^{6}	6.596×10^{6}
Microgobius gulosus	3.484×10^{6}	7.115×10^{4}	3.555×10^{6}
Microgobius sp.?	1.804×10^{7}	9.828×10^{6}	2.787×10^{7}
Triglidae			
Prionotus sp.	6.155×10^{6}	2.938×10^{6}	9.093×10^{6}
Soleidae			
Achirus lineatus	8.324×10^{6}	4.563×10^{6}	1.289×10^{7}
Trinectes maculatus	0	1.657×10^{5}	1.657×10^{5}
Tetraodontidae			
Sphoeroides sp.?	1.046×10^{6}	0	1.046×10^{6}
Unidentified	4.623×10^{7}	2.293×10^{6}	4.852×10^{7}
TOTAL	5.234×10^{9}	3.458×10^{9}	8.692×10^{9}

Appendix 5C-8. Estimated Number of Eggs Entrained During April, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	1.719×10^7	3.983×10^6	2.117×10^7
Unidentified	0	7.924×10^4	7.924×10^4
Engraulidae			
Anchoa hepsetus	4.437×10^6	9.850×10^6	1.429×10^7
Anchoa mitchilli	9.579×10^9	7.245×10^9	1.682×10^{10}
Unidentified	0	2.812×10^7	2.812×10^7
Belonidae			
Strongylura notata	0	6.481×10^4	6.481×10^4
Cyprinodontidae			
Unidentified	1.394×10^6	1.011×10^7	1.150×10^7
Carangidae			
Oligoplites saurus	7.410×10^7	1.779×10^7	9.189×10^7
Unidentified sp. A	7.510×10^6	1.908×10^7	2.659×10^7
Pomadasyidae			
Orthopristis chrysoptera	2.169×10^6	1.139×10^6	3.308×10^6
Sciaenidae			
Bairdiella chrysura	2.852×10^{10}	2.098×10^{10}	4.950×10^{10}
Cynoscion sp.	5.427×10^7	1.269×10^9	1.323×10^9
Menticirrhus sp.	3.171×10^6	2.268×10^6	5.439×10^6
Unidentified	1.666×10^9	4.355×10^9	6.021×10^9
Ephippidae			
Chaetodipterus faber	1.719×10^7	0	1.719×10^7
Triglidae			
Prionotus sp.	5.762×10^6	3.477×10^6	9.239×10^6

Appendix 5C-8. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Soleidae			
Achirus lineatus	8.905×10^{6}	4.521×10^{6}	1.343×10^{7}
Unidentified	2.169×10^{6}	1.225×10^{5}	2.291×10^{6}
TOTAL	3.996×10^{10}	3.395×10^{10}	7.391×10^{10}

Appendix 5C-9. Estimated Number of Larvae Entrained During May, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	3.352×10^6	4.019×10^6	7.371×10^6
Unidentified	0	8.933×10^5	8.933×10^5
Entraulidae			
Anchoa mitchilli	3.950×10^9	1.828×10^9	5.778×10^9
Gobiesocidae			
Gobiesox strumosus	3.615×10^6	0	3.615×10^6
Atherinidae			
Menidia beryllina	1.354×10^7	3.870×10^6	1.741×10^7
Carangidae			
Chloroscombrus chrysurus	7.482×10^7	5.017×10^7	1.250×10^8
Oligoplites saurus	7.131×10^6	8.933×10^6	1.606×10^7
Pomadasyidae			
Orthopristis chrysoptera	4.509×10^7	8.575×10^7	1.308×10^8
Sparidae			
Archosargus probatocephalus	1.205×10^8	2.645×10^8	3.850×10^8
Sciaenidae			
Bairdiella chrysura	6.738×10^7	5.181×10^7	1.192×10^8
Cynoscion arenarius	5.753×10^7	4.481×10^7	1.023×10^8
Cynoscion nebulosus	4.705×10^5	4.615×10^6	5.086×10^6
Menticirrhus americanus	1.045×10^5	0	1.045×10^5
Menticirrhus saxatilis	8.394×10^6	3.111×10^7	3.950×10^7
Pogonias chromis	0	1.339×10^6	1.339×10^6
Unidentified	0	4.213×10^7	4.213×10^7

Appendix 5C-9. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	6.298×10^5	1.339×10^6	1.969×10^6
Hypsoblennius hentzi	8.185×10^6	1.861×10^7	2.679×10^7
Gobiidae			
Gobiosoma robustum	8.991×10^7	1.936×10^7	1.093×10^8
Gobiosoma sp.?	4.705×10^5	0	4.705×10^5
Microgobius gulosus	1.568×10^6	0	1.568×10^6
Microgobius sp.?	1.163×10^7	8.933×10^6	2.056×10^7
Triglidae			
Prionotus sp.	5.920×10^6	1.072×10^7	1.664×10^7
Soleidae			
Achirus lineatus	4.974×10^6	3.126×10^6	8.100×10^6
Trinectes maculatus	0	3.424×10^6	3.424×10^6
Tetraodontidae			
Sphoeroides sp.?	4.705×10^5	0	4.705×10^5
Unidentified	0	1.503×10^7	1.503×10^7
TOTAL	4.476×10^9	2.502×10^9	6.949×10^9

Appendix 5C-10. Estimated Number of Eggs Entrained During May, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	5.113×10^8	8.232×10^7	5.936×10^8
Unidentified	0	1.638×10^6	1.638×10^6
Engraulidae			
Anchoa hepsetus	9.549×10^6	3.573×10^6	1.312×10^7
Anchoa mitchilli	1.350×10^{10}	1.141×10^{10}	2.491×10^{10}
Unidentified	7.244×10^7	5.605×10^8	6.329×10^8
Belonidae			
Strongylura notata	0	1.339×10^6	1.339×10^6
Cyprinodontidae			
Unidentified	6.272×10^5	0	6.272×10^5
Carangidae			
Oligoplites saurus	2.801×10^7	0	2.801×10^7
Unidentified sp. A	1.758×10^8	7.667×10^7	2.525×10^8
Sciaenidae			
Bairdiella chrysura	1.831×10^{10}	7.586×10^9	2.590×10^{10}
Cynoscion sp.	3.080×10^8	1.193×10^8	4.273×10^8
Menticirrhus sp.	6.298×10^6	8.634×10^6	1.493×10^7
Unidentified	8.100×10^6	1.257×10^{10}	1.258×10^{10}
Triglidae			
Prionotus sp.	1.222×10^7	7.145×10^6	1.937×10^7
Soleidae			
Achirus lineatus	9.330×10^6	2.873×10^7	3.806×10^7
Unidentified	0	2.531×10^6	2.531×10^6
TOTAL	3.295×10^{10}	3.246×10^{10}	6.541×10^{10}

Appendix 5C-11. Estimated Number of Larvae Entrained During June, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	1.342×10^6	7.575×10^6	8.917×10^6
Unidentified	0	4.322×10^4	4.322×10^4
Engraulidae			
Anchoa hepsetus	0	3.102×10^5	3.102×10^5
Anchoa mitchilli	9.439×10^8	4.089×10^8	1.353×10^9
Gobiesocidae			
Gobiesox strumosus	2.153×10^5	0	2.153×10^5
Atherinidae			
Membras martinica	7.550×10^4	2.286×10^5	3.041×10^5
Menidia beryllina	1.772×10^6	2.701×10^6	4.473×10^6
Syngnathidae			
Syngnathus louisianae	0	2.721×10^4	2.721×10^4
Carangidae			
Chloroscombrus chrysurus	5.345×10^6	6.183×10^6	1.153×10^7
Oligoplites saurus	9.371×10^5	1.809×10^6	2.746×10^6
Pomadasyidae			
Orthopristis chrysoptera	2.716×10^7	5.432×10^7	8.148×10^7
Sparidae			
Archosargus probatocephalus	9.890×10^6	1.751×10^7	2.740×10^7
Sciaenidae			
Bairdiella chrysura	1.115×10^7	1.425×10^7	2.540×10^7
Cynoscion arenarius	1.921×10^7	8.765×10^6	2.798×10^7
Cynoscion nebulosus	0	2.233×10^5	2.233×10^5
Menticirrhus saxatilis	4.534×10^6	1.041×10^7	1.495×10^7
Pogonias chromis	1.811×10^5	1.343×10^6	1.525×10^6
Unidentified	0	2.343×10^6	2.343×10^6

Appendix 5C-11. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	2.646×10^6	6.481×10^4	2.711×10^6
Hypsoblennius hentzi	2.932×10^6	1.847×10^6	4.779×10^6
Gobiidae			
Gobiosoma robustum	1.162×10^8	5.512×10^7	1.713×10^8
Gobiosoma sp.?	2.114×10^5	0	2.114×10^5
Microgobius gulosus	1.359×10^6	2.939×10^5	1.653×10^6
Microgobius sp.?	5.757×10^6	4.841×10^5	6.241×10^6
Triglidae			
Prionotus sp.	3.211×10^6	2.010×10^6	5.221×10^6
Soleidae			
Achirus lineatus	2.131×10^6	2.764×10^5	2.407×10^6
Trinectes maculatus	4.680×10^5	9.276×10^5	1.396×10^6
Unidentified	1.359×10^5	8.526×10^5	9.885×10^5
TOTAL	1.161×10^9	5.926×10^8	1.754×10^9

Appendix 5C-12. Estimated Number of Eggs Entrained During June, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	2.980×10^7	8.958×10^6	3.876×10^7
Unidentified	0	7.924×10^4	7.924×10^4
Engraulidae			
Anchoa hepsetus	4.813×10^5	1.729×10^5	6.542×10^5
Anchoa mitchilli	3.429×10^9	3.168×10^9	6.597×10^9
Unidentified	9.906×10^7	3.462×10^8	4.453×10^8
Ephippidae			
Chaetodipterus faber	0	2.721×10^4	2.721×10^4
Belonidae			
Strongylura notata	0	6.481×10^4	6.481×10^4
Carangidae			
Oligoplites saurus	0	4.354×10^4	4.354×10^4
Unidentified sp. A	1.126×10^7	1.081×10^7	2.207×10^7
Pomadasyidae			
Orthopristis chrysoptera	3.153×10^6	0	3.153×10^6
Sciaenidae			
Bairdiella chrysura	3.425×10^9	3.744×10^9	7.169×10^9
Cynoscion sp.	6.020×10^7	7.256×10^7	1.328×10^8
Menticirrhus sp.	3.314×10^6	5.970×10^6	9.284×10^6
Unidentified	1.570×10^6	7.590×10^8	7.606×10^8
Triglidae			
Prionotus sp.	6.123×10^6	1.064×10^6	7.187×10^6
Soleidae			
Achirus lineatus	2.254×10^7	8.748×10^6	3.129×10^7
Unidentified	0	1.660×10^5	1.660×10^5
TOTAL	7.092×10^9	8.126×10^9	1.522×10^{10}

Appendix 5C-13. Estimated Number of Larvae Entrained During July, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	1.629×10^7	3.524×10^7	5.153×10^7
Engraulidae			
Anchoa hepsetus	0	4.033×10^6	4.033×10^6
Anchoa mitchilli	4.197×10^9	2.901×10^9	7.098×10^9
Gobiesocidae			
Gobiesox strumosus	1.177×10^6	0	1.177×10^6
Atherinidae			
Membras martinica	9.815×10^5	2.971×10^6	3.953×10^6
Syngnathidae			
Syngnathus louisianae	0	3.538×10^5	3.538×10^5
Carangidae			
Chloroscombrus chrysurus	2.842×10^7	3.395×10^7	6.237×10^7
Oligoplites saurus	8.756×10^6	1.003×10^7	1.879×10^7
Pomadasyidae			
Orthopristis chrysoptera	3.202×10^8	2.031×10^8	5.233×10^8
Sparidae			
Archosargus probatocephalus	1.469×10^7	7.968×10^6	2.266×10^7
Sciaenidae			
Bairdiella chrysura	4.318×10^7	2.993×10^7	7.311×10^7
Cynoscion arenarius	1.509×10^7	7.025×10^7	8.534×10^7
Cynoscion nebulosus	3.420×10^5	4.409×10^5	7.829×10^5
Menticirrhus saxatilis	4.736×10^7	4.533×10^7	9.269×10^7
Pogonias chromis	2.355×10^6	2.751×10^6	5.086×10^6
Unidentified	0	5.064×10^6	5.064×10^6

Appendix 5C-13. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Ephippidae			
Chaetodipterus faber	0	3.674×10^5	3.674×10^5
Blenniidae			
Chasmodes sp.?	2.355×10^6	0	2.355×10^6
Hypsoblennius hentzi	4.482×10^6	5.175×10^6	9.657×10^6
Gobiidae			
Gobiosoma robustum	1.499×10^7	3.035×10^7	4.534×10^7
Gobiosoma sp.?	2.748×10^6	0	2.748×10^6
Microgobius gulosus	1.997×10^7	8.841×10^6	2.881×10^7
Microgobius sp.?	5.888×10^6	1.834×10^6	7.722×10^6
Triglidae			
Prionotus sp.	3.336×10^6	7.076×10^5	4.044×10^6
Soleidae			
Achirus lineatus	4.901×10^6	3.635×10^6	8.536×10^6
Trinectes maculatus	6.084×10^6	2.123×10^6	8.207×10^6
Cynoglossidae			
Symphurus plagiusa	0	3.674×10^5	3.674×10^5
Unidentified	3.742×10^6	1.627×10^6	5.369×10^6
TOTAL	4.764×10^9	3.197×10^9	7.961×10^9

Appendix 5C-14. Estimated Number of Eggs Entrained During July, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Harengula jaguana	4.186×10^7	4.923×10^7	9.109×10^7
Engraulidae			
Anchoa mitchilli	1.673×10^9	3.414×10^9	5.087×10^9
Unidentified	7.458×10^6	1.847×10^7	2.593×10^7
Ephippidae			
Chaetodipterus faber	0	3.538×10^5	3.538×10^5
Carangidae			
Oligoplites saurus	0	5.661×10^5	5.661×10^5
Unidentified sp. A	1.848×10^7	6.957×10^7	9.390×10^7
Pomadasyidae			
Orthopristis chrysoptera	4.907×10^6	0	4.907×10^6
Sciaenidae			
Bairdiella chrysura	2.380×10^9	1.927×10^9	2.165×10^9
Cynoscion sp.	1.126×10^8	1.179×10^8	2.499×10^8
Menticirrhus sp.	8.056×10^7	9.293×10^7	1.735×10^8
Unidentified	1.082×10^8	1.330×10^9	1.439×10^9
Soleidae			
Achirus lineatus	1.523×10^7	8.490×10^6	2.372×10^7
Unidentified	0	5.661×10^5	5.661×10^5
TOTAL	4.442×10^9	7.029×10^9	1.147×10^{10}

Appendix 5C-15. Estimated Number of Larvae Entrained During August, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	5.934×10^9	5.426×10^8	6.477×10^9
Gobiesocidae			
Gobiesox strumosus	3.123×10^5	3.266×10^4	3.450×10^5
Atherinidae			
Membras martinica	0	6.286×10^5	6.286×10^5
Syngnathidae			
Syngnathus louisianae	8.011×10^5	0	8.011×10^5
Carangidae			
Chloroscombrus chrysurus	4.071×10^7	1.841×10^7	5.912×10^7
Oligoplites saurus	5.604×10^6	3.129×10^5	5.917×10^6
Pomadasyidae			
Orthopristis chrysoptera	1.201×10^7	7.102×10^6	1.911×10^7
Sparidae			
Archosargus probatocephalus	1.335×10^6	2.367×10^5	1.572×10^6
Sciaenidae			
Bairdiella chrysura	0	6.286×10^5	6.286×10^5
Cynoscion arenarius	1.545×10^7	6.599×10^6	2.205×10^7
Cynoscion nebulosus	3.468×10^6	2.147×10^6	5.615×10^6
Menticirrhus saxatilis	9.146×10^7	2.164×10^7	1.131×10^8
Pogonias chromis	0	6.286×10^5	6.286×10^5
Unidentified	3.471×10^6	0	3.471×10^6
Cyprinodontidae			
Fundulus grandis	0	2.286×10^5	2.286×10^5

Appendix 5C-15. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Blenniidae			
Chasmodes sp.?	2.670×10^6	4.354×10^4	2.714×10^6
Hypsoblennius hentzi	4.009×10^6	4.109×10^5	4.420×10^6
Gobiidae			
Gobiosoma robustum	9.725×10^6	5.960×10^5	1.032×10^7
Microgobius gulosus	1.243×10^8	2.045×10^7	1.448×10^8
Microgobius sp.?	5.839×10^6	3.535×10^6	9.374×10^6
Unidentified	0	5.443×10^4	5.443×10^4
Triglidae			
Prionotus sp.	3.471×10^6	3.266×10^4	3.504×10^6
Soleidae			
Achirus lineatus	2.598×10^7	2.566×10^6	2.855×10^7
Cynoglossidae			
Symphurus plagiusa	0	5.388×10^5	5.388×10^5
Unidentified	5.872×10^6	3.050×10^6	8.922×10^6
TOTAL	6.290×10^9	6.325×10^8	6.923×10^9

Appendix 5C-16. Estimated Number of Eggs Entrained During August, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	1.613×10^8	1.960×10^8	3.573×10^8
Atherinidae			
Unidentified	0	3.266×10^4	3.266×10^4
Carangidae			
Unidentified sp. A	6.943×10^6	3.510×10^6	1.045×10^7
Sciaenidae			
Cynoscion sp.	2.523×10^7	1.235×10^7	3.758×10^7
Menticirrhus sp.	3.152×10^8	7.799×10^6	3.230×10^8
Unidentified	9.112×10^7	1.400×10^8	2.311×10^8
Triglidae			
Prionotus sp.	0	2.694×10^5	2.694×10^5
Soleidae			
Achirus lineatus	5.380×10^6	0	5.380×10^6
TOTAL	6.052×10^8	3.599×10^8	9.652×10^8

Appendix 5C-17. Estimated Number of Larvae Entrained During September, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	2.902×10^9	2.103×10^8	3.112×10^9
Gobiesocidae			
Gobiesox strumosus	1.874×10^6	1.959×10^5	2.070×10^6
Carangidae			
Chloroscombrus chrysurus	1.394×10^7	7.184×10^6	2.112×10^7
Oligoplites saurus	3.013×10^6	2.613×10^5	3.274×10^6
Pomadasyidae			
Orthopristis chrysoptera	2.601×10^4	5.878×10^5	6.138×10^5
Sparidae			
Archosargus probatocephalus	0	3.919×10^5	3.919×10^5
Sciaenidae			
Bairdiella chrysura	2.601×10^4	0	2.601×10^4
Cynoscion arenarius	6.786×10^6	2.613×10^5	7.047×10^6
Cynoscion nebulosus	5.403×10^6	0	5.403×10^6
Menticirrhus saxatilis	2.872×10^7	1.236×10^7	4.108×10^7
Blenniidae			
Chasmodes sp.?	0	2.613×10^5	2.613×10^5
Hypsoblennius hentzi	2.140×10^7	1.611×10^6	2.301×10^7
Gobiidae			
Gibiosoma robustum	4.824×10^7	2.547×10^6	5.079×10^7
Microgobius gulosus	3.627×10^8	4.580×10^7	4.085×10^8
Microgobius sp.?	2.455×10^7	7.946×10^6	3.250×10^7
Unidentified	0	3.266×10^5	3.266×10^5
Triglidae			
Prionotus sp.	0	1.959×10^5	1.959×10^5

Appendix 5C-17. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Soleidae			
Achirus lineatus	1.502×10^7	2.395×10^6	1.741×10^7
Unidentified	0	1.284×10^6	1.284×10^6
TOTAL	3.434×10^9	2.939×10^8	3.728×10^9

Appendix 5C-18. Estimated Number of Eggs Entrained During September, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	9.298×10^7	3.338×10^7	1.264×10^8
Atherinidae			
Menidia beryllina?	0	1.959×10^5	1.959×10^5
Carangidae			
Unidentified sp. A	0	5.878×10^5	5.878×10^5
Sciaenidae			
Cynoscion sp.	2.676×10^6	1.371×10^6	4.047×10^6
Menticirrhus sp.	1.078×10^7	2.221×10^6	1.300×10^7
Unidentified	1.719×10^8	2.913×10^7	2.010×10^8
Soleidae			
Achirus lineatus	1.926×10^6	0	1.926×10^6
TOTAL	2.803×10^8	6.689×10^7	3.472×10^8

Appendix 5C-19. Estimated Number of Larvae Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	3.689×10^8	1.487×10^7	3.837×10^8
Gobiesocidae			
Gobiesox strumosus	1.935×10^6	0	1.935×10^6
Pomadasyidae			
Orthopristis chrysoptera	7.023×10^5	0	7.023×10^5
Sciaenidae			
Cynoscion arenarius	7.023×10^5	0	7.023×10^5
Menticirrhus saxatilis	5.150×10^6	1.792×10^6	6.942×10^6
Blenniidae			
Chasmodes sp.?	2.544×10^6	2.317×10^5	2.776×10^6
Hypsoblennius hentzi	8.210×10^6	3.227×10^6	1.144×10^7
Gobiidae			
Gobiosoma robustum	2.325×10^7	8.113×10^5	2.406×10^7
Microgobius gulosus	1.989×10^8	8.858×10^6	2.078×10^8
Microgobius sp.?	6.140×10^6	1.283×10^6	7.423×10^6
Soleidae			
Achirus lineatus	7.023×10^5	1.025×10^6	1.728×10^6
Unidentified	1.908×10^6	5.619×10^5	2.470×10^6
TOTAL	6.191×10^8	3.266×10^7	6.517×10^8

Appendix 5C-20. Estimated Number of Eggs Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	2.672×10^7	0	2.672×10^7
Sciaenidae			
Menticirrhus sp.	7.023×10^5	0	7.023×10^5
Unidentified	1.709×10^7	0	1.709×10^7
Soleidae			
Achirus lineatus	1.405×10^6	0	1.405×10^6
TOTAL	4.592×10^7	0	4.592×10^7

Appendix 5C-21. Estimated Number of Larvae Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	8.343×10^5	1.447×10^6	2.281×10^6
Gobiesocidae			
Gobiesox strumosus	1.864×10^6	0	1.864×10^6
Atherinidae			
Membras martinica	9.646×10^5	1.308×10^6	2.272×10^6
Syngnathidae			
Syngnathus floridae	0	1.635×10^5	1.635×10^5
Syngnathus sp.	0	1.635×10^5	1.635×10^5
Blenniidae			
Chasmodes sp.?	0	5.675×10^4	5.675×10^4
Hypsoblennius hentzi	5.475×10^6	8.728×10^5	6.348×10^6
Gobiidae			
Gobiosoma robustum	7.235×10^5	1.987×10^5	9.222×10^5
Microgobius gulosus	3.259×10^6	1.500×10^6	4.759×10^6
Microgobius sp.	0	1.987×10^5	1.987×10^5
Soleidae			
Achirus lineatus	0	1.702×10^5	1.702×10^5
Unidentified	0	5.675×10^4	5.675×10^4
TOTAL	1.312×10^7	6.136×10^6	1.926×10^7

Appendix 5C-22. Estimated Number of Eggs Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Sciaenidae			
Unidentified	9.646×10^5	8.172×10^4	1.046×10^6
TOTAL	9.646×10^5	8.172×10^4	1.046×10^6

Appendix 5C-23. Estimated Number of Larvae Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia smithi?	0	2.340×10^5	2.340×10^5
Gobiesocidae			
Gobiesox strumosus	4.491×10^5	2.340×10^5	6.831×10^5
Atherinidae			
Membras martinica	2.994×10^5	5.962×10^5	8.956×10^5
Syngnathidae			
Syngnathus floridae	0	2.646×10^5	2.646×10^5
Syngnathus sp.	0	3.065×10^4	3.065×10^4
Sparidae			
Lagodon rhomboides	0	1.335×10^5	1.335×10^5
Blenniidae			
Hypsoblennius hentzi	5.987×10^5	4.987×10^5	1.097×10^6
Gobiidae			
Gobiosoma robustum	2.245×10^5	0	2.245×10^5
Microgobius gulosus	2.994×10^5	1.532×10^4	3.147×10^5
TOTAL	1.871×10^6	2.007×10^6	3.878×10^6

Appendix 5C-24. Estimated Number of Eggs Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Sciaenidae			
Unidentified	2.994×10^5	1.532×10^4	3.147×10^5
TOTAL	2.994×10^5	1.532×10^4	3.147×10^5

Appendix 5C-25. Estimated Number of Larvae Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Ophichthidae			
Myrophis punctata	0	2.865×10^5	2.865×10^5
Clupeidae			
Brevoortia smithi?	0	3.581×10^4	3.581×10^4
Atherinidae			
Membras martinica	0	1.432×10^5	1.432×10^5
Sparidae			
Lagodon rhomboides	0	2.436×10^6	2.436×10^6
Sciaenidae			
Leiostomus xanthurus	2.437×10^6	3.581×10^4	2.473×10^6
TOTAL	2.437×10^6	2.937×10^6	5.374×10^6

Appendix 5C-26. Estimated Number of Eggs Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Sciaenidae			
Cynoscion sp.	0	3.581×10^4	3.581×10^4
TOTAL	0	3.581×10^4	3.581×10^4

Appendix 5C-27. Estimated Number of Larvae Entrained During February, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Ophichthidae			
Myrophis punctatus	4.683×10^6	4.824×10^5	5.165×10^6
Clupeidae			
Brevoortia smithi	0	6.030×10^4	6.030×10^4
Gobiesocidae			
Gobiesox strumosus	0	1.306×10^5	1.306×10^5
Atherinicae			
Membras martinica	0	2.413×10^5	2.413×10^5
Sparidae			
Lagodon rhomboides	5.854×10^5	3.136×10^6	3.720×10^6
Sciaenidae			
Leiostomus xanthurus	1.171×10^6	1.909×10^5	1.362×10^6
Blenniidae			
Hypsoblennius hentzi	4.747×10^5	3.919×10^5	8.666×10^5
Gobiidae			
Gobiosoma robustum	0	1.959×10^5	1.959×10^5
TOTAL	6.914×10^6	4.829×10^6	1.174×10^7

Appendix 5C-28. Estimated Number of Eggs Entrained During February, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	0	1.306×10^5	1.306×10^5
Sciaenidae			
Cynoscion	1.648×10^6	3.979×10^6	5.627×10^6
TOTAL	1.648×10^6	4.110×10^6	5.758×10^6

Appendix 5C-29. Estimated Number of Larvae Entrained During March, 1977

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Engraulidae			
Anchoa mitchilli	1.036×10^9	2.578×10^8	1.294×10^9
Gobiesocidae			
Gobiesox strumosus	3.006×10^6	2.556×10^6	5.562×10^6
Atherinidae			
Membras martinica	6.803×10^6	6.748×10^5	7.478×10^6
Sciaenidae			
Bairdiella chrysura	0	5.143×10^5	5.143×10^5
Cynoscion arenarius	0	1.870×10^6	1.870×10^6
Cynoscion nebulosus	0	4.408×10^5	4.408×10^5
Leiostomus xanthurus	0	1.306×10^5	1.306×10^5
Menticirrhus saxatilis	0	2.204×10^5	2.204×10^5
Pogonias chromis	5.592×10^6	7.818×10^5	6.374×10^6
Unidentified	1.919×10^6	5.878×10^5	2.507×10^6
Blenniidae			
Hypsoblennius hentzi	7.988×10^6	4.333×10^6	1.232×10^7
Gobiidae			
Gobiosoma robustum	1.362×10^7	1.238×10^6	1.486×10^7
Microgobius gulosus	1.221×10^7	3.894×10^6	2.693×10^7
Microgobius sp.?	0	5.143×10^5	5.143×10^5
TOTAL	1.087×10^9	2.756×10^8	3.843×10^8

Appendix 5C-30. Estimated Number of Eggs Entrained During March, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Clupeidae			
Brevoortia smithi	5.385×10^5	1.159×10^6	1.697×10^6
Engraulidae			
Anchoa hepsetus	3.590×10^5	1.605×10^5	2.056×10^6
Anchoa mitchilli	1.362×10^{10}	6.885×10^9	2.050×10^{10}
Sciaenidae			
Cynoscion sp.	8.028×10^6	7.728×10^6	1.576×10^7
Unidentified	4.784×10^7	3.083×10^7	7.867×10^7
Triglidae			
Prionotus sp.	0	1.070×10^5	1.070×10^5
TOTAL	1.368×10^{10}	6.925×10^9	2.060×10^{10}

CHAPTER FIVE

PART II

MORTALITY TO FISH EGGS EXPERIENCING PASSAGE THROUGH THE COOLING SYSTEM OF THE BIG BEND POWER PLANT AS DETERMINED BY REARING EXPERIMENTS

BY

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INTRODUCTION

General

Planktonic organisms, including fish eggs and larvae, are subject to mechanical, thermal, and chemical damage while passing through condensor tubes of power plants using once-through cooling systems. The laboratory rearing portion of this study was established to attempt to determine the mortality of fish eggs due to their entrainment through the Big Bend power plant. This mortality can be estimated by comparing the hatching and survival rates of eggs collected at the discharge.

Literature Review

The past thirty years have seen an increase of interest in culturing marine fish larvae. The published results of experiments conducted during this time offer successful

techniques for rearing the larvae of some fish species reported in the Big Bend area, including: the yellowfin menhaden, Brevoortia smithi (Houde and Swanson, 1975); the scaled sardine, Harengula jaguana (Houde and Palko, 1970; Saksena, Steinmetz and Houde, 1972; Houde, Richards, and Saksena, 1974); the Atlantic thread herring, Opisthonema oglinum (Richards and Palko, 1969); the bay anchovy, Anchoa mitchilli (Detwyler and Houde, 1970; Saksena and Houde, 1972); the striped mullet, Mugil cephalus (Nash, Kuo, and McConnel, 1974); the white mullet, Mugil curema (Houde, Berkeley, Klinovsky, and Schekter, 1976); and the lined sole, Achirus lineatus (Houde, Futch, and Detwyler, 1970).

Other workers have cultured additional species not found in the Big Bend area (Blaxter, 1962; Jones, 1972; Houde, 1972; Rao, 1974; Houde, 1975; Stepian, 1976; Middaugh and Lempesis, 1976; May, 1976).

May (1971) assembled an annotated bibliography of papers on attempts to rear marine fish larvae, and Shelbourne (1965) and Houde (1973) have both reviewed the subject. Houde and Taniguchi (1977) outlined the procedures used to culture larvae of marine fishes at the Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida.

The detrimental effects of thermal shock on fish eggs and larvae were revealed in laboratory studies conducted by

Hoss, Hettler, and Coston (1974), Schubel and Auld (1974), Schubel (1974), and Frank (1974).

Limitations

The rearing methods we used in our experiments were identical to the procedures suggested by Houde and Taniguchi (1977). Since the physiological requirements of developing larvae are virtually unknown, the effects of the rearing techniques themselves on the survival of the larvae are also unknown. Certainly mechanical damage inflicted on the eggs by collecting and sorting is an inherent problem in any rearing experiment.

The hatching percentages obtained during the experiments may also have been influenced by the developmental stage of the eggs at the time of their collection. Frank (1974) reported that eggs of carp (Cyprinnus carpio L.) were more susceptible to thermal damage during the cleavage and blastopore closing stages than at any other time. Schubel (1974) observed lower hatching percentages of blueback herring, Alosa aestivalis, and alewife, Alosa pseudoharengus, eggs during the blastopore closing stage of development than during other developmental stages, although he found that these differences were not statistically significant.

Because of technical problems involving aeration and the limitations listed above, we were prevented from obser-

ving any long term survival rates. However, we do not feel that we were deterred from fulfilling the objectives of this study.

METHODS

Experiments were conducted whenever eggs were sufficiently abundant. Eggs were collected with a one-meter diameter, 363 μm mesh plankton net from both the intake and discharge of the plant and were returned to the laboratory to be sorted. Using pipettes, one hundred or one hundred fifty eggs of an abundant species (usually Anchoa mitchilli) were simultaneously removed from the raw samples obtained from the plant intake and discharge. The eggs were initially placed into 600 ml Pyrex beakers containing water from the experimental aquaria, before being stocked into ten gallon aquaria. The interval between the time of the collection of the eggs and their introduction to the experimental aquaria (usually an hour) provided time for the eggs (especially those collected from the plant discharge) to acclimate to room temperature. This acclimation period reduced the possibility of the eggs incurring a temperature shock, resulting from the large temperature differences which were often present between the collecting point and the experimental aquaria. Water for the aquaria was obtained from the discharge canal and filtered through a 35um mesh Nitex nylon cloth and a Vortex diatom filter. Eggs from the intake and discharge were placed into separate ten

gallon aquaria. The aquaria were equipped with heaters and aerators and were provided with continuous fluorescent illumination. The rationale for providing a continuous light source was that some larvae become inactive at low light intensities and sink to the tank bottom. Here they could come into contact with toxic sediments and other detritus which could elicit harmful effects (Houde, 1973). Air was supplied by direct lines from the power plant. Wooden air "stones" were adjusted to provide a low air flow to protect the larvae from abrasion caused by turbulence. The heaters were used to maintain the temperature ($\pm$ 1.5°C) in the tanks at a level corresponding to that of the water from the plant intake. (This procedure was later modified to reflect findings by Rebel (1973). He observed the highest survival rates for laboratory reared Anchoa mitchilli larvae at experimental temperatures of 25.6° - 31.0°C. Beginning with our eighth experiment, when the water temperature in the intake canal was 24°C, the temperatures in all the aquaria were maintained at 29° - 31°C. At these temperatures we hoped to obtain the highest possible longevity and survival rates.)

Each rearing tank contained an algal bloom of either Nannochloris occulata or Isochrysis galbana. It has been suggested (Houde, 1973) that an algal bloom removes from the

culture medium toxic metabolic products of both the growing larvae and their food organisms.

The larvae were fed zooplankton, collected with a $\frac{1}{2}$ - meter diameter, 35 μm mesh plankton net. Using different mesh sizes of Nitex nylon cloth, the zooplankton was separated into three size fractions: that greater than 300 microns; that between 110-300 microns; and that between 53-110 microns. Organisms of the smallest size fraction were fed to the larvae on the first day of eye pigmentation. The food size was increased proportionately with the growth of the larvae.

RESULTS

A total of eleven rearing experiments, utilizing eggs from both the plant intake (station I-6) and discharge (station I-1) were conducted during the study period. The majority (98.8%) of the 3,118 eggs cultured were those of the bay anchovy, Anchoa mitchilli. Eggs of the lined sole, Achirus lineatus, the silver perch, Bairdiella chrysura and an unidentified species, comprised .16%, .38%, and .66% respectively, of the total and were reared only in the first of these experiments. No anchovies hatched in the first experiment utilizing eggs from the plant intake and discharge. The identity of the larvae that did hatch was not discernable.

No larvae survived longer than a week in any of the experiments.

The results of the rearing experiments utilizing eggs from both the intake and discharge are summarized in Table 5.19.

Table 5.18. Results of experiments utilizing eggs collected from the plant intake and discharge.

Eggs collected at the plant intake (1-6)-'control'					Eggs collected at the plant discharge		
Date	Exp. No.	% Hatching	Surf. temp. °C	Aquaria temp °C	% Hatching	Surf temp. °C	Aquaria temp °C
7/27/76	1	4	30.5	29-30.5	3	39	29-30
8/9/76	2	35	31.5	31.5-32.5	0	39	30.5-31.5
8/24/76	3	47	30	28-30	7	38	29-30
	4	47	30	30	7	38	29-30
9/14/76	5	60	30	29.5-31	34	38	29-30
	6	60	30	30	32	38	29-30
	*7	40	30	23-24	37.5	38	22-23
3/29/77	8	87.5	24	29-30	45.6	29	30-31
	9	78.8	24	30-31	46.3	29	30-31
5/19/77	10	26.7	25	30	22.7	29	30
	11	25.3	25	30	14.7	29	30
$\bar{X}$		46.5			26.9		

* no water heaters were available for this experiment.

DISCUSSION

The hatching percentages of eggs collected from the plant discharge were always lower than those of eggs collected from the intake (the mean hatching percentages for all experiments conducted were 26.9% and 46.5% for the discharge and intake, respectively). The disparity was apparently caused by the effects of entrainment through the plant. A Student t-test for paired samples was performed on the results of all experiments conducted. This test indicated that there were significant statistical differences ($\alpha = 0.05$) between the hatching percentages of eggs collected from the plant intake and those collected from the plant discharge.

Table 5.19. illustrates that hatching rates were variable, probably due in part to technical problems, but the results seem to indicate that an inverse relationship exists between hatching success and ambient bay temperature. The highest hatching rates of eggs collected from the plant intake (87.5% and 78.8%) and the plant discharge (46.3% and 45.6%) corresponded to the lowest surface temperatures at the intake (24°C) and discharge (29°C). The lowest hatching rates of eggs collected from the plant intake (4%) and the discharge (0%) corresponded to the second highest surface temperature at the intake (30.5°C) and the highest surface temperature at the

discharge (39°C). Hydrographic data indicated that the average monthly surface temperature ranged from 13.6°C to 29.9°C at the plant intake and from 17.4°C to 38.6°C at the plant discharge during the study period. The relationship between hatching success and ambient bay temperatures would have been more clearly defined had experiments been conducted monthly. Because eggs were not always sufficiently abundant and because of mechanical problems with the collecting boat, monthly experimentation was not always practical or possible.

It should be noted that many species of fish found in Tampa Bay have extended spawning seasons (Springer and Woodburn, 1960; see Chapter V, Part I) and that their eggs and larvae are susceptible to entrainment throughout much of the year. Because of seasonal bay temperature fluctuations, the effects of entrainment may be variable. Since spawning activity is low in the vicinity of the plant during the winter months, fewer eggs and larvae are susceptible to entrainment at this time than during the rest of the year. However, as spawning activity increases during the spring and summer months, the susceptibility of eggs and larvae to damage through entrainment also increases. The eggs and larvae are not only more abundant in the vicinity of the plant, they are also subjected to higher ambient and effluent water temperatures. Rebel (1973) reported on the effects of

temperature on the survival of four species of marine fishes from Biscayne Bay, Florida. Two of these species, the scaled sardine, Harengula jaguana, and the bay anchovy, Anchoa mitchilli, spawn in the vicinity of the Big Bend plant during the summer months. He reported that Harengula jaguana eggs and larvae cultured at 35.0°C suffered 100% mortality prior to reaching the pigmented eye stage of development. He also reported that Anchoa mitchilli eggs and larvae suffered 100% mortality prior to reaching the pigmented eye stage if cultured at 35.8°C. Big Bend hydrographic data collected from June through September, 1976 (Peekstok, 1976, 1977) indicated that the average monthly surface temperatures ranged from 35.0°C to 38.6°C at the plant discharge (station 1-1). Clearly, the survival of eggs and larvae of these species at the plant discharge may be threatened by the high temperatures during these months.

Survival of fish eggs and larvae entrained in power plant condensor systems will depend in part on the length of time the eggs and larvae are exposed to elevated temperatures. The length of exposure time in turn depends on the design of the condensor system. Water entering the Big Bend power plant takes approximately 1.5 minutes to flow through the condensor system and into the discharge canal. Time spent in the discharge canal (and therefore continued exposure to elevated temperatures) is variable due to the amount of effluent dis-

charged by the plant, wind direction and velocity, and tidal stage. Hoss, Hettler, and Coston (1971) conducted experiments to determine the effects of increased temperature on the post-larvae of four fish species. Post-larvae of two of these species, pinfish, Lagodon rhomboides, and spot, Leiostomus xanthurus, are found in the Big Bend area in January and February. Hoss, et al. (1971), reported that 50% of the spot and 17% of the pinfish died three to four hours after being exposed to a temperature 10°C above ambient (15°C). The average monthly surface temperature at the plant intake (station 1-6), in January and February ranged from 14.5°C to 18.7°C in 1976 and from 13.6°C to 13.8°C in 1977. The average monthly surface temperature at the plant discharge (station 1-1), during the same months ranged from 17.4°C to 18.4°C in 1976 and from 21.6° to 22.3°C in 1977. Entrained post-larval spot and pinfish were not exposed to a 10°C difference between ambient and discharge water temperatures during these months, however, exposure to the elevated temperatures in the discharge canal, possibly for hours, after having been subjected to mechanical shock incurred while passing through the plant could have threatened the survival of these entrained individuals during January and February.

The difference between the mean hatching rates of eggs collected from the plant intake and discharge indicates there

is an apparent 42.2% mortality of fish eggs caused by entrainment through the Big Bend power plant. This rate seemingly indicates that local fish populations are being steadily reduced. However, many populations possess a compensatory power sufficient to offset substantial amounts of man-induced mortality (McFadden, 1977). McFadden stated that government regulatory agencies and their scientific staffs involved in power plant licensing proceedings have seemed reluctant to credit many fish populations with significant natural compensatory capacity and have been even more reluctant to make quantitative allowances for this capacity when evaluating power plant impacts. McFadden argued that the repeated removal of 25-50% of a fish population and the sustained reduction of abundance of fish to a level below the pre-fishing stock may seen a drastic proposition, but the practice is a normal and ecologically sound treatment that permits fish stocks to operate at maximum productivity.

To what degree compensation may be occurring in fish populations in Tampa Bay is unknown. In addition, because of the great expanse of Tampa Bay, the transitory nature of many of its different fish species, and the lack of research on its fish populations, the stocks of local fish populations also remain unknown. Since fish stocks and compensatory

behavior are at present unknown, the impact of year-round entrainment of fish eggs and larvae on the local fish populations over a long period of time cannot be assessed.

SUMMARY AND CONCLUSIONS

1) A total of eleven rearing experiments, utilizing eggs from both the plant intake (station I-6) and discharge (station I-1) were conducted during the study period.

2) The majority (98.8%) of the eggs cultured were those of the bay anchovy, Anchoa mitchilli.

3) The hatching percentages of eggs collected from the plant discharge were always lower than those of eggs collected from the intake.

4) The results of the experiments seem to indicate that an inverse relationship exists between hatching success and ambient bay temperatures.

5) Fish eggs and larvae are more susceptible to damage caused by entrainment during the summer months than during the rest of the year because of higher ambient and effluent water temperatures and greater relative abundance.

6) Survival of the fish eggs and larvae entrained in the power plant's condensor system will depend in part on the length of time they are exposed to elevated temperatures.

7) Since Tampa Bay fish stocks and their compensatory behavior are presently unknown, the impact of year-round entrainment of fish eggs and larvae on the local fish populations over a long period of time cannot be assessed.

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CHAPTER SIX

A STUDY ON THE DISTRIBUTION AND ABUNDANCE OF INVERTEBRATE MEROPLANKTON AT BIG BEND, TAMPA BAY (FLORIDA)

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INTRODUCTION

General

The invertebrate meroplankton form a unique and important part of the zooplankton. As larvae, they are subject to the vagaries of a planktonic existence, while as adults they constitute a major portion of the benthic fauna. This study is concentrated on the larvae of the decapod crustacea. Adult decapods are an important fraction of the macrofauna, and their life histories are well known. Their larvae are a distinctive and widespread part of the plankton.

The study of meroplankton in the vicinity of the Big Bend electric generating station was initiated in January, 1976 and sampling continued through March, 1977. Sampling design and program objectives were outlined in the Addenda to Prospectus for Ecological Studies at Big Bend Steam Electric Station (Tampa Electric Station), a 316 Demonstration (TECO, 1975) and in conferences with representatives of governmental regulatory agencies (U.S. Environmental Protection Agency, State of Florida Dept. of Environmental Regulation). Specific objectives of the study have been to:

1. identify and enumerate selected meroplankton at source and receiving water stations;
2. calculate numbers of these organisms entrained.

Project Review and Limitations

This project is basically a survey of the meroplankton in the waters around the power plant. Although estimates of entrainment are presented, assessment of the impact of the plant upon the populations involved was not within the scope of this study. There is very little data available on the magnitude of the adult populations producing the larvae, the fecundity of the adults, and the frequency of spawning of individual breeders. There is insufficient data on the current patterns in the area to allow estimation of the areal extent of the populations whose larvae are susceptible to entrainment or which might be affected by drift into the thermal area. The effect of rapid temperature changes on larvae has not been studied. Although some studies on the effect of temperature and other factors on larval survival have been conducted (Costlow and Bookhout, 1962, 1971; Costlow, Bookhout and Monroe, 1966, others) most of this work has been done at higher latitudes than Tampa Bay.

Our more tropical populations might have different tolerances from their mid-Atlantic counterparts. These studies do tend to show that larval decapods can not only tolerate relatively high temperatures (about 30-35°C) but can sometimes flourish at these temperatures. Other factors can influence these results, e.g. sub-optimum salinity for the species tends to lower the thermal tolerance in the species studied. Diurnal temperature fluctuations of 5° or 10°C, on the other hand, tend to raise the survival rate at high temperatures. Rapid temperature rise, as through power plant entrainment, would, of course, subject the organism to a great deal more stress than would gradual diurnal fluctuations.

No effort has been made to quantify mortality from entrainment in this study. Other studies on zooplankton entrainment have found anywhere from 0 to 100 percent mortality (Lauer et al, 1975). This variable mortality is dependent on intake and outfall temperatures, temperature rise, salinity, and the life stage of the individual organisms involved. Other factors such as food availability, pollution by pesticides, organic wastes or heavy metals, availability of oxygen, and plant design and operation (hydraulic stresses, rapidity and duration of the temperature rise, presence or absence of biocides, etc.) may also affect mortality (Cairns et al., 1975; Clark and Brownell, 1973; Vernberg and Vernberg, 1974; Vargo

and Sastry, 1977).

Few published studies have treated meroplankton in any detail. Sandifer (1973) has produced the most complete work to date on the decapod larvae, and also presents a review of the work to that time. His more recent paper (Sandifer, 1975), has helped delineate the roles planktonic stages play in the life histories of the species.

Tagatz (1968) reported several species of crab zoea from the St. Johns River, but most of the data on breeding populations of decapods in Florida came from records of ovigerous females encountered in studies of the adults. These studies (Wass, 1955; Tabb and Manning, 1961; Williams, 1965; Rouse, 1969; Lyons et al, 1971) show two breeding patterns along the coast of Florida. Northern Florida animals generally breed through the warmer months, while the southern Florida crustaceans show year round breeding, with more species breeding in fall, winter, and spring than during the mid-summer.

In their study of Tampa Bay macrozooplankton, Kelly and Dragovich (1967) used a large (1.024 mm) mesh net which allowed most types of early decapod larvae to pass through, though it did retain penaeid postlarvae, porcellanid crab larvae, and later zoea of some other forms. Quantitative comparison with the present study is therefore inappropriate for most forms.

In terms of total numbers, the decapod crustaceans compose a rather small portion of the meroplankton. Kelly and Dragovich (op cit.) found much of their plankton to be crustacean meroplankton. Their large mesh net did not capture most of the smaller forms which compose a majority of the meroplankton. Hopkins (1966) reported that decapod larvae averaged only some 2.5% of the larval forms collected with a #10 mesh (155 μ mesh diagonal) net. Even with this net, he found that pelecypod veligers were not quantitatively sampled, as most were even smaller than this mesh size. Comparative tows with a #20 mesh (99 μ diagonal) showed nearly five times the number of these veligers as the #10 mesh samples.

METHODS

Samples taken for the ichthyoplankton program were also utilized for meroplankton studies. Sampling methodology (oblique tows with a 1 m diameter 363 μ mesh net) is discussed in the ichthyoplankton section of this report (Chapter 5). Station locations are shown in Figure 5.1 in that section. This sampling design was suggested and approved by the regulatory agencies. Supplementary oblique (January-March, 1975) and vertical (April, 1976 - February, 1977) tows were taken with a 30 cm or 50 cm #20 mesh (75 μ bar mesh) net.

These tows were used for qualitative observation of the smaller

meroplankton present. In addition, mollusk veligers and brachiopod larvae were also counted when encountered in the phytoplankton samples.

Samples were sorted using an Olympus TM300, and Bausch and Lomb Stereozoom and Stereozoom 7 dissecting microscopes. Final identifications were normally made using the B and L Stereozoom 7. Certain fine details were checked using a B and L Dynazoom compound microscope. After thoroughly agitating the sample, aliquots of the samples were taken using 10 ml capacity Tippet dispensers. All decapod crustacean larvae were removed from the sorting dish and placed in numbered vials. Specimens of the other taxa were also held for reference, but most of these specimens were counted without picking them out. Aliquots were taken and sorted until at least 200 decapod larvae were counted. All aliquots were sorted completely. If fewer than 200 decapods were found, the entire sample was counted.

During the warm months, meroplankton abundance was very high. Samples with high numbers of meroplankton were sorted in the usual manner, but in addition, an extra set of aliquots was sorted. For the second set, decapod species with over 30 individuals represented in the first set (i.e. the dominant species) were not counted. Aliquots were taken until at least another 100 decapod larvae were sorted and identified. Usually

no forms other than decapods were counted from the second set of aliquots. Data was stored in the computer as raw counts to facilitate corrections. Conversion of the data was made to numbers per cubic meter and these values were used for analytical procedures and interpretation of abundance levels.

Identification

An artificial key to the larval decapod crustacea of the Big Bend area is presented in Appendix 6A. It includes a bibliography of the literature used to identify decapods in this project. Many other works were consulted from time to time, but were not of direct use in identification and thus are not included.

In recent years, the identification of decapod larvae to species or genus has been simplified by the many studies in which larvae have been reared in the laboratory from the first zoea through metamorphosis (see Appendix 6A). Before these rearing techniques were established, larval identification relied solely on the study of larvae from the plankton. In these cases, the first stages were hatched from gravid females. Late stage larvae from the plankton were held through metamorphosis into the juvenile form. Intermediate stages were described from similar larvae found in the plankton. This method must be used with caution, as larvae of similar species might not be distinguished.

Identification of larvae preserved from plankton samples may present some problems even if the species has been described, since the pigmentation fades fairly rapidly and this major aid to identification becomes useless. This is especially important with damaged specimens where some other character might also be useless. While many forms of decapod larvae have been described, some species inhabiting Tampa Bay are still undescribed. Some of these are recorded as unknown species (i.e. Brachyura sp. A), but it is possible that some undescribed form might have been confused with another species within the same genus or sub-family. Thus, genera with both known and unknown forms present might only have the described form recognized. This is because it is impossible to give each individual the intense study necessary to check all the diagnostic features of the species (especially setation of the endopodites of the maxillipeds and mouth parts).

Many of the caridean shrimp have been examined by Dr. Sheldon Dobkin of Florida Atlantic University to verify our identifications.

RESULTS AND DISCUSSION

General

Total meroplankton as sampled by the 363 μ mesh net showed two peaks of abundance, one in April and the other in October (Figure 6.1). Decapod larvae accounted for 94% of the larval forms recorded overall. Only in the coldest months, when decapod larvae were rare, did other larval types make up a large proportion of the catch.

A total of 105 taxonomic groups were recorded in the 363 μ mesh net samples (Appendix 6B). These included 86 of decapod crustacea taxa and 19 miscellaneous forms of 7 phyla (including Arthropoda). Some 38 decapods were recognized to species while 24 other forms were found which were assigned to arbitrary specific names according to varying higher taxonomic orders (e.g. Pinnixa sp. B, Alpheidae sp. A, Brachyura sp. A) and 24 forms were recognized only to genus or family. Those identified to genus or family only included some forms of damaged larvae whose identity were uncertain, and postlarvae with the adult characters not discernable. Others were genera within which species differences could not be discerned (i.e. Uca spp.).

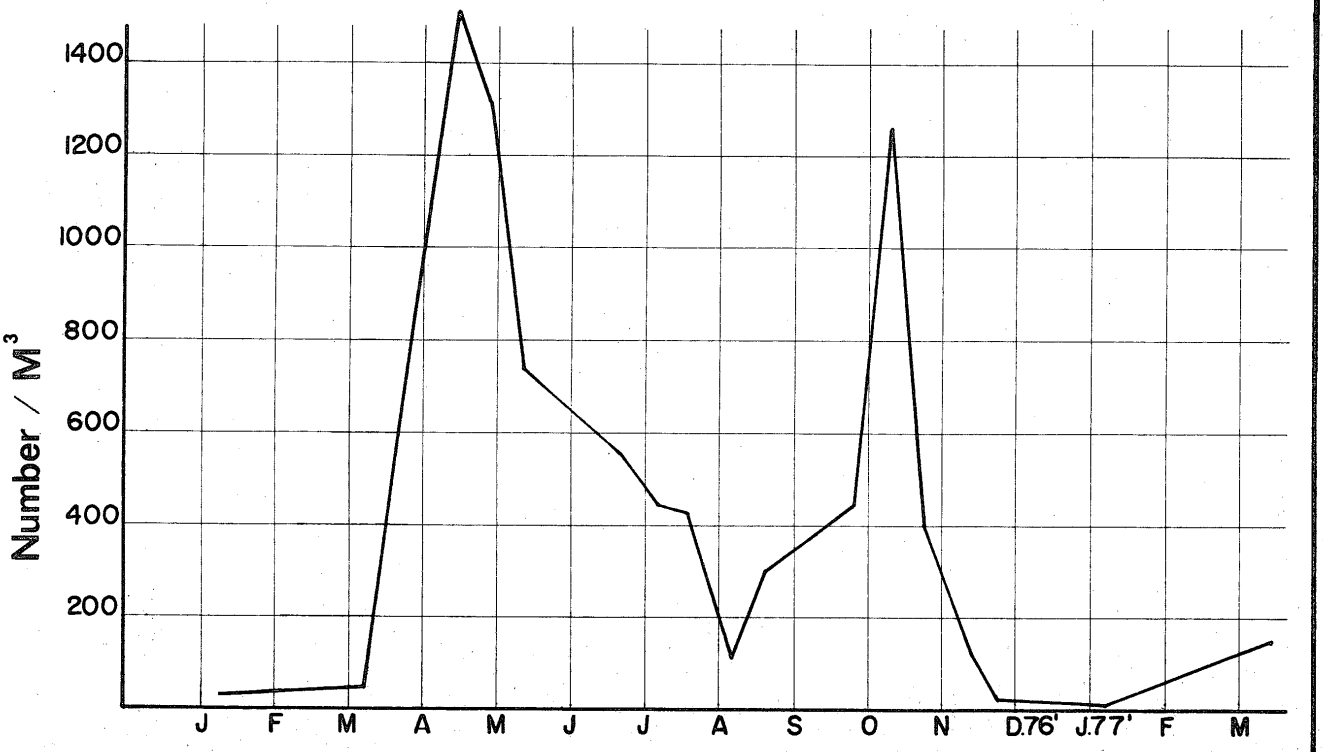

Figure 6. 1. Total meroplankton abundance, average of all Big Bend stations (day and night) over the study period.

Forms other than arthropods were identified only to the major taxonomic level.

A list of species and abundance at each station for each sampling period has been presented in the quarterly reports (Blanchet, 1976 a and b, 1977 a and b; Avery, Leverone & Blanchet, 1977). These reports present the data for each species without respect to larval stage. The data by stage was too voluminous for inclusion in the reports. Persons with an interest in this data can obtain it from Conservation Consultants, Inc. (P. O. Box 35, Palmetto, Florida 33561).

The average daytime water temperatures for some representative stations are presented in Figure 6.2. For more detailed discussion of physical parameters, refer to the Hydrographic section of this report. (Chapter Two).

The following discussion is intended as an outline of the findings of the meroplankton samples taken over the study period.

Species Composition and Seasonal Abundance

Penaeid Shrimps

Penaeus duorarum, the pink shrimp, was found only in the late postlarval stages. Numbers of this species were quite low; only 24 specimens were found during the entire study. Of these, only one was captured in the daytime (October 9 sample).

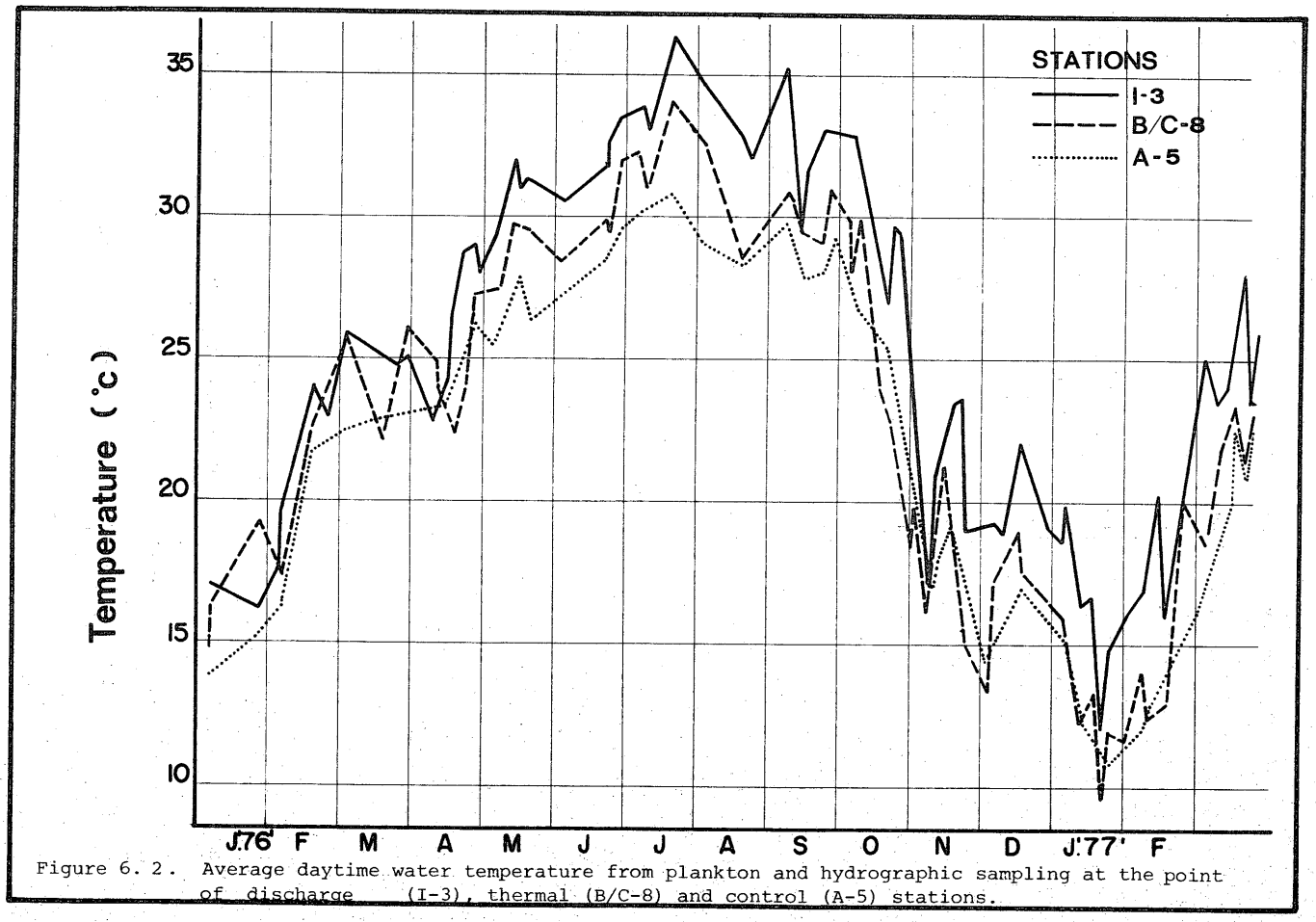

Figure 6. 2. Average daytime water temperature from plankton and hydrographic sampling at the point of discharge (I-3), thermal (B/C-8) and control (A-5) stations.

Three were found at the discharge, in samples from October 22 and November 22. The rest of the specimens were found in July and August samples from several stations, the greatest number (11 total) from station B/C-8. Thorhaug et al. (1971) found the thermal death point (LT100) of the first and second postlarval stages of pink shrimp to be approximately 38° (died within 2.5 hours), with some mortality to the first stage at temperatures as low as 34.9°C with longer experimental exposures (25 hours). Second stage postlarvae were not tested past 2.5 hours. Big Bend effluent temperatures were above 35°C for much of July, August, and September, and entrained postlarvae were probably significantly stressed throughout this period.

A single damaged penaeid postlarva, probably Trachypenaeus or Sicyonia, was found in the daytime discharge sample on August 3. This was the only penaeid found other than P. duorarum.

Caridean Shrimps

Six caridean families were represented in our samples. Altogether, they represented approximately 5% of the decapod larvae found. The seasonal distribution of the six most abundant caridean shrimps is summarized in Figures 6.3 and 6.4. Though larvae of these species were found year round or nearly

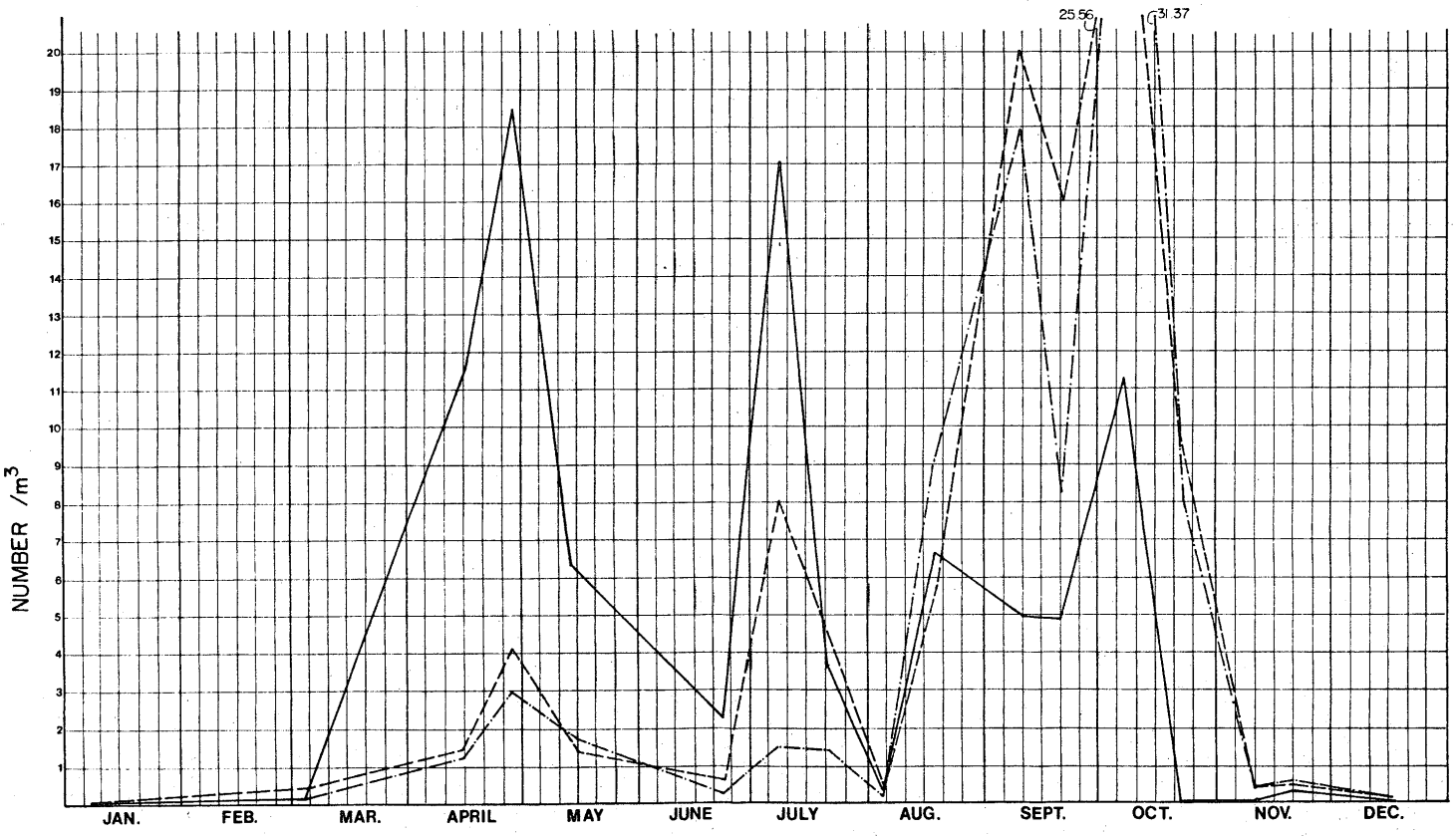

Figure 6.3. The average number per m^3 of the larvae of three caridean shrimp species from January, 1976 to March, 1977 at Big Bend. (--- Ambidexter symmetricus, —— = Alpheidae sp. A, —·—·— = Periclimenes spp.).

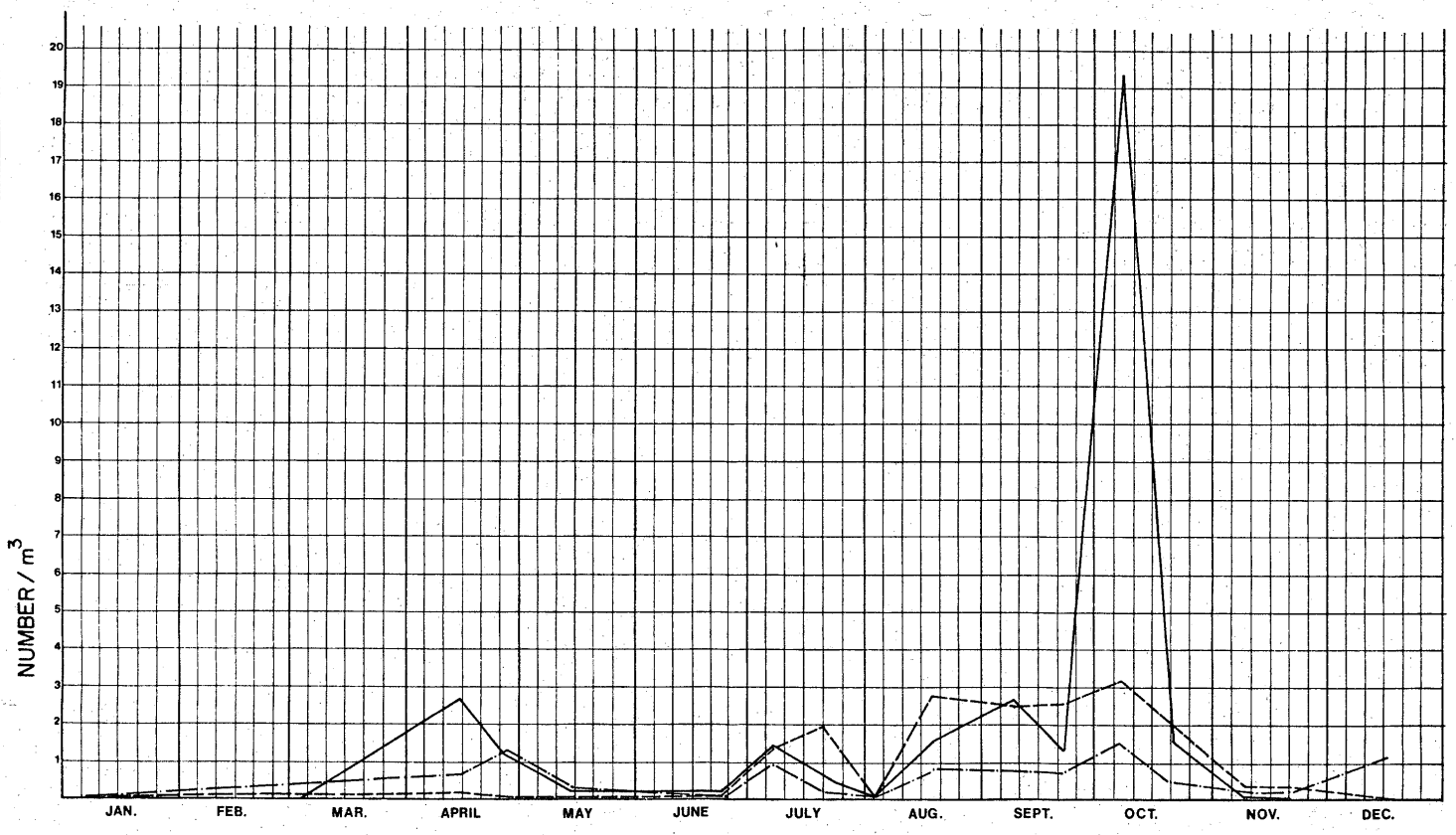

Figure 6.4. The average number per m^3 of the larvae of three caridean shrimp species from January, 1976 to March, 1977 at Big Bend (--- = Ogyrides limicola, —— = Latreutes parvulus, —·—·— = Hippolyte spp.).

so, there are generally one or two strong peaks in abundance. Our abundance figures are presented as an average of the 20 stations (10 day, 10 night) for each sampling period, however, high variation did exist between stations.

The most abundant caridean overall has been tentatively identified as Ambidexter symmetrius (Processidae). The larvae of this species have not been previously described, but are easily distinguished from larvae of Processa, the only other genus reported as an adult in the vicinity. The identification of this larva as Ambidexter is based on a series of eight zoeal stages and postlarvae taken in the plankton during this study. As in other processids, the bases of the antennules are well separated, but the antennules are curved so that one third along their length they are separated only by slightly over half the width of the antennule. In other processids the antennules remain separated by more than their width. More complete description of this larval type (appendage setation patterns, etc.) was not possible due to the time limitations and scope of this project, but hopefully will be pursued at a later date. Figure 6.3 shows the occurrence of Ambidexter larvae through 1976. The major spawning peak coincides with that of Periclimenes spp. Larvae of Processa spp. were also recorded in low numbers mostly from August through

December (greatest numbers in October).

Although no species were identified, five forms of larvae were assigned to the family Alpheidae. The most abundant form, Alpheidae sp. A, is probably of the genus Alpheus (Dobkin, pers. comm.). Its seasonal distribution is shown in Figure 6.3. Larval abundance indicates three breeding pulses between April and the middle of October. More second stage zoea were found than first stage on every sampling date in this period. First stage outnumbered second stage in March and November samples, but abundance of all stages was low at these times (1-3/m^3 total). Although we have not attempted to measure the duration of each stage, many rearing studies of other decapods report approximately equal lengths to the zoeal stages within a species. The abundance of second stage zoea suggests that a significant portion of the larvae of this species comes from outside the study area (assuming each stage is of similar duration). Larvae from areas external to the study area would be older when they drifted into the area than larvae produced locally, and would more likely be recruited at some stage after stage I zoea.

Alpheidae sp. A. was more than ten times as abundant as the next most common alpheid.

Periclimenes spp. was the most abundant palaemonid shrimp. Its seasonal distribution is summarized in Figure 6.3. Periclimenes americanus and P. longicaudatus were found as postlarvae in our samples and as adults in the otter trawl (see Chapter 8) and the benthic grab (see Chapter 4) samples in the area, with P. americanus seemingly more common. No attempt was made to distinguish these species; the larvae were very similar. P. americanus was hatched out, but no ovigerous P. longicaudatus were found for direct comparison of specimens, and there were no distinguishing characters between laboratory hatched larvae and those from the plankton to help separate the two forms. Lyons et al. (1971) found ovigerous P. americanus from May through September, while Tabb and Manning (1961) found them in October and December through April, and Rouse (1969) recorded ovigerous specimens year round, most prevalent in March and April. Rouse (op cit.) also recorded P. longicaudatus as breeding from September through April, but mainly in February and March. From our samples, the main breeding season in the Big Bend area is from August through October. First stage zoea were still relatively common (five per m^3) in the samples from October 21, indicating that breeding persisted at least until then.

The family Ogyrididae was represented by larvae identified as Ogyrides limicola. O. yaquiensis is known to occur in

Florida south of Tampa Bay (Rouse, 1969). Chace (1972) suggested that these two forms might be variations of a single species. Larval development of O. yaquiensis has not been described, and such a study might help elucidate the relationship of these two forms. No differences were noted, however, between our larvae and O. limicola as described by Sandifer (1972). Occurrence of Ogyrides larvae is presented in Figure 6.4. The large peak on October 7 is due to very large numbers of larvae found at the discharge and at the open bay control stations E-5, B/C-5 and A-5.

Larvae of Latreutes parvulus and Hippolyte spp. accounted for most of the hippolytid specimens in the samples. Hippolyte larvae were found year round in low numbers, while L. parvulus was most common from July through October (see Figure 6.4).

The family Pasiphaeidae was represented by larvae of Leptochela sp. (probably L. serritorbita) which was found in low numbers in samples from August to January (highest in October).

Macruran Shrimps

The family Callianassidae was represented by four larval types of Callianassa spp. in low numbers, and by Upogebia affinis. Upogebia larvae were the third most abundant larval type found. Seasonal distribution of the larvae by stage is

shown in Figure 6.5. There is some indication in the August 18 samples that breeding may have started again outside the study area somewhat more rapidly than within the area, after the mid-summer depression, shown by the abundance of second and third stage zoea in these samples. Sandifer (1973) reported most specimens as occurring above 23°C, with peak abundances at 25-27°C. This correlates well with our findings, though Sandifer (op cit.) found his largest numbers from June to October, while our highest numbers were found in spring and early summer samples.

Two larval specimens provisionally identified as Naushonia sp. (N. portoricensis?) of the family Laomediidae were found. One third stage larva was found on October 21 in the daytime sample from the intake (station I-6). A damaged stage V (?) was found at station O-8 on September 23 in the daytime. These larvae fit the description of Gurney and LeBour (1939) from Bermuda specimens in most respects, but they lack the pleural hooks on the first abdominal segment. This is the first record of this genus from the Gulf of Mexico (Dr. Anthony J. Provenzano, Jr., Old Dominion University Institute of Oceanography, Norfolk, Virginia, personal communication July 12, 1977).

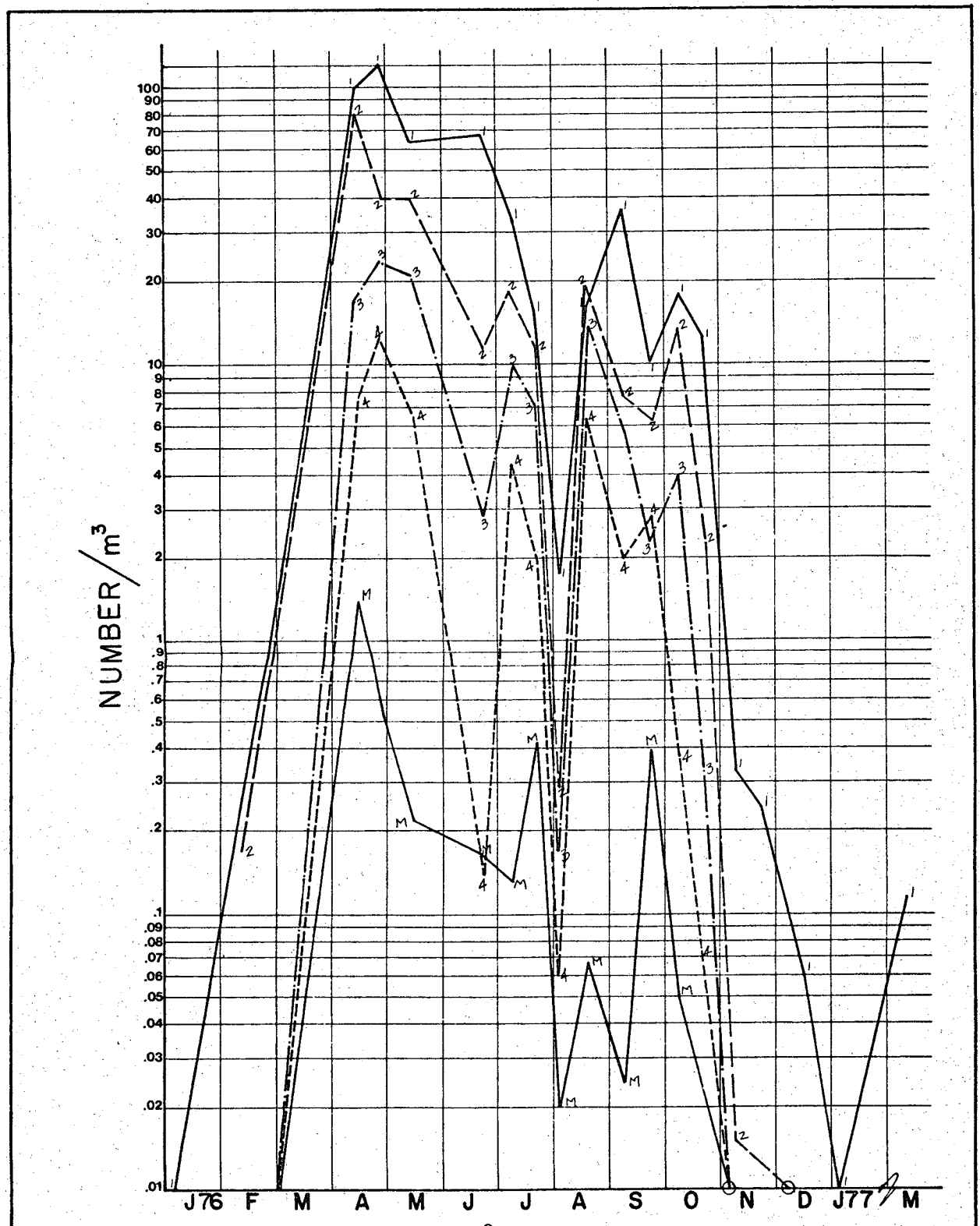

Figure 6.5. The average number per m^3 of the larval stages of Upogebia affinis from January, 1976 to March, 1977 at Big Bend. An open circle indicates <0.01 per m^3 average.

Anomuran Crabs

Larvae of Polyonyx gibbesi (family Porcellanidae) were the second most abundant larval type in our samples. Seasonal distribution of these larvae by stage is shown in Figure 6.6. Abundance of the larvae was quite variable between stations; large swarms were noted throughout the area during the warm months. They were abundant enough to become matted on the travelling screens of the plant intake (see Impingement section, Chapter 7). These mats were composed of both first and second stage zoea, with the second stage predominating. This larva was one of the few species which was commonly found to be more abundant in intake than discharge samples. This may have been due to the removal of the larvae by the screens, or some other unknown factor. Sandifer (1973) found most of his larvae of P. gibbesi in bottom tows, but we have observed many swarms of these zoea near the surface in the daytime. Though swarms are not so easily seen at night, they were noted occasionally.

More P. gibbesi larvae were found in daytime samples than at night in all samples in which they were abundant, except on September 22 when both zoeal stages were more abundant at night.

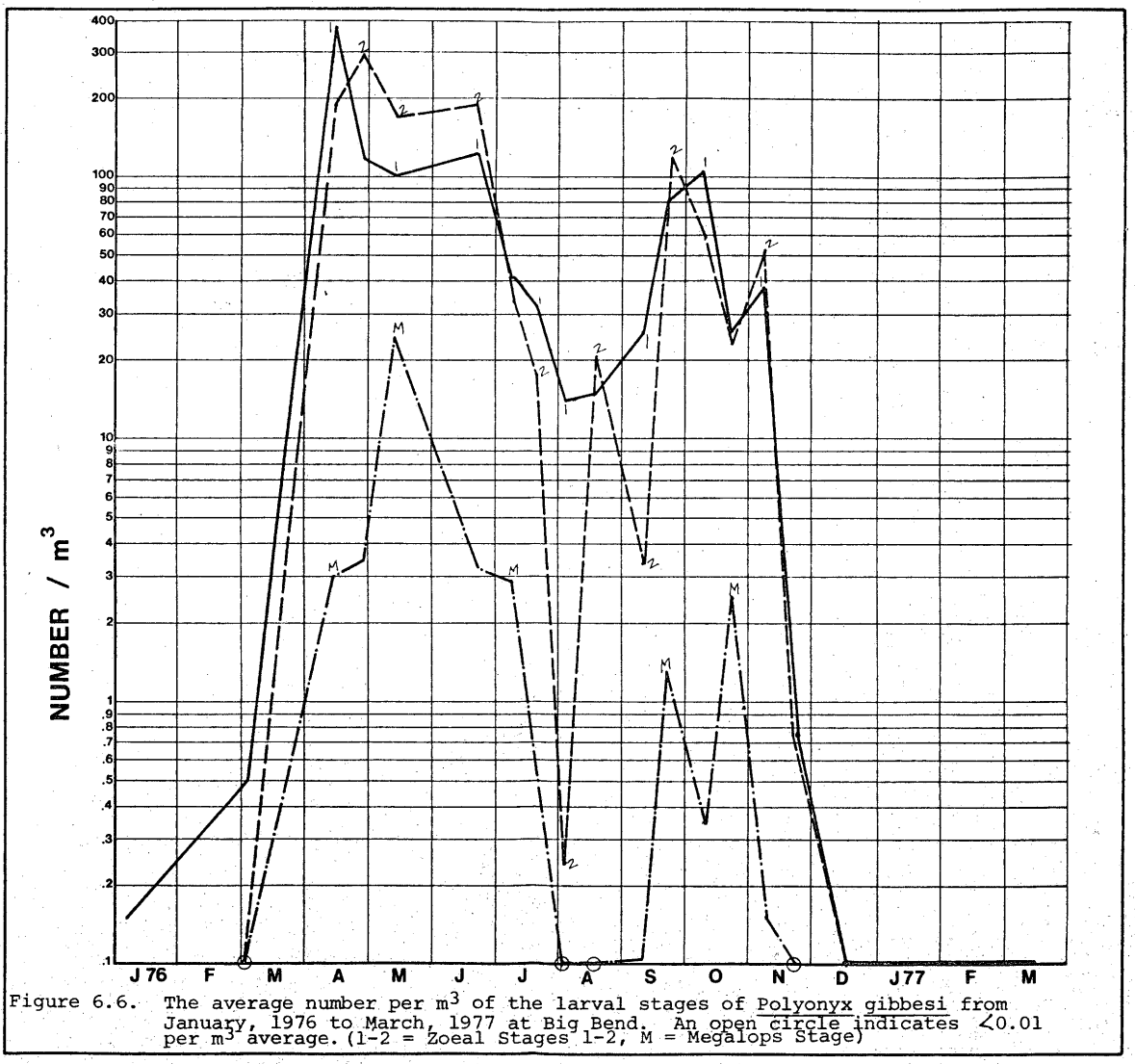

Figure 6.6. The average number per m^3 of the larval stages of Polyonyx gibbesi from January, 1976 to March, 1977 at Big Bend. An open circle indicates <0.01 per m^3 average. (1-2 = Zoeal Stages 1-2, M = Megalops Stage)

Sandifer (op cit.) found some 10% of his P. gibbesi larvae as megalopae, nearly all in bottom samples. About 2% of our larvae were megalopae, but this may be due to the larvae occurring below the level sampled by the net.

Petrolisthes spp. larvae were found in all months sampled except March, but were very rare in November, December, and January. Throughout the rest of the year, numbers of zoea were low, and megalops rarely found.

In general, our figures for abundance of porcellanid larvae agree well with those of Kelly and Dragovich (1967) for their station (Station 13) in the present study site.

Two species of hermit crab (Paguridae) were commonly found. Pagurus longicarpus was the more common species, and was found mostly from late October through April (highest from January to April). Paguridae sp. A was found year round but was highest in September and October. Fogeringham and Bagwall (1976) found a slightly longer breeding season (September-May) for P. longicarpus, but a similar separation of breeding seasons of the hermit crabs of the northeast coast of Texas.

Brachyuran Crabs

Larvae of a leucosiid crab tentatively identified as Persephona aquilonaris (see Blanchet, 1976b) were found in

samples from all months except January. Four zoeal stages and a megalops were recorded. Larvae were common from April through August, with the highest numbers in April samples.

Six species of xanthid crabs were common to abundant as larvae in the samples. Their seasonal pattern of occurrence is presented in Figure 6.7.

Rithropanopeus harrisi zoea were most abundant at slightly cooler temperatures than other xanthids and were almost entirely absent from the warmest part of the summer. Though following the other four species (Neopanope texana, Hexapanopeus angustifrons, Panopeus herbstii and Menippe mercenaria) in spawning during the April and September seasons, Eurypanopeus depressus larvae did not show the mid-summer spawning peak, but remained relatively low. The other four species presented showed similar patterns of abundance, with three spawning peaks in April, July, and September-October.

Menippe mercenaria was common from April through October, but was never abundant. First stage larvae were far more numerous than any other stage, and comprised some 78% of the specimens found. In contrast, 51% of the Neopanope texana larvae found were stage I zoea. Thorhaug et al. (1971) found thermal death points for Menippe zoea to be between 33° and 36°C, and for the zoea/megalops molt to be near 31°C. Big Bend effluent temperatures from the middle of May until the

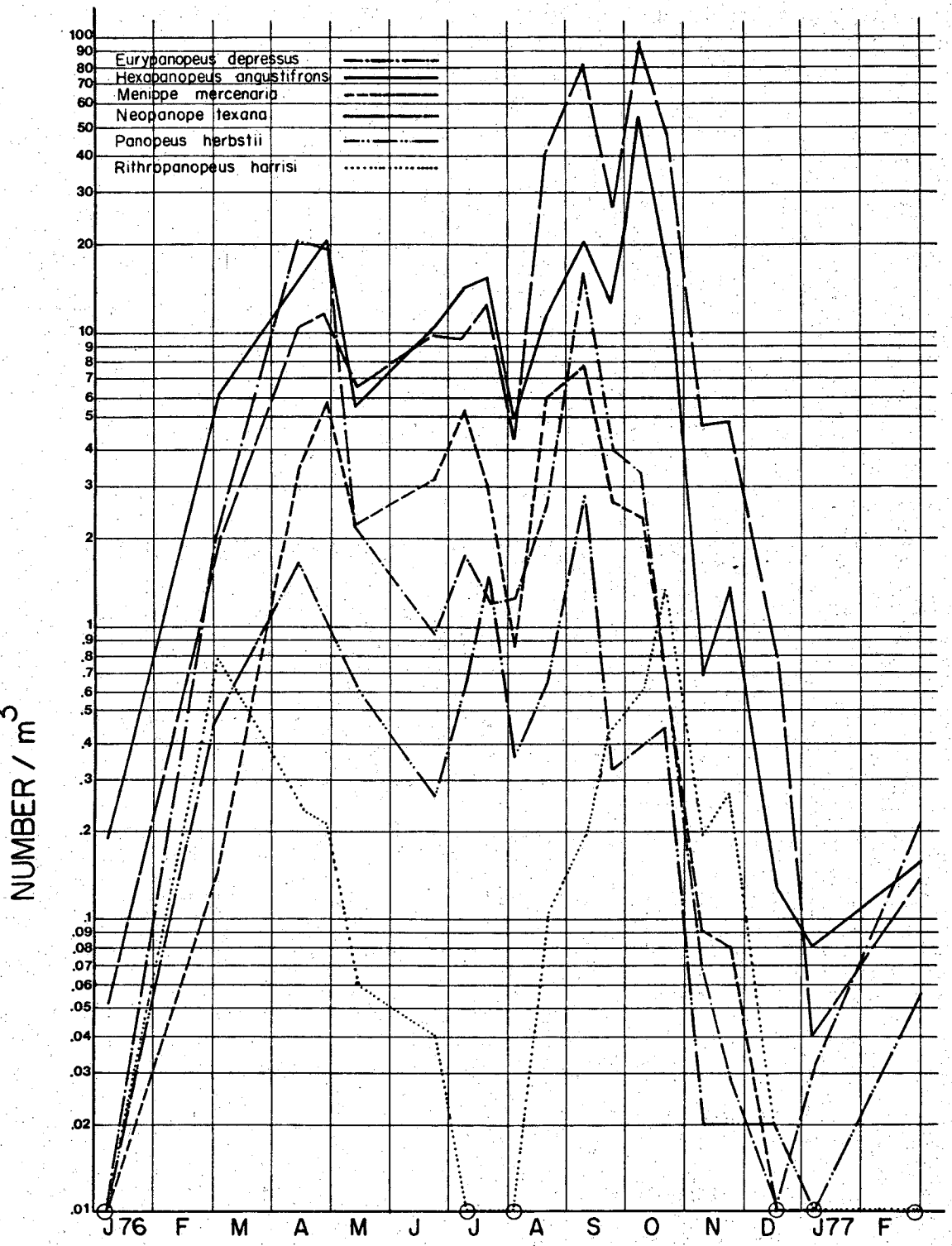

Figure 6.7. Abundance of the six most common types of xanthid crab larva in the Big Bend area, January, 1976 to March, 1977. An open circle indicates <0.01 per m^3 average.

middle of October probably would stress the zoea of this species. Even ambient bay temperatures would seem to affect the molt to the megalops through the hottest part of the summer (see intake temperatures in the Hydrographic chapter).

Neopanope texana and Hexapanopeus angustifrons were the most abundant xanthid species overall, and the fourth and fifth most abundant decapod species. Their larval abundances by stage are presented in Figures 6.8 and 6.9. In both species the late summer/fall breeding season was the strongest, and seems to be bimodal.

Rouse (1969) found Neopanope texana to be ovigerous in the winter, while Lyons et al. (1971) found that the species bred from February to October.

In southwest Florida, Hexapanopeus angustifrons was ovigerous year round, but most commonly between February and July (Rouse op cit.). In Chesapeake Bay, Sandifer (1973) found the larvae from June to October [highest numbers reported in August (25-26°C)]. In North Carolina Williams (1971) found the abundance of megalops highest in August and September. The megalopae found in the present study were often damaged. Problems in distinguishing between the larvae of H. angustifrons and N. texana at this stage were common. The relative abundances of the two species at this stage is subject to some error because of this problem.

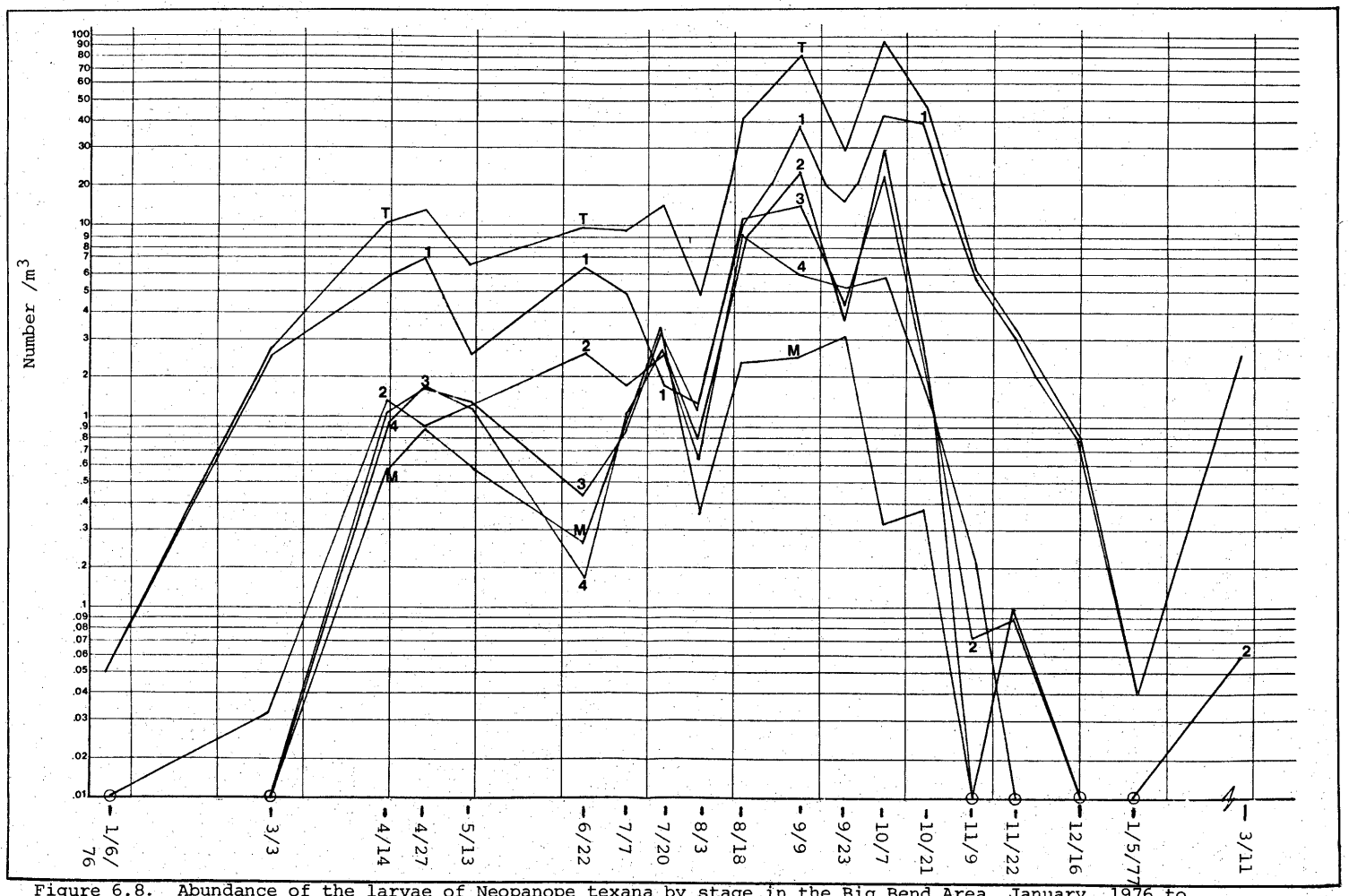

Figure 6.8. Abundance of the larvae of Neopanope texana by stage in the Big Bend Area, January, 1976 to March, 1977. (1-4 = zoeal stages 1-4, m = megalops stage, T = Total Numbers). An open circle indicates <0.01 per m^3 average.

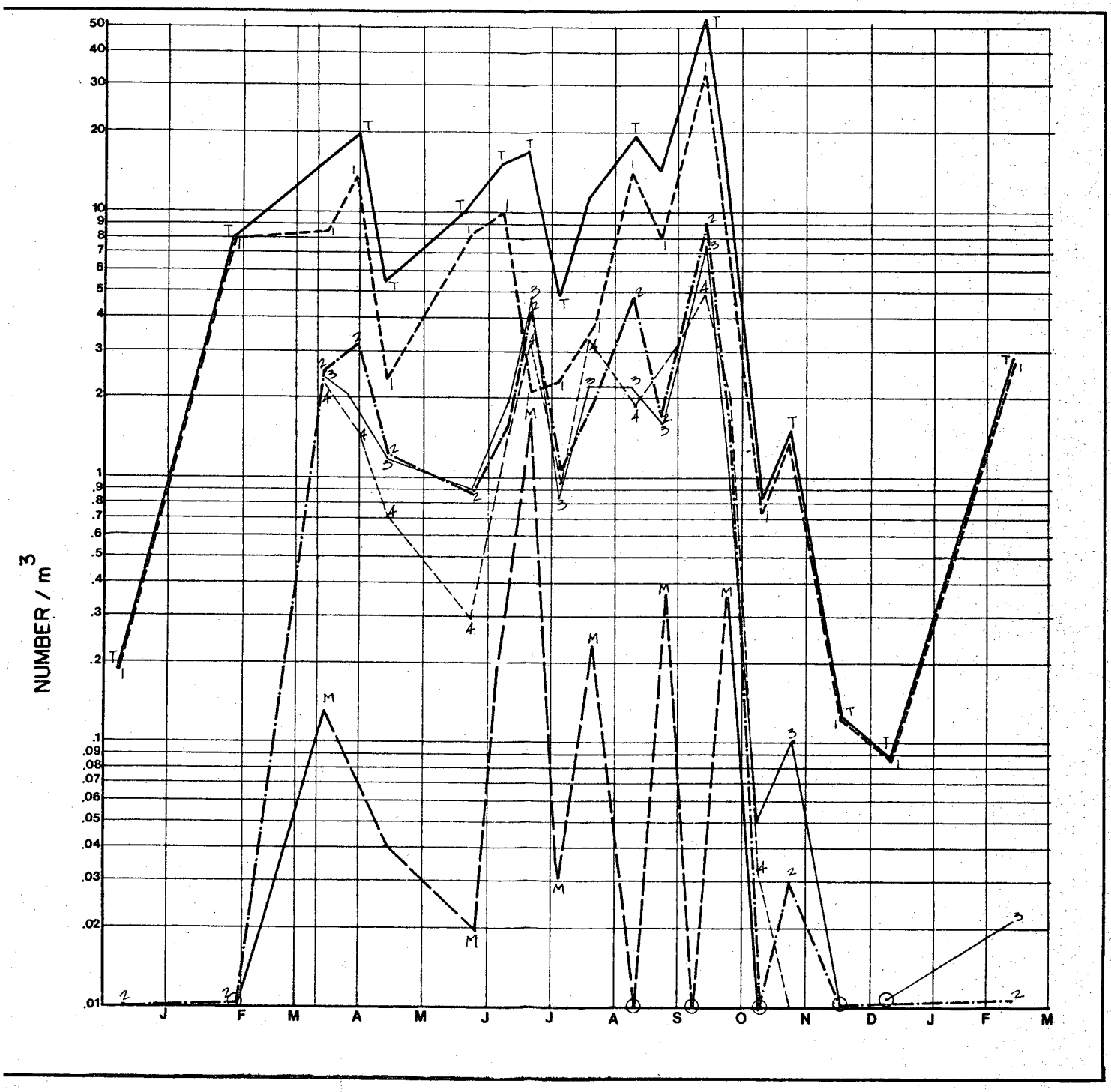

Figure 6.9. Abundance of the larval stages of Hexapanopeus angustifrons in the Big Bend area, January, 1976 to March, 1977. An open circle indicates < 0.01 per m^3 average. (1-4 = zoeal stages 1-4. M = megalops stage, T = Total Numbers).

Both N. texana and H. angustifrons had unusually high relative abundances of late stage larvae in some mid-summer samples. The large numbers of late stage zoea relative to the stage I in the July 20 samples indicate a recent, rather abrupt end to the production of larvae in the area. In August 18 samples, stage I zoea were still rather low, while later zoea increased well over the previous samples' level. These later stage zoea were probably produced outside the study area and were carried into the area by currents, as the low numbers of stage I zoea indicated that breeding within the area was still at a low level.

Pinnixa sayana was the most abundant decapod in the samples. Its seasonal distribution is shown in Figure 6.10. Two major spawning peaks were found, in April and October, with a smaller peak in July. As with Neopanope texana and Hexapanopeus angustifrons larvae, later stage zoea were more abundant than stage I just previous to and at the end of the mid-summer depression in breeding. Stages III and IV also show high values relative to stage I in May 13 samples, after the spring spawning peak. The abundance of the postlarval stage of P. sayana is presented, but may not be accurate, as this stage may not be constantly pelagic. The gross morphology of the stage certainly suggests a benthonic existance, as the body shape and the form of the abdomen and perieopods do not

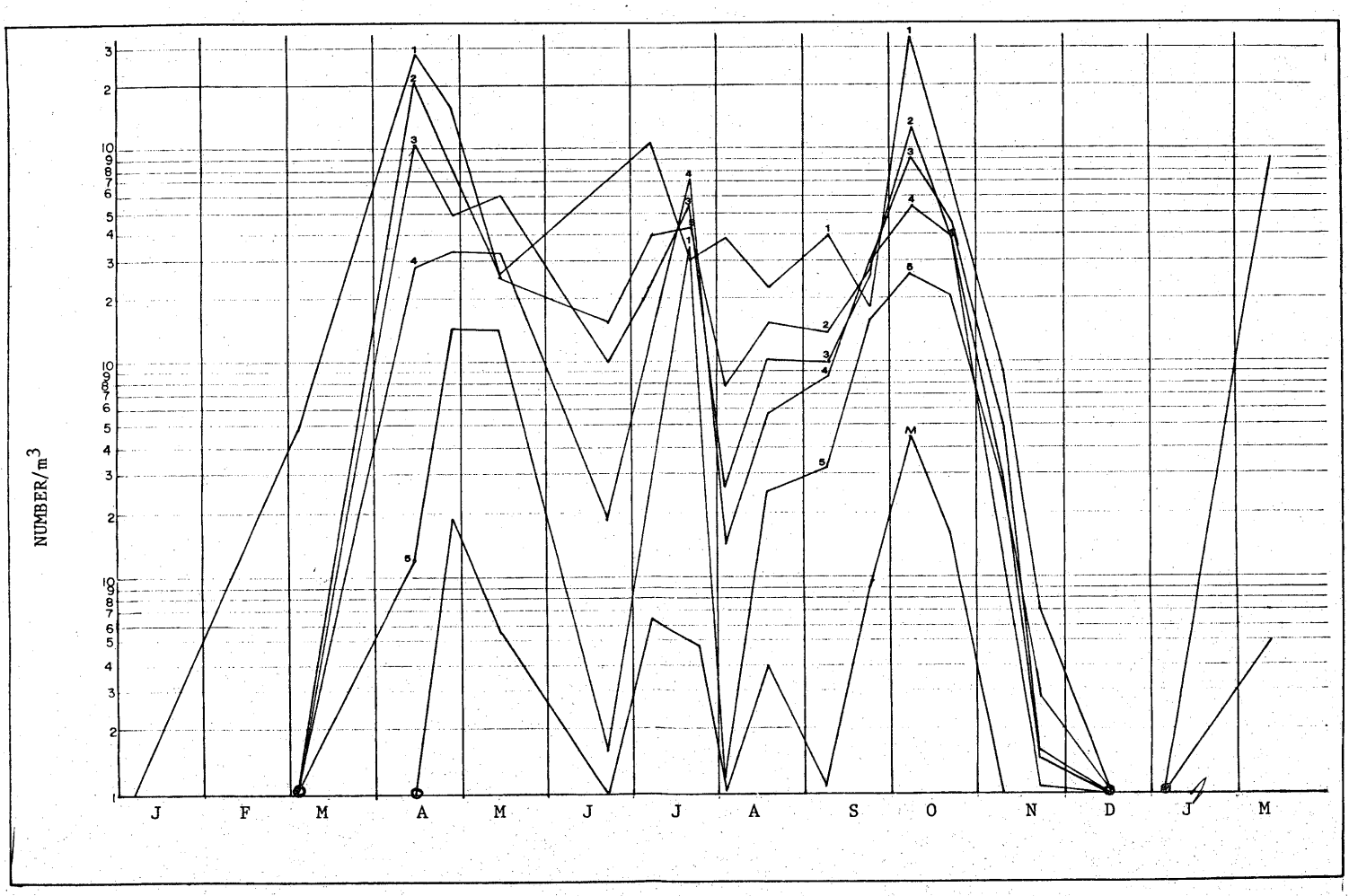

Figure 6.10. Abundance of the larval stages of Pinnixa sayana in the Big Bend area January, 1976 through March, 1977. An open circle indicates <0.1 per m^3 average. 1-5 = zoeal stages 1 through 5. M = megalops stage.

seem adapted for swimming.

Several other pinnotherid species were found, including Pinnixa chaetopterana, Pinnotheres maculatus, unknown species of Pinnixa (sp. A and sp. B) and Pinnotheres (sp. A and sp. B). Pinnixa chaetopterana was found year round, and was common from April through October. Pinnotheres maculatus was also most common in this period, but was not as abundant as P. chaetopterana. Other pinnotherid species were rare, and in general were found only from April to October at Big Bend. The same species were more common in samples from the Port Manatee area (Blanchet, 1976c), where salinity, substrate, and other factors may be more favorable to these species.

In samples from April through June, Uca spp. was combined with Sesarma spp. and identified only as Grapsizoea spp. (Blanchet, 1976b). Most of these larvae are probably Uca, as the stage II larvae are generally more abundant than stage I through most of this period, an anomaly caused by the size of these stages in Uca.

Larvae of Uca spp. were only occasionally found from November to March, but were common through the rest of the year. The early larvae of this genus are so small that many of the stage I and perhaps some of the stage II zoea are not captured by the 363 μ mesh net used for sampling, leading to

underestimation of the abundance of these stages. Stage II Uca spp. were nearly always more abundant than stage I when this genus was identified. The larvae of Sesarma spp. are somewhat larger, and stage I outnumbered stage II through the part of the year when the genus was separated from Uca. The larvae of Uca were more common than Sesarma through this part of the study period. Considering this, and the Uca-like abundance of stage II zoea in the April-June samples, it seems reasonable to assume that Uca was also the dominant form in these samples.

Grapsizoea were most abundant in late April and in May samples. Late stage Uca (stages IV, V, and megalops) were abundant in late July and all stages of Uca peaked in late August, followed by a general decline until November.

Sesarma cinereum were most abundant in July and August samples, while numbers of individuals of S. reticulatum were highest in September. Maximum average abundance of both forms of Sesarma was only around 2 per m^3. Except for a few first stage zoea of each species recorded on November 22, no Sesarma were found from the last of October through March.

Portunid crab larvae were rare in all samples. A few Callinectes zoea were recorded from April to September. An unknown portunid zoea (Portunidae sp. A) was recorded in a few samples from April through December. The few portunid

megalops found were too damaged to identify to genus. They were recorded in July and November.

Miscellaneous Forms

Very little analysis was done on the meroplankton other than the decapod larvae. The abundance of most of these other forms is grossly underestimated by the mesh size of the net used for this study. As previously mentioned, 75 μ mesh net samples were taken along with the 363 μ mesh samples. Most of these samples were not analyzed quantitatively (due to the limited scope of this study), but the abundance of meroplankton has been reported for one date, January 6, 1976 (Blanchet, 1976a). These abundance figures are similar to those presented by Hopkins (1966), and they place the true abundance of these non-decapod larvae far above the figures for the same forms from the large mesh net. Comparison of the fine mesh net values for January, 1976 with the coarse mesh net values for January, 1977 shows a difference of some 2 to 4 orders of magnitude for such forms as barnacle nauplii and gastropod and bivalve veligers. Without considering the values from the fine mesh net, both gastropod veligers and barnacle nauplii accounted for a significant portion of the meroplankton (3.0% and 1.7% of the total respectively, and 5th and 8th most abundant forms). Were their true abundance known, these forms

would probably be the most dominant meroplankton by far.

Though very abundant, many of these larvae come from adult forms whose reproductive potential is much higher than decapod crustaceans and the results of losses due to entrainment may not be as significant to the adult population.

The larvae of oyster (Crassostrea virginica) were recognized in many of the samples from the warmer months. Though some of the gastropod veligers were probably of species predatory on oyster, or otherwise important, no attempt was made to identify them. Without quantitative samples, any study of these forms would have to be very superficial and prone to error.

Entrainment

Entrainment of meroplankton was calculated using the formulas and method outlined in the ichthyoplankton section (Chapter 5) of this report. The estimated monthly entrainment figure for each species by both the dilution pump and the plant between January, 1976 - March, 1977 is listed in Appendices 6C-1 through 6C-15. The entrainment figures for certain crab species, which may be impinged upon the intake screens (for example Polyonyx gibbesi) and for certain small species, which pass through the 363 μ mesh unit (for example molluscan veligers) may be low estimates.

Discussion of entrainment will include the four most abundant species collected in the study area. These are, in order of abundance: Pinnixa sayana (Pinnotheridae); Polyonyx gibbesi (Porcellanidae); Upogebia affinis (Callianassidae); Neopanope texana (Xanthidae). A species of commercial importance, the stone crab (Menippe mercenaria) will also be discussed. In addition, total meroplankton entrainment will also be briefly discussed.

1) Pinnixa sayana

The estimated monthly entrainment of P. sayana by the dilution pumps and by the plant is presented for the period January, 1976 - March, 1977 in Table 6.1. This species was the most abundant species collected in the area, and was also the most abundant species entrained by the plant and dilution pump. Entrainment was high throughout much of 1976, from March through November. A total of 2.349×10^{11} individuals were entrained by the plant and 8.021×10^{10} individuals were entrained by the dilution pump during 1976.

2) Polyonyx gibbesi

The estimated monthly entrainment of P. gibbesi by the dilution pumps and by the plant from January, 1976 - March, 1977 is presented in Table 6.2. This species was both the second most abundant species in the study area and subject to the second highest entrainment of any species. Entrainment of this species

Table 6.1. Estimated number of Pinnixa sayana entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	5.516×10^{7}	0	5.516×10^{7}
March	4.660×10^{9}	1.453×10^{10}	1.919×10^{10}
April	3.728×10^{10}	2.661×10^{10}	6.389×10^{10}
May	1.701×10^{10}	1.504×10^{10}	3.205×10^{10}
June	1.048×10^{10}	3.330×10^{9}	1.381×10^{10}
July	2.623×10^{10}	7.171×10^{9}	3.340×10^{10}
August	1.689×10^{10}	2.138×10^{9}	1.903×10^{10}
September	3.945×10^{10}	2.677×10^{9}	4.213×10^{10}
October	8.028×10^{10}	7.078×10^{9}	8.736×10^{10}
November	2.475×10^{9}	1.629×10^{9}	4.104×10^{9}
December	7.566×10^{7}	7.830×10^{6}	8.349×10^{7}
TOTAL	2.349×10^{11}	8.021×10^{10}	3.151×10^{11}
1977			
January	0	0	0
February	4.533×10^{9}	1.850×10^{9}	6.383×10^{9}
March	6.387×10^{9}	2.606×10^{9}	8.993×10^{9}

Table 6.2. Estimated number of Polyonyx gibbesi entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	1.841×10^{6}	0	1.841×10^{6}
February	1.024×10^{7}	0	1.024×10^{7}
March	1.770×10^{9}	2.551×10^{10}	2.728×10^{10}
April	1.076×10^{10}	4.646×10^{10}	5.722×10^{10}
May	4.765×10^{10}	2.105×10^{10}	6.870×10^{10}
June	5.653×10^{9}	3.757×10^{9}	9.410×10^{9}
July	3.724×10^{9}	1.117×10^{9}	4.841×10^{9}
August	8.849×10^{8}	2.138×10^{8}	1.099×10^{9}
September	2.208×10^{10}	4.134×10^{8}	2.249×10^{10}
October	1.026×10^{10}	6.877×10^{8}	1.095×10^{10}
November	6.640×10^{9}	1.686×10^{8}	6.809×10^{9}
December	1.071×10^{7}	5.860×10^{6}	1.657×10^{7}
TOTAL	1.094×10^{11}	9.938×10^{10}	2.088×10^{11}
1977			
January	0	1.446×10^{6}	1.446×10^{6}
February	0	4.900×10^{5}	4.900×10^{5}
March	0	2.961×10^{5}	2.961×10^{5}

follows a similar monthly pattern to that of Pinnixa sayana. Entrainment is high from March through November, 1976. A total of 1.09×10^{11} individuals were entrained by the plant and 9.938×10^{10} individuals by the dilution pump during 1976.

3) Upogebia affinis

The estimated monthly entrainment of U. affinis by the dilution pump and by the plant for the period of January, 1976 - March, 1977 is presented in Table 6.3. The third most abundant species collected in the study area, this species also had the third highest entrainment figure. Entrainment was high for this species from March - October, 1976. A total of 4.464×10^{10} individuals were entrained by the plant, and a total of 2.341×10^{10} individuals were entrained by the dilution pump during 1976.

4) Neopanope texana

The estimated monthly entrainment of N. texana by the dilution pump and by the plant for the period of January, 1976 - March, 1977 is presented in Table 6.4. The fourth most abundant species collected in the study area, this species also had the fourth highest entrainment figure. Entrainment was highest from August - October, 1976. A total of 4.191×10^{10} individuals were entrained by the plant and 8.087×10^{9} individuals were entrained by the dilution pump during 1976.

5) Menippe mercenaria

The estimated number of M. mercenaria entrained monthly by the dilution pump and by the plant from January, 1976 to March,

Table 6.3. Estimated number of Upogebia affinis entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	7.748×10^{8}	3.951×10^{9}	4.726×10^{9}
April	1.082×10^{10}	7.365×10^{9}	1.819×10^{10}
May	1.220×10^{10}	6.750×10^{9}	1.895×10^{10}
June	3.296×10^{9}	1.501×10^{9}	4.797×10^{9}
July	2.167×10^{9}	1.498×10^{9}	3.665×10^{9}
August	6.889×10^{9}	7.896×10^{8}	7.679×10^{9}
September	7.352×10^{9}	1.160×10^{9}	8.512×10^{9}
October	1.095×10^{9}	3.494×10^{8}	1.444×10^{9}
November	3.455×10^{7}	3.669×10^{7}	7.124×10^{7}
December	8.939×10^{6}	5.140×10^{6}	1.408×10^{7}
TOTAL	4.464×10^{10}	2.341×10^{10}	6.805×10^{10}
1977			
January	0	2.892×10^{5}	2.892×10^{5}
February	2.963×10^{7}	3.523×10^{6}	3.315×10^{7}
March	4.174×10^{7}	4.885×10^{6}	4.663×10^{7}

Table 6.4. Estimated number of Neopanope texana entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	1.668×10^8	3.736×10^8	5.404×10^8
April	9.108×10^8	6.851×10^8	1.596×10^9
May	6.235×10^8	4.061×10^8	1.030×10^9
June	1.381×10^9	2.958×10^8	1.677×10^9
July	9.172×10^8	4.686×10^8	1.386×10^9
August	1.221×10^{10}	1.138×10^9	1.335×10^{10}
September	1.294×10^{10}	2.686×10^9	1.563×10^{10}
October	1.147×10^{10}	1.409×10^9	1.288×10^{10}
November	1.037×10^9	5.215×10^8	1.558×10^9
December	2.534×10^8	1.035×10^8	3.569×10^8
TOTAL	4.191×10^{10}	8.087×10^9	5.000×10^{10}
1977			
January	2.728×10^6	1.879×10^6	4.607×10^6
February	8.786×10^7	3.335×10^7	1.212×10^8
March	1.231×10^8	4.648×10^7	1.696×10^8

1977 is presented in Table 6.5. Entrainment of this species was highest in August and September, 1976. A total of 5.023×10^9 individuals were entrained by the plant and 1.989×10^9 individuals by the dilution pump during 1976.

6) Total Meroplankton

The estimated number of total meroplankton entrained each month by the dilution pump and the plant is presented in Table 6.6. Entrainment was highest from April through October, 1976. A total of 5.5413×10^{11} individuals were entrained by the dilution pump and 2.496×10^{11} individuals by the plant during 1976, for a total of 7.809×10^{11} individuals entrained.

Since a variety of developmental stages were entrained for a given species in a given month, it was not possible to assess the impact of the entrainment of meroplankton species due to the operation of the power plant without a knowledge of the survival rates between stages.

Table 6.5. Estimated number of Menippe mercenaria entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	0	0	0
February	0	0	0
March	6.453×10^7	1.779×10^8	2.424×10^8
April	5.642×10^8	3.237×10^8	8.879×10^8
May	2.782×10^8	1.416×10^8	4.198×10^8
June	3.485×10^9	1.748×10^8	5.233×10^8
July	5.306×10^8	3.579×10^8	8.885×10^8
August	1.025×10^9	2.105×10^8	1.235×10^9
September	1.742×10^9	4.965×10^8	2.238×10^9
October	4.529×10^8	9.596×10^7	5.489×10^8
November	1.585×10^7	9.525×10^6	2.538×10^7
December	9.729×10^5	1.059×10^6	2.032×10^6
TOTAL	5.023×10^9	1.989×10^9	7.012×10^9
1977			
January	0	0	0
February	0	0	0
March	0	0	0

Table 6.6. Estimated number of Total meroplankton entrained by the Big Bend plant and by the dilution pumps per month between January 1976 and March 1977.

Month	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
1976			
January	5.014×10^{7}	8.178×10^{6}	5.832×10^{7}
February	1.119×10^{9}	0	1.119×10^{9}
March	9.379×10^{9}	4.843×10^{10}	5.781×10^{10}
April	7.191×10^{10}	8.859×10^{10}	1.605×10^{11}
May	8.461×10^{10}	4.800×10^{10}	1.326×10^{11}
June	2.346×10^{10}	1.066×10^{10}	3.412×10^{10}
July	4.129×10^{10}	1.410×10^{10}	5.539×10^{10}
August	5.286×10^{10}	8.514×10^{9}	6.137×10^{10}
September	1.081×10^{11}	1.277×10^{10}	1.209×10^{11}
October	1.177×10^{11}	1.258×10^{10}	1.304×10^{11}
November	2.196×10^{10}	4.629×10^{9}	2.660×10^{10}
December	8.873×10^{9}	1.337×10^{9}	1.021×10^{10}
TOTAL	5.413×10^{11}	2.496×10^{11}	7.909×10^{11}
1977			
January	2.652×10^{9}	1.237×10^{9}	3.889×10^{9}
February	8.759×10^{9}	4.110×10^{9}	1.287×10^{10}
March	1.162×10^{10}	5.453×10^{9}	1.707×10^{10}

SUMMARY AND CONCLUSIONS

1. The decapod crustaceans of the Big Bend area showed major spawning peaks through the warmer months of the year. This pattern is similar to that found in other studies along the northwest coast of Florida. Some depression of breeding occurs during the hottest part of the summer.

2. Most of the decapod larvae found in the study area are noncommercial species whose adults are also residents of the area. The stone crab, Menippe mercenaria, was common, and though a minor fraction of the larvae, 7.012×10^9 zoea of this species were entrained in 1976.

3. Estimates of invertebrate larvae other than decapod larvae were not realistic as the mesh size of the net used in this study allowed many of these larvae to escape.

4. It is not possible to quantify the impact of entrainment of the larvae of any species on the adult population in the area with the data available. Lack of published information on the life histories of the meroplankton species collected at Big Bend and the absence of studies of the mechanisms by which their populations are maintained (i.e. compensatory mechanisms of the species, reproductive potential and strategies, etc.) were the primary reasons for not being able to assess the significance of the entrainment estimates. Also, absence of detailed current

studies in the study area makes the estimations of the areal extent of the sub-populations (which might be affected by the entrainment of their larvae) difficult.

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APPENDIX 6.A

KEY TO THE LARVAL DECAPODS
OF THE
LOWER HILLSBOROUGH BAY, TAMPA, FLORIDA

Antennal scale present.....1

Antennal scale absent.....38

1. Uropods present.....22

   Uropods absent.....2

2. Single medial telson spine present (Fig. 3A).....3

   Single medial telson spine absent.....7

3. Medial telson spine largest.....4

   Medial telson spine minute.....Upogebia affinis (11)

4. Prominent dorsal spine or spines on abdomen.....5

   Small dorsal spines on each segment of abdomen
   .....Callianassa sp. D

5. Telson spine arrangement 16-18+1+16-18.....6

   Telson spine arrangement 7-9+1+7-9
   .....Callianassa sp. A (1)

6. Maxillipeds with 13-15 natatory setae
   .....Callianassa sp. C (1)

   Maxillipeds with five natatory setae
   .....Callianassa sp. B (1)

7. Carapace with prominent spines on posterior margin;
   spine four of telson largest.....65

Carapace margin lacking posterior spines.....8

8. Lateral margin of telson with subterminal notch and associated spine (Fig. 3B).....9

Telson with all spines on distal margin (Fig. 3A) .....Upogebia affinis (1)

9. Proximal end of antennules separated from each other by at least width of antennule.....10

Proximal end of antennule separated by less than width of antennule.....12

10. Dorso-lateral spines present on fourth and fifth abdominal segments (Fig. 3C).....11

No spines present on fourth abdominal segment.....17

11. Telson longer than width; antennules recurve .....Ambidexter symmetricus ?

Telson as wide as long; antennules straight .....Processa sp. ?

12. Telson spine length equal except inner pair of spines in stage II.....13

Telson spine length unequal.....17

13. One ventral carapace spine present posterior to acute pterygostomian region (Fig. 3D) Ogyrides limicola

Ventral carapace spine absent.....14

14. Distal margin of telson straight (Fig. 3B).....15

Distal margin of telson slightly concave.....16

15. Stage I total length 3.5 mm.... Palaemonetes intermedius

Stage I total length 2.6 mm .....Palaemonetes pugio

.....or vulgaris

16. Telson width (stage I) 400 μ .....Palaemon floridanus?

Telson width (stage I) 300 μ .....Periclimenes spp.

17. Abdomen with prominent dorsal spine Tozeuma carolinense

Abdomen without prominent dorsal spine.....18

18. Anterio-ventral margin of carapace denticulate.....19

Anterio-ventral margin of carapace smooth.....21

19. Telson with three or more lateral spines (Fig 3K)

.....Leptochela serritorbita

Telson with less than three lateral spines.....20

20. Rostrum triangular at base, becoming acuminate, extending beyond eyes .....Hippolyte spp.

Rostrum reduced and not extending beyond eyes

.....Thor floridanus?

21. Eyes taper to point anteriorly; in second stage fifth pair of legs greatly elongated ....Alpheus spp. (5 sp?)

Eyes spherical, fifth pair of legs equal to fourth in length .....Latreutes parvulus

22. Small dorsal spine present on last abdominal segment

.....Lucifer faxoni

Small dorsal spine absent on last abdominal segment 23

23. Single medial telson spine present.....*Upogebia affinis*

Single medial telson spine absent.....24

24. Carapace with prominent spines on posterior margin....64

Carapace lacking spines on posterior margin.....25

25. Third leg chelate.....Penaeidae (See Cook, 1966)

Third leg simple.....26

26. Epigastric spine(s) present.....27

Epigastric spine(s) absent.....29

27. Abdomen with prominent dorsal spine *Palaemon floridanus*?

Abdomen lacking dorsal spines.....28

28. Stage VI total length 6.8 mm ... *Palaemonetes intermedius*

Stage VI total length 3.7 mm ..... *Palaemonetes pugio*

.....or *vulgaris*

29. Carapace with one spine posterior to acute pterogostomian region (Fig. 3D).....*Ogyrides limicola*

Carapace otherwise.....30

30. Posterio-ventral margin of carapace with distinct hook; Stages IV - post-larvae, rostrum compressed laterally

.....*Latreutes parvulus*

Rostrum otherwise; posterio-ventral margin of carapace smooth.....31

31. Fifth pair of legs extremely elongate ..... *Alpheus* spp.

Fifth pair of legs otherwise.....32

32. Proximal end of antennules separated from each other by at least width of antennule.....33

Antennules otherwise.....34

33. Dorso-lateral spines present on fourth and fifth abdominal segments.....Processidae

No spines on fourth abdominal segment.....34

34. Prominent dorsal spine on abdomen ... *Tozeuma carolinense*

Dorsal spine lacking.....35

35. Posterior margin of telson convex .....*Leptochela serritorbita*

Telson otherwise.....36

36. Anterio-ventral margin of carapace denticulate.....37

Anterior-ventral margin of carapace smooth .....*Periclimenes* spp.

37. Rostrum broad at base, becoming acuminate and extending beyond eyes.....*Hippolyte* spp.

Rostrum a short triangular process and not extending beyond eyes .....*Thor floridanus*?

38. Uropods present.....64

Uropods absent.....39

39. Three spines on posterior margin of carapace .....*Lucifer faxoni*

Carapace otherwise.....40

40. Lateral spines present on carapace.....45

Lateral spines absent on carapace.....41

41. Rostrum at least 2X carapace.....57

Rostrum less than 2X carapace.....42

42. Lateral spines present on telson.....*Libina dubia*

Lateral spines absent on telson.....43

43. Antennae exopodite at least 3/4 rostral length (Fig. 3E).....44

Antennae exopodite rarely 1/2 rostral length... *Uca* spp.

44. Carapace length .5 mm.....*Sesarma reticulatum* (1)

Carapace length .3 mm.....*Sesarma cinereum* (1)

45. Antennae as long or longer than rostrum.....46

Antennae shorter than rostrum.....52

46. Lateral spines present on telson.....50

Lateral spines absent on telson.....47

47. Minute dorsal spine present on each furca of telson (Fig. 3F).....48

Minute dorsal spine absent on furcae.....49

48. Dorsal spine of carapace with distinct hook .....*Eurypanopeus depressus*

Dorsal spine of carapace straight.....*Neopanope texana*

49. Large spines on fourth abdominal segment .....*Rithropanopeus harrisii*

Abdominal spines equal in length .....*Hexapanopeus angustifrons*

50. Rostrum shorter than antennae ..... *Pilimnus* spp.

Rostrum otherwise 51

51. Small hair present adjacent and distally to lateral telson spine (Fig. 3G) ..... *Panopeus herbstii*

Telson with single lateral spine ..... Portunidae

52. Minute dorsal spine present on each furca of telson ..... Unknown Brachyuran A

Minute dorsal spine absent on furcae 53

53. Dorso-lateral spines present on each segment of abdomen ..... *Menippe mercenaria*

Dorso-lateral spines absent on abdomen 54

54. Fifth abdominal segment compressed laterally into lappets (Fig. 3H) 55

Fifth abdominal segment otherwise 56

55. Telson with median deltoid process (Fig. 3H) ..... *Pinnixa chaetopterana*

Telson without median deltoid process .... *Pinnixa sayana*

56. Telson bifurcate 57

Telson broad with 5-6 spines medially ..... *Persephone punctata*

57. Carapace spines equal to carapace length ..... *Pinnotheres maculatus*

Carapace spines less than carapace length ..... *Pinnotheres* sp. A

58. Telson spine length as long as telson.....59

Telson with short spines.....Albuneidae

59. Exopodite of antennae as long as endopodite.....60

Endopodite of antennae longer than exopodite.....62

60. Telson with two short medial spurs (Fig. 31).....61

Telson with median free of spurs (Fig. 3J)

.....Petrolisthes spp.

61. Spines present on posterior margin of carapace

.....Euceramus praelongus

Posterior margin of carapace bare of spines

.....Polyonyx gibbesi

62. Telson with two long medial spines.....63

Telson with single median spine .....Petrolisthes spp.

63. Carapace with spines on posterior margin

.....Euceramus praelongus

Carapace margin bare of spines Polyonyx gibbesi

64. Small dorsal spine present on last segment of abdomen

.....Lucifer faxoni

No dorsal spine present on last segment of abdomen....65

65. Posterior carapace spines pointed ventrally.....66

Posterior carapace spines pointing posteriorly

....Pagurid sp. A

66. Lateral abdominal spines equal in length.....67

Lateral spines of fifth abdominal segment 2X length of others ..... Pagurus longicarpus

67. Carapace length .9-1.3 mm ..... Pagurus annulipes (1)

Carapace length 1.6 mm ..... Pagurus pollicaris (1)

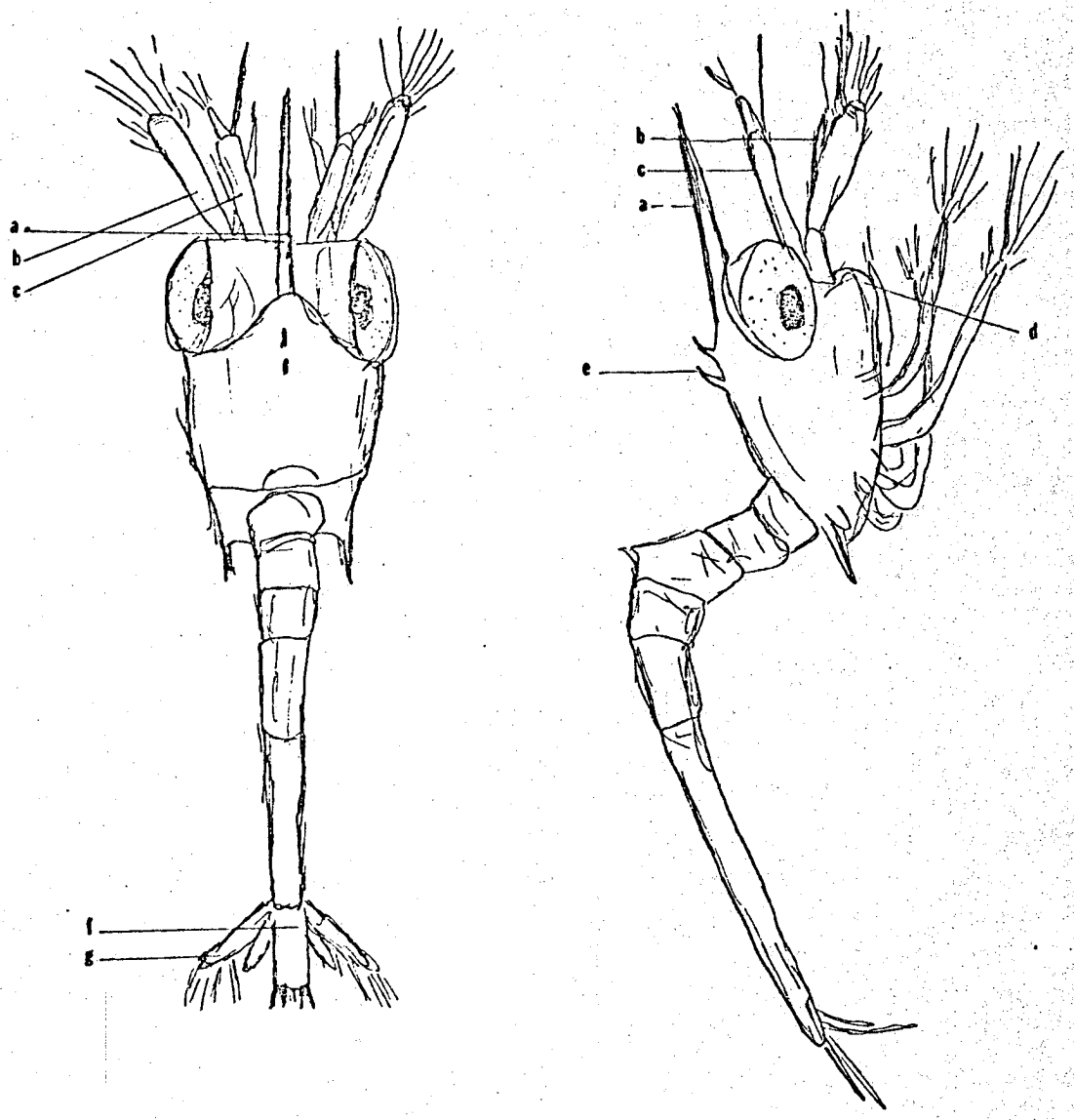


Figure 1.

(Modified after Gurney, 1936)

a. rostrum b. antennal scale c. antennule
d. pterygostimian region e. epigastric spine
f. telson g. uropods

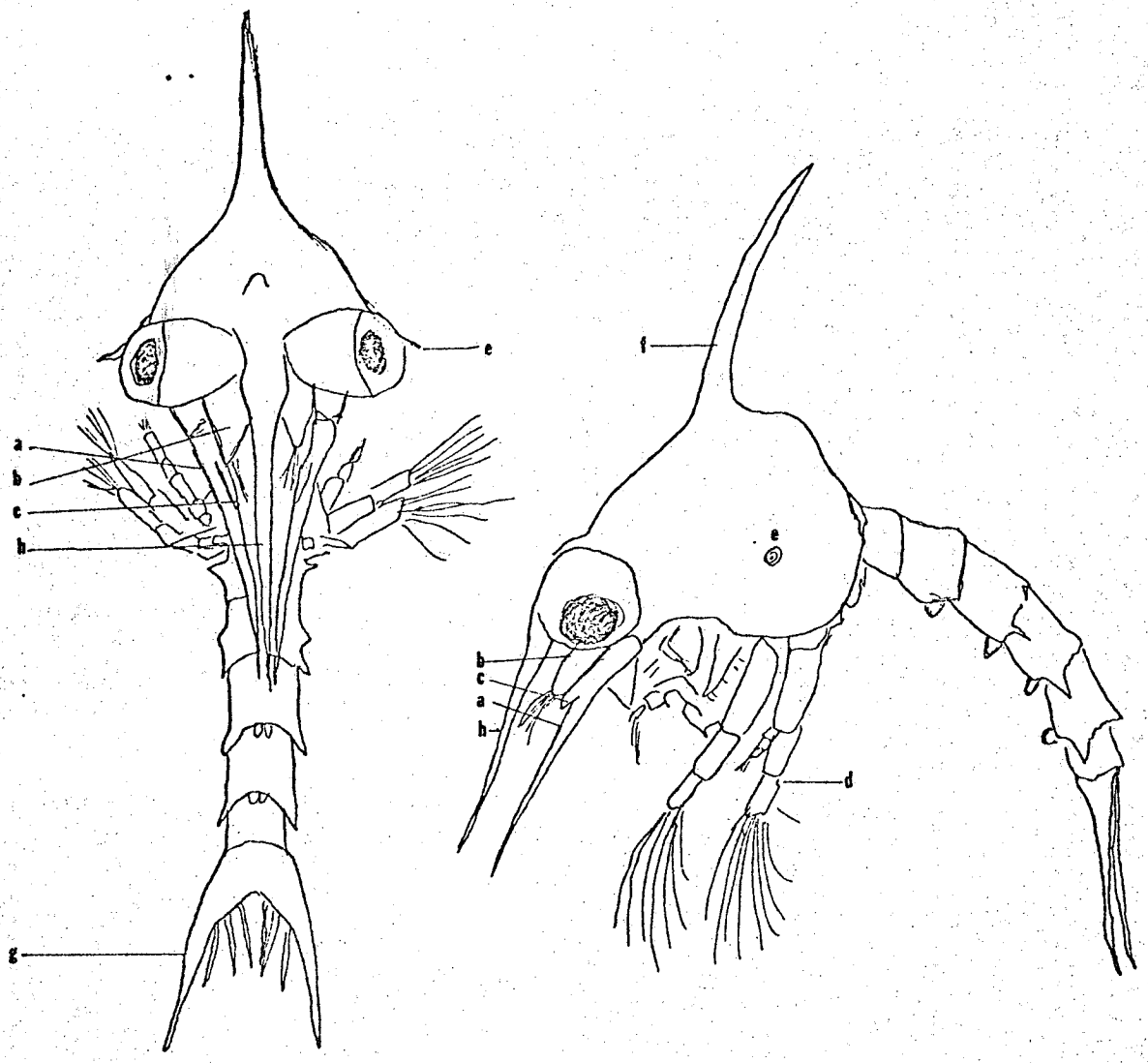
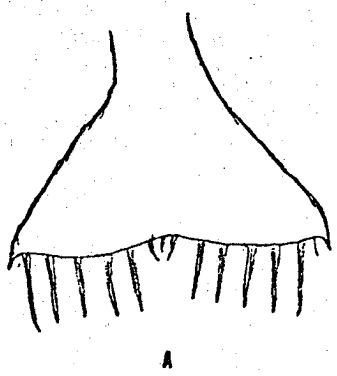


Figure 2.

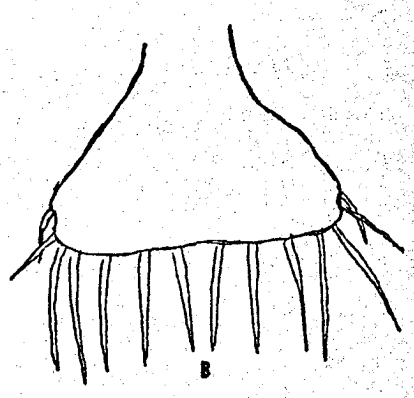
(After McMahan 1967)

a. antenna b. antennule c. endopodite of antenna
d. maxilliped e. lateral carapace spine
f. dorsal carapace spine g. telson furcae
h. rostrum

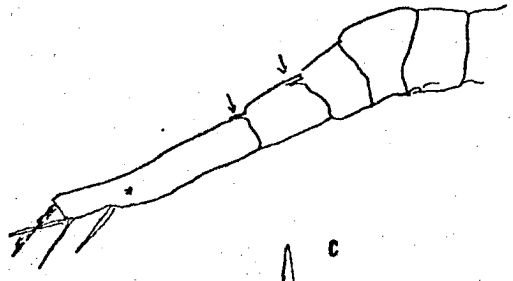
Figure 3.



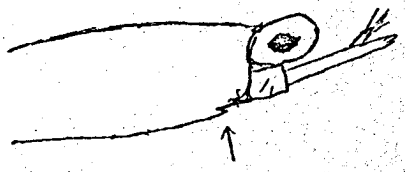
A



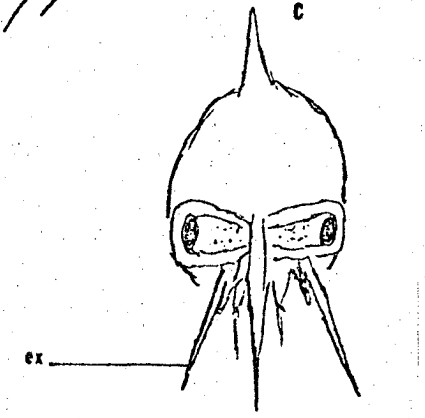
B



C

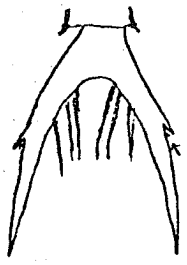


D



E

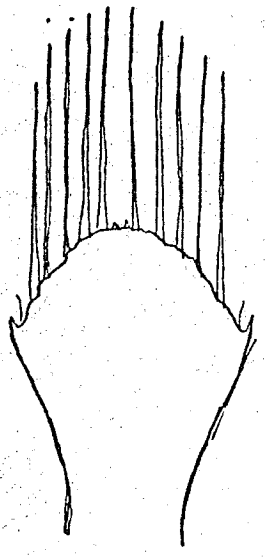
F



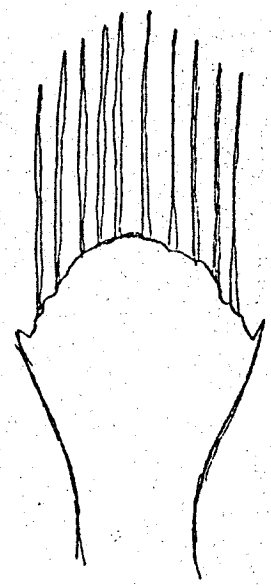
G

H

Figure 3.



I



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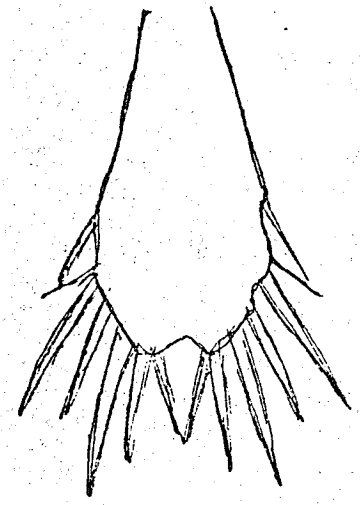

K

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Appendix 6.B. Species list, density and relative abundance for all meroplankton collected at Big Bend area from January 6, 1976 to March 11, 1977.

Species	#/m^3	% Total
Pinnixa sayana	148.41	34.70
Polyonyx gibbesi	120.95	28.28
Upogebia affinis	46.05	10.77
Neopanope texana	18.94	4.43
*Gastropoda	12.69	2.97
Hexapanopeus angustifrons	10.78	2.52
Pinnixa chaetopterana	8.78	2.05
*Balanus sp.	7.26	1.70
Ambidexter symmetricus	5.21	1.22
Xanthidae (damaged)	5.06	1.18
Alpheidae sp. A	4.65	1.09
Periclimenes spp.	4.23	<1.0
Eurypanopeus depressus	3.66	
Grapsizoea spp.	3.15	
Uca spp.	2.83	
Menippe mercenaria	2.31	
Pinnotheres maculatus	2.26	
Persephona punctata	1.94	
*Brachiopoda	1.69	
*Spionidae	1.49	
Ogyrides limicola	1.32	
Echinodermata	1.09	
Pelecypoda	0.93	
Latreutes parvulus	0.925	
Panopeus herbstii	0.838	
Petrolisthes spp.	0.830	
Porcellanidae (damaged)	0.732	

Appendix 6.B. Continued.

Species	#/m^3	% Total
Caridea (damaged)	0.678	
Hippolyte spp.	0.615	
Pagurus longicarpus	0.575	
*Nereidae	0.474	
Sesarma cinereum	0.460	
Decapoda (damaged)	0.450	
Paguridae sp. A	0.381	< 0.1
Alpheidae sp. C	0.368	
Sesarma reticulatum	0.362	
Alpheidae (damaged)	0.348	
Processa spp.	0.338	
*Polychaeta	0.305	
Rithropanopeus harrisii	0.262	
Palaemonetes intermedius	0.253	
Pinnotheridae (damaged)	0.247	
Palaemonidae (damaged)	0.228	
Libinia dubia	0.200	
Squilla sp.	0.195	
Palaemonetes spp.	0.151	
Urochordata	0.140	
Brachyura (unidentified)	0.123	
Hippolytidae (damaged)	0.122	
Neopanope packardii	0.103	
Leptochela sp.	0.101	
Alpheidae sp. B	0.098	
Megalops (unidentified)	0.094	
Periclimenes americanus (postlarvae)	0.075	
Palaemonetes pugio/vulgaris	0.059	

Appendix 6.B. Continued.

Species	#/m^3	% Total
Palaemonidae sp. C	0.058	
Portunidae sp. A	0.053	
Alpheidae sp. D	0.048	
Palaemon floridanus	0.047	
Callianassa sp. A	0.046	
Tozeuma carolinense	0.046	
*Polynoidae	0.043	
Pinnixa sp. A	0.043	
Pagurus annulipes	0.039	< 0.01
Pinnotheres sp. A	0.038	
Brachyura sp. A	0.031	
Processidae (damaged)	0.029	
Callinectes sp. A	0.029	
Hippolytidae sp. D	0.029	
Callianassa sp. D	0.025	
Paguridae (damaged)	0.023	
Penaeus duorarum	0.022	
Euceramus praelongus	0.020	
Aegathoa	0.020	
*Phoronida	0.019	
Zoea (unidentified)	0.015	
Callianassa sp. C	0.014	
Paguridae sp. C	0.012	
*Flabelligeridae	0.012	
Pinnotheres sp. B	0.012	
Postlarvae (unidentified)	0.010	
*Syllidae	0.010	
Brachyura sp. B	0.008	
Callianassa sp. B	0.007	

Appendix 6.B. Continued

Species	#/m^3	% Total
Leptochela serritorbita	0.007	
Leucosiidae (damaged)	0.007	
Hippolytidae sp. B	0.006	
*Branchiostoma caribaeum	0.006	
Majidae (damaged)	0.006	
Palaemonidae sp. B	0.005	
Periclimenes longicaudatus (postlarvae)	0.005	
Grapsizoea sp. A	0.005	
*Limulus polyphemus	0.005	
Portunidae (damaged)	0.004	< 0.001
Thor floridanus	0.003	
Grapsidae (damaged)	0.003	
Pinnixa sp. B	0.003	
Hippolytidae sp. A	0.002	
Hippolyte zostericola (postlarvae)	0.002	
*Orbiniidae	0.002	
Alpheidae sp. E	0.002	
Pagurus pollicaris	0.002	
Alpheus sp. (postlarvae)	0.002	
Alpheus heterochaelis (postlarvae)	0.001	
Porcellana sayana	0.001	
Leander sp.	0.001	
Naushonia sp.	0.001	
Penaeidae (damaged)	0.001	
Callianassidae (damaged)	0.001	
*Cirratulidae	0.001	
Callinectes sapidus (postlarvae)	0.001	
TOTAL	427.706	

*Qualitatively sampled

Appendix 6C-1. Estimated Number of Meroplankton Entrained During January, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Decapoda			
Unidentified	2.046×10^5	0	2.046×10^5
Palaemonidae			
Unidentified	2.251×10^6	1.983×10^5	2.251×10^6
Caridea			
Unidentified	4.502×10^6	4.956×10^5	4.998×10^6
Porcellanidae			
Polyonyx gibbesi	1.841×10^6	0	1.841×10^6
Unidentified	2.046×10^5	0	2.046×10^5
Paguridae			
Pagurus annulipes	4.092×10^5	9.913×10^4	5.083×10^5
Pagurus longicarpus	2.762×10^7	5.948×10^6	3.357×10^7
Pagurus pollicaris	4.092×10^5	0	4.092×10^5
Unidentified	4.092×10^5	0	4.092×10^5
Xanthidae			
Unidentified	1.208×10^7	1.437×10^6	1.352×10^7
Isopoda			
Aegathoa sp.	2.046×10^5	0	2.046×10^5
TOTAL	5.014×10^7	8.178×10^6	5.832×10^7

Appendix 6C-2. Estimated Number of Meroplankton Entrained During February, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Decapoda			
Unidentified	2.310×10^4	0	2.310×10^4
Palaemonidae			
Unidentified	5.778×10^5	0	5.778×10^5
Caridea			
Unidentified	2.786×10^7	0	2.786×10^7
Porcellanidae			
Polyoyx gibbesi	1.024×10^7	0	1.024×10^7
Unidentified	4.231×10^6	0	4.231×10^6
Paguridae			
Pagurus annulipes	4.620×10^4	0	4.620×10^4
Pagurus longicarpus	2.561×10^7	0	2.561×10^7
Pagurus pollicaris	4.620×10^4	0	4.620×10^4
Unidentified	4.620×10^4	0	4.620×10^4
Xanthidae			
Unidentified	9.901×10^8	0	9.901×10^8
Pinnotheridae			
Pinnixa sayana	5.516×10^7	0	5.516×10^7
Unidentified	1.618×10^6	0	1.618×10^6
Majidae			
Libinia dubia	1.618×10^6	0	1.618×10^6
Isopoda			
Aegathoa sp.	1.642×10^6	0	1.642×10^6
TOTAL	1.119×10^9	0	1.119×10^9

Appendix 6C-3. Estimated Number of Meroplankton Entrained During March, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	0	4.156×10^6	4.156×10^6
Decapoda			
Unidentified	4.170×10^7	8.428×10^7	1.260×10^8
Palaemonidae			
Periclimenes spp.	5.932×10^6	1.361×10^8	1.420×10^8
Palaemonetes spp.	5.932×10^6	8.309×10^6	1.424×10^7
Unidentified	2.023×10^7	4.156×10^6	2.439×10^7
Alpheidae			
Unidentified sp. A	2.146×10^8	1.936×10^8	4.082×10^8
Unidentified sp. B	0	7.054×10^7	7.054×10^7
Unidentified sp. C	4.983×10^6	4.156×10^6	9.139×10^6
Unidentified sp. D	1.987×10^7	8.309×10^6	2.818×10^7
Unidentified	2.965×10^6	2.733×10^7	3.029×10^7
Hippolytidae			
Hippolyte spp.	0	8.309×10^6	8.309×10^6
Unidentified sp. B	0	9.507×10^6	9.507×10^6
Unidentified sp. C	0	4.156×10^6	4.156×10^6
Unidentified	0	4.156×10^6	4.156×10^6
Processidae			
Ambidexter symmetricus	2.283×10^7	1.170×10^8	1.398×10^8
Caridea			
Unidentified	2.520×10^7	1.254×10^7	3.774×10^7
Calliannasside			
Upogebia affinis	7.748×10^8	3.951×10^9	4.726×10^9
Unidentified sp. C	4.983×10^6	0	4.983×10^6

Appendix 6C-3. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Porcellanidae			
Petrolisthes spp.	0	4.156×10^{6}	4.156×10^{6}
Polyonyx gibbesi	1.770×10^{9}	2.551×10^{10}	2.728×10^{10}
Unidentified	2.772×10^{7}	1.247×10^{7}	4.019×10^{7}
Paguridae			
Pagurus longicarpus	4.754×10^{7}	1.635×10^{8}	2.110×10^{8}
Unidentified sp. A	0	6.199×10^{7}	6.199×10^{7}
Unidentified	0	4.156×10^{6}	4.156×10^{6}
Leucosiidae			
Persephone aquilonaris	3.878×10^{7}	1.426×10^{8}	1.814×10^{8}
Portunidae			
Unidentified sp. A	0	4.156×10^{6}	4.156×10^{6}
Xanthidae			
Eurypanopeus depressus	1.311×10^{8}	6.504×10^{8}	7.815×10^{8}
Hexapanopeus angustifrons	1.321×10^{8}	8.428×10^{8}	9.749×10^{8}
Menippe mercenaria	6.453×10^{7}	1.779×10^{8}	2.424×10^{8}
Neopanope texana texana	1.668×10^{8}	3.736×10^{8}	5.404×10^{8}
Panopeus herbstii	1.690×10^{7}	0	1.690×10^{7}
Unidentified	1.027×10^{9}	5.192×10^{8}	1.546×10^{9}
Pinnotheridae			
Pinnixa chaetopterana	3.777×10^{7}	3.016×10^{8}	3.394×10^{8}
Pinnixa sayana	4.660×10^{9}	1.453×10^{10}	1.919×10^{10}
Pinnotheres maculatus	5.932×10^{6}	0	5.932×10^{6}
Unidentified	1.145×10^{7}	3.324×10^{7}	4.469×10^{7}
Grapsizoea spp.	7.645×10^{7}	3.987×10^{8}	4.752×10^{8}
Majidae			
Libinia dubia	9.439×10^{6}	0	9.439×10^{6}

Appendix 6C-3. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Brachyura			
Unidentified	0	4.156×10^{6}	4.156×10^{6}
Mollusca			
Gastropoda	4.983×10^{6}	4.753×10^{7}	5.252×10^{7}
Pelecypoda	4.983×10^{6}	0	4.983×10^{6}
Isopoda			
Aegathoa sp.	1.492×10^{6}	0	1.492×10^{6}
TOTAL	9.379×10^{9}	4.843×10^{10}	5.781×10^{10}

Appendix 6C-4. Estimated Number of Meroplankton Entrained During April, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	2.717×10^7	1.097×10^7	3.814×10^7
Decapoda			
Unidentified	1.112×10^8	1.572×10^8	2.684×10^8
Palaemonidae			
Periclimenes spp.	2.138×10^8	2.501×10^8	4.639×10^8
Palaemonetes spp.	1.582×10^7	1.578×10^7	3.160×10^7
Unidentified	8.031×10^7	9.313×10^6	8.962×10^7
Alpheidae			
Alpheus heterochaelis	0	3.818×10^5	3.818×10^5
Unidentified sp. A	1.360×10^9	3.586×10^8	1.719×10^9
Unidentified sp. B	0	1.266×10^8	1.266×10^8
Unidentified sp. C	5.207×10^7	7.404×10^6	5.947×10^7
Unidentified sp. D	5.298×10^7	1.971×10^7	7.269×10^7
Unidentified	4.669×10^7	5.636×10^7	1.030×10^8
Hippolytidae			
Hippolyte spp.	1.049×10^8	1.548×10^7	1.204×10^8
Tozeuma carolinense	2.717×10^7	0	2.717×10^7
Unidentified sp. B	0	1.693×10^7	1.693×10^7
Unidentified sp. C	0	7.785×10^6	7.785×10^6
Unidentified	0	7.627×10^6	7.627×10^6
Processidae			
Ambidexter symmetricus	1.269×10^8	2.135×10^8	3.404×10^8
Caridea			
Unidentified	0	2.672×10^7	2.672×10^7

Appendix 6C-4. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Callianassidae			
Upogebia affinis	1.082×10^{10}	7.365×10^{9}	1.819×10^{10}
Unidentified sp. C	1.329×10^{7}	0	1.329×10^{7}
Porcellanidae			
Petrolisthes spp.	7.772×10^{7}	8.549×10^{6}	8.627×10^{7}
Polyonyx gibbesi	1.076×10^{10}	4.646×10^{10}	5.722×10^{10}
Unidentified	6.358×10^{7}	2.515×10^{7}	8.873×10^{7}
Paguridae			
Pagurus longicarpus	1.764×10^{8}	2.914×10^{8}	4.678×10^{8}
Unidentified sp. A	0	1.109×10^{8}	1.109×10^{8}
Unidentified	0	7.404×10^{6}	7.404×10^{6}
Leucosiidae			
Persephone aquilonaris	5.617×10^{8}	2.589×10^{8}	8.206×10^{8}
Portunidae			
Unidentified sp. A	0	8.383×10^{6}	8.383×10^{6}
Xanthidae			
Eurypanopeus depressus	1.445×10^{9}	1.175×10^{9}	2.620×10^{9}
Hexapanopeus angustifrons	1.374×10^{9}	1.512×10^{9}	2.886×10^{9}
Menippe mercenaria	5.642×10^{8}	3.237×10^{8}	8.879×10^{8}
Neopanope texana texana	9.108×10^{8}	6.851×10^{8}	1.596×10^{9}
Panopeus herbstii	2.974×10^{8}	7.637×10^{5}	2.982×10^{8}
Rithropanopeus harrisii	3.879×10^{7}	3.818×10^{5}	3.917×10^{7}
Unidentified	5.507×10^{8}	9.355×10^{8}	1.486×10^{9}
Pinnotheridae			
Pinnixa chaetopterana	2.326×10^{9}	5.733×10^{8}	2.899×10^{9}
Pinnixa sayana	3.728×10^{10}	2.661×10^{10}	6.389×10^{10}
Pinnotheres maculatus	9.734×10^{7}	2.190×10^{6}	9.953×10^{7}
Unidentified	2.657×10^{7}	5.943×10^{7}	8.600×10^{7}

Appendix 6C-4. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Grapsizoea spp.	1.528×10^{9}	7.708×10^{8}	2.299×10^{9}
Majidae			
Libinia dubia	8.716×10^{7}	0	8.716×10^{7}
Brachyura			
Unidentified	2.717×10^{7}	7.404×10^{6}	3.457×10^{7}
Mollusca			
Gastropoda	4.949×10^{8}	8.717×10^{7}	5.821×10^{8}
Pelecypoda	1.687×10^{8}	1.527×10^{6}	1.702×10^{8}
Cirripedia			
Balanus sp.	0	3.047×10^{6}	3.047×10^{6}
Polychaeta			
Spionidae	0	6.053×10^{5}	6.053×10^{5}
Brachiopoda	0	1.145×10^{6}	1.145×10^{6}
Echniodermata			
Ophiuroidea	0	5.453×10^{6}	5.453×10^{6}
TOTAL	7.191×10^{10}	8.859×10^{11}	1.605×10^{11}

Appendix 6C-5. Estimated Number of Meroplankton Entrained During May, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	1.223×10^7	7.369×10^7	8.592×10^7
Decapoda			
Unidentified	5.071×10^7	1.466×10^8	1.973×10^8
Palaemonidae			
Periclimenes spp.	3.108×10^8	1.596×10^8	4.704×10^8
Palaemonetes spp.	1.701×10^7	2.025×10^7	3.726×10^7
Unidentified	1.223×10^7	3.945×10^7	5.168×10^7
Alpheidae			
Alpheus heterochaelis	0	7.890×10^6	7.890×10^6
Unidentified sp. A	4.731×10^8	2.844×10^8	7.575×10^8
Unidentified sp. B	0	2.025×10^7	2.025×10^7
Unidentified sp. C	1.745×10^7	0	1.745×10^7
Unidentified sp. D	0	1.014×10^8	1.014×10^8
Unidentified	2.206×10^8	1.587×10^8	3.793×10^8
Hippolytidae			
Hippolyte spp.	4.720×10^7	1.400×10^7	6.120×10^7
Tozeuma carolineuse	1.223×10^7	0	1.223×10^7
Unidentified sp. C	0	7.890×10^6	7.890×10^6
Unidentified	1.701×10^7	4.615×10^6	2.163×10^7
Processidae			
Ambidexter symmetricus	2.968×10^7	1.064×10^8	1.361×10^8
Unidentified	5.071×10^7	0	5.071×10^7
Caridea			
Unidentified	3.401×10^7	9.051×10^7	1.245×10^8
Callianassidae			
Upogebia affinis	1.220×10^{10}	6.750×10^9	1.895×10^{10}

Appendix 6C-5. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Porcellanidae			
Petrolisthes spp.	1.027×10^{8}	2.367×10^{7}	1.264×10^{8}
Polyonyx gibbesi	4.765×10^{10}	2.105×10^{10}	6.870×10^{10}
Unidentified	0	6.089×10^{7}	6.089×10^{7}
Paguridae			
Pagurus longicarpus	4.720×10^{7}	4.615×10^{6}	5.182×10^{7}
Unidentified sp. A	0	9.382×10^{6}	9.382×10^{6}
Leucosiidae			
Persephone aquilonaris	3.599×10^{8}	9.993×10^{7}	4.598×10^{8}
Portunidae			
Unidentified sp. A	0	2.025×10^{7}	2.025×10^{7}
Xanthidae			
Eurypanopeus depressus	6.128×10^{8}	3.371×10^{8}	9.499×10^{8}
Hexapanopeus angustifrons	6.800×10^{8}	2.313×10^{8}	9.113×10^{8}
Menippe mercenaria	2.782×10^{8}	1.416×10^{8}	4.198×10^{8}
Neopanope texana texana	6.235×10^{8}	4.061×10^{8}	1.030×10^{9}
Panopeus herbstii	1.646×10^{8}	1.578×10^{7}	1.804×10^{8}
Rithropanopeus harrisii	1.745×10^{7}	7.890×10^{6}	2.534×10^{7}
Unidentified	2.299×10^{8}	2.212×10^{8}	4.511×10^{8}
Pinnotheridae			
Pinnixa chaetopterana	1.238×10^{9}	7.451×10^{8}	1.983×10^{9}
Pinnixa sayana	1.701×10^{10}	1.504×10^{10}	3.205×10^{10}
Pinnotheres maculatus	7.070×10^{7}	4.526×10^{7}	1.160×10^{8}
Unidentified	8.472×10^{7}	4.615×10^{6}	8.934×10^{7}
Grapsizoea spp.	1.164×10^{9}	1.251×10^{9}	2.415×10^{9}
Majidae			
Libinia dubia	4.669×10^{7}	0	4.669×10^{7}

Appendix 6C-5. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Brachyura			
Unidentified	1.223×10^{7}	0	1.223×10^{7}
Mollusca			
Gastropoda	2.507×10^{8}	5.181×10^{7}	3.025×10^{8}
Pelecypoda	6.992×10^{7}	3.156×10^{7}	1.015×10^{8}
Cirripedia			
Balanus sp.	3.968×10^{8}	6.298×10^{7}	4.598×10^{8}
Polychaeta			
Spionidae	0	1.251×10^{7}	1.251×10^{7}
Brachiopoda	0	2.367×10^{7}	2.367×10^{7}
Echinodermata			
Ophiuroidea	0	1.127×10^{8}	1.127×10^{8}
TOTAL	8.461×10^{10}	4.800×10^{10}	1.326×10^{11}

Appendix 6C-6. Estimated Number of Meroplankton Entrained During June, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	1.014×10^7	7.497×10^6	1.764×10^7
Decapoda			
Unidentified	3.882×10^6	1.938×10^7	2.327×10^7
Palaemonidae			
Periclimenes spp.	2.238×10^7	2.788×10^7	5.026×10^7
Palaemonetes pugio/ vulgaris	1.011×10^6	0	1.011×10^6
Palaemonetes spp.	4.677×10^7	6.698×10^6	5.347×10^7
Unidentified sp. A	1.588×10^7	1.851×10^6	1.773×10^7
Unidentified	5.344×10^7	1.801×10^7	7.145×10^7
Alpheidae			
Alpheus heterochaelis	0	4.636×10^5	4.636×10^5
Unidentified sp. A	9.852×10^7	5.773×10^7	1.562×10^8
Unidentified sp. B	1.596×10^7	1.190×10^6	1.715×10^7
Unidentified sp. C	1.096×10^7	4.844×10^6	1.580×10^7
Unidentified sp. D	5.865×10^7	5.957×10^6	6.461×10^7
Unidentified	1.011×10^6	5.951×10^7	6.052×10^7
Hippolytidae			
Hippolyte spp.	5.934×10^7	1.318×10^6	6.066×10^7
Latreutes parvulus	1.121×10^7	1.355×10^6	1.256×10^7
Tozeuma carolineuse	7.288×10^6	0	7.288×10^6
Unidentified sp. C	0	4.636×10^5	4.636×10^5
Unidentified	9.262×10^6	4.337×10^7	5.263×10^7
Processidae			
Ambidexter symmetricus	1.509×10^7	1.298×10^7	2.807×10^7
Processa spp.	0	1.269×10^7	1.269×10^7
Unidentified	2.870×10^6	4.853×10^7	5.140×10^7

Appendix 6C-6. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Caridea			
Unidentified	1.992×10^7	1.077×10^7	3.069×10^7
Callianassidae			
Upogebia affinis	3.296×10^9	1.501×10^9	4.797×10^9
Unidentified sp. B	0	2.754×10^6	2.754×10^6
Unidentified sp. C	0	1.006×10^7	1.006×10^7
Unidentified sp. D	0	4.354×10^4	4.354×10^4
Porcellanidae			
Petrolisthes spp.	5.635×10^7	4.847×10^7	1.048×10^8
Polyonyx gibbesi	5.653×10^9	3.757×10^9	9.410×10^9
Unidentified	0	4.190×10^7	4.190×10^7
Paguridae			
Pagurus annulipes	1.842×10^6	6.096×10^5	2.452×10^6
Pagurus longicarpus	0	3.743×10^6	3.743×10^6
Unidentified sp. A	7.982×10^6	7.404×10^6	1.539×10^7
Unidentified	0	2.171×10^6	2.171×10^6
Leucosiidae			
Persephone aquilonaris	6.779×10^7	4.553×10^7	1.133×10^8
Portunidae			
Unidentified sp. A	0	1.233×10^6	1.233×10^6
Unidentified	0	3.353×10^6	3.353×10^6
Xanthidae			
Eurypanopeus depressus	2.154×10^8	6.954×10^7	2.849×10^8
Hexapanopeus angustifrons	5.075×10^8	2.675×10^8	7.750×10^8
Menippe mercenaria	3.485×10^8	1.748×10^8	5.233×10^8
Neopanope texana texana	1.381×10^9	2.958×10^8	1.677×10^9
Panopeus herbstii	4.813×10^7	2.094×10^7	6.907×10^7

Appendix 6C-6. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Rithropanopeus harrisii	7.288×10^6	4.636×10^5	7.752×10^6
Unidentified	1.758×10^8	1.385×10^8	3.143×10^8
Pinnotheridae			
Pinnixa chaetopterana	1.329×10^8	1.811×10^8	3.140×10^8
Pinnixa sayana	1.048×10^{10}	3.330×10^9	1.381×10^{10}
Pinnotheres maculatus	1.513×10^7	1.901×10^7	3.414×10^7
Unidentified	1.310×10^7	4.235×10^5	1.352×10^7
Grapsidae			
Sesarma cinereum	2.038×10^6	3.543×10^6	5.581×10^6
Sesarma reticulatum	2.854×10^6	2.466×10^6	5.320×10^6
Ocypodidae			
Uca spp.	2.283×10^7	1.454×10^7	3.737×10^7
Grapsizoea spp.	1.518×10^8	2.474×10^8	3.992×10^8
Majidae			
Libinia dubia	1.623×10^7	4.262×10^6	2.049×10^7
Brachyrua			
Unidentified sp. A	1.842×10^6	0	1.842×10^6
Mollusca			
Gastropoda	1.049×10^8	1.560×10^7	1.205×10^8
Pelecypoda	8.993×10^6	4.146×10^6	1.314×10^7
Isopoda			
Aegathoa sp.	0	3.516×10^6	3.516×10^6
Cirripedia			
Balanus sp.	2.246×10^7	2.826×10^7	5.072×10^7
Polychaeta			
Nereidae	0	1.128×10^7	1.128×10^7

Appendix 6C-6. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Spionidae	1.024×10^8	2.448×10^7	1.269×10^8
Unidentified	2.367×10^7	0	2.367×10^7
Brachiopoda	1.190×10^8	2.375×10^7	1.428×10^8
Echinodermata			
Ophiuroidea	0	6.621×10^6	6.621×10^6
Unidentified	0	5.714×10^5	5.714×10^5
TOTAL	2.346×10^{10}	1.066×10^{10}	3.412×10^{10}

Appendix 6C-7. Estimated Number of Meroplankton Entrained During July, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	3.710×10^7	7.459×10^6	4.456×10^7
Decapoda			
Unidentified	2.902×10^7	8.398×10^7	1.130×10^8
Penaeidae			
Penaeus duorarum	0	7.347×10^5	7.347×10^5
Unidentified	1.026×10^6	0	1.026×10^6
Pasiphaeidae			
Leptochela spp.	3.762×10^6	0	3.762×10^6
Palaemonidae			
Periclimenes americanus	1.026×10^6	0	1.026×10^6
Periclimenes spp.	2.863×10^7	4.648×10^6	3.328×10^7
Palaemonetes intermedius	2.066×10^7	1.881×10^7	3.947×10^7
Palaemonetes pugio/ vulgaris	1.708×10^7	2.336×10^7	4.044×10^7
Unidentified sp. A	2.064×10^8	2.406×10^7	2.305×10^8
Unidentified sp. C	0	2.449×10^5	2.449×10^5
Alpheidae			
Unidentified sp. A	9.924×10^8	1.718×10^8	1.164×10^9
Unidentified sp. B	3.268×10^6	0	3.268×10^6
Unidentified sp. C	6.487×10^7	5.546×10^7	1.203×10^8
Unidentified	1.315×10^7	9.905×10^6	2.305×10^7
Ogyrididae			
Ogyrides limicola	6.176×10^6	2.939×10^6	9.115×10^6
Hippolytidae			
Hippolyte spp.	0	1.511×10^7	1.511×10^7
Latreutes parvulus	1.643×10^8	4.813×10^7	2.124×10^8
Unidentified	1.315×10^7	0	1.315×10^7

Appendix 6C-7. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	1.198×10^8	1.849×10^8	3.047×10^8
Unidentified	1.882×10^6	5.661×10^5	2.448×10^6
Caridea			
Unidentified	2.649×10^7	2.005×10^7	4.654×10^7
Callianassidae			
Upogebia affinis	2.167×10^9	1.498×10^9	3.665×10^9
Unidentified sp. A	0	7.347×10^5	7.347×10^5
Unidentified sp. C	3.268×10^6	0	3.268×10^6
Unidentified sp. D	1.026×10^6	2.182×10^6	3.208×10^6
Porcellanidae			
Petrolisthes spp.	2.275×10^8	6.374×10^7	2.912×10^8
Polyonyx gibbesi	3.724×10^9	1.117×10^9	4.841×10^9
Paguridae			
Pagurus annulipes	2.395×10^7	7.924×10^6	3.187×10^7
Unidentified sp. A	5.643×10^6	1.125×10^7	1.690×10^7
Unidentified	0	6.439×10^6	6.439×10^6
Leucosiidae			
Persephone aquilonaris	1.068×10^8	3.899×10^7	1.458×10^8
Portunidae			
Unidentified sp. A	0	5.661×10^5	5.661×10^5
Xanthidae			
Eurypanopeus depressus	3.343×10^8	1.506×10^8	4.849×10^8
Hexapanopeus angustifrons	1.146×10^9	3.864×10^8	1.532×10^9
Menippe mercenaria	5.306×10^8	3.579×10^8	8.885×10^8
Neopanope texana texana	9.172×10^8	4.686×10^8	1.386×10^9
Panopeus herbstii	1.248×10^8	4.476×10^7	1.696×10^8
Unidentified	1.318×10^8	3.362×10^8	4.680×10^8

Appendix 6C-7. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pinnotheridae			
Pinnixa chaetopterana	3.623×10^{8}	1.835×10^{8}	5.458×10^{8}
Pinnixa sayana	2.623×10^{10}	7.171×10^{9}	3.340×10^{10}
Pinnotheres maculatus	8.692×10^{7}	4.273×10^{7}	1.297×10^{8}
Unidentified	1.315×10^{7}	1.697×10^{7}	3.012×10^{7}
Grapsidae			
Sesarma cinereum	6.046×10^{7}	7.925×10^{7}	1.397×10^{8}
Sesarma reticulatum	4.925×10^{7}	5.878×10^{7}	1.080×10^{8}
Ocypodidae			
Uca spp.	4.114×10^{8}	2.996×10^{8}	7.110×10^{8}
Grapsizoea spp.	0	1.451×10^{7}	1.451×10^{7}
Majidae			
Libinia dubia	0	1.245×10^{7}	1.245×10^{7}
Unidentified	1.401×10^{6}	0	1.401×10^{6}
Brachyura			
Unidentified sp. A	2.395×10^{7}	9.798×10^{4}	2.405×10^{7}
Unidentified	0	6.783×10^{6}	6.783×10^{6}
Mollusca			
Gastropoda	3.541×10^{8}	2.376×10^{8}	5.917×10^{8}
Pelecypoda	2.083×10^{8}	3.848×10^{7}	2.468×10^{8}
Isopoda			
Aegathoa sp.	0	1.061×10^{7}	1.061×10^{7}
Cirripedia			
Balanus sp.	2.983×10^{7}	1.540×10^{8}	1.839×10^{8}
Polychaeta			
Nereidae	3.470×10^{8}	1.545×10^{8}	5.015×10^{8}
Polynoidae	0	9.552×10^{5}	9.552×10^{5}
Spionidae	1.788×10^{9}	3.540×10^{8}	2.142×10^{9}
Unidentified	1.587×10^{7}	0	1.587×10^{7}

Appendix 6C-7. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Brachiopoda	1.074×10^{8}	7.811×10^{7}	1.855×10^{8}
Echinodermata			
Unidentified	0	2.220×10^{7}	2.220×10^{7}
TOTAL	4.129×10^{10}	1.410×10^{10}	5.539×10^{10}

Appendix 6C-8. Estimated Number of Meroplankton Entrained During August, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Stomatopoda			
Squilla sp.	7.210×10^6	9.821×10^6	1.703×10^7
Decapoda			
Unidentified	0	6.204×10^5	6.204×10^5
Penaeidae			
Unidentified	2.395×10^6	0	2.395×10^6
Pasiphaeidae			
Leptochela spp.	1.449×10^7	1.306×10^6	1.580×10^7
Palaemonidae			
Periclimenes americanus	2.395×10^6	1.347×10^6	3.742×10^6
Periclimenes spp.	3.680×10^8	8.019×10^7	4.482×10^8
Palaemonetes intermedius	1.896×10^8	1.605×10^6	1.912×10^8
Palaemonetes pugio/ vulgaris	9.177×10^6	1.065×10^7	1.983×10^7
Unidentified sp. C	2.631×10^6	8.871×10^6	1.150×10^7
Unidentified	0	4.310×10^6	4.310×10^6
Alpheidae			
Unidentified sp. A	7.009×10^8	3.782×10^7	7.387×10^8
Unidentified sp. B	0	2.789×10^6	2.789×10^6
Unidentified sp. C	1.506×10^8	5.536×10^7	2.060×10^8
Unidentified	3.077×10^6	4.310×10^6	7.387×10^6
Ogyrididae			
Ogyrides limicola	2.324×10^8	6.320×10^7	2.956×10^7
Hippolytidae			
Hippolyte spp.	1.549×10^8	1.903×10^7	1.739×10^8
Latreutes parvulus	3.491×10^8	7.262×10^7	4.217×10^8
Unidentified sp. D	0	1.850×10^5	1.850×10^5
Unidentified	3.077×10^6	0	3.077×10^6

Appendix 6C-8. Continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	1.088×10^9	2.137×10^8	1.302×10^9
Processa spp.	5.263×10^6	4.213×10^6	9.476×10^6
Unidentified	4.390×10^6	0	4.390×10^6
Caridea			
Unidentified	2.006×10^8	4.701×10^7	2.476×10^8
Callianassidae			
Upogebia affinis	6.889×10^9	7.896×10^8	7.679×10^9
Unidentified sp. A	0	4.408×10^6	4.408×10^6
Unidentified sp. B	7.210×10^6	0	7.210×10^6
Unidentified sp. D	2.395×10^6	3.896×10^6	6.291×10^6
Porcellanidae			
Petrolisthes spp.	5.230×10^7	6.343×10^6	5.864×10^7
Polyonyx gibbesi	8.849×10^8	2.138×10^8	1.099×10^9
Paguridae			
Pagurus pollicaris	7.210×10^6	0	7.210×10^6
Unidentified sp. A	3.716×10^7	1.012×10^7	4.728×10^7
Unidentified	0	6.204×10^5	6.204×10^5
Leucosiidae			
Persephone aquilonaris	1.395×10^8	3.583×10^7	1.753×10^8
Portunidae			
Callinectes sp. A	0	4.310×10^6	4.310×10^6
Xanthidae			
Eurypanopeus depressus	1.010×10^9	2.276×10^8	1.238×10^9
Hexapanopeus angustifrons	1.598×10^9	3.738×10^8	1.972×10^9
Menippe mercenaria	1.025×10^9	2.105×10^8	1.235×10^9
Neopanope packardi	0	3.090×10^8	3.090×10^8
Neopanope texana texana	1.221×10^{10}	1.138×10^9	1.335×10^{10}

Appendix 6C-8. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Panopeus herbstii	1.956×10^8	2.780×10^7	2.234×10^8
Rithropanopeus harrisii	2.907×10^7	9.108×10^6	3.818×10^7
Unidentified	1.267×10^9	1.868×10^8	1.454×10^9
Pinnotheridae			
Pinnixa chaetopterana	5.064×10^8	1.699×10^8	6.763×10^8
Pinnixa sayana	1.689×10^{10}	2.138×10^9	1.903×10^{10}
Pinnotheres maculatus	2.456×10^8	7.576×10^7	3.214×10^8
Unidentified	0	2.155×10^6	2.155×10^6
Grapsidae			
Sesarma cinereum	3.053×10^8	4.452×10^7	3.498×10^8
Sesarma reticulatum	9.925×10^7	2.222×10^7	1.215×10^8
Ocypodidae			
Uca spp.	2.813×10^9	7.570×10^8	3.570×10^9
Grapsizoea spp.	6.409×10^7	2.721×10^7	9.130×10^7
Majidae			
Libinia dubia	2.970×10^7	1.141×10^7	4.111×10^7
Brachyura			
Unidentified sp. A	0	5.527×10^6	5.527×10^6
Unidentified	8.551×10^7	9.688×10^6	9.520×10^7
Mollusca			
Gastropoda	1.559×10^9	3.734×10^8	1.932×10^9
Pelecypoda	3.529×10^8	2.115×10^6	3.550×10^8
Isopoda			
Aegathoa sp.	7.210×10^6	1.486×10^6	8.696×10^6
Cirripedia			
Balanus sp.	5.011×10^8	3.070×10^8	8.081×10^8

Appendix 6C-8. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Polychaeta			
Nereidae	2.369×10^7	1.381×10^7	3.750×10^7
Spionidae	3.422×10^7	5.892×10^7	9.314×10^7
Unidentified	5.287×10^7	3.188×10^7	1.460×10^8
Brachiopoda	4.391×10^8	1.203×10^8	5.594×10^8
Echinodermata			
Unidentified	0	1.387×10^8	1.387×10^8
Urochordata	6.200×10^6	0	6.200×10^6
Phoronida	0	1.284×10^7	1.284×10^7
TOTAL	5.286×10^{10}	8.514×10^9	6.137×10^{10}

Appendix 6C-9. Estimated Number of Meroplankton Entrained During September, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total Entrained
Stomatopoda			
Squilla sp.	0	3.723×10^6	3.723×10^6
Decapoda			
Unidentified	0	3.723×10^6	3.723×10^6
Penaeidae			
Penaeus duorarum	5.403×10^6	0	5.403×10^6
Pasiphaeidae			
Leptochela spp.	3.641×10^7	7.837×10^6	4.425×10^7
Palaemonidae			
Periclimenes americanus	7.362×10^7	0	7.362×10^7
Periclimenes spp.	1.009×10^9	3.533×10^8	1.362×10^9
Palaemonetes intermedius	1.510×10^8	1.141×10^7	1.624×10^8
Palaemonetes pugio/ vulgaris	4.021×10^6	0	4.021×10^6
Unidentified sp. C	1.579×10^7	3.461×10^6	1.925×10^7
Alpheidae			
Unidentified sp. A	3.041×10^8	7.895×10^7	3.830×10^8
Unidentified sp. B	0	1.110×10^6	1.110×10^6
Unidentified sp. C	3.426×10^7	2.221×10^6	3.648×10^7
Unidentified	1.846×10^7	0	1.846×10^7
Ogyrididae			
Ogyrides limicola	6.237×10^8	3.061×10^7	6.543×10^8
Hippolytidae			
Hippolyte spp.	1.370×10^8	2.684×10^7	1.638×10^8
Latreutes parvulus	8.792×10^8	1.017×10^8	9.809×10^8
Tozeuma carolineuse	5.204×10^4	0	5.204×10^4
Unidentified sp. D	0	1.110×10^6	1.110×10^6
Unidentified	1.846×10^7	0	1.846×10^7

Appendix 6C-9. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	2.298×10^{9}	6.744×10^{8}	2.972×10^{9}
Processa spp.	3.292×10^{7}	2.528×10^{7}	5.820×10^{7}
Caridea			
Unidentified	2.252×10^{8}	3.788×10^{7}	2.631×10^{8}
Callianassidae			
Upogebia affinis	7.352×10^{9}	1.160×10^{9}	8.512×10^{9}
Unidentified sp. D	0	1.045×10^{7}	1.045×10^{7}
Porcellanidae			
Petrolisthes spp.	2.174×10^{8}	2.372×10^{7}	2.411×10^{8}
Polyonyx gibbesi	2.208×10^{10}	4.134×10^{8}	2.249×10^{10}
Paguridae			
Pagurus longicarpus	5.375×10^{5}	0	5.375×10^{5}
Unidentified sp. A	5.165×10^{7}	3.971×10^{7}	9.136×10^{7}
Unidentified	0	3.723×10^{6}	3.723×10^{6}
Leucosiidae			
Persephone aquilonaris	1.114×10^{8}	1.580×10^{6}	1.133×10^{8}
Xanthidae			
Eurypanopeus depressus	2.703×10^{9}	8.645×10^{8}	3.567×10^{9}
Hexapanopeus angustifrons	4.599×10^{9}	8.878×10^{8}	5.487×10^{9}
Menippe mercenaria	1.742×10^{9}	4.965×10^{8}	2.238×10^{9}
Neopanope texana texana	1.294×10^{10}	2.686×10^{9}	1.563×10^{10}
Panopeus herbstii	7.759×10^{8}	8.142×10^{7}	8.573×10^{8}
Rithropanopeus harrisii	1.770×10^{8}	1.935×10^{7}	1.963×10^{8}
Unidentified	2.594×10^{9}	4.153×10^{8}	3.009×10^{9}

Appendix 6C-9. Continued.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pinnotheridae			
Pinnixa chaetopterana	8.991×10^{8}	3.018×10^{8}	1.201×10^{9}
Pinnixa sayana	3.945×10^{10}	2.677×10^{9}	4.213×10^{10}
Pinnotheres maculatus	3.318×10^{8}	1.165×10^{8}	4.483×10^{8}
Laomediidae			
Unidentified	0	1.850×10^{6}	1.850×10^{6}
Grapsidae			
Sesarma cinereum	2.275×10^{8}	3.983×10^{7}	2.673×10^{8}
Sesarma reticulatum	1.668×10^{8}	5.584×10^{7}	2.226×10^{8}
Ocypodidae			
Uca spp.	4.170×10^{8}	2.585×10^{8}	6.755×10^{8}
Majidae			
Libinia dubia	9.426×10^{7}	1.156×10^{7}	1.058×10^{8}
Brachyura			
Unidentified	3.720×10^{7}	0	3.720×10^{7}
Mollusca			
Gastropoda	3.479×10^{9}	6.528×10^{8}	4.132×10^{9}
Pelecypoda	9.339×10^{7}	2.394×10^{7}	1.173×10^{8}
Cirripedia			
Balanus sp.	1.049×10^{9}	6.250×10^{7}	1.111×10^{9}
Polychaeta			
Nereidae	6.316×10^{7}	0	6.316×10^{7}
Spionidae	1.263×10^{8}	3.737×10^{7}	1.637×10^{8}
Brachiopoda	2.954×10^{8}	6.347×10^{7}	3.589×10^{8}
Urochordata	3.720×10^{7}	0	3.720×10^{7}
Phoronida	5.375×10^{5}	0	5.375×10^{5}
TOTAL	1.080×10^{11}	1.277×10^{10}	1.209×10^{11}

Appendix 6C-10. Estimated Number of Meroplankton Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pasiphaeidae			
Leptochela serritorbita	3.800×10^7	6.835×10^6	4.484×10^7
Leptochela spp.	5.821×10^7	0	5.821×10^7
Palaemonidae			
Periclimenes americanus	5.805×10^7	6.835×10^6	6.489×10^7
Periclimenes spp.	6.681×10^8	7.423×10^7	7.423×10^8
Palaemonetes floridanus	3.784×10^7	0	3.784×10^7
Palaemonetes intermedius	2.999×10^7	7.730×10^6	3.772×10^7
Palaemonetes pugio/ vulgaris	1.245×10^8	1.043×10^6	1.255×10^8
Unidentified sp. C	3.164×10^7	6.233×10^7	9.397×10^7
Unidentified	1.590×10^7	0	1.590×10^7
Alpheidae			
Unidentified sp. A	1.744×10^8	4.351×10^7	2.179×10^8
Unidentified sp. B	0	4.634×10^5	4.634×10^5
Unidentified sp. C	3.784×10^7	0	3.784×10^7
Ogyrididae			
Ogyrides limicola	2.024×10^9	3.529×10^7	2.059×10^9
Hippolytidae			
Hippolyte spp.	7.570×10^7	3.000×10^7	1.507×10^8
Latreutes parvulus	4.190×10^8	2.409×10^7	4.431×10^8
Tozeuma carolinense	1.747×10^7	0	1.747×10^7
Unidentified sp. D	3.230×10^5	4.634×10^5	7.864×10^5
Unidentified	1.615×10^5	0	1.615×10^5
Processidae			
Ambidexter symmetricus	1.039×10^9	3.490×10^8	1.388×10^9
Processa spp.	3.678×10^7	1.158×10^7	4.836×10^7
Caridea			
Unidentified	0	7.295×10^6	7.295×10^6

Appendix 6C-10. Estimated Number of Meroplankton Entrained During October, 1976. continued

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Callianassidae			
Upogebia affinis	1.095×10^9	3.494×10^8	1.444×10^9
Unidentified sp. D	3.784×10^7	0	3.784×10^7
Unidentified	0	2.897×10^6	2.897×10^6
Porcellanidae			
Petrolisthes spp.	1.541×10^8	1.372×10^7	1.678×10^8
Polyonyx gibbesi	1.026×10^{10}	6.877×10^8	1.095×10^{10}
Paguridae			
Pagurus longicarpus	5.251×10^7	0	5.251×10^7
Unidentified sp. A	1.606×10^7	2.897×10^6	1.896×10^7
Unidentified	3.116×10^7	0	3.116×10^7
Leucosiidae			
Persephone aquilonaris	7.462×10^7	3.698×10^6	7.832×10^7
Xanthidae			
Eurypanopeus depressus	2.955×10^8	1.200×10^8	4.155×10^8
Hexapanopeus augustifrons	2.130×10^9	4.159×10^8	2.546×10^9
Menippe mercenaria	4.529×10^8	9.596×10^7	5.489×10^8
Neopanope texana texana	1.147×10^{10}	1.409×10^9	1.288×10^{10}
Panopeus herbstii	3.000×10^8	8.193×10^6	3.082×10^8
Rithropanopeus harrisii	7.842×10^8	4.836×10^7	8.326×10^8
Unidentified	2.708×10^8	5.023×10^8	7.731×10^8
Pinnotheridae			
Pinnixa chaetopterana	2.457×10^9	3.762×10^8	2.833×10^9
Pinnixa sayana	8.028×10^{10}	7.078×10^9	8.736×10^{10}
Pinnotheres maculatus	3.220×10^8	8.327×10^7	4.053×10^8
Unidentified sp. A	0	1.854×10^6	1.854×10^6
Unidentified	2.792×10^8	0	2.792×10^8
Laomediidae			
Unidentified	0	8.018×10^5	8.018×10^5

Appendix 6C-10. Estimated Number of Meroplankton Entrained During October, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Grapsidae			
Sesarma cinereum	1.086×10^8	1.168×10^7	1.203×10^8
Sesarma reticulatum	4.492×10^7	6.140×10^6	5.106×10^7
Ocypodidae			
Uca spp.	3.041×10^7	3.489×10^7	6.530×10^7
Majidae			
Libinia dubia	3.230×10^5	1.390×10^6	1.713×10^6
Mollusca			
Gastropoda	1.310×10^9	1.964×10^8	1.506×10^9
Pelecypoda	2.747×10^8	1.589×10^8	4.336×10^8
Isopoda			
Aegathoa sp.	0	4.634×10^5	4.634×10^5
Cirripedia			
Balanus sp.	2.196×10^8	1.867×10^8	4.063×10^8
Polychaeta			
Spionidae	0	1.880×10^7	1.880×10^7
Syllidae	1.909×10^7	0	1.909×10^7
Unidentified	0	9.848×10^6	9.848×10^6
Brachiopoda	1.451×10^7	3.684×10^7	5.135×10^7
Echinodermata	0	5.850×10^7	5.850×10^7
Phoronida	1.451×10^7	0	1.451×10^7
Total	1.177×10^{11}	1.258×10^{10}	1.304×10^{11}

Appendix 6C-11. Estimated Number of Meroplankton Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	5.344×10^6	5.344×10^6
Penaeidae			
Penaeus duorarum	1.206×10^6	0	1.206×10^6
Pasiphaeidae			
Leptochela serritorbita	4.673×10^6	1.674×10^6	6.347×10^6
Leptochela spp.	2.503×10^6	8.505×10^5	3.354×10^6
Palaemonidae			
Periclimenes americanus	0	6.532×10^6	6.532×10^6
Periclimenes spp.	3.383×10^7	4.401×10^7	7.784×10^7
Palaemonetes intermedius	0	8.580×10^6	8.850×10^6
Palaemonetes longicaudatus	1.723×10^6	2.065×10^6	3.788×10^6
Palaemonetes pugio/ vulgaris	5.547×10^6	9.841×10^5	6.531×10^6
Unidentified sp. C	8.956×10^6	1.854×10^7	2.750×10^7
Unidentified	1.206×10^6	0	1.206×10^6
Alpheidae			
Unidentified sp. A	7.509×10^6	7.698×10^6	1.521×10^7
Unidentified sp. B	2.653×10^6	7.207×10^5	3.374×10^6
Ogyrididae			
Ogyrides limicola	4.432×10^6	6.829×10^6	1.126×10^7
Hippolytidae			
Hippolyte zostericola	1.688×10^6	8.505×10^5	2.539×10^6
Hippolyte spp.	2.403×10^7	1.278×10^7	3.681×10^7
Latreutes parvulus	2.164×10^7	1.179×10^7	3.343×10^7
Thor floridanus	0	2.429×10^5	2.429×10^5
Tozeuma carolinense	3.467×10^6	0	3.467×10^6
Unidentified sp. D	5.006×10^6	1.135×10^5	5.120×10^6
Unidentified	2.503×10^6	4.858×10^5	2.989×10^6

Appendix 6C-11. Estimated Number of Meroplankton Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Ambidexter symmetricus	2.708×10^7	5.745×10^7	8.453×10^7
Processa spp.	9.888×10^6	2.837×10^6	1.272×10^7
Caridea			
Unidentified	9.646×10^5	1.268×10^6	2.232×10^6
Callianassidae			
Upogebia affinis	3.455×10^7	3.669×10^7	7.124×10^7
Unidentified	0	7.094×10^5	7.094×10^5
Porcellanidae			
Petrolisthes spp.	2.503×10^6	1.674×10^6	4.177×10^6
Polyonyx gibbesi	6.640×10^9	1.686×10^8	6.809×10^9
Paguridae			
Pagurus longicarpus	1.359×10^7	3.158×10^6	1.675×10^7
Unidentified sp. A	2.503×10^6	9.523×10^5	3.455×10^6
Leucosiidae			
Persephone aquilonaris	1.688×10^6	1.560×10^6	3.248×10^6
Unidentified	0	6.072×10^5	6.072×10^5
Xanthidae			
Eurypanopeus depressus	6.602×10^6	1.139×10^7	1.799×10^7
Hexanopanopeus angustifrons	9.910×10^7	6.540×10^7	1.645×10^8
Menippe mercenaria	1.585×10^7	9.525×10^6	2.538×10^7
Neopanopeus texana texana	1.037×10^9	5.215×10^8	1.558×10^9
Panopeus herbstii	0	1.163×10^6	1.163×10^6
Rithropanopeus harrisii	6.645×10^7	2.667×10^7	9.312×10^7
Unidentified	5.818×10^7	1.169×10^8	1.751×10^8
Pinnotheridae			
Pinnixa chaetopterana	4.972×10^7	8.321×10^7	1.329×10^8
Pinnixa sayana	2.475×10^9	1.169×10^9	4.104×10^9
Pinnotheres maculatus	2.237×10^7	1.741×10^7	3.978×10^7
Unidentified sp. A	0	4.540×10^5	4.540×10^5

Appendix 6C-11. Estimated Number of Meroplankton Entrained During November, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Grapsidae			
Sesarma cinereum	1.929×10^6	1.649×10^6	3.578×10^6
Sesarma reticulatum	0	1.504×10^6	1.504×10^6
Ocypodidae			
Uca spp.	0	3.153×10^6	3.153×10^6
Majidae			
Libinia dubia	5.006×10^6	4.713×10^6	9.719×10^6
Brachyura			
Unidentified	7.235×10^5	0	7.235×10^5
Mollusca			
Gastropoda	1.110×10^{10}	1.080×10^9	1.218×10^{10}
Pelecypoda	5.064×10^6	3.710×10^7	4.217×10^7
Isopoda			
Aegethoa sp.	2.894×10^6	1.590×10^7	1.880×10^7
Cirripedia			
Balanus sp.	1.454×10^8	5.743×10^8	7.197×10^8
Polychaeta			
Nereidae	1.206×10^6	0	1.206×10^6
Spioinidae	0	1.220×10^6	1.220×10^6
Syllidae	1.929×10^6	0	1.929×10^6
Unidentified	2.894×10^6	2.412×10^6	5.306×10^6
Brachipoda	0	4.794×10^6	4.794×10^6
Echinodermata	0	1.433×10^7	1.433×10^7
Total	2.196×10^{10}	4.629×10^9	2.660×10^{10}

Appendix 6C-12. Estimated Number of Meroplankton Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	1.550×10^6	1.550×10^6
Peuaeidae			
Penaeus duorarum	3.742×10^5	0	3.742×10^5
Pasiphaeidae			
Leptochela serritorbita	1.243×10^7	0	1.243×10^7
Leptochela spp.	0	2.392×10^5	2.392×10^5
Palaemonidae			
Peridimenes americanus	1.623×10^6	1.600×10^6	3.223×10^6
Perichmenes spp.	5.838×10^6	8.915×10^6	1.475×10^7
Palaemonetes intermedius	1.988×10^7	2.318×10^7	4.306×10^7
Palaemonetes longicaudatus	2.627×10^6	8.147×10^5	3.442×10^6
Palaemonetes pugio/ vulgaris	1.721×10^6	2.050×10^5	1.926×10^6
Unidentified sp. C	4.491×10^5	1.039×10^6	1.488×10^6
Unidentified	3.742×10^5	0	3.742×10^5
Alpheidae			
Unidentified sp. A	0	1.117×10^6	1.117×10^6
Unidentified sp. B	8.233×10^5	2.174×10^5	1.041×10^6
Ogyrididae			
Ogyrides limicola	2.222×10^6	2.050×10^5	2.427×10^6
Hippolytidae			
Hippolyte zostericola	5.239×10^5	2.392×10^5	7.631×10^5
Hippolyte spp.	1.782×10^8	6.520×10^7	2.434×10^8
Latreutes parvulus	2.589×10^7	4.743×10^6	3.063×10^7
Thor floridanus	0	6.833×10^4	6.833×10^4
Tozeuma carolinense	2.994×10^5	1.366×10^5	4.360×10^5
Unidentified	0	6.833×10^4	6.833×10^4

Appendix 6C-12. Estimated Number of Meroplankton Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Processidae			
Amdidexter symmetricus	1.956×10^7	6.637×10^6	2.620×10^7
Processa spp.	7.003×10^6	1.399×10^5	7.143×10^6
Caridea			
Unidentified	2.994×10^5	3.247×10^6	3.546×10^6
Callinnassidae			
Upogebia affinis	8.939×10^6	5.140×10^6	1.408×10^7
Porcellanidae			
Petrolisthes spp.	1.056×10^6	0	1.056×10^6
Polyonyx gibbesi	1.071×10^7	5.860×10^6	1.657×10^7
Unidentified	0	3.731×10^5	3.731×10^5
Paguridae			
Pagurus longicarpus	4.121×10^7	1.495×10^7	5.616×10^7
Pagurus pollicaris	0	2.340×10^5	2.340×10^5
Unidentified sp. A	1.623×10^6	5.831×10^5	2.206×10^6
Leucosiidae			
Persephone aquilonaris	5.239×10^5	2.392×10^5	7.631×10^5
Portunidae			
Callinectes sapidus	0	2.340×10^5	2.340×10^5
Unidentified	1.623×10^6	1.708×10^5	1.794×10^6
Xanthidae			
Eurypanopeus depressus	1.712×10^6	1.218×10^6	2.930×10^6
Hexanopeus augustifrons	2.333×10^7	7.827×10^6	3.116×10^7
Menippe mercenaria	9.729×10^5	1.059×10^6	2.032×10^6
Neopanope texana texana	2.534×10^8	1.035×10^8	3.569×10^8
Panepeus herbstii	7.707×10^6	4.681×10^5	3.646×10^8
Rithropanopeus harrisii	1.694×10^7	5.581×10^6	2.252×10^7
Unidentified	1.011×10^7	5.401×10^6	1.551×10^7

Appendix 6C-12. Estimated Number of Meroplankton Entrained During December, 1976.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Pinnotheridae			
Pinnixa chaetopterana	6.736×10^5	8.273×10^5	1.501×10^6
Pinnixa sayana	7.566×10^7	7.830×10^6	8.349×10^7
Pinnotheres maculatus	5.388×10^6	1.400×10^6	6.788×10^6
Grupsidae			
Sesarma cinereum	5.987×10^5	1.366×10^5	7.353×10^5
Ocypodidae			
Uca spp.	0	1.366×10^5	1.366×10^5
Majidae			
Libinia dubia	2.028×10^6	2.049×10^6	4.077×10^6
Brachyura			
Unidentified	2.245×10^5	0	2.245×10^5
Mollusca			
Gastropoda	7.341×10^9	6.822×10^8	8.023×10^9
Pelecypoda	7.504×10^7	5.726×10^7	1.323×10^8
Isopoda			
Aegathoa sp.	3.737×10^6	6.804×10^6	1.054×10^7
Cirripedia			
Balanus sp.	6.951×10^8	2.448×10^8	9.399×10^8
Polychaeta			
Nereidae	8.142×10^5	3.506×10^5	1.165×10^6
Spionidae	0	1.890×10^6	1.890×10^6
Syllidae	8.306×10^6	6.317×10^5	8.938×10^6
Unidentified	8.981×10^5	0	8.981×10^5
Urochordata	3.432×10^6	5.805×10^7	6.148×10^7
Total	8.873×10^9	1.337×10^9	1.021×10^{10}

Appendix 6C-13. Estimated Number of Meroplankton Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	2.892×10^5	2.892×10^5
Palaemonidae			
Unidentified sp. C	0	7.229×10^5	7.229×10^5
Alpheidae			
Unidentified sp. B	0	2.892×10^5	2.892×10^5
Hippolytidae			
Hippolyte spp.	0	2.313×10^6	2.313×10^6
Latreutes paruulus	0	1.012×10^6	1.012×10^6
Processa spp.			
Processa spp.	6.547×10^6	8.673×10^5	7.414×10^6
Callinuassidae			
Upogebia affinis	0	2.892×10^5	2.892×10^5
Porcellanidae			
Petrolisthes spp.	6.547×10^6	0	6.547×10^6
Polyonyx gibbesi	0	1.446×10^6	1.446×10^6
Unidentified	0	2.313×10^6	2.313×10^6
Paguridae			
Pagurus longicarpus	2.292×10^7	9.544×10^6	3.246×10^7
Unidentified sp. A	0	2.892×10^5	2.892×10^5
Xanthidae			
Eurypanopeus depressus	2.728×10^6	4.192×10^6	6.920×10^6
Hexapanopeus angustifrons	6.547×10^6	1.301×10^7	1.956×10^7
Neopanope texana texana	2.728×10^6	1.879×10^6	4.607×10^6
Unidentified	0	5.783×10^5	5.783×10^5
Pinnotheridae			
Pinnixa chaetopterana	0	2.892×10^5	2.892×10^5

Appendix 6C-13. Estimated Number of Meroplankton Entrained During January, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Mollusca			
Gastropoda	1.124×10^9	3.527×10^8	1.477×10^9
Pelecypoda	8.075×10^7	2.718×10^8	3.525×10^8
Isopoda			
Aegathoa sp.	0	8.673×10^5	8.673×10^5
Cirripedia			
Balanus sp.	1.375×10^9	3.387×10^8	1.714×10^9
Polychaeta			
Nereidae	2.728×10^6	7.229×10^5	3.451×10^6
Spionidae	0	1.027×10^7	1.027×10^7
Syllidae	0	2.892×10^5	2.892×10^5
Urochordata	2.128×10^7	2.221×10^8	2.434×10^8
Total	2.652×10^9	1.237×10^9	3.889×10^9

Appendix 6C-14. Estimated Number of Meroplankton Entrained During February, 197 .

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Merostomata			
Limulus polyphemus	0	5.597×10^4	5.597×10^4
Palaemonidae			
Palaemonetes intermedius	1.341×10^7	2.626×10^6	1.604×10^7
Palaemonetes pugio/ vulgaris	1.559×10^7	0	1.559×10^7
Unidentified sp. C	0	1.085×10^6	1.085×10^6
Alpheidae			
Unidentified sp. B	0	5.597×10^4	5.597×10^4
Hippolytidae			
Hippolyte spp.	1.266×10^8	4.089×10^7	9.344×10^7
Latreutes paruulus	0	1.959×10^5	1.959×10^5
Processidae			
Ambidexter symmetricus	0	8.406×10^5	8.406×10^5
Processa spp.	1.267×10^6	1.679×10^5	9.771×10^6
Callianassidae			
Upogebia affinis	2.963×10^7	3.523×10^6	3.315×10^7
Porcellanidae			
Petrolisthes spp.	1.267×10^6	0	1.267×10^6
Polyonyx gibbesi	0	4.900×10^5	4.900×10^5
Unidentified	0	4.477×10^5	4.477×10^5
Paguridae			
Pagurus longicarpus	1.523×10^8	5.257×10^7	2.049×10^8
Unidentified sp. A	1.559×10^7	3.838×10^6	1.943×10^7
Portunidae			
Callinectes sp. A	0	3.887×10^6	3.887×10^6
Xanthidae			
Eurypanopeus depressus	1.709×10^8	1.404×10^8	3.113×10^8

Appendix 6C-14. Estimated Number of Meroplankton Entrained During February, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Hexapanopeus angustifrons	9.637×10^7	1.446×10^8	2.410×10^8
Neopanope texana texana	8.786×10^7	3.335×10^7	1.212×10^8
Panopeus herbstii	0	1.093×10^7	1.093×10^7
Rithropanopeus harrisii	0	1.061×10^7	1.061×10^7
Unidentified	1.029×10^8	2.732×10^7	1.302×10^8
Pinnotheridae			
Pinnixa chaetopterana	3.181×10^7	2.997×10^6	3.481×10^7
Pinnixa sayana	4.533×10^9	1.850×10^9	6.383×10^9
Majidae			
Libinia dubia	7.795×10^6	2.626×10^6	1.042×10^7
Mollusca			
Gastropoda	2.176×10^8	9.758×10^7	3.152×10^8
Pelecypoda	1.030×10^8	7.708×10^7	1.801×10^8
Isopoda			
Aegathoa sp.	0	1.679×10^5	1.679×10^5
Cirripedia			
Balanus sp.	2.112×10^9	1.437×10^9	3.549×10^9
Polychaeta			
Nereidae	5.280×10^5	1.399×10^5	6.679×10^5
Spionidae	3.181×10^7	4.528×10^7	7.709×10^7
Syllidae	1.622×10^7	5.307×10^6	2.153×10^7
Echinodermata	8.875×10^8	7.048×10^7	9.580×10^8
Urochordata	4.119×10^6	4.299×10^7	4.710×10^7
Total	8.759×10^9	4.110×10^9	1.287×10^{10}

Appendix 6C-15. Estimated Number of Meroplankton Entrained During March, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Palaemonidae			
Palaemonetes intermedius	1.890×10^7	3.701×10^6	2.260×10^7
Palaemonetes pugio/ vulgaris	2.197×10^7	0	2.197×10^7
Unidentified sp. C	0	1.332×10^6	1.332×10^6
Hippolytidae	0	5.699×10^7	5.699×10^7
Hippolyte spp.	1.784×10^8	0	1.784×10^8
Processidae			
Ambidexter symmetricus	0	1.184×10^6	1.184×10^6
Callianassidae			
Upogebia affinis	4.174×10^7	4.885×10^6	4.663×10^7
Porcellanidae			
Polyonyx gibbesi	0	2.961×10^5	2.961×10^5
Paguridae			
Pagurus longicarpus	2.803×10^8	7.148×10^7	2.798×10^8
Unidentified sp. A	2.197×10^7	5.329×10^6	2.730×10^7
Portunidae			
Callinectes sp. A	0	5.477×10^6	5.477×10^6
Xanthidae			
Eurypanopeus depressus	2.408×10^8	1.967×10^8	4.375×10^8
Hexanopeus angustifrons	1.340×10^8	2.003×10^8	3.343×10^8
Neopanopeus texana texana	1.231×10^8	4.648×10^7	1.696×10^8
Panopeus herbstii	0	1.539×10^7	1.539×10^7
Rithropanopeus harrisii	0	1.495×10^7	1.495×10^7
Unidentified	1.450×10^8	3.834×10^7	1.833×10^8
Pinnotheridae			
Pinnixa chaetopterana	4.482×10^7	4.145×10^6	4.896×10^6
Pinnixa sayana	6.387×10^9	2.606×10^9	8.993×10^9

Appendix 6C-15. Estimated Number of Meroplankton Entrained During March, 1977.

Species	# Entrained By Plant	# Entrained By Dilution Pump	Total # Entrained
Majidae			
Libinia dubia	1.098×10^7	3.701×10^6	1.468×10^7
Mollusca			
Gastropoda	0	4.130×10^7	4.130×10^7
Pelecypoda	1.231×10^8	3.449×10^7	1.576×10^8
Cirripedia			
Balanus sp.	2.601×10^9	1.933×10^9	4.534×10^9
Polychaeta			
Spionidae	4.482×10^7	6.101×10^7	1.058×10^8
Syllidae	2.285×10^7	7.399×10^6	3.025×10^7
Echinodermata	1.251×10^9	9.932×10^7	1.350×10^9
Total	1.162×10^{10}	5.453×10^9	1.707×10^{10}

CHAPTER SEVEN

A STUDY ON THE IMPINGEMENT OF FISHES AND MACROINVERTEBRATES AT THE BIG BEND STEAM ELECTRIC STATION, TAMPA, FLORIDA

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INTRODUCTION

General

Fish kills due to impingement on power plant cooling water intake screens have been documented for a large number of power plants (Landry and Strawn, 1974; Edwards, Hunt, Miller and Senic, 1975; Grimes, 1975; Benda, 1976; Bernhard and Latvaites, 1976). Impingement usually occurs when fish become entrained in the current of cooling water being drawn into power plants (at Big Bend this current is 0.59 m/sec. at the screen opening). Trash racks are usually set up to catch large fish and debris but the actual intake screens impinge many smaller fish, invertebrates and debris. Some fish and invertebrates become impinged after being attracted to an intake structure for possible protection or to feed on already impinged organisms and encrusting molluscs and crustaceans. Pumping sounds have also been suggested to attract fish to intake structures (Clark and Brownell, 1973).

The impact of power plant impingement of fish and invertebrates is certainly site specific and difficult to generally assess. Clark and Brownell (1973) rated impingement as one of the major problems faced by power plants located in coastal

areas. Conversely, several studies have concluded that impingement rates are either negligible or do not represent significant damage to resident populations (Landry and Strawn, 1974; Voightlander et al., 1976; Bernhardt and Latvaitis, 1976; Mather et al., 1977). In general, most reports on impingement have failed to adequately assess actual impact. This failure has usually been due either to a lack of preoperational data or to a general lack of knowledge of standing crop, fecundity, and natural mortality rates of the local fish and invertebrates.

Specific Objectives

The present paper is the result of 15 consecutive months of sampling at Units 1 and 2 of Big Bend Station. This sampling scheme was designed to fulfill monitoring requirements set by the Environmental Protection Agency and included a monitoring of all impinged organisms over 24 hour periods once every two weeks.

The specific objectives of monitoring the kinds and numbers of organisms impinged on the intake screens at Big Bend Station have been:

1. to determine the total number of organisms impinged per unit of sampling time;
2. to average these data to give estimated seasonal daily impingement rates;

3. to determine size-class distribution of selected species;

4. to elucidate species dominance of impinged organisms; and

5. to identify differences in night impingement rates with and without lighting of the intake structure.

Information from each of the above categories has been used to evaluate and describe the impact of impingement at Big Bend. Data derived from objectives 1-4 have been compared with local commercial catch data and literature on the natural abundance and seasonal distribution of species impinged (e.g. does impingement trap a large number of species that are rarely found at the site, or possibly, small numbers of a species that is found abundantly year round, etc.).

Sampling was on Units 1 and 2 only, as the study was meant to document effects of these units. These units are closest to the entrance to the intake channel and probably represent the worst case. Also, Unit 3 was not in operation until almost 1/3 of our sampling was completed.

The Site and Intake Structure

Tampa Electric Company's Big Bend Station is located on the southeast shore of Hillsborough Bay in the Tampa Bay system. The plant intake is located near the east end of

a .04 km intake channel (Figure 7.1). Approximately 240,000 gpm of cooling water is pumped through each of the three units independent of unit load. In an effort to reduce impingement, the vertical travelling screens (0.38" mesh) are hung perpendicular to the intake channel (Figure 7.2). As the screens become clogged, they are rotated and cleaned by a jet of water which frees impinged organisms, forcing them into a sluicing trough and thence to a holding tank from which they are periodically collected and then buried. A trash rack (vertical bars 3" apart) surrounds the intake screens to filter the top layer of floating debris.

Limitations

This study is primarily limited by a paucity of historical data for comparative purposes. Although there is no information on the standing stock of any fish or macroinvertebrate population in Tampa Bay, estimates of seasonal abundance of dominant species in the study area is presented in Chapter 8. The basic task therefore has been to compare the number of species and individuals that were captured per unit effort or per unit time with data such as average seasonal abundance and commercial catch data. Such relative impact assessment, although augmented by comparisons with available literature concerning other areas is, necessarily, subjective and qualitative in nature.

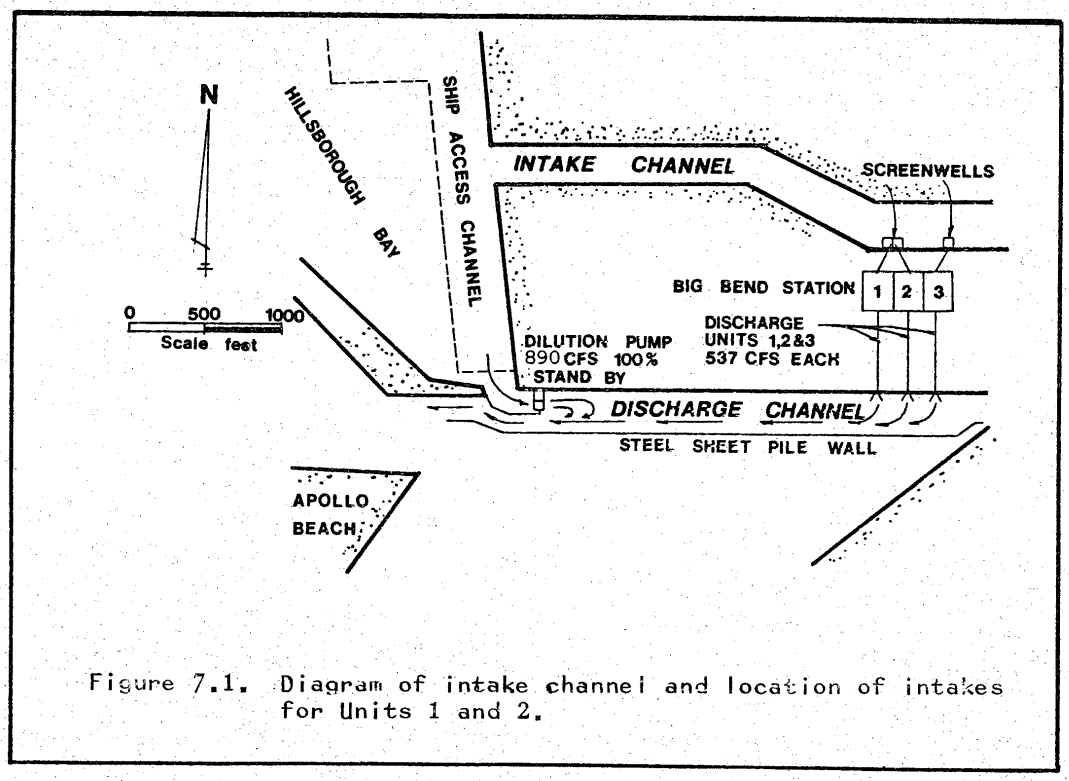

Figure 7.1. Diagram of intake channel and location of intakes for Units 1 and 2.

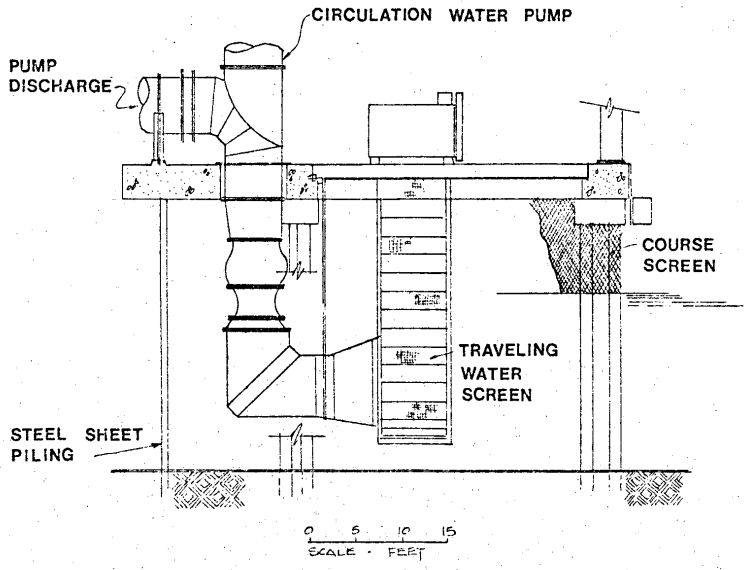

Figure 7.2. Circulating Water intake. Big Bend Station, Tampa Electric Company.

Two technical limitations are:

1. It was not always possible to determine whether an organism died from inpingement or from other causes (i.e. was dead before impingement). The major speculative cause of death other than impingement was cold water due to a severe winter (see Results). Some other inaccuracies in our estimates have probably been incurred due to the number of crabs feeding on impinged fish.
2. Only a single unit (Unit 1 or Unit 2) was sampled during any given 24 hour sampling period. Entrained organisms pass these units first in the intake canal. Although all three units pump equal volumes of water (and volume is independent of unit load in all three), we cannot rule out some behavioral attraction to one unit more than any other and, consequently, our data can only structly be interpreted for Unit 1 or Unit 2. However in an attempt to appreciate the impact of the plant as a whole (All 3 Units), one may triple the per unit estimates.

METHODS

The vertical travelling screens at Big Bend (Units 1 or 2) were sampled once every two weeks from January, 1976 through March, 1977. Unit 1 was the primary unit sampled. Whenever Unit 1 was offline, the screens of Unit 2 were

sampled. The intake screens of both units are on the same intake structure within a few feet of each other. Impingement samples were collected by plant personnel in the following manner:

1. At 0001 hours the screens were washed to begin the sampling period.
2. At 0600, 1200, 1800 and 2400 hours the screens were washed for two full cycles. The screen wash was filtered into a 0.38 inch mesh basket and the resultant filtrate was placed into a labeled container.

Laboratory Procedures

Laboratory personnel separated fish and macroinvertebrates from the encrusting organisms and other debris. Each individual was then identified using accepted taxonomic keys (Williams, 1965; Felder, 1973; Cliburn, 1974; Gallaway, Parker and Moore, 1972), weighed and measured. Fish standard length, squid pen (gladii) length, shrimp total length, and decapod carapace width (carapace length in Limulus polyphemus) were measured to the nearest millimeter (L. polyphemus to nearest 0.5 centimeter). Individuals with a biomass of less than 150.0 grams were weighed to the nearest 0.1 gram on a Torbal Model St-1 balance or an Ohaus Model 311 balance. Larger individuals

were weighed to the nearest 0.5 g. on a Mettler balance (Model P-6).

Qualitative observations were made on the ability of selected species to survive 24 hours after impingement. Organisms were placed in aquaria kept at room temperature and observed intermittently over 24 hours.

Effects of Intake Structure Lighting

A three month period (January-March, 1976) was used to study the effects of intake structure lighting on impingement rates. An additional five nights (60 hours) were sampled when the intake structure lights were off. Each of these five samples were collected within a few nights of the regular 24 hour collections. Samples were processed as indicated above.

RESULTS AND DISCUSSION

Invertebrates

Relative Abundance and Seasonality

A total of 9,382 invertebrate organisms representing 27 species were collected from the travelling screens (Unit 1 or Unit 2) from a total of 31 days (744 hours) of sampling from January, 1976 to March, 1977. This resulted in an average of 302.6 invertebrates impinged per sampling day (12.6/hour).

The following six species comprised 84.8% of the total number of invertebrates collected: Penaeus duorarum (pink

shrimp), Callinectes sapidus (blue crab), Limulus polyphemus (horseshoe crab), Portunus gibbesii (a portunid crab), Lolliguncula brevis (brief squid) and Squilla empusa (mantis shrimp). Of all invertebrates collected, P. duorarum accounted for 35.6%, C. sapidus 13.6%, L. polyphemus 13.4%, P. gibbesii 8.4%, L. brevis 7.5% and S. empusa 6.3%.

Table 7.1 presents seasonal abundances of these dominant species according to the six hour sampling intervals. Also presented are total numbers of invertebrates collected during each season and the estimated number of invertebrates impinged per day within each season. Higher numbers of invertebrates were collected during the summer (July - September) and the winters (January - March) of 1976 and 1977. Lower numbers were collected during the spring (April - June) and fall months (October - December). The rates of impingement followed this same pattern, with the higher rates occurring in the summer and winters and the lower rates during the spring and fall.

The relative abundance of impinged species varied seasonally. P. duorarum accounted for almost 76% of the invertebrates collected during the summer, while no individuals of this species were collected during the spring. During the winter months (January - March) of 1976, the samples were dominated by P. duorarum (37.9%), C. sapidus (18.0%) and L. polyphemus (22.5%). During the winter of 1977, samples were dominated by

Table 7.[1]. List of most abundant invertebrate species impinged at Big Bend (one unit) between January, 1976 - March, 1977. (1 = 0001-0600 hrs., 2 = 0601-1200 hrs., 3 = 1201-1800 hrs., and 4 = 1801-2400 hrs).

	Jan - March '76				April - June				July - Sept.				Oct. - Dec.				Jan. - Mar.'77				Total
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Penaeus duorarum Pink shrimp	271	90	312	256	0	0	0	0	362	305	491	763	60	52	22	56	80	75	20	114	3329
Callinectes sapidus Blue crab	210	56	61	115	5	20	1	8	1	0	0	0	49	37	78	17	216	164	54	185	1277
Limulus polyphemus Horseshoe crab	215	54	180	103	26	55	21	31	38	33	8	14	35	35	10	29	90	111	67	103	1258
Portunus gibbesii Portunid crab	68	12	23	40	0	0	0	0	3	9	10	8	56	76	96	39	98	128	31	89	786
Lolliguncula brevis Brief squid	25	6	17	28	45	53	20	55	110	92	24	93	25	8	9	41	26	10	11	6	704
Squilla empusa Mantis shrimp	36	17	10	54	2	3	6	4	0	0	0	0	19	51	82	4	152	51	50	57	598
Total Invertebrates	2454				1064				2529				1293				2024				
Number of sampling days	6				7				6				7				5				
Estimated invertebrates impinged per day (# collected ÷ # of sampling days)	409.0				152				421.5				184.7				408.4				

P. duorarum (14.2%), C. sapidus (30.5%), L. polyphemus (18.2%), P. gibbesii (16.9%) and S. empusa (15.2%). During the spring, the horseshoe crab L. polyphemus (13.6%) and the squid L. brevis (16.3%) dominated the samples collected. Dominance within the samples collected in the fall of 1976 was evenly distributed between all six of the cited dominant species.

Effects of Temperature

Figure 7.3 presents graphically the total number of invertebrates collected on each sampling date and the average water temperature at the intake at the time of sampling. Generally, peaks in invertebrate impingement occurred at temperature extremes while depressions in impingement occurred during moderate temperatures. This follows from Table 7.1, which demonstrated that impingement was more pronounced during the summer and winter months and depressed during the spring and fall months. It was not possible to discern whether these peaks in impingement were the result of temperature stress on the organisms impinged or simply a result of increased abundance of the organisms in the Big Bend area at these times of year (summer, 1976 and the winters of 1976 and 1977).

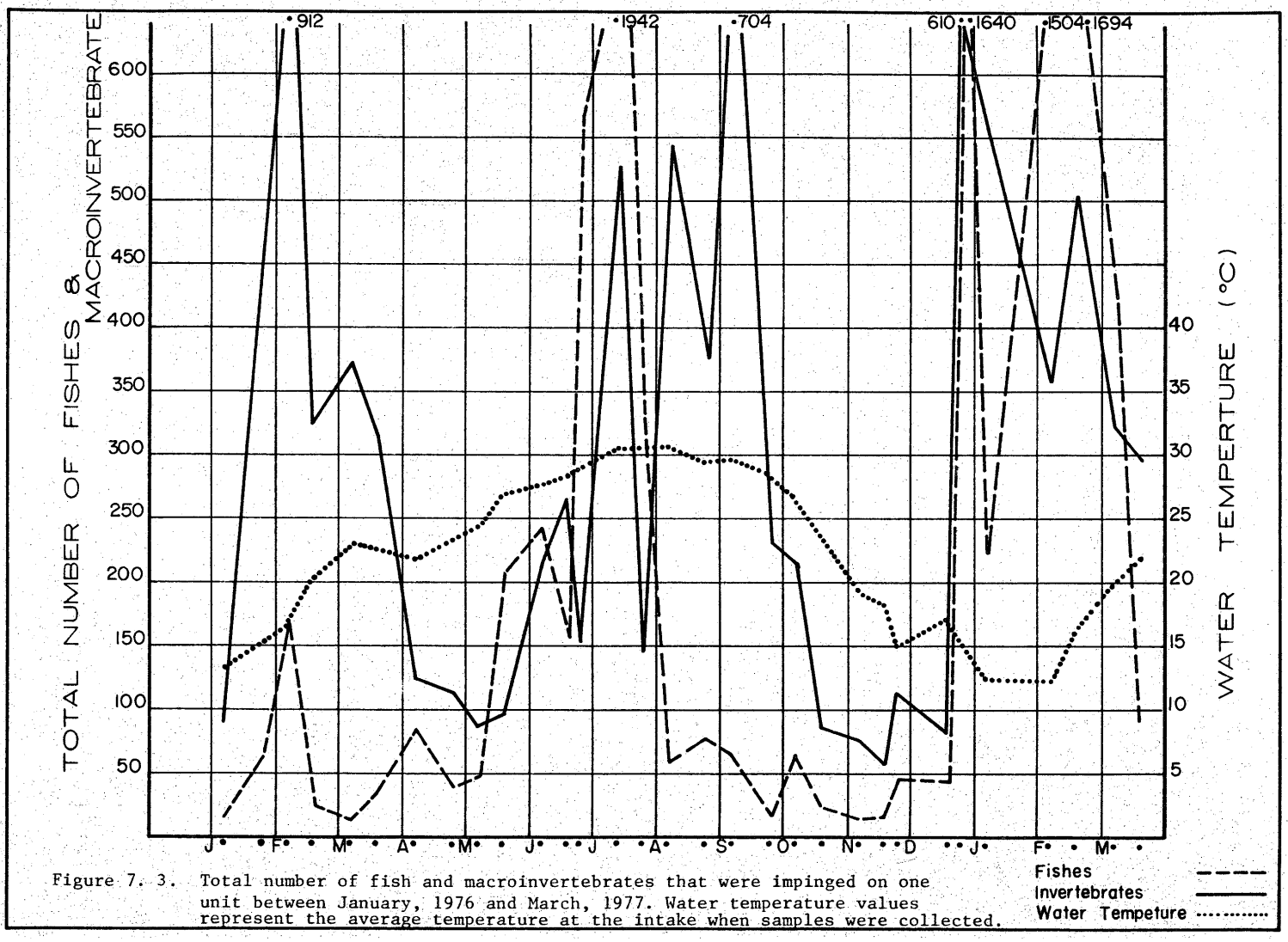

Figure 7. 3. Total number of fish and macroinvertebrates that were impinged on one unit between January, 1976 and March, 1977. Water temperature values represent the average temperature at the intake when samples were collected.

Day Versus Night Impingement

A seasonal breakdown of the numbers of invertebrates impinged at night and during the day is presented in Appendix 7A. More invertebrates were impinged during the night hours (1800-2400 hours). However, a statistical analysis (t-test) of the data showed that there was no significant difference ($\alpha = 0.05$) between day and night impingement.

Effects of Lighting

In an attempt to evaluate the effects of lighting at the intake structure, five nights were sampled with lights on and another five nights were sampled with lights off. The results of this sampling are presented in Appendix 7.B. Although more invertebrates were collected during the sampling periods with the lights on, the difference was not significant ($\alpha = 0.05$).

Size Classes

Limited size class data was generated for all invertebrates impinged at Big Bend. This data is presented for each of the six dominant species in the following section.

Dominant Species

Penaeus duorarum

The decapod, Penaeus duorarum (pink shrimp) was the dominant invertebrate impinged comprising 35.4% of the total

invertebrate catch. A total of 3,329 individuals (107.4 organisms/24 hours) were impinged over the 15 sampling months. Greatest impingement occurred during February, June, July and August, 1976 and the least during April and May. Approximately 68% of the total impingement of this species occurred at night. Utilizing operational data, it is estimated that 25,773 individuals would have been impinged during the 15 months of 1976 and 1977 (based on an impingement rate of 107.4 per day over the eight months of noted abundance).

Cummings (1961) stated that the greatest spawning of pink shrimp in Florida waters occurs from April - July, although ripe and nearly ripe females were found at other times of the year. Eldred, Ingle, Woodburn, Hutton and Jones (1961) found that shrimp which were spawned in late March or April could reach 45 to 65 mm by July and that those spawned in May could reach 25 to 35 mm by July.

Individuals impinged during the months of July, August and September were probably spawned in late March or April. Sampling indicated that an extended spawning season or multiple spawning seasons do occur. Total length of impinged shrimp ranged from 19 to 156 mm. Figure 7.4 presents monthly size class data for P. duorarum.

From the extrapolated number of shrimp impinged over the 15 month study period it was estimated that approximately 920

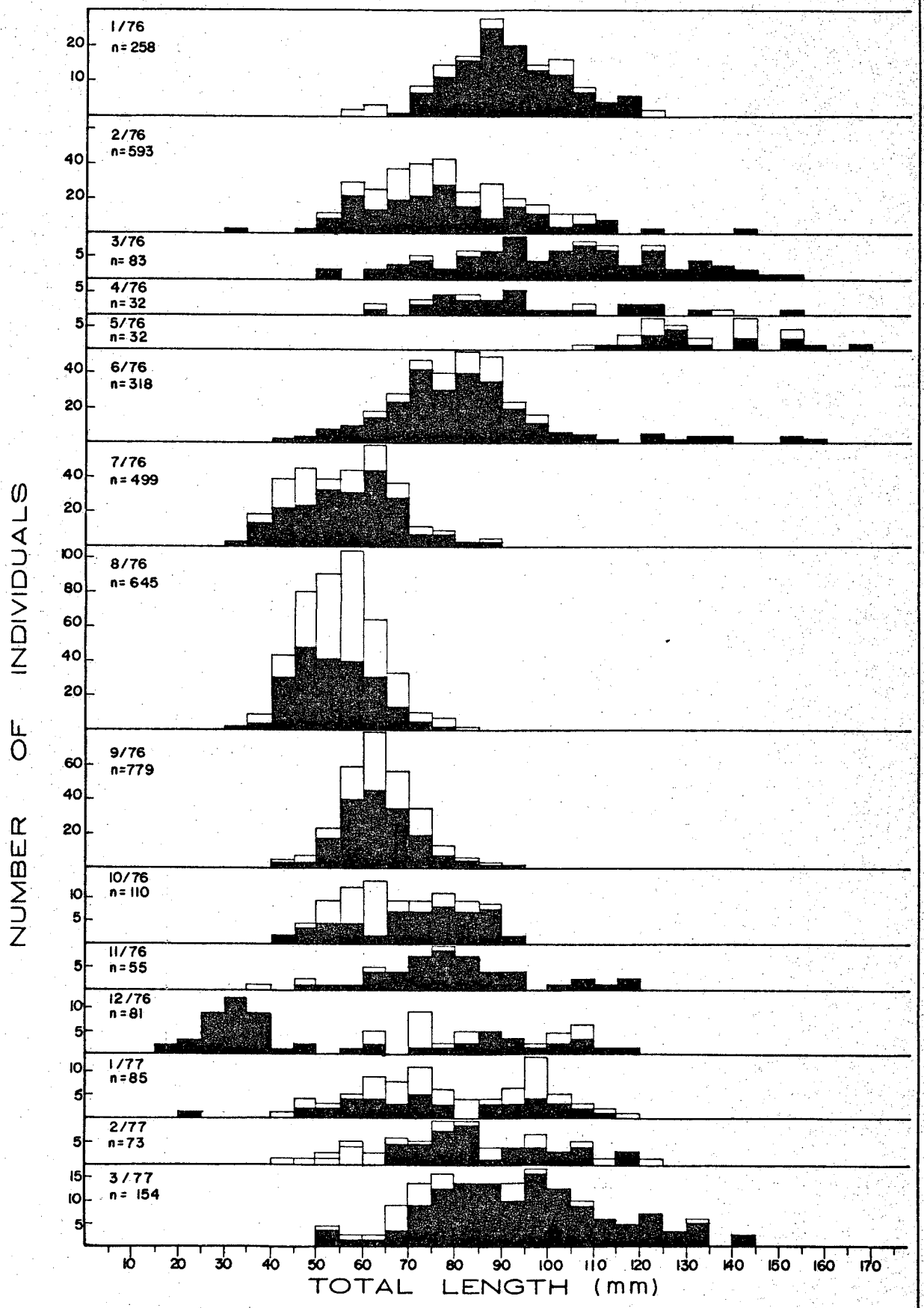

Figure 7.4. Length distribution of Penaeus duorarum (Pink shrimp) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

pounds (based on an average of 28 shrimp per lb) of shrimp were impinged by one unit. Based on these figures it was estimated that the number of shrimp impinged at Big Bend (one unit) represented approximately 0.23% of the Tampa Bay shrimp landing from 1975 (USDC, 1975).

It was observed that large numbers of shrimp were alive in the sluicing trough and in the samples (and survived 24 hours under experimental conditions).

Callinectes sapidus

C. sapidus (blue crab) is a commercially important species in the Tampa Bay area. Impingement totaled 1,277 individuals (41.2 individuals/24 hours) and was the second most abundant invertebrate captured. Maximum impingement occurred during cooler months and minimum impingement occurred during the warmer months. Blue crab impingement during December, 1976, January and February, 1976 and 1977 accounted for 92.4% of the total catch for this species. Using plant operational data, it is estimated that 7,414 individuals (based on six months of greatest abundance) would have been impinged by Unit 1 (or Unit 2) during the 15 months of 1976 and 1977.

Carapace width ranged from 9 to 170 mm. The only growth trends that were evident occurred during the final four sampling months. Mean carapace width increased from 40 mm in December, 1976 to 76 mm by March, 1977. Monthly size

class data for C. sapidus is presented in Figure 7.5. A large number of individuals were alive in samples and observed alive in the sluicing trough. Based on commercial catch statistics provided by the National Marine Fisheries Service, it was estimated that approximately 0.7% of the commercial blue crab catch was impinged by 1 unit in 1976.

Limulus polyphemus

Limulus polyphemus (horseshoe crab) was the third most abundant invertebrate impinged (1,258 individuals). Impingement was greatest during the cooler months and least during the warmer months. Impingement during February, 1976 and 1977 accounted for 61.4% of the total catch for this species which may have been due to an inshore spawning migration. After spawning, L. polyphemus spends the rest of the summer feeding in shallow water until the onset of winter when they move back into the deeper water (Lewis, 1975). Little variation in impingement was noted between day and night, or between males and females. Approximately 7,304 individuals (based on 6 months of noted abundance) would have been impinged by Unit 1 (or Unit 2) throughout the study period.

L. polyphemus

All individuals (except 5) were alive at the time of sample collection.

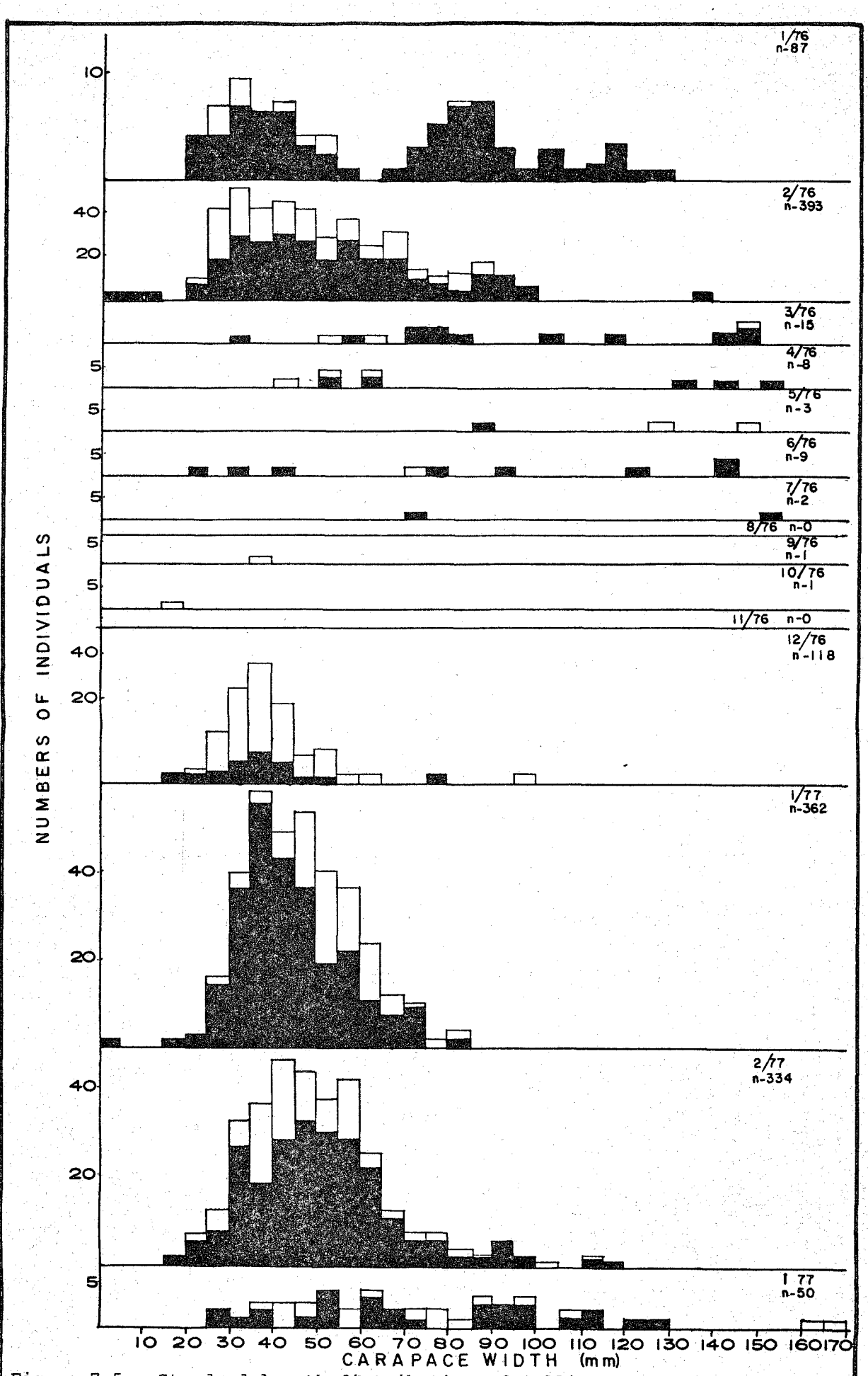

Figure 7.5. Standard length distribution of Callinectes sapidus (Blue crab) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingemer

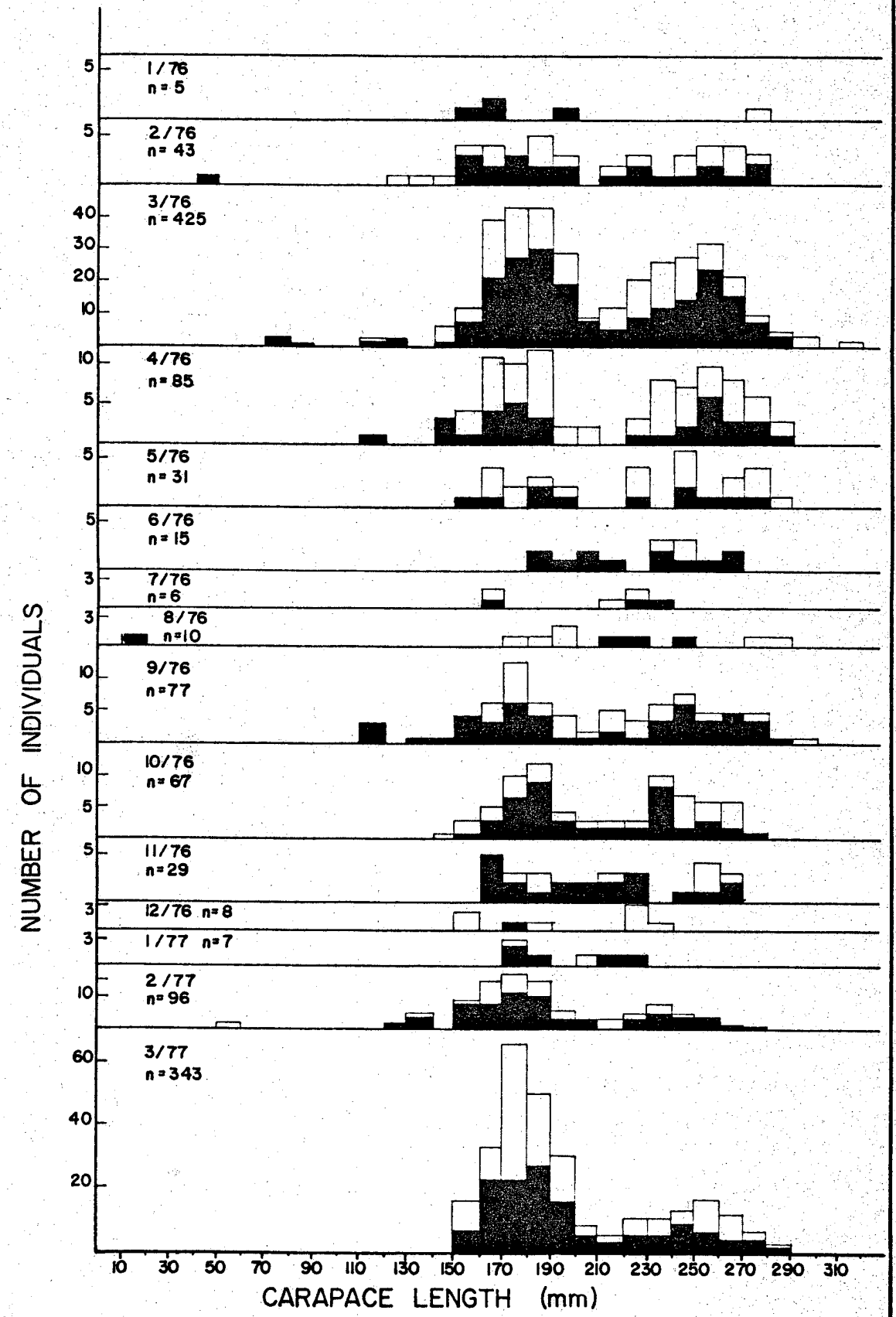

Figure 7.6. Standard length distribution of Limulus polyphemus (Horseshoe crab) from January, 1976 through March, 1977. Each bar represents a 10mm size class. Dark areas represent night impingement.

Portunus gibbesi

P. gibbesi (Portunid crab) was the fourth most abundant invertebrate species impinged. Impingement occurred primarily during the winter months (81.1% of total for this species during December, 1976 and January and February, 1976 and 1977).

Carapace width ranged from 10 to 68 mm. Mean carapace width increased approximately 13 mm from January through May, 1976. No growth trends were noted throughout the remainder of the sampling period. Monthly mean carapace width ranged from 29 to 45 mm. A presentation of monthly size class data is made in Figure 7.7.

Extrapolated values for the number of P. gibbesi impinged over the study period show that 4,564 individuals would have been impinged (based on a rate of 25 per day over six months of noted abundance) over the 15 months.

A large number of the captured individuals survived impingement and remained alive in the sluicing trough.

Lolliguncula brevis

Lolliguncula brevis (brief squid) was the fifth most abundant invertebrate impinged (704 individuals). This is a commercially important species in the Tampa Bay area, being used primarily as bait. Maximum impingement at Big Bend

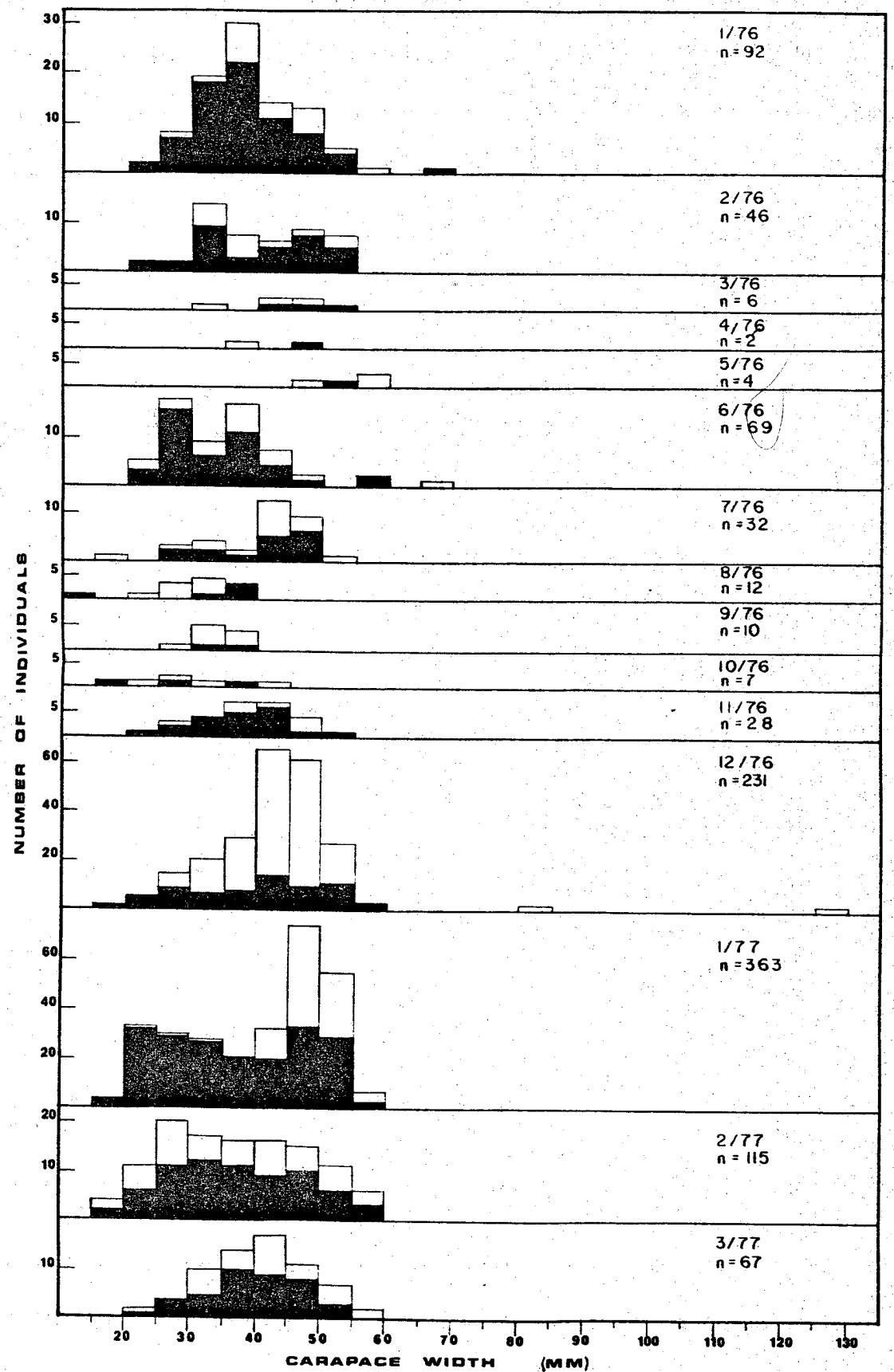

Figure 7.7. Standard length distribution of Portunus gibbesi (Portunid crab) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

occurred during June, July and August (51.9%) and least during January, 1976, and April and February, 1977 (5.4%). Night capture totaled 67.9% of the catch. Approximately 8289 individuals (based on 12 months noted abundance) would have been impinged by Unit 1 (or Unit 2) during operational hours throughout the study period. Utilizing commercial catch data provided by the National Marine Fisheries Service, it was estimated that approximately 5.1% of the commercial brief squid catch has the potential of being impinged by 1 unit in a full operational year.

Pen length ranged from 16 to 127 mm with several size classes being captured nearly year round. No distinct growth trends were noted over the entire sampling period. Figure 7.8 presents monthly size class data for L. brevis.

Squilla empusa

Squilla empusa (mantis shrimp) was the sixth most abundant invertebrate impinged (598 individuals). Impingement occurred primarily during the months of December, January and February, 1976 and January and February, 1977 (94.8% of the species total). No individuals were captured from July through November. Night impingement accounted for 63.5% of the total catch. Approximately 3,472 individuals would have been impinged by Unit 1 (or Unit 2) during operational hours in 1976 (at an estimated rate of 19.3 per day over six months of noted abundance).

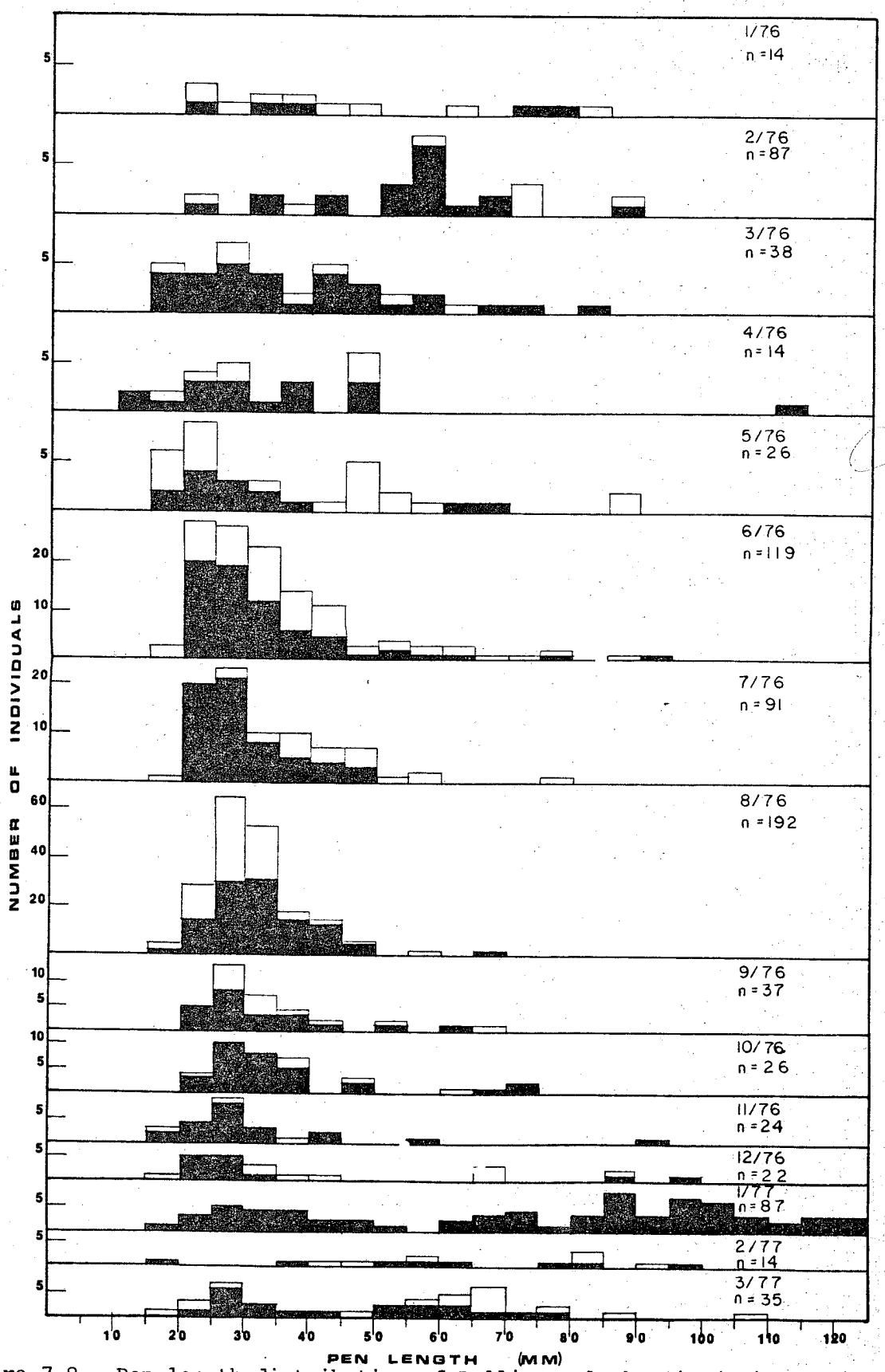

Figure 7.8. Pen length distribution of Lolliguncula brevis (Bried squid) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

Total length ranged from 65 to 150 mm. No discernable growth trends were evident. Monthly size class data is presented in Figure 7.9.

Mantis shrimp appeared capable of surviving impingement since large numbers of individuals were observed alive in the sluicing trough.

Impingement of the remaining 21 invertebrates species accounted for 15.2% of the total number of invertebrates and 1.1% of the total invertebrate biomass.

Fishes

Relative Abundance and Seasonality

A total of 9,946 fishes (60 species) were impinged on Unit 1 or Unit 2 during 744 sampling hours between January, 1976 and March, 1977. Based on this information, an average of 13.4 fish were impinged on one unit per hour of sampling time.

Table 7.2 outlines the relative abundance of the six most commonly impinged fishes (*Anchoa mitchilli*, bay anchovy; *Bairdiella chrysura*, silver perch; *Lagodon rhomboides*, pinfish; *Cynoscion arenarius*, sand seatrout; *Prionotus scitulus*, leopard searobin; and *Chloroscombrus chrysurus*, Atlantic bumper). These six species constituted 85.6% of the total number of fishes that were impinged during sampling hours.

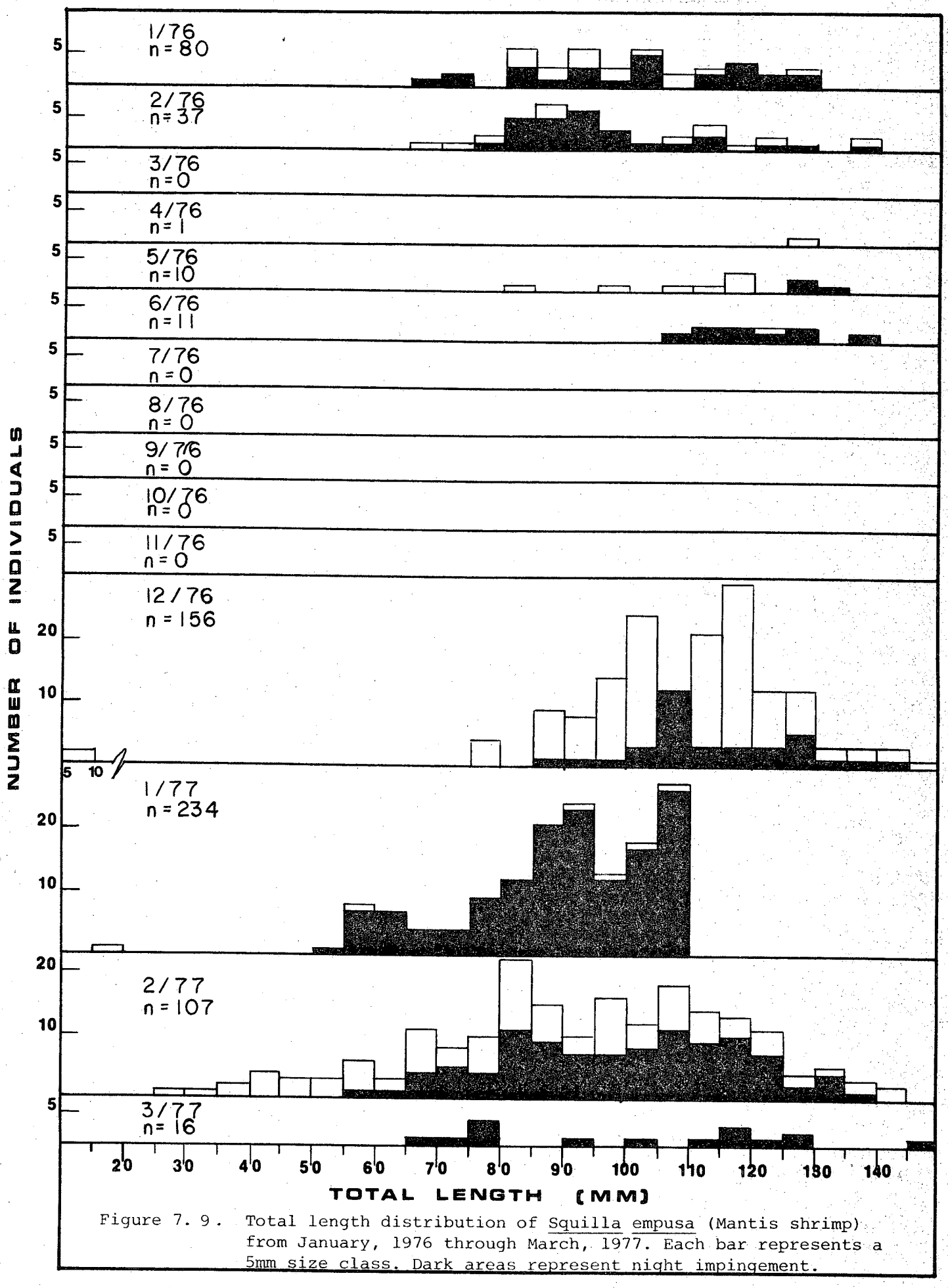

Figure 7.9. Total length distribution of Squilla empusa (Mantis shrimp) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

Table 7.2 . List of most abundant vertebrate species impinged at Big Bend (one Unit) between January, 1976 - March, 1977. (1 = 0001-0600 hrs., 2 = 0601-1200 hrs., 3 = 1201-1800 hrs., 4 = 1801-2400 hrs.)

	Jan - March '76				April - June				July - Sept.				Oct- Dec.				Jan. - Mar '77				Total
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	
Anchoa mitchilli Bay anchovy	22	6	7	5	24	13	14	14	7	8	5	13	252	179	292	226	982	171	299	506	4045
Bairdiella chrysura Silver perch	17	1	5	4	142	84	39	236	1184	251	160	499	41	80	3	32	107	57	53	33	3028
Lagodon rhomboides Pinfish	13	2	6	3	14	65	40	48	4	1	40	45	0	0	1	3	58	97	19	17	476
Cynoscion arenarius Sand seatrout	8	1	6	0	4	53	2	29	31	16	1	5	31	41	12	22	66	10	3	2	343
Prionotus scitulus Leopard searobin	14	1	6	6	15	29	4	21	10	1	0	1	10	7	47	7	98	24	12	6	319
Chloroscombrus chrysurus Atlantic bumper	0	0	0	0	0	0	0	3	10	31	19	20	52	67	20	31	33	9	0	7	302
Total vertebrates	315				1339				2504				1852				3936				
No. of Sampling Days	6				7				6				7				5				
Estimated vertebrates impinged per day (#Collected ÷ #days sampled)	52.5				191.3				417.3				264.6				787.2				

Most of the fishes (59.2%) were impinged during the night sampling hours (0001 to 0600 and 1800 to 2400 hours). However, a t-test indicated that there was not a significant difference between the number of fishes impinged during the day and the number impinged at night ($\alpha = 0.05$).

Seasonal variations in impingement were evident (Appendix 7.A). The summer (1976) and winter (1977) months accounted for the highest rates of impingement. (Appendix 7.C presents a list of the fishes and macroinvertebrates that were impinged during this study, and the season in which they were impinged.)

An average of 52.5 fish per sampling day were collected between January and March, 1976. This rate increased each quarter of sampling until a peak impingement rate of 417.3 fish per sampling day occurred between July and September, 1976. Another peak occurred between January and March, 1977 when the impingement rate rose to an average of 787.2 fish per sampling day.

Throughout the fifteen month sampling period, three species were seasonally abundant on the travelling screens. These three species were Sciaenops ocellata (red drum), which were abundant between January and March, 1976; Bairdiella chrysura (sand seatrout), which were abundant between April and September, 1976; and Anchoa mitchilli (bay anchovy) which peaked in abundance between October, 1976 and March, 1977.

Effects of Lighting

During sixty night sampling hours between January 24 and March 19, 1976 a total of 183 fishes were impinged on the travelling screens of Unit 1, when there was no lighting on this structure. This corresponds to an average impingement rate of 3.05 fishes per sampling hour.

Conversely, a total of 190 fishes (3.2/hour) were impinged on the screens of Unit 1 during sixty night sampling hours when normal lighting was in operation at this unit. While slightly fewer fishes were impinged when the lights were off, this difference was not significant (t-test; $\alpha = 0.05$). Appendix 7.B outlines the differences in abundance between lights on and lights off sampling.

Certain regulations concerning lighting procedures forced the premature termination of this phase of the study. While the data is inconclusive, it does suggest that the effects of lighting (e.g. attracting fish to the intake structure) on impingement were negligible.

Effects of Temperature

Figure 7.3 outlines the relative abundance of impinged organisms in relation to water temperature. Peak periods of abundance on the travelling screens appeared to correspond to high and low water temperatures recorded at the intake.

Whether this trend is coincidental (e.g. a large number of fish were present during these times and, therefore, more susceptible to impingement) or causative (e.g. extreme low or high temperatures may induce lethargy thereby increasing the probability of impingement) is not known.

Dominant Species

Anchoa mitchilli

The bay anchovy (A. mitchilli) was the most abundant fish impinged on the travelling screens. This species constituted 40.7% of the total number of vertebrates that were impinged during sampling hours. An average impingement rate of 5.4 individuals per hour (129.6/day) was determined for the 744 hours that were sampled.

Most of the specimens (96.6%) were collected between October, 1976 and March, 1977. The period between January and March, 1977 accounted for 73.1% of the individuals.

Of the 4,045 individuals that were collected, 50.7% were impinged at night.

Bay anchovies were abundant in the Big Bend area from October through December, 1976 (Comp, 1977), and in February and March, 1977 (see Chapter 8). Most of the anchovies captured by the screens were adults (average standard length was over 50 mm). This was probably due to mesh size selectivity

of the screens, since juvenile bay anchovies were also abundant during the periods of high temperature (see Chapter 8), yet they were rarely found on the screens.

There are two possible explanations for the disparity in abundance that was noted in the catches for January through March, 1976 and for those made in January through March, 1977. Relatively few anchovies were collected on the screens in early 1976. This species was absent from the seine catches during this same period (Comp and Morris, 1976). It is possible that, for some reason, this species did not move into the shallow inshore waters during early 1976 as they did in early 1977. Accordingly, it is possible that the likelihood of impingement during early 1977 increased as a result of the presence of large numbers of individuals in the Big Bend area.

Another possibility is that sustained cold weather (and water) may have induced lethargy thus increasing the susceptibility of this fish to impingement.

Between the sampling periods from December 29, 1976 and February 8, 1977, water temperature at the intake ranged from 12.6°C to 15°C. However, anchovies have been captured in areas with low water temperatures (16°C, Comp, Chapter 8; 10.8°C, Springer and Woodburn, 1960; 7.9°C, Dahlber, 1972). That increased rates of impingement were due to cold water is speculation.

Extrapolating the data that was collected in 744 sampling hours, one unit would impinge approximately 47,627 individuals in one year (assuming that the unit was in operation every day).

This species is abundant in the Tampa Bay area (Chapter 8; Springer and Woodburn, 1960), so it is doubtful that the impingement rates that were determined for this species, signify a detrimental depletion of this species.

Monthly size class data for A. mitchilli is presented in Figure 7.10.

Bairdiella chrysura

The silver perch (Bairdiella chrysura) constituted 30.4% of the total number of fish that were impinged during sampling hours. The average impingement rate of this species was approximately 98 fish per day (35,770 individuals/year/unit).

Of the 3028 specimens that were collected, 75.8% of the individuals were impinged at night. Most of the individuals (85.7%) were impinged between April and September, 1976. Peak catches occurred in July.

Standard length distribution of this species is presented in Figure 7.11. Growth patterns are difficult to discern.

Eggs of this species were found in the Big Bend area in February and March, 1976 (T. D. Phillips, pers. comm.). This indicates a late winter - spring spawning season. This agrees with the findings of Springer and Woodburn (1960). Based on

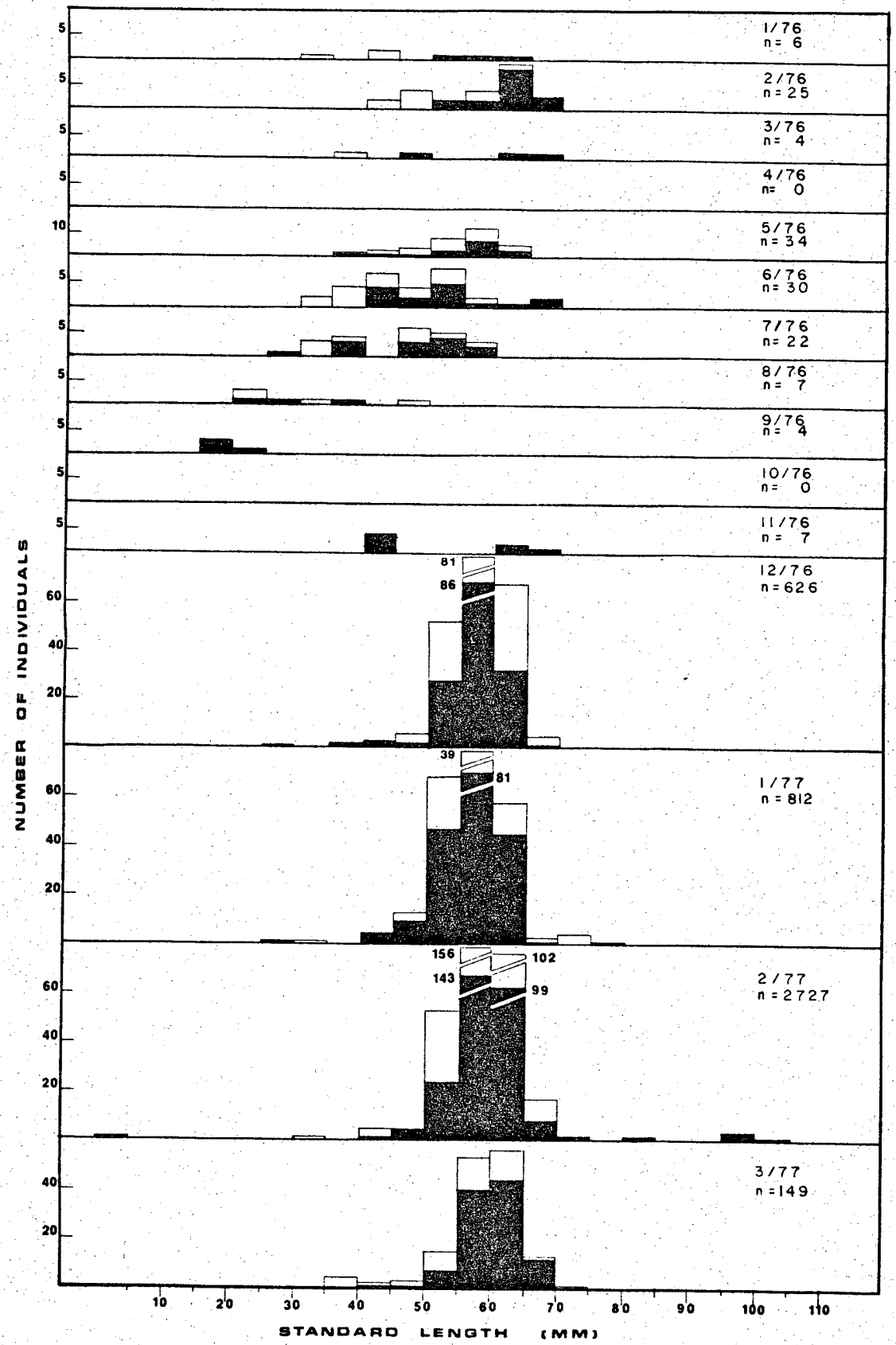

Figure 7.10. Standard length distribution of Anchoa mitchilli (Bay anchovy) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

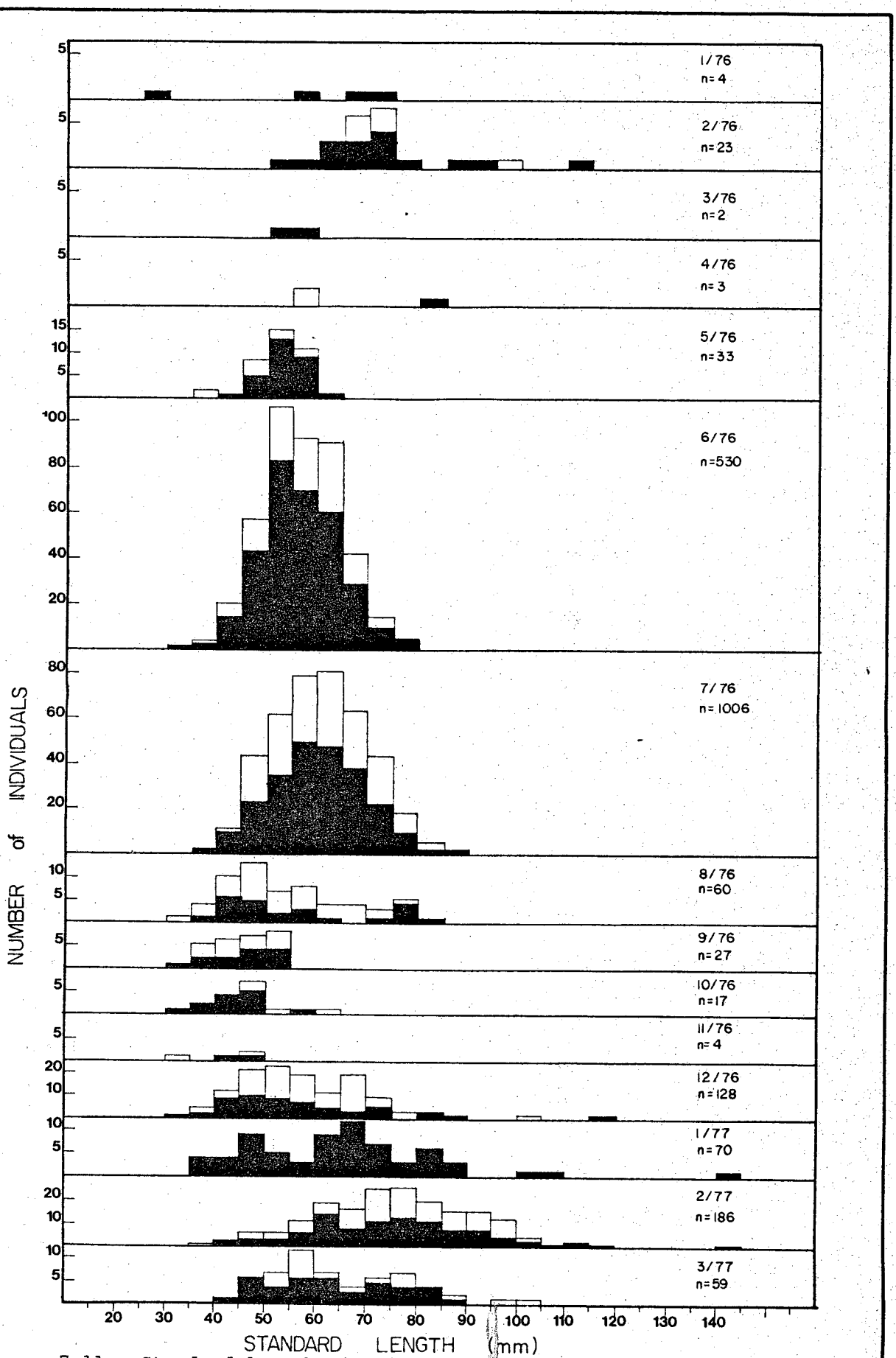

Figure 7.11. Standard length distribution of Bairdiella chrysura (Silver perch) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

the data collected from the travelling screens, it is conceivable that the adults move to offshore areas in the bay to spawn. Upon cessation of spawning periods, the adults migrate back to the shallower areas. This migration apparently occurs during the summer and fall months. Merely by their relative abundance in this area during the summer and fall, this species becomes more susceptible to impingement.

Lagodon rhomboides

Pinfish (Lagodon rhomboides) accounted for 4.8% of the total number of fishes that were impinged within 744 sampling hours. Based on the actual number of pinfish that were collected, an average of 15.4 fish per day were impinged (5621 individuals/year/unit).

Of the 476 pinfish that were collected on the screens during sampling hours, 56.9% were impinged during the day.

Pinfish were most frequently impinged between January and March, 1977. Fewest individuals were impinged between October and December, 1976. Since spawning apparently occurs in the Gulf during late fall and early winter (Springer and Woodburn, 1960) this species would not be expected to be abundant in inshore areas during this time. Pinfish were noticeably absent from the seine catches during this period (Comp, 1977), which supports the belief that much of the population had migrated to the Gulf, or offshore regions.

Pinfish have been collected in water with temperatures as low as 10.0°C (Springer and Woodburn, 1960). It is not known if sustained low temperatures in the discharge area increased the susceptibility of impingement for this species during early 1977. Again, it is possible that the normal seasonal abundance may have contributed more to impingement than the effects of temperature.

Figure 7.12 presents monthly standard length distributions of L. rhomboides.

Cynoscion arenarius

The sand seatrout (Cynoscion arenarius) was the fourth most abundant fish impinged during sampling hours. This species constituted 3.4% of the total fish catch. Based on this data, an average of 11.2 sand seatrout were impinged per day.

Of the 343 individuals that were impinged, 57.7% were impinged during the night. Peak impingement occurred between April and June, 1976 and again between October and December, 1976.

Based on actual data, approximately 4,088 individuals would be impinged by one unit during the year.

Larvae of this species are common in the Big Bend area throughout the summer months (Phillips, 1977). Reid (1954) captured sexually mature adults of this species in the spring. This indicates a spring - summer breeding season.

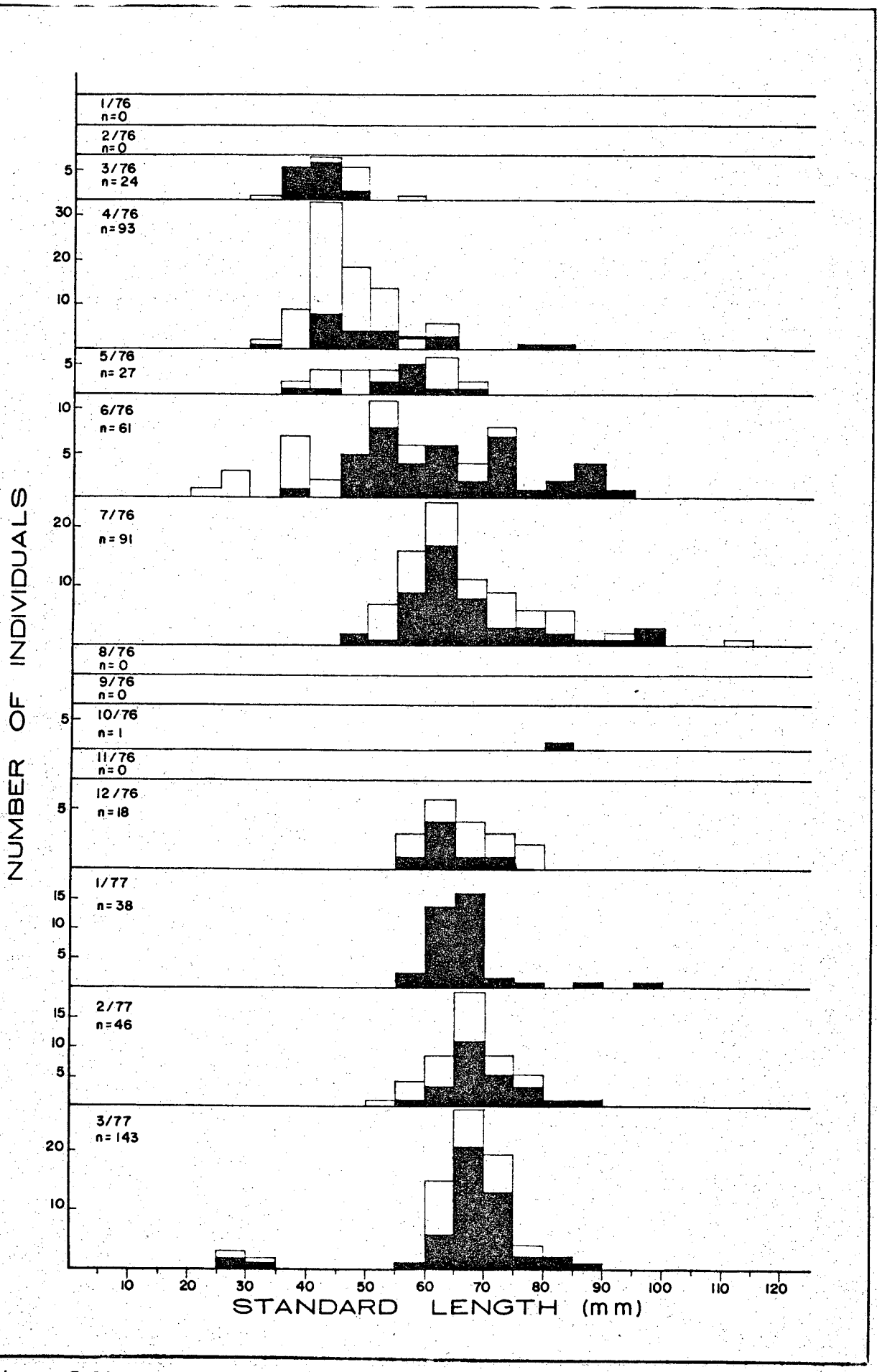

Figure 7.12 Standard length distribution of Lagodon rhomboides (Pinfish) from January, 1976 through March, 1977. Each bar represents a 5 mm size class. Dark areas represent night impingement.

Small specimens (SL < 35 mm) were impinged in May, June, July and September, 1976. These findings also indicate an extended breeding season for this species.

A length distribution outline for C. arenarius is presented in Figure 7.13. Average standard length appears to steadily increase from October, 1976 through March, 1977.

IMPACT ASSESSMENT

To accurately assess the impact of impingement on fish and macroinvertebrate communities, the standing crop and/or productivity potential of those communities should be enumerated. Unfortunately, this is a difficult, if not impossible task in estuarine areas since these regions support such dynamic communities. Constant migrations to and from these areas cause significant changes in seasonal abundance and species composition.

Assessment of impact in these regions is limited to comparing impingement data with other methods of sample collection in the same area (e.g. seines and trawls); known seasonal patterns of abundance; other impingement studies; and commercial catch data.

When compared to other studies (Mathur, Heisey and Magnusson, 1977; Edwards, Hunt, Milla, and Sevic, 1975; Landry

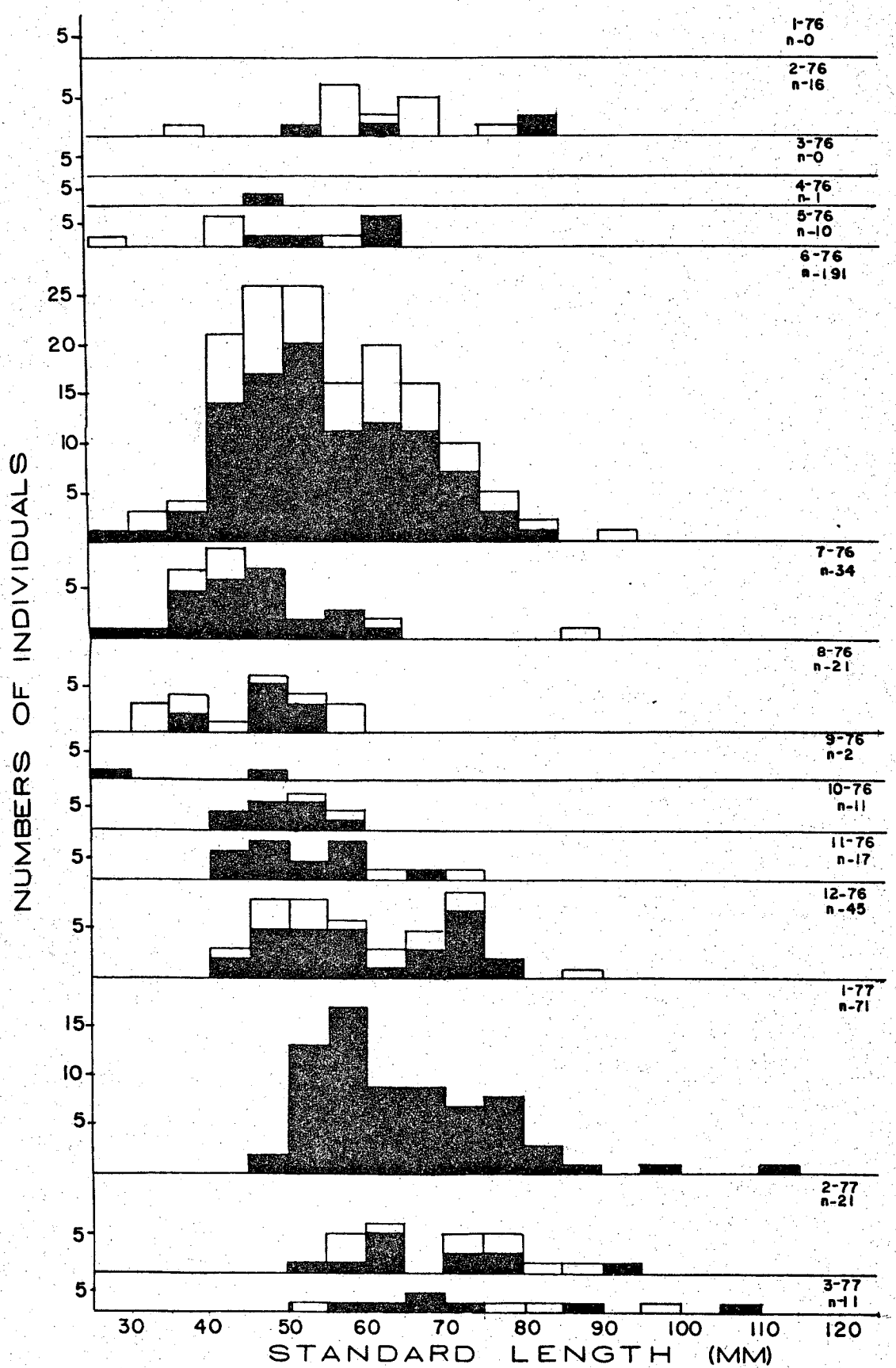

Figure 7.13. Standard length distribution of Cynoscion arenarius (sand seatrout) from January, 1976 through March, 1977. Each bar represents a 5mm size class. Dark areas represent night impingement.

and Strawn, 1974) the impingement rate at Big Bend is rather low. This is due in part to the location of the intake structure. Since the travelling screens are removed from a major source of water (see Figure 7.2) most fishes and invertebrates would not be subjected to impingement. The current (flow) due to the intake mechanism is negligible at the west end of the intake canal. Therefore, only those individuals which enter the canal voluntarily would be susceptible to impingement.

Coal barges dock at the west end of the intake canal. As these barges approach the dock, there is a remote possibility that the barges will "herd" schools of fishes into the canal. Subjective visual observations have not substantiated this occurrence. However, we are cognizant of the possibility that herding may occur.

Most increases and/or decreases in impingement rates appear to correspond to seasonal changes in abundance. Seasonality has also been a factor which influenced impingement rates at other sites (Mathus, et al., 1977; Edwards, et al., 1975; Landry and Strawn, 1974; Grimes, 1971).

The time of day (or night) can also influence impingement rates (Appendix 7.D). During this study, more individuals were impinged during the night, especially between 0001 and 0600 hours, but this was not statistically significant.

Impingement at Big Bend does not appear to be significantly depleting the commercial stock in this area. Based on the 1976 commerical catch for Hillsborough County (B. Gassinger, National Marine Fisheries Service, pers. comm.) one unit may have impinged approximately 0.23% of the commercial pink shrimp catch and 0.7% of the commercial blue crab catch. Extrapolated impingement data for one year indicated that one unit has the potential of impinging approximately 5.1% of the commercial catch of brief squid (L. brevis). Since rates of impingement vary with the seasons, these estimates are probably exaggerated.

Based on the data that was collected during 7 4 sampling hours between January, 1976 and March, 1977, it does not appear that impingement at Big Bend is significantly depleting the commercial fish and macroinvertebrate populations in this area.

SUMMARY AND CONCLUSIONS

1. A total of 9,382 macroinvertebrates (27 species) were impinged on either Unit 1 or Unit 2 during 744 sampling hours.
2. The average rate of impingement for Unit 1 was 302.6 invertebrates per day.
3. Pink shrimp (Penaeus duorarum), blue crabs (Callinectes sapidus), horseshoe crabs (Limulus polyphemus), portunid crabs (Portunus gibbesii), brief squid (Lolliguncula brevis), and mantis shrimp (Squilla empusa) constituted 84.8% of the total number of invertebrates that were impinged.
4. The pink shrimp (P. duorarum) constituted 35.6% of the total invertebrate catch.
5. The highest number of invertebrates were impinged during summer and winter, the periods of temperature extremes.
6. There was no significant difference ($\alpha = .05$) in the number of invertebrates impinged when the intake structure lights were off and then when they were on.
7. A total of 9946 fishes (60 species) were impinged on Unit 1 or Unit 2 during 744 sampling hours between January, 1976 and March, 1977.

8. The average rate of impingement was 320.8 fishes per day for one unit.

9. Bay anchovies (Anchoa mitchilli), silver perch (Bairdiella chrysura), pinfish (Lagodon rhomboides), sand seatrout, (Cynoscion arenarius), leopard searobin (Prinotus scitilus), and Atlantic bumper (Chloroscombrus chrysurus) constituted 85.6% of the total number of fishes that were impinged.

10. Most of the fishes (59.2%) were impinged at night.

11. The summer and winter months accounted for the highest rates of impingement.

12. Lighting on the intake structure did not appear to significantly increase the impingement rate for fishes.

13. Rates of impingement appear to be dependent on seasonal variations in abundance.

14. Impingement at Big Bend does not appear to be significantly depleting the commercial fish or invertebrate stock in this area.

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Appendix 7.A. Seasonal abundance of invertebrates and vertebrates impinged during the day and night.

	INVERTEBRATES			VERTEBRATES			
	Day	Night	Total	Day	Night	Total	Total
Jan.- Mar.	945	1509	2454	120	195	315	2769
Apr.-June	418	646	1064	451	888	1339	2403
July-Sept.	1075	1454	2529	603	1901	2504	5033
Oct.-Dec.	721	572	1293	1017	835	1852	3145
Jan.-Mar.	790	1252	2042	1871	2065	3936	5978
TOTALS	3949	5433	9382	4062	5844	9946	19328

Appendix 7.B . Comparison of impingement with the intake structure lights on and with the lights off. (1=0001-0600 hrs; 4=1800-2400 hrs).

Date(1976)	Time	Total Vertebrates	Total Invertebrates	Total Individuals	Total Species
Lights Off					
1/24	1	46	162	208	21
	4	93	383	476	23
2/10	1	4	164	168	14
	4	1	61	62	12
2/17	1	3	130	133	13
	4	12	102	114	17
3/5	1	4	88	92	9
	4	8	36	44	9
3/19	1	5	60	65	8
	4	7	75	82	14
TOTALS		183	1261	1444	
Lights off					
1/21	1	12	94	106	16
	4	23	289	312	17
2/5	1	81	319	400	29
	4	15	93	108	13
2/16	1	20	233	253	19
	4	7	21	28	12
3/3	1	6	74	80	8
	4	3	102	105	9
3/17	1	16	173	189	12
	4	7	76	83	11
TOTALS		190	1474	1664	

Appendix 7. C. A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, refer to previous quarterly reports).

Macroinvertebrate Species	Jan.- Mar.	April- June	July- Sept.	Oct.- Dec.	Jan.- March
Aurelia aurita	X	X	X	X	
Chrysura quinquecirrha			X	X	X
Aplysia willcoxi		X			
Lolliguncula brevis	X	X	X	X	X
Squilla empusa	X	X	X	X	X
Limulus polyphemus	X	X	X	X	X
Penaeus duorarum	X			X	X
Trachypenaeus constrictus	X	X		X	X
Alphèus heterochalis	X	X		X	X
Upogebia sp.		X			
Petrolisthes armatus	X			X	X
Petrolisthes sp.			X	X	
Pagurus longicarpus				X	X
Portunus gibbesii	X		X	X	X
Portunus sp.			X	X	
Callinectes ornatus	X	X			
Callinectes sapidus	X	X	X	X	X
Callinectes sp.			X	X	
Menippe mercenaria	X	X	X	X	X
Hexapanopeus angustifrons		X	X		
Neopanope texana texana	X	X	X	X	X
Eurypanopeus depressus	X	X	X	X	X
Panopeus herbstii	X	X	X	X	X
Sesarma cinerium	X	X	X	X	X
Sesarma reticulatum	X	X	X	X	X
Libinia dubia	X		X		X

Appendix 7.C. (continued) A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, refer to previous quarterly reports).

Macroinvertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Mogula sp.	X	X	X	X	X
Vertebrate Species					
Sphyrna tiburo				X	
Dasyatis americana			X		
Dasyatis sayi		X			
Gymnura micrura	X				X
Rhinoptera bonasus					X
Elops saurus					X
Ophichthus gomesi					X
Harengula jaguana		X		X	X
Opisthonema oglinum	X		X	X	X
Anchoa hepsetus				X	X
Anchoa mitchilli	X	X	X	X	X
Synodus foetens	X				
Arius felis	X		X	X	X
Bagre marinus				X	
Opsanus beta	X	X	X	X	X
Porichthys porosissmus	X				
Gobiesox strumosus	X	X	X		
Urophycis floridanus					X
Hyporhamphus unifasciatus	X	X			
Strongylura timucu					X
Cyprinodon variegatus					X
Lucania parva		X			
Membras martinica	X			X	X
Menidia beryllina	X	X			X

Appendix 7.C. (Continued) A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, refer to previous quarterly reports).

Vertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Hippocampus erectus	X	X		X	X
Syngnathus louisianae					X
Syngnathus scovelli				X	
Caranx hippos					X
Chloroscombrus chrysurus		X	X	X	X
Hemicaranx amblyrhynchus			X	X	
Oligoplites saurus			X	X	
Selene vomer			X	X	
Diapterus plumieri	X			X	
Eucinostomus argenteus	X	X	X	X	X
Eucinostomus gula	X	X	X	X	X
Orthopristis chrysoptera		X	X	X	X
Archosargus probatocephalus			X		
Lagodon rhomboides	X	X	X	X	X
Bairdiella chrysura	X	X	X	X	X
Cynoscion arenarius	X	X	X	X	X
Cynoscion nebulosus		X	X	X	X
Leiostomus xanthurus		X			
Menticirrhus americanus		X			
Menticirrhus saxatilis		X		X	X
Micropogon undulatus		X			
Sciaenops ocellata	X	X		X	X
Chaetodipterus faber	X	X	X	X	X
Mugil cephalus		X			

Appendix 7.C. (Continued) A list of fishes and macroinvertebrates that were impinged on the travelling screens between January, 1976 and March, 1977. (For more information, ref r to previous quarterly reports).

Vertebrate Species	Jan.-Mar.	April-June	July-Sept.	Oct.-Dec.	Jan.-March
Astroscopus y-graecum		X		X	
Hypsoblennius hentzi	X			X	X
Bathygobius soporator			X		
Prionotus scitulus	X	X	X	X	X
Prionotus tribulus	X	X		X	X
Achirus lineatus	X	X	X	X	X
Trinectes maculatus			X	X	X
Symphurus plagiusa	X	X	X	X	X
Monocanthus hispidus	X	X		X	X
Acanthostracion quadricornis					X
Sphoeroides nephalus	X	X		X	X
Chilomycterus schoepfi	X	X	X	X	X

Appendix 7.D. Seasonal abundance of the total number of individuals impinged during the four sampling periods. (1 = 0001-0600 hrs; 2 = 0601-1200 hrs; 3=1201-1800 hrs; 4 = 1801-2400 hrs).

	Jan.-Mar.	April-June	July-Sept.	Oct-Dec.	Jan.-Mar.	Total
1	1029	692	1810	795	2118	6444
2	325	609	837	849	2001	4621
3	740	260	841	889	660	3390
4	675	842	1545	612	1199	4873
TOTAL	2769	2403	5033	3145	5978	19328

CHAPTER EIGHT

AN ASSESSMENT OF THE IMPACT OF THERMAL DISCHARGE ON FISH AND MACROINVERTEBRATE COMMUNITIES AT BIG BEND, TAMPA (FLORIDA)

BY

GARY S. COMP

AUGUST, 1977

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INTRODUCTION

The increasing demand for electrical energy has continually warranted expansion of the power industry. The potential of debilitating effects, resulting from power plant operation, has proportionately increased as these plants discharge waste heat into marine and aquatic environments.

The direct effects of thermal discharge can fluctuate between beneficial and detrimental, depending partially on the site location, the season, and the extent of water temperature increase attributable to power plant operation. Thermal effluent may affect organismic physiological or chemical processes. The effects may be beneficial, e.g. enhancing the growth rates of certain species, or detrimental, e.g. causing a synergistic effect with a pollutant already present in the water.

Generally, most effects are concentrated in an area around the discharge site. Roessler and Tabb (1974), in a study at the Turkey Point nuclear power plant (Biscayne Bay, Florida), found that a localized area of three hundred acres was detrimentally affected by the thermal discharge.

The warm water which permeates the discharge area can influence abundance and diversity values, depending on the season. Studies at the Crystal River Power Plant (Grimes, 1971) showed that diversity increased with distance away from the outfall in summer and toward the outfall in winter. Gallaway and Strawn (1974) found that a seasonal change in abundance and distribution patterns of dominant fish species was occurring in the discharge area of a generating station on Galveston Bay. However, they concluded that, overall, the detrimental effects of the heated effluent were negligible on the fish fauna in the discharge area.

Changes in fish populations or in community structure may occur as a direct result of physiological stress, or as a response to a change in a lower trophic level, e.g. a plankton community. If a temperature increase causes the reduction or elimination of a source of food, changes in community structure may become evident as certain species are forced to move elsewhere in search of a suitable food supply.

However, not all fish movement can be interpreted as a response to a stress induced situation. Fish populations are generally characterized by constant movement in response to feeding, breeding and seasonal patterns. Drastic deviation from such established (natural) patterns could, however, indicate a stressed environment.

Fish and macroinvertebrate populations in the vicinity of Tampa Electric Company's Big Bend steam electric station, have been monitored on a quarterly basis since 1970. This baseline information (1970 - 1975) has been summarized in a previous report (TECO, 1975).

In January 1976, a "316 (a) and (b) demonstration" was initiated at the study site. These studies continued through March, 1977. The results and conclusions derived from the seine and trawl collections of this study are presented in this final report.

Specific Objectives

The purpose of this section of the 316 demonstration is to assess the effects of thermal discharge on the fish and macroinvertebrate populations in the vicinity of the Big Bend Steam Electric Station. To ensure a comprehensive impact assessment, the following factors were considered:

1) the species composition and community structure of the fish and macroinvertebrate populations in the area;
2) the relative abundance of these species;
3) the migratory and seasonal habits of the indigenous and transient species;
4) nursery areas;
5) the distribution of commercially important species;

6) changes in the species composition or relative abundance that could be directly or indirectly attributed to the discharging of the thermal effluent; and

7) the long term implications of changes in community structure, if such changes are the result of thermal alteration of habitats.

Sampling Scope and Limitations

Inherent limitations are prevalent in any study that involves actively sampling fish populations. If similar methods of sample collection and data analysis are utilized throughout the period of study, these limitations should not reduce the validity of the study for detecting trends.

The number of replicates that are required at each station to adequately sample a given population, is site and season specific. In the present study, two replicate seine hauls or trawl tows were collected at each station. The biological staff of Conservation Consultants, Inc., along with representatives from the Environmental Protection Agency, the Florida Department of Environmental Regulation and the U. S. Fish and Wildlife Service felt that this number (of replicates) would be sufficient to achieve the specific objectives of this study.

Previous studies have supported this decision. The use of three or less replicate hauls or tows per station is a

widely accepted sampling method which has been implemented in various ecological studies (Gallaway and Strawn, 1974; Haedrich and Haedrich, 1974; McErlean, O'Connor, Mihursky and Gibson, 1973; Bechtel and Copeland, 1970; Dahlberg and Odum, 1970). Depending on the area being sampled, the number of trawl replicates may vary between 7 and 10 (Livingston, 1975; Roessler and Tabb, 1974; and Roessler, 1965).

The data collected in this study was not subjected to rigorous statistical analysis (and testing) because of the inherent problems associated with fitting catch data to statistical hypotheses. However, we did utilize certain specific statistical methods to provide a baseline for comparing our results with those of previous studies, and to allow a mathematical comparison of catch data between stations, seasons, and thermally affected and non-affected areas. Conclusions of this study were not, however, based solely on the interpretation of statistical analyses.

Sampling limitations should not significantly affect the results of a study if standardized sampling methods are incorporated. McErlean, et al. (1973) stated that serial comparisons of successive samplings using the same method are justifiable. Katz and Gaufin (1953) found such obvious differences in the fish populations they sampled, that the sampling errors were relatively unimportant. Regardless of the limitations of sampling with a seine, Subrahmanyam and Drake (1975) were able

to show seasonal patterns and changes in communities related to tides in a Florida salt marsh.

From previous literature, it appears that comprehensive analysis and interpretation of data, collected by a limited number of replicates over a long period of time, is a valid approach to attain the goals of this study. We feel, therefore, that sampling errors were within reason and that there is little, if any, doubt concerning the validity of the conclusions arrived at during the recent study.

Specific Limitations of the Sampling Gears

The detection of changes in abundance or species composition does not necessarily imply that these changes can be attributed to thermally altered water.

The spatial and temporal distribution of fishes and macroinvertebrates often biases sample collections. Highly mobile fishes can avoid a net simply by swimming away from the net's path. Otter trawls are generally selective for bottom dwelling species and some schooling species which frequent areas close to the bottom.

The type of substrate over which sampling occurs can influence net efficiency. A muddy or irregular bottom can inadvertantly cause a trawl to bog down, thereby decreasing its effectiveness. A rocky bottom may cause the lead line

of a seine to rise off the bottom and allow individuals to escape underneath.

The dimensions of the sampling net may influence its efficiency. Kjelson (1977) implied that, while absolute catch efficiency was 52% for a 6.1 m trawl for juvenile pinfish (Lagodon rhomboides), absolute catch efficiency for this same species would drop to 8% if a 3.0 m trawl was used.

Since a 3.0 m trawl was used in this study, the catch efficiency may have been low.

METHODS

Seine Stations

Seine sampling was conducted monthly at six stations. Sampling sites were chosen on the basis of their proximity to or distance from the thermal plume, substratum composition and type of habitat.

The station locations are depicted in Figure 8.1, and described in Table 8.1 (also see Comp and Morris, 1976; and Comp, 1976).

Sampling

The seine used in this study was 150′ x 6′, and was constructed of 3/4 inch stretch mesh multifilament nylon. A bag (4′ x 4′ x 12′) constructed of 1/2 inch stretch mesh multifilament nylon was added to the center of the seine to facilitate the collection of specimens. A 6′ x 10′ panel

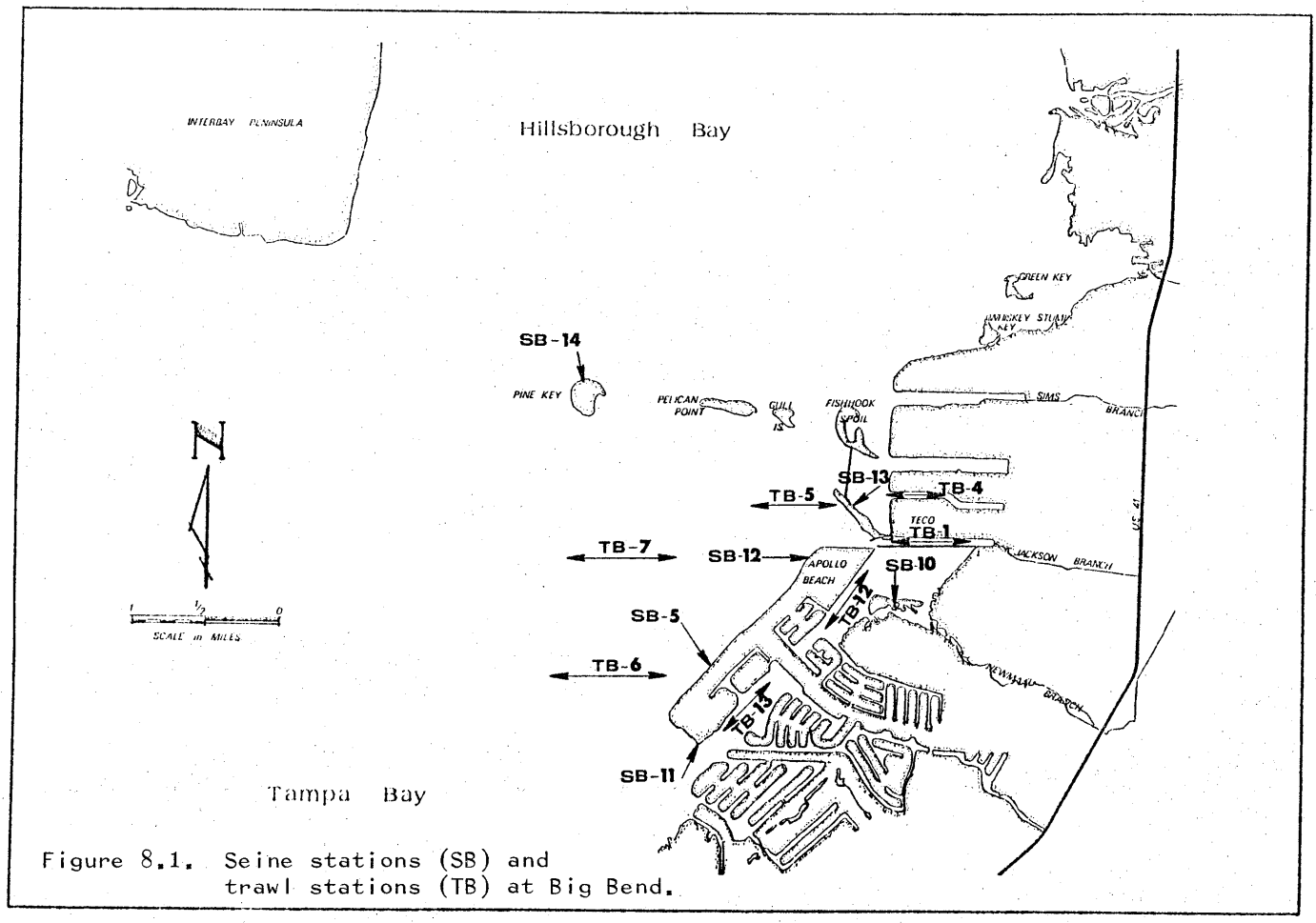


Figure 8.1. Seine stations (SB) and trawl stations (TB) at Big Bend.

Table 8.1. Outline of Big Bend Seine Stations.

Station	Substrate Composition	Thermal Plume +	Location	Comments
SB-12	Sand	Within	Open bay; N.W. end of Apollo Beach	Shallow area; numerous sandbars.
SB-5	Sand	Outside	Open bay; S.W. end of Apollo Beach	Shallow area; some rocks extend beyond the littoral zone.
SB-14	Sand	Farfield region	Open bay; north shore of Pine Key	Sloping beach; bordering a ship channel.
SB-10	Mud	*	Inshore; north embayment	Very shallow area; much of it exposed during a low tide. Seasonal algal growth.
SB-11	Sand	Outside	Inshore; south embayment; S.E. end of Apollo Beach	Shallow point; bordering a ship channel.
SB-13	Sand	Outside	Inshore; west of intake canal	Shallow area; source water for the plant.

+Refers to the thermal plume as outlined in the hydrographic section of this report.

*Discharge water penetrates this area during an incoming tide. However, due to the shallowness of this area, solar heating probably exerts a greater influence on water temperature than the thermal discharge.

of 1/2 inch stretch mesh multifilament nylon was added to the body of the seine on both sides of the bag.

The seine was deployed by boat at all but one (SB-10) of the sampling stations. One end of the net was anchored to shore. The remaining net was payed out as the boat was backed perpendicular to the shore. A half circle configuration was then formed as the boat dragged the net toward shore. The seine was then hauled onto the beach. Duplicate hauls (2) were taken at each station.

It was not feasible to use the boat at station SB-10, due to the shallowness of this area. Instead the seine was set and hauled by hand.

To assess sampling efficiency, five replicate seine hauls (instead of two) were taken at two different stations on consecutive days. This procedure was implemented once during this study.

Trawl Stations

Trawl samples were collected along seven transects each quarter. The transect sites were chosen on the basis of their location in relation to the thermal plume, depth, substratum composition, and habitat. Transect locations are depicted in Figure 8.1 and described in Table 8.2.

Table 8.2. Outline of Big Bend trawl transects.

Station	Substrate Composition	Bottom Pattern	Thermal Plume *	Average Depth (m)	Depth Range (m)	General Location
TB-1	Sand	Smooth	Within	4.9	4.6 - 5.2	Discharge Canal
TB-5	Sand	Smooth	Within	2.4	1.8 - 3.0	Open Bay
TB-7	Mud	Smooth	Within	3.3	3.0 - 3.6	Open Bay
TB-6	Mud	Smooth	Outside	3.6	3.0 - 4.3	Open Bay
TB-13	Mud	Irregular	Outside	4.0	3.0 - 5.2	Southern Embayment
TB-12	Mud	Irregular	+	3.6	2.4 - 4.6	Northern Embayment
TB-4	Mud	Smooth	Outside	5.8	5.5 - 6.1	Intake Canal

+Thermal effluent penetrates this area during an incoming tide.

*Refers to the thermal plume boundaries as outlined in the hydrographic section of this report.

Sampling

A 10′ otter trawl constructed of 1 1/2 inch stretch mesh multifilament nylon was used during this study. A 4′ bag constructed of 1/4 inch ACE nylon was added to the cod end to facilitate the capture of small specimens.

The trawl was towed behind a 24′ Pro-line boat equipped with twin 85 h.p. engines. To minimize variability in tow duration, all tows were scaled to the shortest transect (intake canal). Approximately five minutes were required to trawl the intake canal at a speed of 2-3 knots. Therefore, the remaining transects were sampled for a comparable period of time and speed. Duplicate tows (2) were made along each transect. In an attempt to further reduce variation, replicate tows were made in the same direction as the inital tow at each station.

To assess sampling efficiency, five replicate tows (instead of two) were taken along two different transects on consecutive days. This procedure was implemented once during this study.

Seine and Trawl

Physical and Chemical Parameters

Physical and chemical parameters were recorded at each station using the instruments outlined as follows:

Parameter	Measuring Instrument
Air Temperature	Mercury Thermometer (-20 °C to 50 °C)
DO and Water Temperature	YSI Model 54 Pressure Compensated Oxygen Meter
Salinity	YSI Model 33 S-C-T Meter
Turbidity	Hach Model 2100 A Turbidimeter
Depth	Ray Jefferson Model 5300 Recorder/Flasher

The following parameters were measured at the seine stations after the second replicate haul was made: wind speed and direction; air temperature; and surface readings of water temperature, dissolved oxygen, salinity, and turbidity. When possible, these readings (except turbidity) were also measured two weeks following a seine sample collection so that changes in these parameters could be monitored more efficiently.

The following parameters were measured at the beginning and end of the second replicate tow along trawl transects: wind speed and direction; air temperature; depth; surface and bottom readings of air temperature, dissolved oxygen, and salinity; and bottom measurements of turbidity.

Laboratory Methods

All specimens were preserved in the field in 10% buffered formalin and seawater. The individuals were sorted, identified, weighed (wet weight to the nearest 0.1 g), and measured (standard length to the nearest 1 mm) at the laboratory.

Up to 75 individuals per species per replicate were measured and sorted into 10 mm size classes. Total weight was obtained by combining the weights of all the size classes. If the total number of individuals of a single species exceeded 75 in one replicate, a random sample of 75 individuals were measured, sorted, and weighed. The balance was counted and weighed as a group.

Certain species (Fundulus similis, Menidia beryllina, Membras martinica, Lagodon rhomboides and Mugil cephalus) were weighed and measured individually (up to 75 individuals per replicate) so that a condition factor could be calculated.

Random samples of selected species were dissected each month and were cursorily examined for gonad development and stomach contents.

Data Reduction and Analyses

A variety of bioindices and statistical tests were utilized to aid in the interpretation of data. A Data General Nova 3 computer was used to generate the bioindices listed below. The statistical procedures and tests were calculated with a Texas Instruments SR-52A programmable calculator. The reader is referred to the Benthic Section of this report for a more detailed description of the computer facilities.

The reader is referred to Mahadevan (1976) for a detailed description of some of the following indices.

Bioindices

1) Shannon-Weaver Index of Diversity (Shannon and Weaver, 1963).

$$H' = {}^{C}/_{N} \; (N \log_{10} N - ni \log_{10} ni)$$

2) Margalef's Species Richness Index (Margalef, 1958)

$$D = {}^{S-1}/_{\log N}$$

3) Pielou's Equitability Index (Pielou, 1966)

$$J' = H'/\log S$$

4) Morisita's Index of Similarity (Morisita, 1959)

$$C\lambda = 2\sum_{i=1}^{S} \frac{n_{1i} \; n_{2i}}{(\lambda 1 + \lambda 2)} \; (N_1 \; N_2)$$

5) Condition Factor (Modified from Lagler, 1956)

$$K = \frac{W \times 10^5}{L^3}$$

W = weight in grams

L = standard length in mm

K = condition factor

Statistical Procedures and Tests

1) Multiple Regression (Snedecor and Cochran, 1967).

2) Linear Regression (Snedecor and Cochran, 1967).

3) Student's T-test (Snedecor and Cochran, 1967).

RESULTS AND DISCUSSION

Seine

Physical and Chemical Parameters

Of the parameters that were monitored during this study, water temperature and salinity probably would exert the greatest influence on estuarine community structure.

The annual averages and ranges of these two parameters are outlined below. The monthly values of these parameters have been presented in previous reports (Comp and Morris, 1976; Comp, 1976; Comp, 1977a; Comp, 1977b) and in TECO, (1977).

Station	Temperature °C		Salinity o/oo	
	Average	Range	Average	Range
SB-12	25.4	15-34	23.8	20-29
SB-5	24.1	14-32	23.7	20-29
SB-14	22.8	12-31	23.1	18-27
SB-10	25.8	18-34.5	23.6	19-27
SB-11	23.8	16-32.5	23.7	20-29
SB-13	24.2	12-34	23.4	19.5-27

The highest yearly average water temperature (25.8°C) occurred at station SB-10 (northern embayment). Due to the shallowness of this station, solar heating probably exerted

a greater influence than the thermal discharge on the water temperature in this area.

The greatest influence that the thermal discharge had at any one seine station occurred at station SB-12 (northwest end of Apollo Beach). This area is inundated by the effluent as it enters Hillsborough Bay. The yearly average water temperature at this station was 25.4°C. Station SB-5 (approximately 1500 m. south of SB-12) is out of the range of the thermal plume. Water temperature at this station averaged 24.1 °C for the fifteen month period. When the bi-monthly readings were taken, the water temperature at SB-5 was usually 2°C cooler than the water temperature at SB-12. Since these two stations have similar locations, depths and substrata, the thermal effluent must be directly responsible for the temperature differences that were noted between these two stations. The water temperatures at these two stations have been plotted in Figure 8.2.

The water temperature at the seine stations correspond to seasonal fluctuations in air temperature. Solar heating also contributed to the high temperatures that were recorded at some stations outside of the thermal plume boundaries.

Dissolved oxygen and salinity values probably did not fluctuate enough to be limiting factors in community structure, abundance, or distribution. Salinity ranged from a high of 29 °/oo at stations SB-5, SB-12, and SB-11 in May, 1976 to

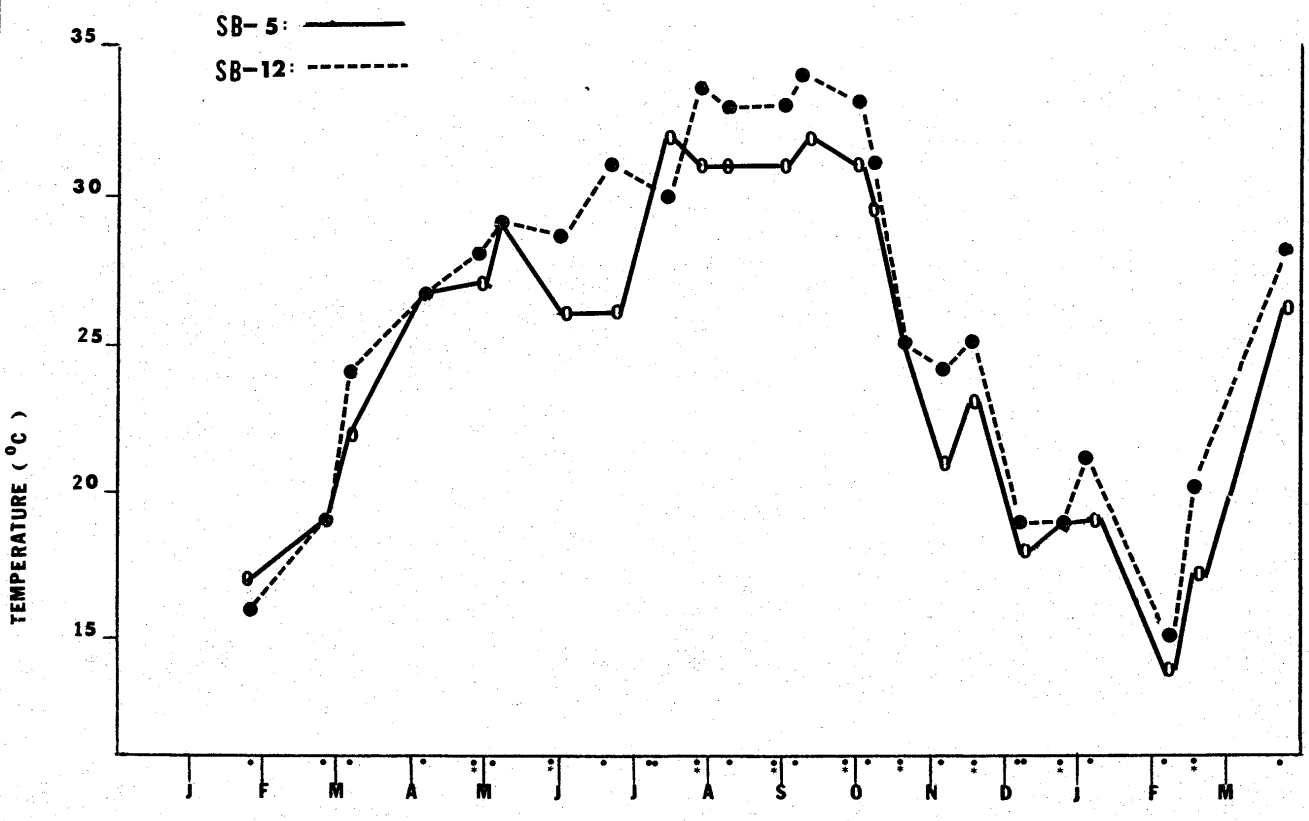


Figure 8.2. Water temperature values at seine stations SB-5 and SB-12.

* Temperatures on these dates were recorded within a few minutes of each other. At least one hour elapsed between sampling times on the other dates.

a low of 18 °/oo at stations SB-12 and SB-14 in February, 1977. DO fluctuated between a high of 11.7 ppm at station SB-5 in February, 1976 to a low of 5.0 ppm at station SB-10 in August, 1976.

Systematic Account

The following is a systematic account of some of the fishes and macroinvertebrates that were collected by seine between January, 1976 and March, 1977. The species listed in this account were chosen on the basis of their commercial importance in the Tampa Bay area and/or their relative abundance in the seine catches.

When possible, these data will be compared with the baseline data that was collected in this area prior to the inception of this program. A table presented by Phillips (1976a) will be the primary source of information for this comparison. This table lists, by season, the total number of fishes that were collected with seines, trawls, travelling screens, and crab traps between fall, 1970 and fall, 1975.

Information, compiled from studies that were conducted in relatively unstressed areas, is also included in this account. This enables a comparison of the trends noted in the Big Bend area to those of other studies. Deviations from usual life histories could be indicative of a stressed environment.

The ranges listed in this account refer to the ranges that were observed (measured) between January, 1976 and March, 1977.

The generic and common names of the fishes listed in this account follow those of the American Fisheries Society (Bailey, et al., 1970).

Harengula jaguana
Scaled sardine
Number collected: 1721
Size range: 62-138 mm
Temperature range: 12-34°C
Salinity range: 18-25 °/oo

The scaled sardine was formerly referred to as H. pensacolae. Whitehead (1973) has presented evidence which indicates that H. jaguana is the correct generic name for this species.

H. jaguana is an inhabitant of the open bay in the Big Bend area. All but 3 of the 1721 specimens collected between January, 1976 and March, 1977 were captured at seine stations on the open bay. Most of the individuals (98%) were captured during the summer and fall months. This corresponds to the time when Springer and Woodburn (1960) found this species in abundance.

This species apparently inhabits the Big Bend area in all but the winter months. Although few adults were captured before late summer, Phillips (1976b, 1977) reported the presence of eggs and larvae of this species in the Big Bend area between late April and July. The adults apparently spawn in offshore waters during this time (April - July) and are not accessible by our sampling methods. Springer and Woodburn (1960) indicated that spawning of this species occurs in April and May.

There are conflicting reports concerning the influence of temperature and salinity on this species. Springer and Woodburn (1960) in their study of Tampa Bay, and Gunter (1945) in his study of the Texas Coast, caught few H. jaguana when salinity concentrations dropped below 25 °/oo. In the Big Bend area, H. Jaguana was most abundant at the Pine Key station (SB-14), during September and October. Salinity values at the time of sample collection were 22 and 23 °/oo for September and October respectively.

Gunter (1945) also noted the disappearance of H. jaguana when water temperature fell below 24°C. However, Reid (1954) captured individuals of this species in March, when surface water temperature was 20.8°C and Mountain (1972) captured specimens at a temperature of 17.1°C. We captured one specimen in November when the water temperature was 20°C and 2 specimens the following February when the water temp-

erature was 14°C. The coldest water temperature at which Springer and Woodburn (1960) captured live specimens was 16.8°C. They found 2 cold-killed specimens after a severe cold wave. The water temperature had dropped to 13°C. Those that we captured at 14°C showed no ill-effects as a result of low water temperature, even though this temperature was apparently close to their lethal minimum temperature.

Scaled sardines were collected at temperatures as high as 35.1°C by Springer and Woodburn (1960) and 37.9°C by Springer and McErlean (1962).

Anchoa mitchilli Valenciennes
Bay anchovy
Number collected: 9171
Size range: 18-65 mm
Temperature range: 16-32°C
Salinity range: 20-24 °/oo

A. mitchilli were abundant in seine catches in October through December, 1976 and again in February and March of 1977.

Most of the specimens were collected at shallow inshore stations, and were probably utilizing these areas as nursery grounds.

An extended spawning season was indicated since two distinct groups of young individuals inhabited the shallows at two different times. Those individuals collected in October through December had a mean standard length of less than 31 mm. Those collected in February had a mean standard

length of less than 26 mm. Phillips (pers. comm.) indicated that an extended spawning season (between March and October) occurs in the Big Bend area. Gunter (1945) also noted that the spawning season for this species in Texas, may extend from spring through fall.

Bay anchovies have been collected at temperatures as low as 7.9°C (Dahlberg, 1972) and as high as 32.5°C (Springer and Woodburn, 1960). Salinity extremes range from 0 °/oo (Tabb and Manning, 1961) to 35 °/oo (Springer and Woodburn, 1960).

Cyprinodon variegatus Lacépéde
Sheepshead minnow
Number collected: 2961
Size range: 14-58 mm
Temperature range: 14-34.5°C
Salinity range: 19-27 °/oo

C. variegatus were captured consistently at station SB-10, an embayment station. Of the 2,961 individuals that were collected, only 28 were found at stations other than SB-10. The relative abundance of this species at this station reflects its habitat preference (Martin, 1972; Springer and Woodburn, 1960; Kilby, 1955).

This species was collected during every month, but it was most abundant from May through August, 1976. The fish is eurythermal (Springer and Woodburn, 1960) and has been collected in areas where the water temperature ranged from 8.8 to 34.9°C (Gunter, 1945).

The greatest decrease in the relative abundance of this species between two sampling periods, occurred between August and September, 1976. A total of 449 individuals were captured at SB-10 in August, as opposed to a total catch of only 11 at SB-10 in September. Water temperature at this station rose from 32 to 34.5°C between the August and September collections. Abundance levels rose to 94 individuals captured at SB-10 in November. A corresponding decrease in water temperature (to 28°C) was also noted.

While this species is eurythermal, it is possible that temperatures above 35°C are approaching the critical thermal maximum for this species.

Young specimens ($\bar{X}$ SL $\leq$ 20mm) were captured in April, May, November and December, 1976, and January, 1977. These results contradict the findings of Springer and Woodburn (1960) who felt that spawning apparently occurred only during the summer months. Kilby (1955) thought that spawning could occur year-round in the warmer waters of the Gulf.

Fundulus similis (Baird and Girard)
Longnose killifish
Number collected: 7704
Size range: 9-117mm
Temperature range: 12-34.5°C
Salinity range: 18-29 °/oo

This was one of the most ubiquitous and abundant species captured within the course of this study, and during several preceeding years (Phillips, 1976a). Specimens were captured

at 3 to 6 seine stations each month.

Growth progression was outlined in Table 8.3. Young specimens ($\bar{X}$ SL $\leq$ 23 mm) were captured almost every month, thus indicating year-round spawning activity. Kilby (1955) also found young specimens in his collections throughout the seasons.

Other studies show temperature and salinity ranges for longnose killifish of 13.0 - 33.5°C and 3.2 - 76.1 °/oo (Mountain, 1972; Springer and Woodburn, 1960; Simpson and Gunter, 1956).

The distribution of this species did not appear to be influenced by temperature or salinity variations.

Menidia beryllina (Cope)
Tidewater silverside
Number collected: 20,256
Size range: 14-96mm
Temperature range: 12-34.5
Salinity range: 18-29

M. beryllina was abundant in the area throughout this sampling period. It has been common in the catches collected at Big Bend during the previous several years (Phillips, 1976a). Individuals were collected at atleast 4 seine stations (usually 5 or 6) each month during the present study.

Growth rates are presented in Table 8.4 but patterns are difficult to discern. The presence of young individuals ($\bar{X}$ SL $\leq$ 23mm) was apparent in January (1977), February (1976 and 1977).

Table 8.3. Growth progression of Fundulus similis captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
8			1												
11											5				
14											11				
17					1		1			1	26	16			
20											13	7	1	1	
23				1	1			1			5	1	3		1
26		1		1	3						17	2		2	1
29					4	1			1		6	2	1	2	2
32					8		1				3	1	4	8	1
35					17	1	3	5			1	3	8	15	1
38			1		52	2	10	11	3	1	3	2	16	15	3
41		2	2	10	20	19	23	22	13	1	4	7	13	9	3
44		7	6	13	22	29	9	30	10	6	8	4	12	16	5
47	1	10	5	16	14	27	11	22	13	10	4	12	25	16	1
50		5	4	20	6	17	17	36	19	6	6	3	16	17	6
53	1	5	6	15	6	18	24	36	17	7	3	8	13	11	2
56		4	4	17	3	21	24	34	32	9	1	8	11	9	16
59	2	4	4	16	7	5	27	33	29	13	9	16	14	14	8
62	2	6	1	14	4	9	12	21	16	19	6	14	9	8	13
65	3	4	9	12	5	4	14	22	28	25	7	24	11	7	25
68	4	10	7	6	2	6	5	15	14	18	12	26	11	14	18
71	4	15	7	7	4	4	2	8	13	14	14	25	25	28	17
74	3	25	8	5	11	2	4	9	9	12	14	29	24	26	21
77	3	30	8	2	4	1	4	8	5	7	8	20	43	20	15
80	4	34	12	2	9	1	4	4	4	10	13	23	46	26	17
83	5	42	9	3	8	1	6	1	4	9	8	11	29	13	10
86	4	33	13	5	10	1	1	1	4	5	9	6	30	12	16
89	7	36	6	4	15	3		1	3	2	4	1	29	9	8
92	6	27	9		8				2	5	1	2	18	5	14
95	7	22	10	2	14	1				5	1	3	9	9	5
98	2	22	12	1	11	2		1	1	2		2		3	8
101	1	20	7	3	11	1	1	2	2	4			5	3	3
104		13	7		7	1				1			2	3	2
107		7	1		4					2	1				
110		8	1	1							1				
113		2													
116		3													
119									1						
TOTAL	59	397	160	176	291	179	204	323	243	194	224	278	748	321	242

Table 8.4. Growth progression of *Menidia beryllina* captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
11		1													
14		1	1	4	1					1					
17		6		3						1	1	4	5		
20		9		18	5					1			5	1	
23		7		11	6				1	2		3	7	2	
26		5		13	7	1				2	1	2	7	1	2
29		16	2	2	14					1	5	13	16	2	
32		3	3	4	7			1			4	22	23		
35		2	6	8	2			1	1		3	20	6	1	2
38			11	4	2	1		7		2	1	5	11	1	1
41	1	1	16	12	4	2	2	9	3	8	5	12	19	1	
44	1	3	10	15	11	25	10	38	5	29	5	10	9	2	1
47	1	10	16	6	34	74	50	103	24	28	33	10	21	4	2
50	2	15	14	11	53	105	94	143	45	70	65	26	30	9	5
53	1	16	20	5	55	92	103	114	76	72	80	52	25	13	10
56	3	16	14	3	39	52	106	103	93	84	70	83	62	23	10
59	1	8	6	6	13	15	56	69	132	72	87	83	53	46	23
62	6	4	3	3	12	9	24	34	108	63	71	77	67	43	32
65	11	13	4	1	4	6	11	13	60	59	87	64	62	55	30
68	9	33	22	1	11	1	3		28	23	75	63	73	79	47
71	48	35	61	2	4				20	6	42	67	98	65	68
74	26	56	67	8	4		1		9	9	26	42	104	77	56
78	30	60	53	9	1	2	1		8	12	9	24	43	45	55
80	18	32	45	4	6	1				3	9	11	53	42	59
83	9	40	40	6	1						7	12	28	32	24
86	7	21	30	4	2						6		16	19	20
89	1	20	16	1							2	1	17	12	16
92	2	4	7										2	4	7
95		2	7											1	3
98															
TOTAL	177	438	474	164	298	386	461	635	613	548	694	706	862	580	473

March, April, May, September, October, November and December, 1976. Ripe individuals were captured in every month except October and November. This indicates the possibility of a greatly extended spawning season. Kilby (1955) found very young fish in his collections during all seasons.

This species did not appear to be influenced by the temperature and salinity ranges that were prevalent within the sampling area. This concurs with the findings of other investigators who have recorded temperature and salinity extremes of 16-35.3°C and 0 -58.6°/oo (Dahlberg, 1972; Mountain, 1972; Renfro, 1961; Tabb and Manning, 1961).

Trachinotus falcatus (Linnaeus)
Permit
Number collected: 114
Size range: 15-410mm
Temperature range: 18-33°C
Salinity range: 22-25.5°/oo

T. falcatus are seasonally common in the Big Bend and Tampa Bay areas. Springer and Woodburn collected 226 individuals between November and December, 1957, and in July through December, 1958. All but 4 of the 114 individuals captured during our study were collected between July and November, 1976.

Reid (1954) implied that this species is rare throughout its known range. The findings of Finucane (1969), Springer and Woodburn (1960), and of this study clearly refutes this statement.

Hundreds of I. falcatus were caught by local fishermen in the vicinity of the warm water discharge during February, 1977. These findings were obtained by personal observation and by the results of a creel census that was taken in the Big Bend area. Unseasonably cold weather had penetrated the Tampa Bay area at this time. The fish were undoubtedly attracted to the warm water discharge.

Previous studies (Phillips, 1976a) revealed that I. falcatus has been consistently captured in the Big Bend area since 1970.

The size range of individuals collected in July, 1976 was 26-71 mm. This same year class was represented in the September, 1976 collection. Size range at this time was 67-84 mm. Springer and Woodburn (1960) also noted a rapid growth rate for individuals of this species. They found that individuals ranging in size from 8.2 to 19.8mm in June, increased to 63.6 to 109.6 the following November.

The presence of another year class was also noted in September, 1976, since 9 specimens ranging in size from 143 to 160mm were also captured that month.

Young individuals were again captured in October and November, 1976. This indicates that two spawning periods occurred, or that this species exhibits an extended spawning season. Similar results and conclusions are given by Finucane (1969).

Eucinostomus argenteus Baird and Girard
Spotfin mojarra
Number collected: 5541
Size range: 11-105mm
Temperature range: 14-34.5°C
Salinity range: 18-29 °/oo

Peak abundance levels of E. argenteus occurred between September and December, 1976. Young individuals (SL ≤ 20mm) appeared in the August, September, November and December, 1976 seine catches, and in the February, 1977 collection.

Kilby (1955) felt that only the young of this species made any appreciable use of marshes or inshore waters of the Gulf, since very few of the fish that he collected were over 50mm. As evidenced by the growth progression table for this species (Table 8.5), a considerable number of the E. argenteus that we collected were over 50mm, and were utilizing the inshore waters of the bay. Perhaps habitat availability and selectivity (preference) influence the distribution of this species between different study sites.

Kilby (1955) felt that the adults spawn in the Gulf and that the young migrate to inshore waters. We were not able to detect where spawning occurred. Abundance levels of this species steadily declined from November, 1976 to February, 1977, which may have indicated a spawning migration toward the Gulf.

Table 8.5. Growth progression of *Eucinostomus argenteus* captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
11									1						
14												2			
17									6		5	2			
20		1						1	13		10	4			
23		2						19	11	2	15	16	4		
26		2	1					24	13	6	10	35	28	2	
29			3			9		12	18	20	13	39	21		1
32		1	9			3	1	27	41	40	30	21	7		2
35		1	10			5	2	24	27	48	22	29	2		8
38		2	15	1		4	8	21	14	43	33	28	1		9
41			15	3		13	19	25	17	44	43	27	2	1	12
44			13	4		22	21	17	29	36	34	26	1		12
47		1	9	3	1	21	29	22	30	21	48	26	1		14
50		1	9	1	1	23	13	25	25	23	42	12	3		16
53			11	5	11	16	4	13	39	8	34	10	5		5
56			6	2	17	8	1	2	25	9	23	10	2		
59			13	6	15		2	1	38	3	9	6	1		3
62			11	2	20	1	1	1	31	4	5	2			1
65			7	1	17	1		3	22	3	3				1
68			5		25	3	1	1	20	5	5				
71			5	1	20	2		6	8		1				
74			4	1	18	1		4	24	5	2				
77			2	1	13	2	1	2	24	6	3				
80			2		18	4	3	6	41	10	2				
83			1	2	9	3	4	2	26	7	4				
86			1		8	1	2	2	36	3	3				
89				1	6		6		17	5					
92					4	1	6		9	7	2				
95				1	5		2		8	6					
98				1	1	2			2	7	1				2
101			1		1		2		3	2	1				
104									1	2					
107															
110															
TOTALS	0	11	152	37	210	160	128	260	619	376	403	295	78	3	86

Eucinostomus gula (Quoy and Gainard)
Silver jenny
Number collected: 2451
Size range: 31-100mm
Temperature range: 15-34.5°C
Salinity range: 18-29°/oo

Peak abundance levels of this species were noted in September through November, 1976. Relative abundance levels were low in the Big Bend area during the winter and spring. The fish may have migrated to the Gulf during this time to spawn. This species disappeared from Kilby's (1955) catches by December. Springer and Woodburn (1960) noted that E. gula populations moved from Tampa Bay to Boca Ciega bay as winter approached.

Other investigators have captured E. gula at temperatures between 12.8 and 33.6°C and salinities between 2.0 and 37.9 °/oo (Springer and McErlean, 1962; Springer and Woodburn, 1960; Kilby, 1955).

Temperature and salinity did not appear to be a limiting factor in the distribution of this species in the Big Bend area.

Lagodon rhomboides (Linnaeus)
Pinfish
Number collected: 1465
Size range: 16-136mm
Temperature range: 18-34.5°C
Salinity range: 22-29°/oo

Young specimens of L. rhomboides first appeared in the seine catches in February and March, 1976, and again in

March, 1977. This corresponds to the winter spawning period suggested by Springer and Woodburn (1960) and Reid (1954). Phillips (pers. comm.) captured young specimens (10-15mm) in January and February, 1976 and 1977. A growth progression outline is presented in Table 8.6.

The limited number of individuals collected after the September seine collection was probably indicative of a spawning migration to the Gulf.

Most specimens were found in shallow, sandy areas. This supports the findings of Springer and Woodburn (1960) who found L. rhomboides to be a common inhabitant of such areas. Reid (1954) found that this species was poorly represented in areas devoid by vegetation.

L. rhomboides have been captured in areas exhibiting a wide range of temperature and salinity values (10.0-35.3°C; 0.8-37.9 °/oo) (Turner and Johnson, 1973; Mountain, 1972; Springer and McErlean, 1972; Springer and Woodburn, 1960; Kilby, 1955; Reid, 1954).

Leiostomus xanthurus Lacépéde
Spot
Number collected: 1035
Size range: 16-104mm
Temperature range: 14-27.5°C
Salinity range: 20-29°/oo

This species was first collected in the February, 1976 sample, and was present in the seine catches through May, 1976. Young specimens were present in the catch in February and

Table 8.6. Growth progression of Lagodon rhomboides captured by seine between January, 1976 and March, 1977.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
17		3	2												1
20		17	10												21
23		29													40
26		24	22												25
29		19	59	12											26
32		7	38	25			1								7
35		1	4	30	1										3
38			2	38	1										
41				55	1										
44				43	7										
47				23	14										
50				6	35										
53					34	6	1	1							
56					41	11									
59				1	37	10	1	1							
62					21	18	9						1		
65					14	14	18	7							
68					7	14	32	1					1		
71					2	12	21	3							
74					2	7	31	5							
77						4	12	7							
80					1		24	4	2						
83							22	3	1						
86							13	3	1						
89							16	2	2						
92						2	3		3						
98							2		2						
101							2	1	6	1					
104									1						
107									1						
110									2						
113									1						
119									2						
125									1						
128								1							
137								1							
TOTALS	0	100	137	237	218	98	215	41	27	1	0	0	2	0	105

March of both 1976 and 1977. The presence of young L. xanthurus at this time of year supports the findings of other investigators (Springer and Woodburn, 1960; Reid, 1954; Kilby, 1955; Gunter, 1938).

Rapid growth rates have been indicated for this species (Kilby, 1955; Reid, 1954; Gunter, 1938). Kilby (1955) determined that this species moves out of marsh areas once it attains a length of about 80mm. As evidenced by the growth progression in Table 8.7, most individuals would be 80mm or larger by June, which corresponds to the time that they were absent from the seine catches. It is conceivable that this species moved from the shoreline areas into the deeper waters of the bay.

In the Tampa Bay area, the adult L. xanthurus probably migrate to the Gulf (where spawning occurs) during the winter and early spring (Springer and Woodburn, 1960).

Menticirrhus saxatilis (Block and Schneider)
Northern kingfish
Number collected: 243
Size range: 15-137mm
Temperature range: 16-31.5°C
Salinity range: 20-27°/oo

This species was formerly referred to as M. focaliger. Irwin (1970) indicated that this was not a valid species. Phillips (1976b) provided a brief account of this name change.

Peak abundance levels of this species occurred in the

Table 8.7. Growth progression of Leiostomus xanthurus captured by seine between January, 1976 and March, 1976.

Mid Class (mm)	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M
17														12	
20														6	1
23		1	2												1
26		2	5												8
29			5												18
32			21												41
35			2												39
38				3											31
41				2											16
44				18											11
47				26											16
50				20											9
53				5	1										14
56				4	2										1
59				2	5										1
62				1	10										
65					11										
68					12										
71					10										
74					12										
77					11										
80					20										
83					19										
86					18										
89					11										
92					5										
95					4										
98					3										
101					2										
104					2										
TOTALS	0	3	35	81	157	0	0	0	0	0	0	0	0	18	207

seine catches between May and August, 1976. The young of this species were present in August, September, November and December, 1976. This indicates a spring and summer breeding season in the Big Bend area (Phillips, 1976b, Phillips, 1977).

Springer and Woodburn (1960) noted the presence of this species most often in areas where the salinity was above 25°/oo. In the Big Bend area, this species was most abundant at the Pine Key station (SB-14) between May and August, 1976. Salinities at this station ranged from 27°/oo in May to 22.5 °/oo in August.

Mugil cephalus Linnaeus
Striped mullet
Number collected: 3005
Size range: 15-360mm
Temperature range: 12-34°C
Salinity range: 19-29°/oo

Striped mullet are important commercial species in the Tampa Bay area.

Individuals of this species were captured by seine during each sampling month. Young M. cephalus first appeared in the seine catches in January, 1976 and again in November, 1976. This indicates a late fall and/or early winter spawning season. Springer and Woodburn (1960) assumed that spawning occurs in the Gulf from October to December.

The young apparently migrate into shallow protected areas and utilize them as nursery grounds and areas of refuge. During the summer and fall months, or when a size of 60-100mm

is attained, this species tends to "scatter out" (Anderson, 1958; Kilby, 1955). This effect was reflected by decreased catches of this species during these months. Adults were most abundant in the Big Bend area between May and November, 1976. While we captured many adults over 100mm, many more were able to escape simply by jumping over the net.

Springer and Woodburn (1960) presented an informative discussion of M. cephalus activity in the Tampa Bay area. They noted that a migration toward the Gulf occurs in the fall. This phenomenon would explain the relative paucity of adults in the area during this period.

Striped mullet have been captured in areas exhibiting wide ranges of temperature and salinity. Therefore, it is doubtful that these factors would influence the distribution of the young or adults of this species.

Melongena corona Gmelin
Crown conch
Number collected: 385
Size range: 10-113 mm
Temperature range: 12-34°C
Salinity range: 19-29°/oo

M. corona was the most abundant macroinvertebrate captured by seine during this study. This species was concentrated primarily on the mud flats of the embayment station (SB-10). Dragovich and Kelly (1964) noted that species was abundant on mud flats of Old Tampa, Hillsborough, and Boca Ciega Bays.

Young of this species were captured in May and June, 1976; and in September, 1976 through February, 1977. Peak abundance occurred between September and December.

Penaeus duorarum Burkenroad
Pink shrimp
Number collected: 41
Size range (total length): 28-80mm
Temperature range: 18-34.5°C
Salinity range: 22-26 °/oo

This species constitutes an important part of the shrimp industry in the Tampa Bay area.

Relatively few individuals of this species were captured during this sampling period. This was probably due, in part, to gear selectivity and the burrowing habits of this species during the daylight hours (Wickham and Minkler, 1975).

The results of the meroplankton and impingement sections of this report confirm the belief that this species is relatively abundant in this area. Copeland and Bechtel (1974) indicated that this species exhibits a preference for areas with a temperature range of 20-35°C and a salinity range of 20-36°/oo.

Callinectes sapidus Rathburn
Blue crab
Number collected: 57
Size range (carapace width): 9-182mm
Temperature range: 15-34°C
Salinity range: 22-27°/oo

Blue crabs comprise a large percentage of the commercial fishing industry on Tampa Bay.

Individuals of this species were captured by seine in all months, except February, 1977. Dragovich and Kelly (1964) collected this species throughout Tampa Bay during their entire investigation (August 1961 to August 1962). Almost half (21) of the total number that were collected in the Big Bend area, were caught at the embayment station (SB-10).

Most spawning occurs in the spring and summer months (Oesterling, 1976). The adults migrate to the low salinity estuaries to molt and mate (Oesterling, 1976). The young blue crabs utilize protected estuarine waters as nursery areas.

Blue crabs can apparently tolerate wide ranges of temperature and salinity. Copeland and Bechtel (1974) found that optimum catches of this species occurred in water temperatures between 10 and 35°C; and salinity ranges between 0 and 27°/oo.

Relative Abundance and Distribution

Between January, 1976 and March, 1977, a total of 61,273 fishes (56 species; 32 families) and 646 macroinvertebrates (21 species) were captured in 180 seine hauls. The number of fishes and macroinvertebrates captured at each station is listed below.

Station	Total Number of Fishes	Total Number of Macroinvertebrates	% of Total Catch
SB-12	6,787	87	11.1
SB-5	4,388	34	7.1
SB-14	3,352	102	5.6
SB-10	22,981	350	37.7
SB-11	11,554	11	18.7
SB-13	12,211	62	19.8
TOTALS	61,273	646	100.0

The inshore stations (SB-10; SB-11; SB-13) accounted for 76.2% of the total catch. Macroinvertebrates were most abundant at SB-10. Fishes were most abundant at station SB-10 and least abundant at SB-14. Fewest macroinvertebrates were captured at SB-11.

Seasonal peaks in abundance were noted at most of the stations. These peaks generally occurred during the spring and fall months. The lowest abundance levels occurred during the winter months.

Relative abundance values were plotted against temperature and salinity values for each station over the fifteen month period. This information is presented in Figures 8.3 and 8.4.

Peak abundance at station SB-12 (thermally altered) occurred between December, 1976 and February, 1977. The average water temperature at this station was higher than at any other station during this same period. Since upward trends in abundance were not noted at any other station

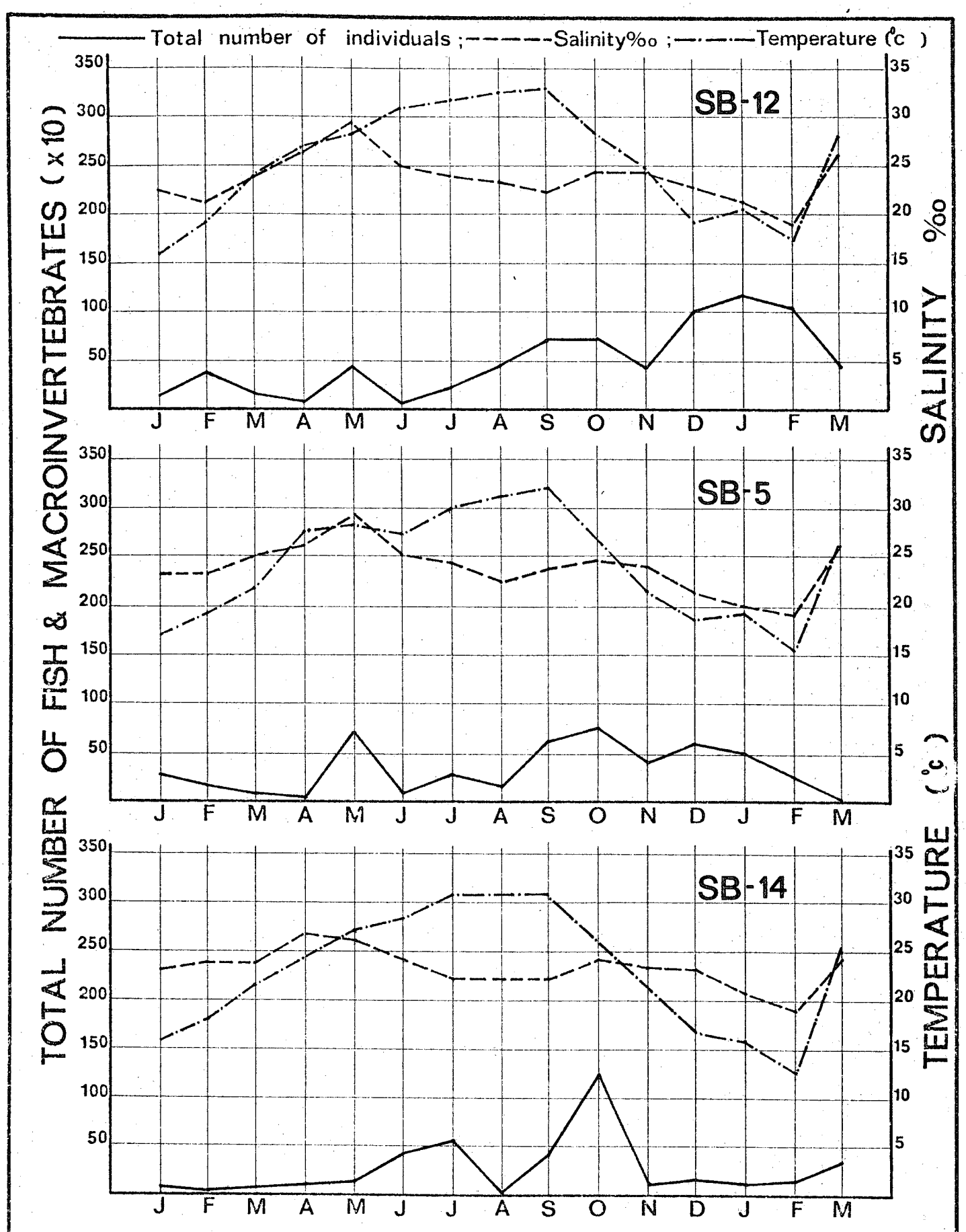


Figure 8.3. Temperature and salinity values, and total number of fish and macroinvertebrates for Stations SB-12, SB-5, and SB-14.

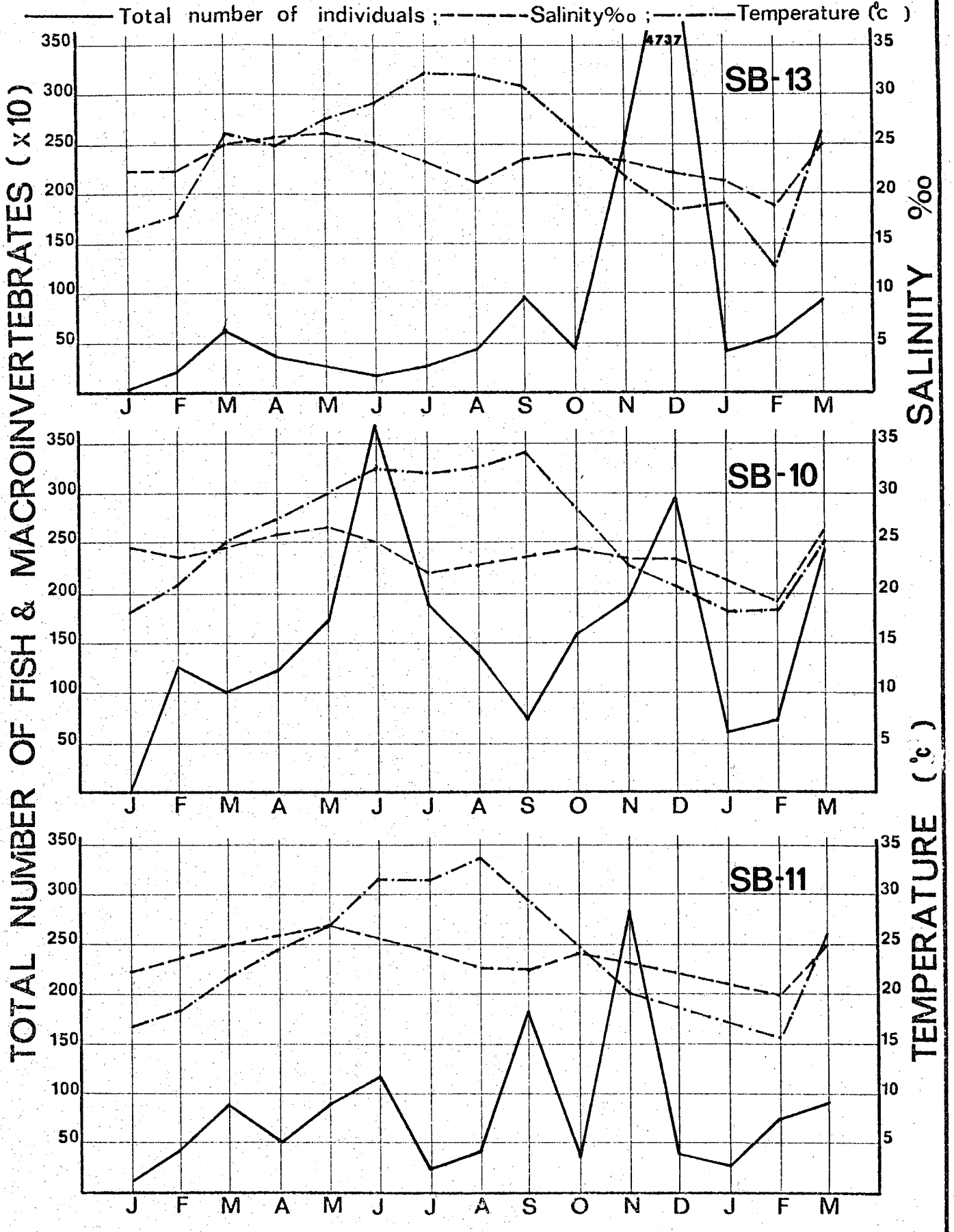


Figure 8.4. Temperature and salinity values, and total number of fish and macroinvertebrates for Stations SB-13, SB-10, and SB-11.

during this time (December - February), it is possible that fishes were attracted to this area (SB-12) because of the presence of the thermal effluent.

Depending on the season, most seine catches were dominated by 2 to 6 species per month. Throughout the course of this study, Menidia beryllina (tidewater silverside) and Fundulus similis (longnose killifish) were usually the two numerically dominant species.

Numerical dominance by a few species is often noted in ecological studies (Livingston, 1976; Gallaway and Strawn, 1975; Dahlberg and Odum, 1970). Changes in numerical dominance are criteria on which impact assessments can be based. If certain opportunistic species consistently increase in abundance over a period of time, it may indicate the deterioration of an environment. Bechtel and Copeland (1970) indicated that this was occurring in a stressed area in Galveston Bay, Texas. This phenomenon does not appear to be occurring in the Big Bend area, since most changes in numerical dominance and distribution can be attributed to natural seasonal variations rather than to a deteriorating environment.

Tables which outline the abundance, dominance, and distribution of the species that were caught by seine each quarter, have been presented in previous reports (Comp and Morris, 1976; Comp, 1976; Comp, 1977a; Comp, 1977b), and

in TECO (1977).

Stations SB-5 (non-thermal) and SB-12 (within the thermal plume boundaries) are both sand beach stations with similar sloping shorelines. Throughout the course of this study the average water temperature at SB-5 was slightly lower than the average water temperature at SB-12. A t-test indicated that there was a significant difference (α=.05) in the water temperature between these two stations. However, this same test indicated that there was not a significant difference (α=.05) between the number of animals captured at the two stations. From this information, it does not appear that water temperature significantly alters the abundance levels between these two stations.

Bioindices and Statistical Analyses

The Shannon-Weaver (1963) index of diversity is often used in ecological studies as a basis for determining general community structure or environmental quality (Livingston, 1976; Subrahmanyam and Drake, 1975; Livingston, 1975; McErlean et al., 1973; Bechtel and Copeland, 1970).

Generally, as the distance from a source of pollution increases, the diversity of a community will also increase. Again, stations SB-5 (non-thermal) and SB-12 (within the thermal plume boundaries) were used as a basis for comparison. Overall, there was not a significant difference

(t-test; α=.05) between the diversity values at the two stations.

Diversity levels plotted with temperature are shown in Figures 8.5 and 8.6. A t-test revealed that seasonal differences in diversity were significant (α=.05) only at station SB-13 (non-thermal).

Diversity values were lowest during the winter months, and highest during the summer months at most stations. Grimes (1971) found that diversity values increased away from the outfall area during the summer and toward the outfall in winter at Crystal River. This trend was not noted during this study.

The highest correlation between water temperature and diversity (r=.66) occurred at station SB-12 (within the thermally plume area). All other stations exhibited low linear correlations between diversity and temperature (r<.66).

To further analyze the effects of certain physical parameters on the fishes and macroinvertebrates in the Big Bend area, several multiple regression analyses were performed using temperature, salinity, and one of the following sets of data:

1) number of species for each month (r^2 = .34)

2) total number ($\log_{10}$ transformation) of animals at all the seine stations (r^2 =.13)

3) total number ($\log_{10}$ transformation) of animals captured at the outside seine stations (SB-5,

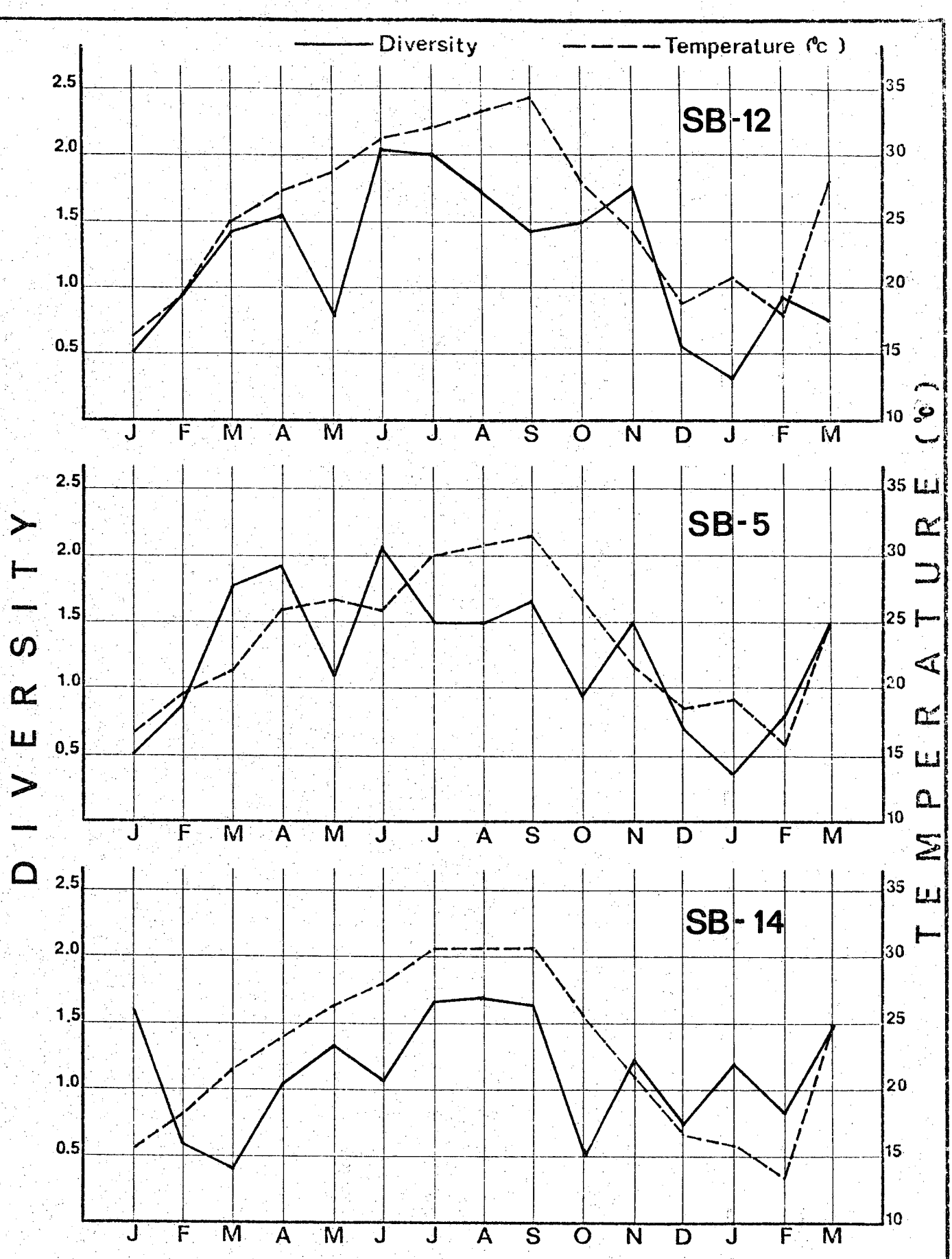


Figure 8.5. Temperature and diversity values at seine stations SB-12, SB-5, and SB-14.

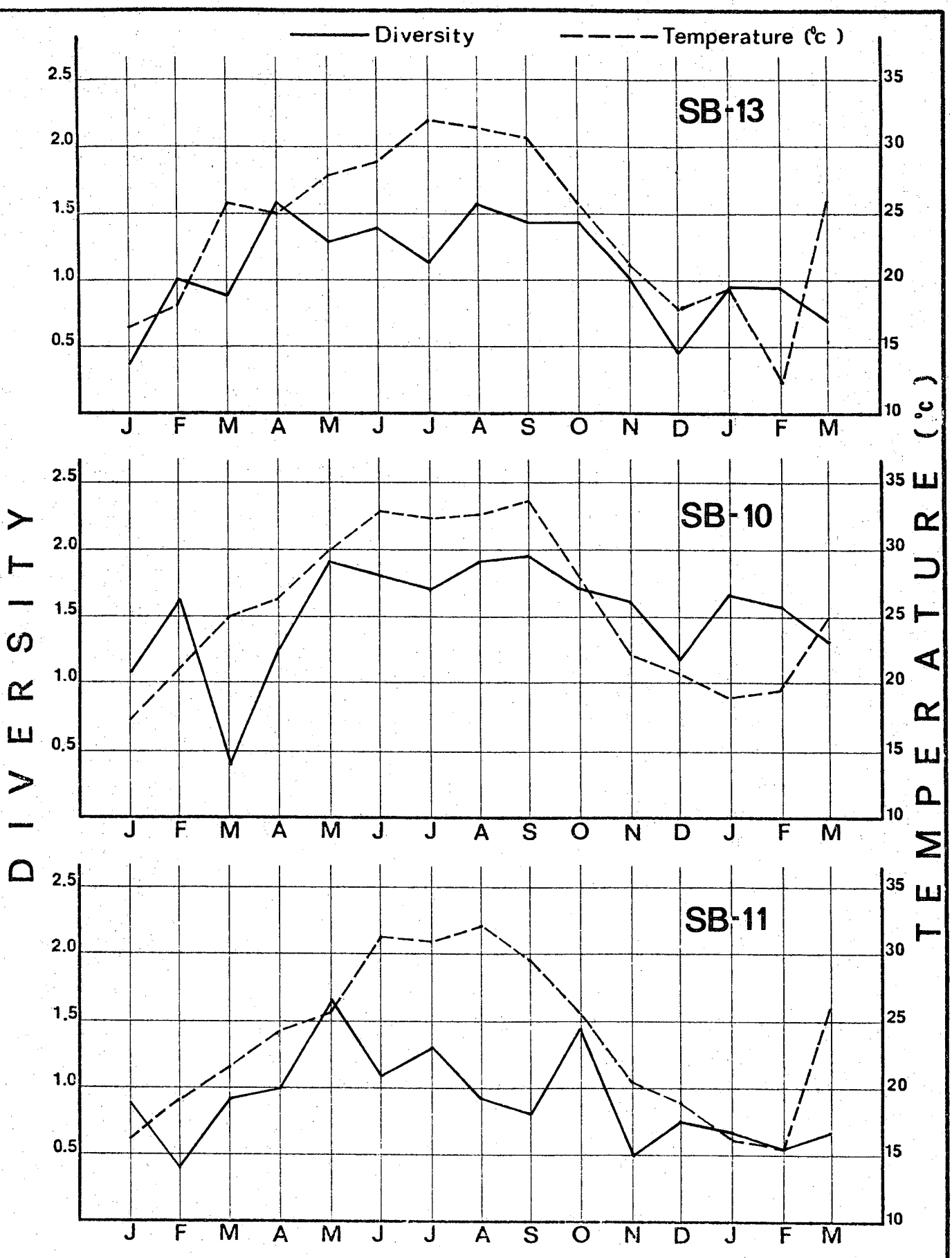


Figure 8.6. Temperature and diversity values at seine stations SB-13, SB-10 and SB-11.

SB-12, SB-14) (r^2 = .22)

4) total number ($\log_{10}$ transformation) of animals captured at the inside seine stations (SB-10, SB-11, SB-13) (r^2 = .1)

5) total number of a commercially important species (M. cephalus, striped mullet) (r^2 = .02)

6) total number of an abundant species (M. beryllina, tidewater silverside) (r^2 = .06). Average temperatures and average salinities were used for this calculation.

The r^2 values remained low. This indicates that most of the differences noted in abundance or distribution can be attributed to a combination of factors other than temperature and salinity.

Species Composition

Another method of assessing the extent of impact due to thermal addition, is to monitor changes in the species composition at the various sampling sites. If the fauna of a particular area is subjected to an intolerable thermal stress, it is conceivable that those species less tolerant of temperature increases would vacate the area.

The number of species that were captured each month at the various stations did not appear to change significantly during the course of this study; nor was the disappearance of any particular species noted.

Figures 8.7 and 8.8 outline the number of species that were captured at each seine station in relation to water temperature and salinity between January, 1976 and March, 1977.

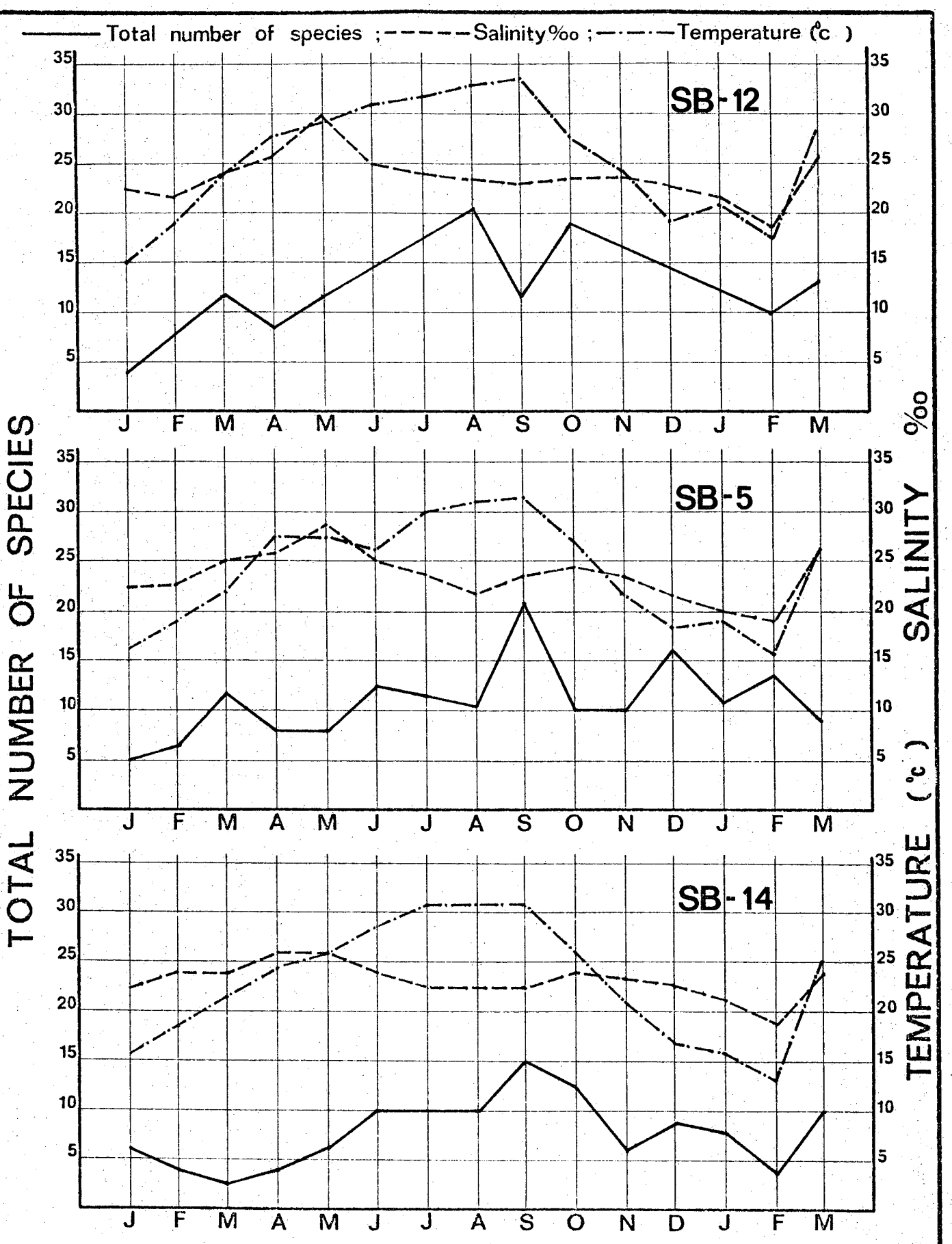


Figure 8.7. Temperature and salinity values, and total number of fish and macroinvertebrate species for Stations SB-12, SB-5, and SB-14.

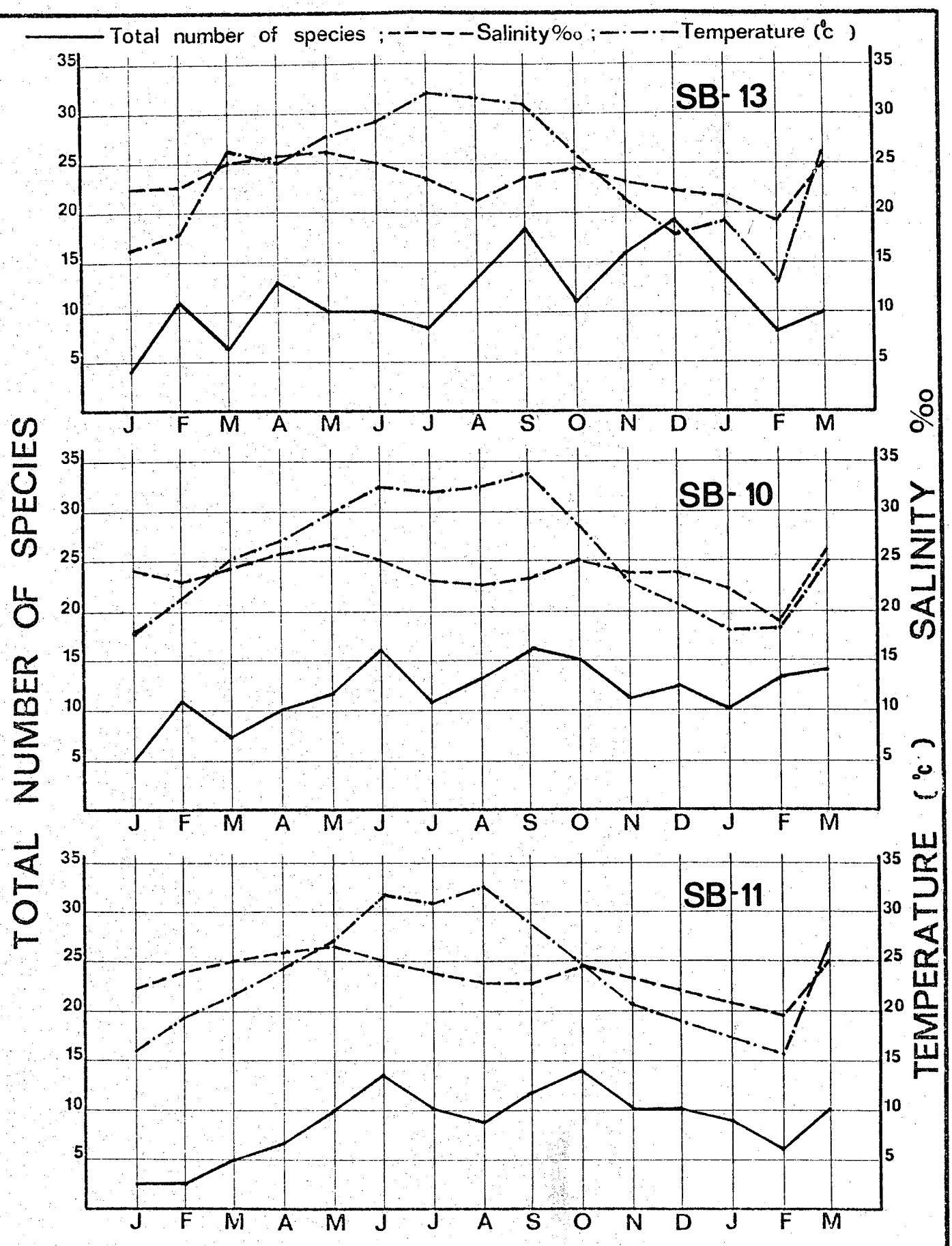


Figure 8.8. Temperature and salinity values, and total number of fish and macroinvertebrate species for Stations SB-13, SB-10, and SB-11.

The total number of species collected at each seine station over the 15 month period (January, 1976 - March, 1977) is outlined below.

Station	Total Number of Species
SB-12	47
SB-5	38
SB-14	14
SB-10	28
SB-11	32
SB-13	42

As shown above, the greatest number of species was found at Station SB-12 (within the thermal plume boundaries).

The Systematic Account, presented earlier, indicated that most of the species in the Big Bend area adhere to the seasonal and migratory trends that were previously elucidated by other investigators. The trends that were used as a basis for comparison with Big Bend data, have been established in areas that were not exposed to the direct effects of pollution or stress. These areas probably supported "natural" populations of marine fishes.

The fishes and macroinvertebrates in the Big Bend area have exhibited patterns of growth, spawning and migration that are similar to those found in unaffected areas.

Tidewater silversides (M. beryllina) and longnose killifish (F. similis) were two of the most dominant species at several of the seine stations. Their numerical dominance

and distribution did not appear to be influenced by the thermal effluent, as these species were dispersed throughout the sampling area.

Seasonal changes in species composition appeared to influence community structure more than did the location of the thermal plume.

Faunal Similarity

Morisita's index (Morisita, 1959) was used to compare the faunal similarity at the different stations over a 15 month period. Due to the dynamic nature of fish populations, the validity of the Morisita's index is questionable for use in a fishery study and our results have been interpreted with great caution. Certain seasonal trends were highlighted by this index, and these will be discussed briefly.

Most of the stations exhibited high ($C\lambda > .7$) to moderate ($C\lambda = .5$ to $.7$) faunal similarities throughout most of the study. Faunal similarity was very low ($C\lambda < .3$) to moderate during the fall months. Changes in species composition and numerical abundance were noted in the fall (probably due to the seasonal influx of large numbers of transient fish species) and this may account for the changes in $C\lambda$ at this time.

Trellis diagrams which outline the similarity of catches at the individual stations over time (15 months), showed

similar seasonal patterns. These diagrams are presented in Figures 8.9 through 8.14.

The catch collected at station SB-10 during March, 1977, was dissimilar to most of the catches collected during the other months. This was due to the seasonal influx of young striped mullet (M. cephalus) at this station during March. Likewise, the catches made at station SB-11 during November, 1976 and February, 1977 had a very low similarity ($C\lambda < .3$) when they were compared to the catches collected at this station during the other months. Large increases in the number of bay anchovies (A. mitchilli) occurred at SB-11 during Nobember, 1976 and February, 1977 thus affecting the similarity values.

The influx of A. mitchilli during November and December, 1976, also affected the faunal similarity at station SB-13. High similarity ($C\lambda = .96$) was noted between the catches made at this station in November and December, 1976. This indicates that the faunal composition at this station was comparable during November and December, 1976, when large numbers of anchovies were present. The catch made at this station during November and December had a low similarity when it was compared to the catches made at this station during the other months, when the anchovies were not present in great numbers.

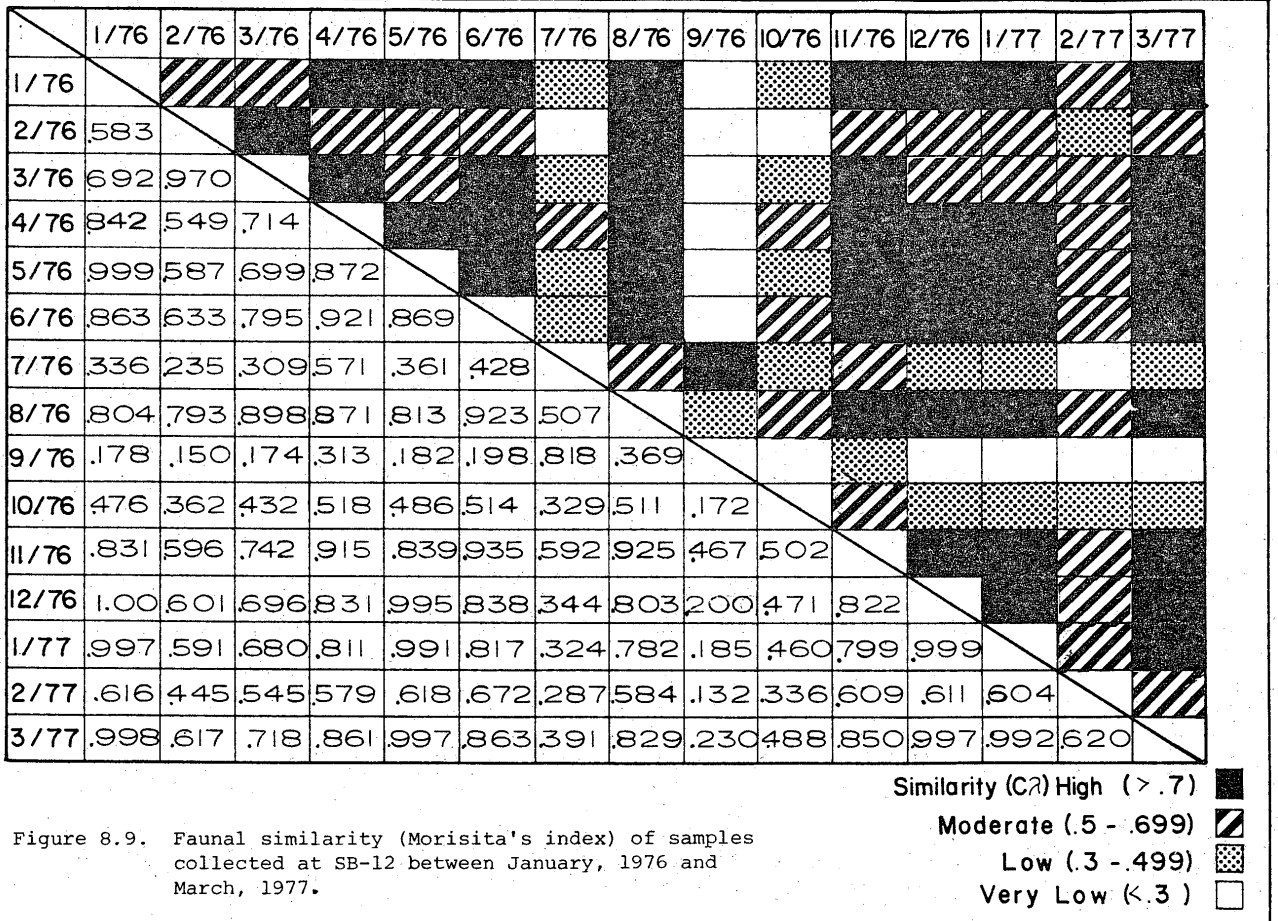


Figure 8.9. Faunal similarity (Morisita's index) of samples collected at SB-12 between January, 1976 and March, 1977.

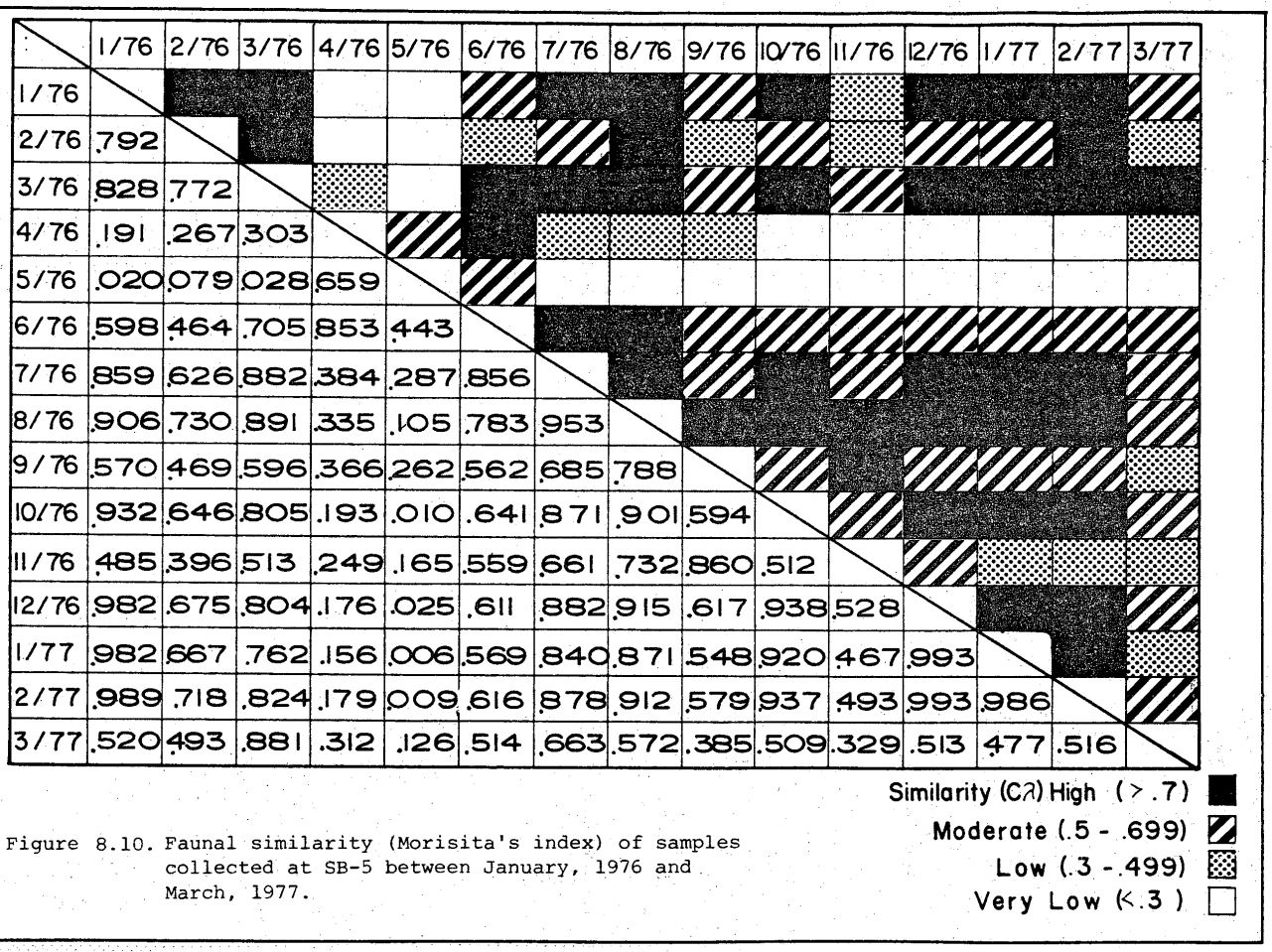


Figure 8.10. Faunal similarity (Morisita's index) of samples collected at SB-5 between January, 1976 and March, 1977.

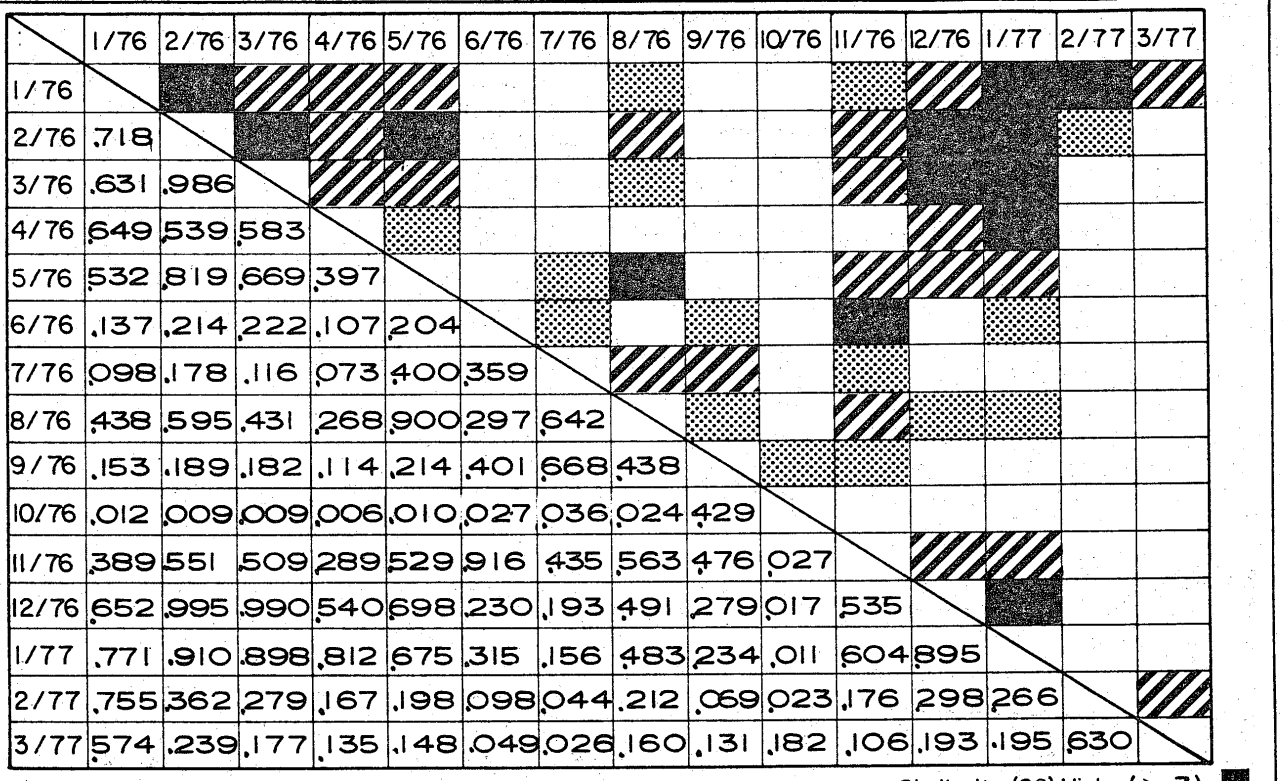


Figure 8.11. Faunal similarity (Morisita's index) of samples collected at SB-14 between January, 1976 and March, 1977.

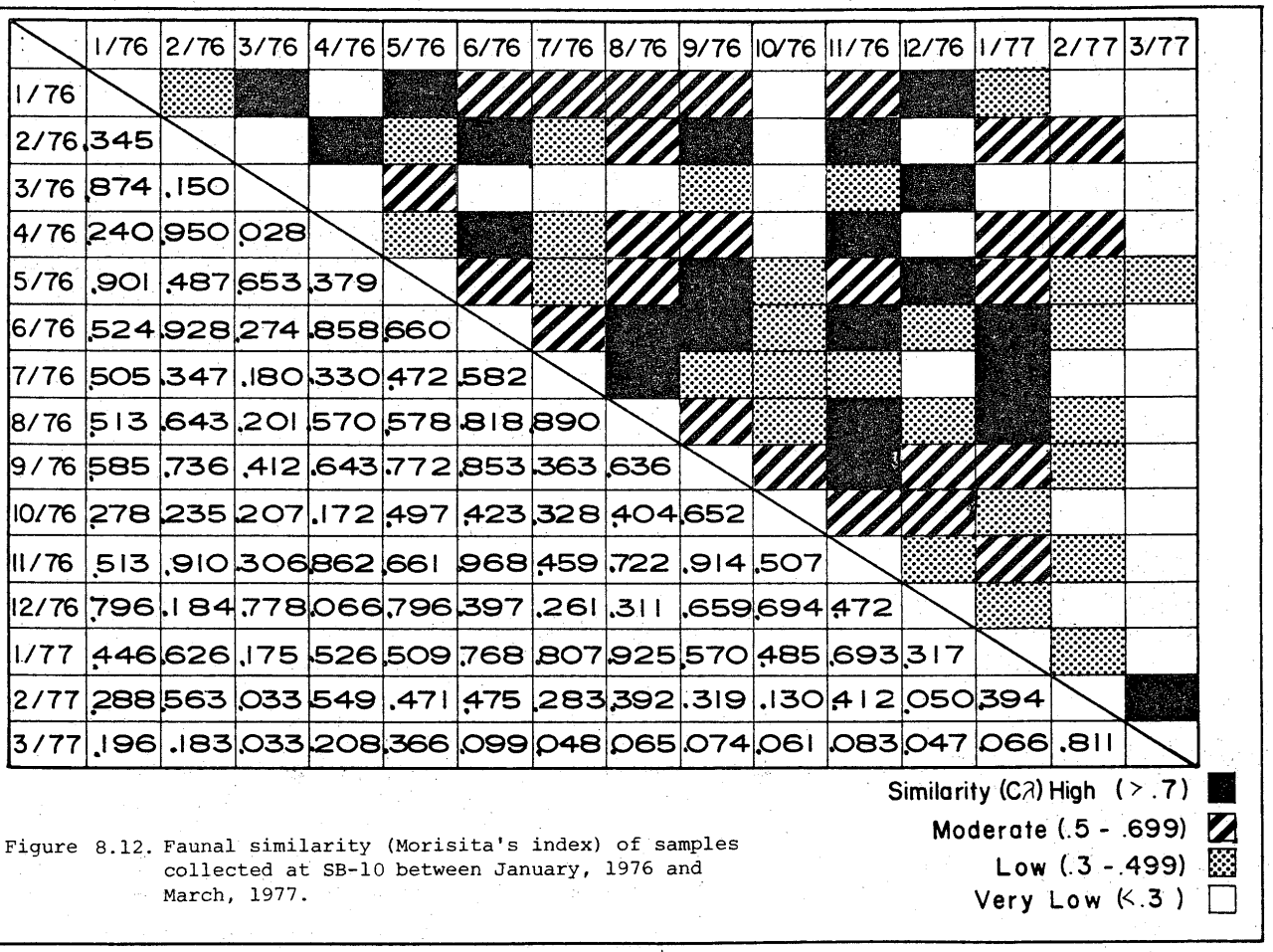
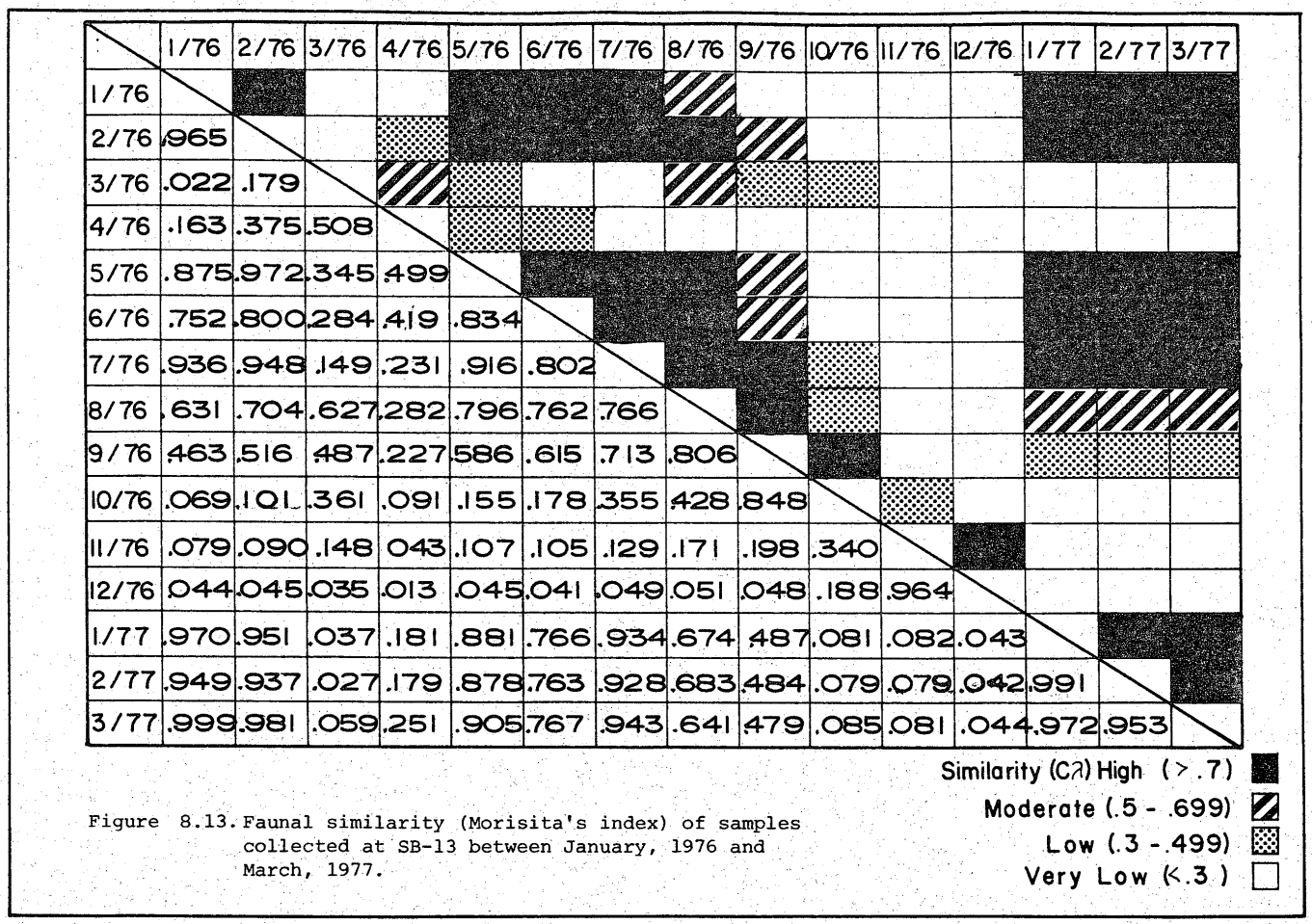


Figure 8.12. Faunal similarity (Morisita's index) of samples collected at SB-10 between January, 1976 and March, 1977.



	1/76	2/76	3/76	4/76	5/76	6/76	7/76	8/76	9/76	10/76	11/76	12/76	1/77	2/77	3/77
1/76															
2/76	.965														
3/76	.022	.179													
4/76	.163	.375	.508												
5/76	.875	.972	.345	.499											
6/76	.752	.800	.284	.419	.834										
7/76	.936	.948	.149	.231	.916	.802									
8/76	.631	.704	.627	.282	.796	.762	.766								
9/76	.463	.516	.487	.227	.586	.615	.713	.806							
10/76	.069	.101	.361	.091	.155	.178	.355	.428	.848						
11/76	.079	.090	.148	.043	.107	.105	.129	.171	.198	.340					
12/76	.044	.045	.035	.013	.045	.041	.049	.051	.048	.188	.964				
1/77	.970	.951	.037	.181	.881	.766	.934	.674	.487	.081	.082	.043			
2/77	.949	.937	.027	.179	.878	.763	.928	.683	.484	.079	.079	.042	.991		
3/77	.999	.981	.059	.251	.905	.767	.943	.641	.479	.085	.081	.044	.972	.953	

Figure 8.13. Faunal similarity (Morisita's index) of samples collected at SB-13 between January, 1976 and March, 1977.

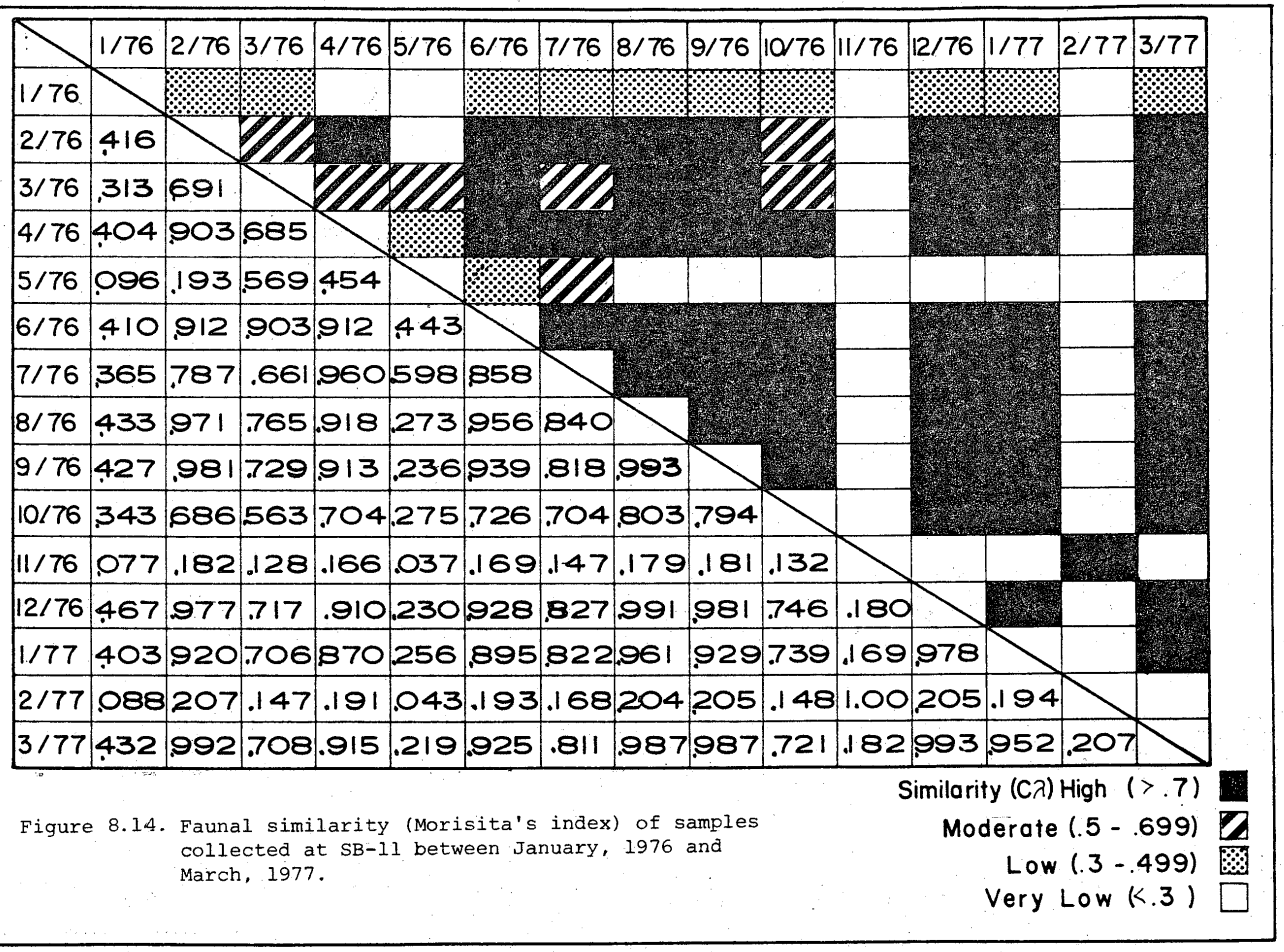


Figure 8.14. Faunal similarity (Morisita's index) of samples collected at SB-11 between January, 1976 and March, 1977.

While these results are not meant to be conclusive, they do indicate that many of the differences in faunal composition between stations and/or months can be attributed to natural occurrences such as schooling, migration, etc.

Nursery Areas

A variety of locations within the Big Bend area appear to be functioning as nursery grounds for several species. The inshore stations, SB-11, SB-13, and especially SB-10, are the predominant nursery areas.

In early 1976, the sheet pile wall adjacent to the thermal discharge area was extended to the western shore of the embayment. This, in effect, further enclosed the embayment and prevented the effluent from directly entering the embayment at this site. This shielded the inhabitants of the embayment from direct exposure to thermally altered water (excluding, of course, tidal introduction of heated water at the western inlet of the embayment).

Juvenile specimens representing a variety of species were captured in this area (SB-10) throughout the course of this study. Several species (notably striped mullet) were found in a wide range of size classes (juvenile to adult). Growth progressions of some of the species which inhabit this area were presented in the Systematic Account section of this report.

This area is often used concurrently by the juveniles of many different species. The migration of young adults out of the embayment often coincides with the migration of post-larval or juvenile specimens of another species into the embayment.

Young striped mullet (M. cephalus) are present at this station between December and June. The young of Leiostomus xanthurus (spot) appeared in the embayment in February and March. They remained there until May, when they had attained an average length of 84mm. At this time they apparently migrated from the embayment to the open bay. Young specimens of Lagodon rhomboides (pinfish) were captured between February and April, while young Cyprinodon variegatus (sheepshead minnow) were present in May and June.

The young of Eucinostomus argenteus (spotfin mojarra) inundate this area between August and December. Young longnose killifish (F. similis) are present between November and December.

The young of several other species are captured sporadically at SB-10. Not enough data was available to discern the approximate length of time that these individuals utilized this area as a nursery ground.

Young bay anchovies (A. mitchilli) were the most prevalent juveniles at stations SB-11 and SB-13. The presence of young A. mitchilli was first noted at SB-11 during November, 1976, and February, 1977; and at SB-13 during October, November and December, 1976. Both locations are very shallow and probably afford protection for the young from larger predators.

Station SB-13 also supported populations of pinfish (L. rhomboides) from February through September, 1976. During this time, the average length of the juveniles increased from 25mm to 91mm. The young of this species (average length = 25mm) reappeared at SB-13 in March of 1977. This species apparently migrates to the Gulf or open bay during the fall and winter. The young return to the shallow inshore waters during the spring.

Neither stations SB-11 nor SB-13 are within the boundaries of the thermal plume. Like most shallow stations, the water temperature at both SB-11 and SB-13 is probably regulated by solar heating.

All three of these stations (SB-10, SB-11, and SB-13) are important since they apparently provide a suitable habitat for juveniles of several species. From the data collected during this study, it does not appear that the thermal effluent is exerting a detrimental effect on the juvenile communities that are inhabiting the nursery areas.

The growth progression data, presented earlier, has supported the belief that many species inhabit the nursery areas when they are young, and that they remain in these areas until maturity is reached. The individuals then vacate these areas in response to migratory and/or seasonal drives.

If the nursery areas were experiencing detrimental conditions, the juveniles would avoid the area or they would vacate the areas earlier than they normally would. Trends such as these were not noted in the Big Bend area during the course of this study.

Condition Factor

A condition factor (K) was calculated for 5 selected species (tidewater silverside, M. beryllina; rough silverside, Membras martinica; longnose killifish, Fundulus similis; pinfish, Lagodon rhomboides, and striped mullet, M. cephalus).

K values have been used as a means of measuring such factors as fatness, gonad development, and suitability of the environment(LeCren, 1951). The purpose of incorporating a condition factor into this study was to determine the difference, if any, in the condition factor of fishes residing within and outside of the thermal plume boundaries.

Since a condition factor is a ratio of length to weight, many factors can lead to the erroneous interpretation of results. These factors include: feeding activity, spawning activity (sexual maturity), and age of the specimens.

Condition factors were calculated for each of the five species (up to 75 individuals of each species per replicate) at each station throughout the course of the study. Only those individuals within 3 size classes (40-49mm; 50-59mm; and 60-69mm) were utilized for calculating K values.

Some of the species selected for condition factor analysis were not sufficiently abundant, in the respective size classes, to allow any obvious trends to be discerned. Sufficient data was available to allow valid comparisons to be made of the individuals of two species, M. beryllina and F. similis, residing within and outside of the thermal plume.

The condition factor results for these two species are summarized in Tables 8.8 and 8.9 .

Both species exhibited the highest monthly average K values between April and August, 1976. The average values declined after this period.

Several factors, including seasonality, could be expected to affect the K values. An ANOVA, comparing the K values for each of these two species over the seasons, was calculated. For each species, there was a significant difference (α =.05) in the K values between the seasons. However, there

Table 8.8. Annual averages of condition factors (K) for *Menidia beryllina* and *Fundulus similis*.

Species	Station	Annual Average K value for size class 40-49	50-59mm	60-69
M. beryllina	SB-12	1.34	1.37	1.33
	SB-5	1.31	1.31	1.36
	SB-14	*	*	*
	SB-10	1.34	1.27	1.25
	SB-11	1.27	1.28	1.20
	SB-13	1.39	1.37	1.33
F. similis	SB-12	1.74	1.83	1.77
	SB-5	2.11	1.67	1.80
	SB-14	2.19	1.71	1.75
	SB-10	1.75	1.89	1.75
	SB-11	1.77	1.81	1.72
	SB-13	1.86	1.59	1.75

*insufficient data

Table 8.9. Monthly condition factor values (K) for *Menidia beryllina* and *Fundulus similis* at all stations.

	J	F	M	A	M	J	J	A	S	O	N	D
M. beryllina	1.38	1.40	1.20	1.59	1.45	1.57	1.58	1.55	1.36	1.30	1.15	1.10
		J	F	M								
		1.10	1.10	1.16								
F. similis	1.66	1.76	1.65	2.05	2.37	2.26	2.34	2.10	1.70	1.71	1.55	1.52
		J	F	M								
		1.42	1.42	1.69								

was not a significant difference (α =0.5) in the K values for each species, between the different stations over a 15 month period.

A t-test indicated that there was no significant difference (α=.05) between the overall condition factor of M. beryllina and F. similis at station SB-5 (non-thermal) and at SB-12 (within the thermal plume boundaries).

Replicate Sampling

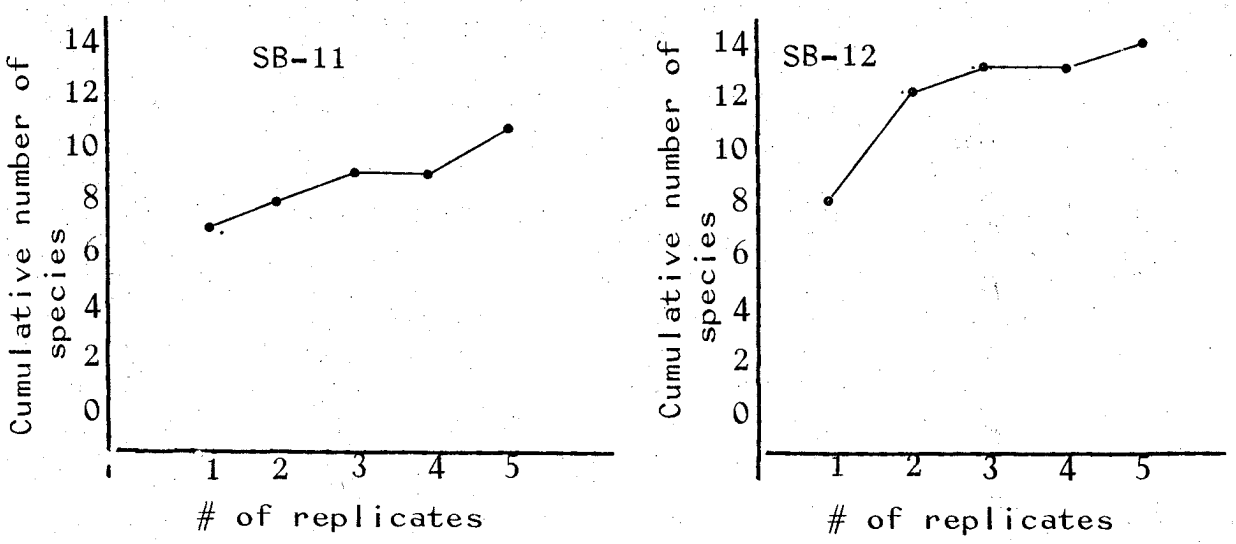
In April, 1977, a series of 5 consecutive replicate seine hauls were taken at station SB-11. The following day, 5 consecutive replicate hauls were made at station SB-12. The purpose of this survey was to acquire additional information on the sampling efficiency of the seine. Since this procedure was implemented only once at each of 2 stations, the following results are not conclusive.

Species saturation curves for the seine replicates (Figure 8.15) indicate a "levelling out" after the second replicate haul at SB-12. This did not appear to occur at SB-11. The 3 additional replicates (after the usual 2) at SB-12 accounted for 2 additional species; while 3 additional replicates at SB-11 accounted for 3 additional species.

It appears that the numerically dominant species were represented within the first 2 hauls, since the additional species that were captured after 2 hauls were usually

represented by 2 or fewer individuals.

Figure 8.15 Species saturation curves for replicate seine hauls.



Trawl

Physical and Chemical Parameters

The quarterly values of all parameters collected during trawl sampling have been presented in previous reports (Comp, 1976; Comp, 1977a; Comp, 1977b) and in Teco, 1977.

The averages and ranges of the temperature and salinity values are outlined below.

Transect	Water Temperature (°C) Average Surf.	Bot.	Range Surf.	Bot.	Salinity (°/oo) Average Surf.	Bot.	Range Surf.	Bot.
TB-1	27.0	25.1	35-21	34-20.5	22.4	22.3	20-25	20-25
TB-12	24.2	20.0	31-18	30-18	22.2	22.2	20-26	20.5-26
TB-5	23.2	21.1	31-16	30-16	22.0	21.6	20-25	20.5-25
TB-7	22.7	20.1	31.5-16	30-15	22.2	22.3	20-25	21-24
TB-6	22.2	20.0	31-16	29-16	21.9	22.1	20-25	20-25
TB-13	21.8	20.0	30-17	28-16	21.6	21.9	19-25	20-24
TB-4	21.3	19.4	31-16	28-15	21.3	21.9	18.5-24	19.5-24

Although the highest temperature that was recorded during trawling was 35°C at the discharge site, temperatures in this area often exceed 35°C. See the hydrographics section of this report for a list of temperature ranges in the discharge canal.

Water temperature decreased as distance from the point of discharge increased.

From the limited data that was collected during trawl sample collection, it appears that the thermal effluent penetrates at least a portion of the TB-12 transect. Surface water temperature at this station averaged 2.4°C higher than a similar embayment transect (TB-13) that lies outside of the thermal plume boundaries. Average bottom water temperatures were similar at both stations (TB-12 and TB-13). Thermal stratification is apparent at TB-12.

In most cases, the water temperature at the south end of transect TB-12 is lower than at the north end of the transect. Therefore, it is possible that the influence of the thermal effluent is apparent only in the northern portion of the embayment. The area that the effluent permeates is probably governed by wind direction and tidal stage. R. Peekstok (pers. comm.) has determined that thermally altered water penetrates a large portion of the northern embayment during a flood tide.

The reader is referred to the hydrographics section of this report for a more complete explanation of the hydrography of the sampling area.

The number of generating units that were operating when a sample was collected would influence the water temperature along some of the transects. Since trawling occurred infrequently, the collection of physical and chemical data at the trawl stations also occurred infrequently. This limited amount of data made it impossible to discern the temperature rise that can be attributed to each unit. Again, the reader is referred to the hydrographics section of this report for a more detailed explanation.

Relative Abundance and Distribution

Only four sets of trawl data were collected during the course of this study, so abundance and distribution patterns are difficult to discern.

Day trawling accounted for a total of 2,109 fishes (26 families; 34 species) and 383 macroinvertebrates (24 species) in 56 trawl tows. Night trawling in February, 1977, accounted for an additional 4,349 fishes and 247 macroinvertebrates in 14 tows.

Trawl catches, listed in numerical abundance, have been presented in previous reports (Comp, 1976; Comp, 1977a; Comp, 1977b) and in TECO (1977).

As a summary of this information, the following table lists the number of fishes and macroinvertebrates captured (day samples only) along 7 transects between June, 1976 and February, 1977.

Transect	Total Number of Fishes	Total Number of Macroinvertebrates	% of Total Catch
TB-1	75	15	3.6
TB-12	566	25	23.7
TB-5	121	53	7.0
TB-7	482	34	20.7
TB-6	63	19	3.3
TB-13	473	198	26.9
TB-4	329	39	14.8
TOTALS	2,109	383	100%

The presence of large numbers of tunicates (Molgula sp.) in the trawl catch at TB-13 in February may have biased the true macroinvertebrate distribution percentages. The following table outlines fish and macroinvertebrate distribution at the various stations, excluding the number of tunicates that were captured.

Transect	Total Number of Fishes	Total Number of Macroinvertebrates excluding Molgula sp.	% of Total Catch
TB-1	75	15	3.9
TB-12	566	22	25.3
TB-5	121	53	7.5
TB-7	482	34	22.2
TB-6	63	19	3.5
TB-13	473	31	21.7
TB-4	329	39	15.8
TOTALS	2,109	213	

Transects TB-12, TB-7 and TB-13 accounted for the greatest number of fishes in the day samples. Fewest fishes were captured along transects TB-1 and TB-6.

The apparent abundance of macroinvertebrates along transects TB-13 is undoubtedly due to the large numbers of Molgula sp. that were captured in February, 1977. Transect TB-13 accounted for only 31 macroinvertebrates, excluding the tunicate, Molgula sp.

Disregarding the number of tunicates that were captured, macroinvertebrates were most abundant along transect TB-5 (open bay; within the thermal plume); and least abundant along transect TB-6 (open bay; outside of the thermal plume boundaries).

Transects TB-7 (within the plume) and TB-6 (outside of the plume boundaries) have similar depths, habitats, and location. Transect TB-7 consistently accounted for more organisms that did transect TB-6. The reason for this is not completely understood. It may be that the plume area is attracting the fishes for some reason other than temperature (e.g. food abundance) since the average water temperatures along these two transects are similar.

The trawl catch was generally dominated by one species each quarter. The bay anchovy (A. mitchilli) was numerically dominant in 3 of the 4 sampling periods. The pinfish (L. rhomboides) was dominant in the February, 1977 sample.

Diversity

An increase in diversity values and/or abundance might be expected as distance from the source of discharge increases if the thermal effluent was exerting a detrimental effect on the marine organisms. This has been shown to occur in previous studies in other areas (Livingston, 1975; Bechtel and Copeland, 1970; Tsai, 1968; Katz and Gaufin, 1953).

The following table lists the diversity values of the trawl catches throughout the sampling period.

Transect	June	September	November	February		Average
				Day	Night	
TB-1	1.29	0+	1.04	0.68	0.83	0.77
TB-12	0.056	0.29	0.80	1.62	1.34	0.82
TB-5	1.60	0.86	1.13	1.94	0.52	1.21
TB-7	0.85	1.62	1.18	0.50	0.38	0.91
TB-6	1.57	0+	1.15	1.48	1.88	1.22
TB-13	1.56	0.70	1.0	1.40	1.68	1.27
TB-4	0.56	0+	0.94	1.11	1.44	0.81

+insufficient number of species to calculate diversity.

While both stations TB-7 and TB-12 accounted for large numbers of individuals, the average diversity of the catches at these stations was low. This is, undoubtedly, due to the numerical dominance of A. mitchilli at these stations.

The lowest average diversity was recorded in the discharge canal (TB-1). Diversity values did not appear to increase as distance from the discharge area increased.

Day Versus Night Trawling

During sample collection in February, 1977, trawl tows were also conducted at night to supplement the day catches.

The number of fishes, macroinvertebrates, and total species captured along the trawl transects in February, 1977 (only) are outlined below.

Transect	Total Number of Fishes		Total Number of Macroinvertebrates		Total Number of Species	
	Day	Night	Day	Night	Day	Night
TB-1	63	183	2	3	7	7
TB-12	61	377	10	85	14	21
TB-5	10	1733	4	9	8	16
TB-7	131	1304	0	5	6	14
TB-6	41	159	3	34(33)+	9	19
TB-13	451	332	188(21)	80(28)	12	17
TB-4	309	261	23	31	12	15

+number of macroinvertebrates that were captured excluding *Molgula* sp.

Several factors were probably responsible for the numerical differences that were noted between the day and night catches. The fishes were, apparently, actively feeding during the night (as evidenced by cursory stomach analysis). Schooling in areas abundant with food may have facilitated the collection of more fishes at night.

Since the trawl is less visible at night, it would be more difficult for fishes and macroinvertebrates to avoid its path.

Crabs and shrimp are usually more active at night, and would, therefore, be more susceptible to capture.

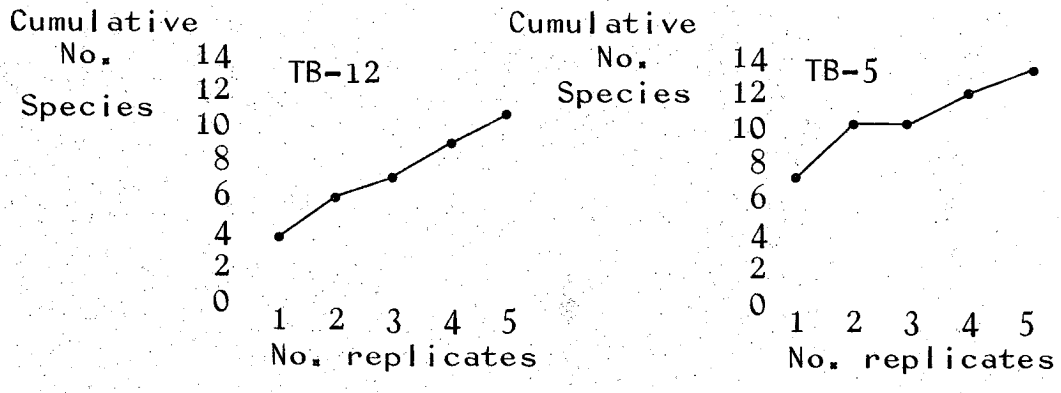
All these factors led to an increase in the number of organisms that were captured by trawling at night.

These data also indicate that the abundance of fishes along the trawl transects (especially TB-1) is greater than that which is indicated by the day trawl samples.

Replicate Sampling

In April, 1977, a series of 5 consecutive replicate tows were made along 2 different transects (TB-12 and TB-5). The purpose of this survey was to acquire additional information on the sampling efficiency of the trawl. Since this procedure was only implemented once at each of 2 stations, the following results are not conclusive.

Species saturation curves given below indicate a slight "levelling out" after the second replicate along TB-5, although the curve rises again after the third replicate. This "levelling out" affect was not noted after 5 replicates along TB-12.



The data collected during this survey indicates that, at least the numerically dominant species were captured within the first two replicates, since the additional species that were captured after two hauls were usually represented by two or fewer individuals.

However, the curves do indicate that additional tows would be necessary to achieve species saturation in the samples.

Fisherman Survey

A creel census was initiated at the boat launching ramp which is adjacent to the discharge area at Big Bend. A box containing printed questionnaires was erected at this site. The fishermen were asked to supply us with the following information: number and kinds of fish that were caught, approximate size of the fish; number of hours of fishing; type of boat that was used; general location of fishing; and general comments.

A total of 86 completed forms were returned between April, 1976 and early March, 1977. Unfortunately, repeated vandalism of the questionnaire box interrupted the survey several times, and forced the premature termination of this survey in March, 1977.

While the data collected from this census was not quantitative, it did indicate that the Big Bend area, especially the discharge canal, is heavily fished by both

sport and commercial fishermen.

This survey also supported our belief that many species of fish are present in the discharge area, even though these species are poorly represented in our trawl catches in that area. Results of this survey confirmed the presence of substantial numbers of snook (Centropomus undecimalis), spotted seatrout (Cynoscion nebulosus), redfish (Sciaenops ocellata), gray snapper (Lutjanus griseus), spadefish (Chaetodipterus faber, and black drum (Pogonias cromis).

Interviews with local fishermen revealed that fishing is generally poor in the discharge canal during the summer months when peak temperatures in this area (and the bay) are reached. Conversely, the warm water appears to attract many species of fish during the winter, hence fishing activity and catch success increases.

The sport and commercial fishing activity (and success) in the Big Bend area apparently was not reduced as a result of the addition of a third generating unit. Rather, the operation of those units appears to enhance the fishing activity in this area, at least during the winter months.

IMPACT ASSESSMENT

In early May, 1977, a third generating unit became operational at Big Bend. This increased the capacity of this power station from a normal output of 750 megawatts (mw) to 1125 mw. The primary objective of this seine and trawl study was to assess the extent of environmental impact on fishes and macroinvertebrates in the Big Bend area due to the additional thermal effluent produced by the third unit.

When using community structure or population shift studies to assess impact at power plants, pre- and post-operational data should always be collected. These data should include identification of the species that are present within the sampling area; determination of the relative abundance of these species; and determination of the faunal distribution. This allows a basis for comparisons to be made between pre- and post-operational community structures.

Seasonal changes in abundance, distribution and diversity will inevitably occur at each sampling station. Such seasonal changes have been well documented (Cain and Dean, 1976; Subrahmanyam and Drake, 1975; Gallaway and Strawn, 1974; Haedrich and Haedrich, 1974; and Dahlberg and Odum, 1970). It is imperative that the natural seasonality of species within the sampling area be understood, so that erroneous

interpretations of changes in community structure or abundance do not occur.

The seasonal data that was collected at Big Bend was compared to the data collected at other sites. These other studies were cited extensively in the Systematic Account section of this report. Once the natural patterns of seasonality are established, unnatural changes resulting from stressed situations are more apparent.

Some baseline data has been collected at Big Bend since 1970 (see page 8-19). However, extensive sampling did not begin until January, 1976, four months prior to the date of operation for Unit 3. Comparisons of the data collected prior to May, 1976 (this includes some of the pre- January 1976 data, and all of the baseline data collected after January, 1976) with the data collected after that date revealed no apparent changes in species composition, distribution, or diversity that could be directly attributed to the discharging of thermal effluent. Most of the differences that were noted were attributed to natural variations due to seasonality.

The occurrence of significant changes in community structure or abundance, as a result of thermal addition, is not a common phenomenon according to many impact analysis.

Gallaway and Strawn (1974) studied the seasonal abundance and distribution of fishes in Galveston Bay, Texas. They concluded that the detrimental effects on the fish

fauna were neglibible in the vicinity of a hot water discharge. They found that no significant differences in populations occurred when the power plant output increased from 900 mw to 1,465 mw. Most of the species in that area were abundant in water tempetatures of 33°C to 35°C. Certain species (striped mullet and sand seatrout) were observed in water that was 40°C. Abundance at the seine stations at Big Bend did not appear to decrease as temperatures approached 33°C and above.

Cairns (1976) summarized the findings of investigations implemented at three power stations (Potomac Steam Electric Power Plant at Fredrich, Maryland; Savannah River Plant, Aiken, South Carolina; and Paradise Steam Plant, Kentucky). No effects that could be directly attributed to the thermal discharge were evident at two of the three sites. Effects were noted at the third site (Paradise Steam Plant).

Grimes (1971) found that the diversity of communities increased away from the discharge area during the summer, and toward the discharge during the winter at Crystal River, Florida. He concluded that there was no indication that the heated effluent had eliminated native species or caused any significant changes in abundance.

Other investigators have found that significant effects can result as a consequence of thermal addition. Roessler and Tabb (1974) in a study of Biscayne Bay, Florida, determined that an average temperature increase of 3 or 4°C above ambient summer water temperatures caused serious depletion of the biota in the vicinity (100 acres) of a thermal discharge.

It appears that most effects are site specific and that generalized conclusions or predictions, concerning the possible effects of discharging thermal effluent into aquatic environments, are not feasible.

Insufficient data was collected in the discharge canal at Big Bend (seining was not possible because of the absence of a suitable beach). Hypothetically, if significant differences in abundance and/or community structure were occurring as a result of thermal addition, the effects would be confined to the discharge canal since this area is exposed to a maximum temperature increase.

No significant differences in relative abundance or faunal composition were found between the seine stations during the course of this study. More importantly, the fauna at each seine station exhibited seasonal variations which appeared normal for this region. Actually, the Hillsborough Bay seine stations appear to be removed from the direct influence of the warm water discharge. The temperature of

the effluent has cooled considerably by the time it is discharged into Hillsborough Bay. Cooler bay water is mixed with the thermal effluent in the dilution (discharge) canal before this water enters Hillsborough Bay.

Since the area that is most susceptible to the effects of the heated effluent is small (discharge canal), the mobility of fishes will enable them to avoid this area during periods of excessive heating. This avoidance can easily occur without the loss of an irreplaceable ecological niche. The habitat created by the discharge canal does not appear to be vital to the survival of any particular species. Similarly, fishes can easily utilize this warm area during the winter months when ambient bay temperatures decline.

Seine station SB-12 is located close to the point of discharge into Hillsborough Bay. No significant differences in abundance and/or distribution that can be directly attributed to the effluent were found.

Station SB-10 appeared to be the most important station in terms of its function as a nursery area. No detrimental effects, due to the thermal discharge, were apparent in this area.

It can therefore be surmised that overall the discharging of thermal effluent into Hillsborough Bay is eliciting a negligible effect on the indigenous and transient fishes and macroinvertebrates in the Big Bend area.

GENERAL CONCLUSION

No immediate, significant, deleterious effects (except, for, possibly, seasonal effects in the discharge canal) on the fish and macroinvertebrate populations in the Big Bend area have been found, using methods as described in this report.

SUMMARY AND CONCLUSIONS

1) Intensive sampling (by trawl and seine) of the fish and macroinvertebrate communities in the vicinity of the Big Bend steam electric station was conducted between January, 1976 and March, 1977.

2) Annual average water temperatures at the seine stations ranged from 22.8°C at station SB-14 (Pine Key) to 25.8°C at station SB-10 (northern embayment).

3) Seining (180 hauls) accounted for a total of 61,272 fishes (56 species; 32 families) and 647 macroinvertebrates (21 species).

4) Station SB-10 (northern embayment) accounted for 37.5% of the fishes and 54.1% of the macroinvertebrates that were captured during the course of this study.

5) The tidewater silverside (Menidia beryllina) was the most abundant fish captured by seine throughout most of the study period.

6) Most changes in numerical dominance and distribution were attributed to natural seasonal variations

rather than to a deteriorating environment.

7) Generally, diversity values were lowest during the winter months, and highest during the summer months at most of the seine stations.

8) There was little correlation between temperature, salinity and: a) the total number of animals captured at each station each month; b) the total number of species captured at each station each month; c) the total number of animals captured at the outside stations (SB-5; SB-12; SB-14); d) the total number of animals captured at the inside stations (SB-10, SB-11, SB-13); e) abundance of a commercially important species (Mugil cephalus); and f) abundance of Menidia beryllina (average temperature and average salinity values were used for this calculation).

9) The number of species that were captured each month at the various seine stations did not appear to change significantly during the course of this study, nor was the disappearance of any particular species noted.

10) The fishes and macroinvertebrates in the Big Bend area have exhibited patterns of growth, spawning and migration that are similar to those found in unaffected areas.

11) Seasonal changes in species composition appeared to influence community structure more than did the location of the thermal plume.

12) The northern embayment station (SB-10) and, to a lesser extent, stations SB-11 and SB-13 are functioning as nursery areas for a variety of species.

13) The data that was collected between January and May, 1976 (and some of the 1970-1975 baseline data) was compared to the data collected after Unit 3 became operational (May, 1976). These comparisons revealed no significant changes in species composition, distribution or diversity that could be directly attributed to the discharge of thermal effluent.

14) The fauna at each seine station exhibited seasonal variations which appeared normal for the region.

15) Annual average bottom water temperatures along the trawl transects ranged from a high of 25.1°C in the discharge canal (TB-1) to a low of 19.4°C in the intake canal (TB-4). Bottom water temperature in the discharge canal ranged from a high of 34°C in September, 1976 to a low of 20.5°C (during night sampling) in February, 1977.

16) Day trawls (56 tows) accounted for a total of 2,109 fishes (26 families; 34 species) and 383 macroinvertebrates (24 species). Night trawling in February, 1977 accounted for an additional 4,349 fishes and 247 macroinvertebrates in 14 tows.

17) Stations TB-1 (discharge canal) and TB-6 (open bay) accounted for the lowest number of organisms.

18) No significant, immediate deleterious effects (except for, possibly, in the discharge canal during the warm months) on the fish and macroinvertebrate populations in the Big Bend area have been found using methods as described in this report.

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CHAPTER NINE

A SUMMARY AND OVERVIEW OF THE '316 DEMONSTRATION' BIOLOGICAL STUDY AT BIG BEND, TAMPA BAY (FLORIDA).

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INTRODUCTION

The 316 Demonstration presented in the preceding six chapters (Chapters 3 to 8) encompasses four major biological components of the Big Bend ecosystem, namely,

Phytoplankton

Meroplankton (Invertebrate larvae and fish eggs and larvae)

Benthos

Nekton (Adult fishes and macroinvertebrates)

Water quality aspects (temperature, salinity, DO, pH and turbidity) of the study area were also intensively studied (Chapter 2). The study produced a voluminous amount of data which was presented in five quarterly reports. Data analysis was intensive and each of the preceding seven chapters provides information on the methods of collection and processing of samples, data management and analysis aspects, results of the study and a discussion of the results. Significant and relevant findings have been summarized at the end of every chapter.

This concluding chapter presents an overview and a general narrative summary of the significant findings of each of the seven studies. Impact assessment conclusions (or statements) generated from the seven studies are also presented. An attempt is also made to provide the reader with a comparative analysis of the three major biological components at Big Bend (Phytoplankton, Meroplankton and Benthos).

GENERAL SUMMARY

1. Hydrography

A primarily surface thermal plume was described. The plume generally extended 1.5 miles into Hillsborough Bay, but was highly influenced by tide, wind and other weather factors. At ebbing tide, the plume extended further westward and south along Apollo Beach. Ranges of average monthly differences in temperature between selected stations are presented below.

Stations	Average Monthly ΔT Range
Intake/Discharge	5.5 - 7.5°C
Discharge/P.O.D.	2.5 - 5.0°C
Dilution Pump Intake/ Dilution Pump Discharge	3.0 - 3.5°C
Source Water/Receiving Water	Equal
North Embayment/South Embayment	0.5 - 3.5°C

The plume generally exhibited a 45 - 66% decay in temperature from the discharge flume to the point of discharge to Hillsborough Bay. This means that on the average, temperatures at I-3 (point of discharge to Hillsborough Bay) were 2.5 - 3.0°C above ambient. Heated water remained close to the surface and seldom exceeded 6 feet in depth (average Bay bottom is approximately 15 feet). The plume configuration appeared greatly influenced by tidal stage and wind condition, and was often difficult to distinguish from large areas warmed by solar heating (nearshore stations,

transects Z and Y, the most northern sampling transects, and stations south of Interbay Peninsula).

The bottom thermal plume was generally restricted to the immediate area adjacent to the point of discharge to Hillsborough Bay. Higher than ambient temperatures ($\Delta T \geq 1^{o}C$) were seldom noticed in the offshore stations (beyond 1 mile from the shore).

The north Apollo Beach embayment appeared influenced by tidal influx of heated water and subsequent dispersion at low tide. However, the embayment did not return completely to ambient temperatures (such as those in the south embayment) at low tide. (Extent of temperature reduction was to a level of about $1^{o}C$ above ambient). Fingerfill canals did not appear affected.

Maximum temperatures were recorded during the summer of 1976 (July - September) and were considered as "worst case" conditions. The $1^{o}C$ plume during this time was detected up to $2\frac{1}{2}$ miles offshore.

Spatial variations in salinity were not apparent. Temporal changes in salinity subjectively correlated with meteorological conditions.

Temporal and spatial variations in dissolved oxygen content and pH could not be attributed to the thermal effluent. Turbidity was higher in the discharge canal than offshore stations.

2. Phytoplankton

Phytoplankton sampling revealed a total of 133 species (83 species of diatoms, 42 species of dinoflagellates, and

8 species from other taxa) or nearly more than twice as many as reported in previous surveys of other portions of Tampa Bay. The phytoplankton community was nearly always dominated by a single species in high concentrations (Skeletonema costatum in fall and winter, and a variety of successive dinoflagellate blooms in the summer, e.g. Ceratium hircus, Gonyaulax polygramma, G. ditalis). Oscillatoria sp., a blue green algae (and suggested to be a thermally tolerant species) was the second most abundant species collected at Big Bend. (S. costatum was the most abundant species collected at Big Bend). Oscillatoria sp. was present in large numbers from mid-summer through early fall of 1976, and its abundance levels were moderately correlated to temperature. Similarly abundant levels of this species were recorded during the previous summer (August, 1975) also (i.e. prior to the operation of Unit 3).

The oligomictic nature of the phytoplankton communities at Big Bend (ten species accounted for over 90% of all phytoplankton sampled) made bioindices difficult to interpret.

A significant reduction in total seston biomass was noted at the*POD (1-3) when compared with the plant intake (1-6). The number of replicates taken for chlorophyll 'a'/phaeopigment determination were sufficient to detect only gross changes. Such changes between thermal and control areas were not evident.

Spatial variations in phytoplankton abundance or in bioindices were not apparent (although the latter were difficult

*POD - Point of thermal discharge to Hillsborough Bay.

to interpret due to the oligomictic nature of the community). Little difference in abundance, community structure, or total seston biomass was noted between the intake and discharge. Abundance temporally varied greatly at both stations.

A physical alteration to filamentous species (e.g. Oscillatoria sp.) was noted as numbers increased from intake to discharge suggesting that the filaments may be broken up as they pass through the power plant.

Except in the immediate vicinity of the thermal discharge (discharge canal - up to the point of discharge to Hillsborough Bay), no deleterious thermal or entrainment effects on the phytoplankton communities were discernable at the study site.

3. Benthos

A total of 352 species were recorded from the Big Bend area. Oligomictic conditions were common but were slightly greater in the thermal transect when compared with the non-thermal transect. Based on community parameters and abundance of dominant species, three identifiable faunal zones were demarcated. Zone I (discharge canal and station I-2) consisted of a pioneer environment characterized by low faunal density, high species diversity (H'), low species richness and an abundance of pollution indicator species. Zone II (thermal transect) was characterized by moderate diversity (H'), high faunal density, moderate species richness and low numbers of pollution indicator species. Zone III (non-thermal transect) was characterized

by high species diversity (H') moderate faunal density, high species richness and negligible numbers of pollution indicator species.

Based on an assessment of information collected on the abundance of fifteen dominant species, the discharge canal stations and station 1-2 were shown to be detrimentally affected, the thermal transect stations and E-6 'mildly' affected (alteration, but possibly no deleterious effect), and station 1-17 of the north embayment possibly 'mildly' (adversely) affected.

Probable impact on biomass was evident at stations 1-1, 1-16, 1-2, 1-17 and SP-2. During August, biomass was severely reduced at stations 1-1, 1-2, and 1-17. An evaluation of the impact on community structure at Big Bend in relation to the thermal effluent revealed that the discharge canal and station 1-2 were adversely affected. The adverse effect at station 1-2 probably resulted from extreme solar heating and the thermal effluent. Thermal transect stations exhibited "altered" faunal conditions (detrimental effects were not clearly evident).

A cumulative impact assessment indicated that mildly adverse conditions due to the thermal effluent were restricted to a one kilometer radius from the discharge flume. The most persistent adverse impact was limited to the discharge canal (approximately 0.04 square kilometers).

Although faunal changes have occurred at some Big Bend stations since the start-up of Unit 3, based on the extensive

sample collection and analysis of benthic data reported in this study, (876 petite Ponar Grab samples analyzed; 400,700 organisms counted; 352 species identified), it is believed that no significant impact had occurred to jeopardize the "protection and propagation of a balanced indigenous" benthic community at the study site.

4. Ichthyoplankton

Although spawning occurred during all sampling months, peak densities of both eggs and larvae occurred during spring and summer months. Larvae of 41 species were collected; however, eggs and larvae of the bay anchovy (Anchoa mitchilli) were more abundant than any other species during spring and summer (engraulids accounted for 73.1% of all eggs and 87.4% of all larvae collected). Sciaenids, represented by seven species of larvae, were second in abundance making up 26.2% of all eggs and 3.9% of all larvae. Clupeids accounted for 0.5% of all larvae and 0.2% of all eggs collected.

It is estimated that 1.858×10^{11} eggs and 3.855×10^{10} larvae were entrained by the plant during 1976. Egg entrainment was observed during all months except January, 1976. Larvae were entrained during every month of the study. The greatest amount of egg entrainment occurred in April, 1976. April, 1976 also was the month of highest larval entrainment.

Total sciaenid entrainment (seven species) during 1976 was estimated to be 1.252×10^{11} and 1.269×10^{9} for eggs

and larvae, respectively.

H. jaguana entrainment occurred during the months of April through July, 1976. The estimated number of entrained eggs was 7.446×10^8. Larval entrainment was estimated as 7.196×10^7 individuals. A comparison of the number of eggs produced in the open bay area to the number of eggs entrained revealed that an estimated 0.22% impact on the spawned eggs is induced by the power plant (generating units and the dilution pump).

Bay anchovy, A. mitchilli, were investigated in greater detail than other species because of their abundance and their importance as a forage species. Estimated numbers entrained during 1976 were 5.795×10^{10} eggs and 3.352×10^{10} larvae. Comparison between the number of eggs produced by spawning at open bay stations and the number of eggs lost through plant entrainment showed that the loss represented only a small percentage (2.16%) of the total eggs produced in the study area.

Based on the assessment of the significance of entrainment of eggs for two dominant species at Big Bend (A. mitchilli and H. jaguana), it appears that entrainment effects on the dominant ichthyoplankton populations in the area are minimal.

Rearing experiments in bay anchovies indicated an average of 42% cropping of hatchable eggs through entrainment. Lowest hatching rates occurred in the summer months when abundance was highest and ambient and effluent water temperatures were highest.

5. Meroplankton (Invertebrate larvae)

The decapod crustaceans of the Big Bend area showed major spawning peaks through the warmer months of the year. This pattern is similar to that found in other studies along the northwest coast of Florida. Some depression of breeding occurred during the hottest part of the summer.

Large numbers of larvae were entrained through the Big Bend steam electric station. Decapod larvae entrainment alone was estimated to be 3 to 4.5 hundred billion in 1976.

A total of 105 taxonomic groups were recorded in the 363 μ mesh net samples. These included 86 of decapod crustacea taxa and 19 miscellaneous forms of 7 phyla (including Arthropoda). Eleven species accounted for about 91% of the individuals collected during the course of the study. Four species were dominant, occurred more frequently and accounted for approximately 80% of the total individuals collected in the study. They were: Pinnixa sayana (Average density = 148.41/m^3; 34.70%), Polyonyx gibbesi (Average density = 120.95/m^3; 28.28%), Upogebia affinis (Average density = 46.05/m^3; 10.77%) and Neopanope texana (Average density = 18.94/m^3; 4.43%).

Most of the decapod larvae found in the study area were non-commercial species whose adults are also residents of the area. The commercially important stone crab, Menippe mercenaria, was frequently collected, and though a minor part of the larvae, 2 to 8 million zoea of this species were entrained in 1976. Only 24

specimens of larval pink shrimp (Penaeus dourarum) were collected throughout this study. The offshore spawning behavior of this commercially important species appears to be the reason for the low numbers collected in the present study.

Estimates of invertebrate larvae other than decapod larvae were not realistic as the mesh of the net used in this study allowed many of these larvae to escape.

Entrainment estimates for the four most abundant species in the area (during 1976) are:

Pinnixa sayana: 3.151×10^{11} Neopanope texana: 5.000×10^{10}

Polyonyx gibbesi: 2.088×10^{11}

Upogebia affinis: 6.805×10^{10}

and for the commercially important species, the stone crab, Menippe mecenaria is 7.012×10^{9}. These estimates include the entrainment of all three generating units and the dilution pump.

Entrainment of the species were seasonal in nature and generally matched seasonal abundance patterns of species in the area.

It was not possible to quantify the impact of entrainment of the larvae of any species on the adult population in the area with the data available. Lack of published information on the life histories of the meroplankton species collected at Big Bend and the absence of studies of the mechanisms by which their populations are maintained (i.e. compensatory mechanisms of the

species, reproductive potential and strategies, etc.) were the primary reasons for not being able to assess the significance of the entrainment estimates.

6. Impingement of Fishes and Macroinvertebrates

A total of 9,382 macroinvertebrates (27 species) and 9,946 fishes (60 species) were impinged on either Unit 1 or Unit 2 during 744 sampling hours. The average rate of impingement for one unit was 302.6 macroinvertebrates and 320.8 fishes per day. Highest rates of impingement for both fish and macroinvertebrates were during the summer and winter months. Rates of impingement appear to be dependent on seasonal variations in abundance.

Pink shrimp (Penaeus duorarum), blue crabs (Callinectes sapidus), horseshoe crabs (Limulus polyphemus) portunid crabs (Portunus gibbesii), brief squid (Lolliguncula brevis), and mantis shrimp (Squilla empusa) constituted 84.8% of the total number of invertebrates that were impinged. Pink shrimp (P. duorarum) alone constituted 35.6% of the total invertebrate impingement.

Bay anchovies (Anchoa mitchilli), silver perch (Bairdiella chrysura), pinfish (Lagodon rhomboides), sand seatrout, (Cynoscion arenarius), leopard searobin (Prinotus scitilus), and Atlantic bumper (Chloroscombrus chrysurus) constituted 85.6% of the total number of fishes that were impinged.

Impingement at Big Bend does not appear to be significantly depleting the commercial stock in this area. Based on the 1976

commercial catch for Hillsborough County (Marine Fisheries Service, pers. comm.) one unit may have impinged approximately 0.23% of the commercial pink shrimp catch and 0.7% of the commercial blue crab catch. Extrapolated impingement data for one year indicated that one unit has the potential of impinging approximately 5.1% of the commercial catch of brief squid (L. brevis). Since rates of impingement vary with the seasons, these estimates are probably exaggerated.

Based on the data that was collected during 744 sampling hours between January, 1976 and March, 1977, it does not appear that impingement at Big Bend is significantly depleting the commercial fish and macroinvertebrate populations in this area.

7. Fishes and Macroinvertebrates

Intensive sampling (by trawl and seine) of the fish and macroinvertebrate communities in the vicinity of the Big Bend steam electric station was conducted between January, 1976 to March, 1977.

Seining (180 hauls) accounted for a total of 61,272 fishes (56 species; 32 families) and 647 macroinvertebrates (21 species). Day trawls (56 tows) accounted for a total of 2,109 fishes (26 families; 34 species) and 383 macroinvertebrates (24 species). Night trawling in February, 1977 accounted for an additional 4,349 fishes and 247 macroinvertebrates in 14 tows.

Throughout the course of the study, Menidia beryllina (tidewater silverside) and Fundulus similis (longnose killifish)

were two of the most dominant fish species at several seine stations. The bay anchovy (Anchoa mitchilli), striped mullet (Mugil cephalus), scaled sardine (Harengula jaguana), sheepshead minnow (Cyprinodon variegatus), spotfin mojarra (Eucinostomus argenteus), silver jenny (E. gula), pinfish (Lagodon rhomboides) and spot (Leiostomus xanthurus) were the other abundant fish species collected in the area. Macroinvertebrates were dominated by the crown conch, Melongena corona. A few individuals of the commercially important macroinvertebrate species Penaeus duorarum (pink shrimp) and Callinectes sapidus (blue crab) were also collected.

In seine hauls, station SB-10 (northern embayment) accounted for 37.5% of the fishes and 54.1% of the macroinvertebrates that were captured during the course of this study.

The northern embayment station (SB-10) and, to a lesser extent, some adjacent stations appear to be functioning as nursery areas for a variety of species. No detrimental effects, due to the thermal discharge, were apparent in this area.

There was little correlation between temperature, salinity and: a) the total number of animals captured at each station each month; b) the total number of species captured at each station each month; c) the total number of animals captured at the outside stations (SB-5; SB-12; SB-14); d) the total number of animals captured at the inside stations (SB-10, SB-11, SB-13); e) abundance of a commercially important species (Mugil cephalus);

and f) abundance of Menidia beryllina (average temperature and average salinity values were used for this calculation).

Changes in numerical dominance and distribution were attributed to natural seasonal variation rather than to a deteriorating environment.

No significant differences in relative abundance or faunal composition were found between the seine stations during the course of this study. More importantly, the fauna at each seine station exhibited seasonal variations which appeared normal for this region. Actually, the Hillsborough Bay seine stations appeared to be removed from the direct influence of the warm water discharge. The temperature of the effluent has cooled considerably by the time it is discharged into Hillsborough Bay.

Since the area that was most susceptible to the effects of the heated effluent is small (discharge canal), the mobility of fishes will enable them to avoid this area during periods of excessive heating. This avoidance can easily occur without the loss of an irreplaceable habitat. The habitat created by the discharge canal does not appear to be vital to the survival of any particular species. Similarly, fishes can easily utilize this warm area during the winter months when ambient bay temperatures decline.

Seine station SB-12 is located close to the point of discharge into Hillsborough Bay. No significant differences in

abundance and/or distribution that can be directly attributed to the effluent were found.

It appears that, overall, the discharging of thermal effluent into Hillsborough Bay is eliciting a negligible effect on the indigenous and transient fishes and macroinvertebrates in the Big Bend area.

8. An Endangered Species

Sporadic sightings of the endangered Manatee, Trichechus manatus were reported to the National Fish and Wildlife Laboratory Service in Gainesville, Florida. Sightings of the manatee in a thermally affected area is of particular interest. Hartman (1974) indicated that manatees seek a habitat where temperature fluctuations are minimal and, thus, may be attracted to a thermal effluent when ambient temperatures drop. The manatee may be stressed by low temperatures and the resulting weakened condition invites disease (Hartman, 1971).

Three sightings in the discharge canal were reported in 1976. Only one sighting, involving two manatees, occurred during the cooler months, winter (November 25). The other two sightings were in July and August involving three and five manatees, respectively.

9. Overview

The value of each of the studies included here in assessing a "balanced indigenous population" has been variable. As stated

in the introductory chapter, impact assessment on nekton and plankton communities is plagued by wide variations in seasonal abundance, normal spatial patchiness, and the qualitative nature of sampling. We feel that we have been able to identify general trends and/or shifts in these populations and such conclusions as stated herein are perfectly valid. We have attempted to point out all the limitations of this study in the hope that no erroneous interpretations of our data would be made by us or construed by others.

Data on numbers of meroplanktonic organisms entrained by the power plant should be considered as estimates which are tempered by the "state of art" scientific limitations (e.g. sampling problems, patchiness, avoidance, etc.). Benthic studies, as predicted, have yielded the most complete array of quantitative data on community structure, and consequently the most complete impact assessment.

Generally, a lack of impact was noted for the benthos and for fish and macroinvertebrates in Hillsborough Bay. Adverse impact was found for benthos in the discharge canal. A light to moderate impact was found for phytoplankton only in the immediate vicinity (discharge canal) of the plant. Impingement rates appeared low and were insignificant for commercially important species when compared to commercial catches. Ichthyoplankton and meroplankton (decapod larvae) were both entrained in extremely large numbers. An evaluation of the significance

of the entrainment estimates on a species by species basis was not feasible due to lack of published life history studies on many of the species collected at Big Bend. However, an estimation of the entrainment impact on the eggs of two dominant ichthyoplankton species (Anchoa mitchilli and Harengula jaguana) showed minimal levels of cropping by the power plant (including the dilution pump).

An area of particular concern, the north embayment was seen to be inundated at least partially by thermal effluent (at high tide) and also to be greatly affected by solar radiation. Even so, this area contained the greatest number of fish and macroinvertebrates of any other area sampled and appeared to serve as a nursery area.

IMPACT ASSESSMENT CONCLUSIONS

Hydrography

Intensity of the spatial extent of the temperature increase due to the thermal discharge was limited to the surface water layers, to the discharge canal and to the nearshore areas in the vicinity of the power plant (less than 0.8 km from the point of discharge to Hillsborough Bay). The 1°C thermal plume was generally detected (surface only) up to a distance of approximately 2.3 km from the point of discharge to the bay and to a maximum of about 3.8 km in the summer. Spatial variations in other hydrographic parameters (salinity, DO, pH and turbidity) in the open bay appear unrelated to the thermal discharge.

Phytoplankton

Except in the immediate vicinity of the thermal discharge (discharge canal), no deleterious thermal or entrainment effects on the phytoplankton communities were discernable at the study site (subject to scientific limitations of the study).

Benthos

A cumulative impact assessment indicated that the mildly adverse conditions due to the thermal effluent were restricted to a one kilometer radius from the discharge flume. The most persistent adverse impact was limited to the discharge canal (approximately 0.04 square kilometers).

Although faunal changes have occurred at some Big Bend stations since the start-up of Unit 3, based on the extensive sample collection and analysis of benthic data reported in this study, it is believed that no significant impact had occurred to jeopordize the "protection and propagation of a balanced indigenous" benthic community at the study site.

Ichthyoplankton

Based on the assessment of the significance of entrainment of eggs of two dominant species at Big Bend, it appears that entrainment effects on the dominant ichthyoplankton populations in the area are minimal. Although large numbers of eggs and larvae were entrained by the power plant, the significance of the entrainment could not be evaluated due to a lack of published life history studies on the various species collected at Big Bend. However, in general, entrainment rates functioned as a variable dependent on seasonal abundance of various species in the open bay stations, and therefore, were higher only when populations were denser in the study area.

Meroplankton (Invertebrate larvae)

Large numbers of decapod larvae (3-4.5 hundred billion/year) were entrained by the power plant in 1976 (calculated using actual unit days for 1976). Approximately 7.012×10^5 zoea of the commercially important stone crab (Menippe mercenaria) were entrained in 1976. Not enough information is presently

available on the life history of the decapod species collected in the area to assess the significance of the above entrainment.

Impingement

Impingement does not appear to be significantly depleting the commercial fish or invertebrate stock in the Big Bend area.

Fish and Macroinvertebrates

No immediate, significant, deleterious effects (except for possible seasonal effects in the discharge canal) on the fish and macroinvertebrate populations in the Big Bend area have been found, using methods as described in this study.

General

Results from the impact assessment studies described in this report appear to indicate that the operation of Unit 3 at Big Bend does not significantly alter the indigenous fish and shellfish populations of the receiving body of water (Hillsborough Bay). Also, entrainment effects of phytoplankton, and dominant ichthyoplankton and impingement effects appear to be minimal.

A COMPARATIVE ANALYSIS OF BENTHIC, PHYTOPLANKTON AND MEROPLANKTON COMMUNITIES AT BIG BEND

This analysis is presented to provide the reader an overview of the density, biomass and diversity (species richness) of three dominant components of the ecosystem at Big Bend, viz., Benthos, Phytoplankton and Meroplankton. Density is estimated as number of organisms/m^2 for the benthic fauna and as number of organisms/m^3 for the phytoplankton and meroplankton. (Meroplankton includes both fish and invertebrate larvae). Biomass is estimated as grams ash free dry weight/m^2 for the benthos and as milligrams ashfree dry weight/liter for the phytoplankton. Species diversity (species richness) is estimated as the number of species/station for all three groups. Only open bay subtidal stations have been utilized in this analysis. Station values were averaged for each sampling period (temporal point).

The results of this analysis should be viewed with caution because of the following reasons:

1) sampling intensity, both spatial and temporal, for the three components varies widely;
2) sampling methods and replication for the three components are different;
3) spatial variation for the three components were generally extensive (thus making the temporal points deviate widely);

4) factors governing the abundance and distribution of the three groups are different;

5) average life spans for the three groups are not uniform

6) power plant impact processes are essentially different for the three components.

The analysis is aimed at only providing estimates of the temporal patterns in the standing crop and species richness of the three essentially different trophic levels.

Faunal Density

Temporal trends in density were essentially similar between thermal and control open bay areas for all three components. Therefore, only average trends for the Big Bend area are presented in Figure 9.1. (Density values were log transformed). Temporal variation was far more extensive in the planktonic components than in the benthos. Decreases in benthos density generally followed decreases in the density of meroplankton (apparent correlation between secondary and tertiary trophic levels). Higher levels of abundance of phytoplankton generally appeared to deplete meroplankton abundance (This would be expected, since phytoplankton blooms tend to access the available water column, thereby pre-empting the meroplankton). The month of October was unusual in that both planktonic components were abundant. Meroplankton exhibited spring-early summer and late fall peaks in abundance, while phytoplankton exhibited a series of abundance peaks throughout the year. Benthos exhibited a

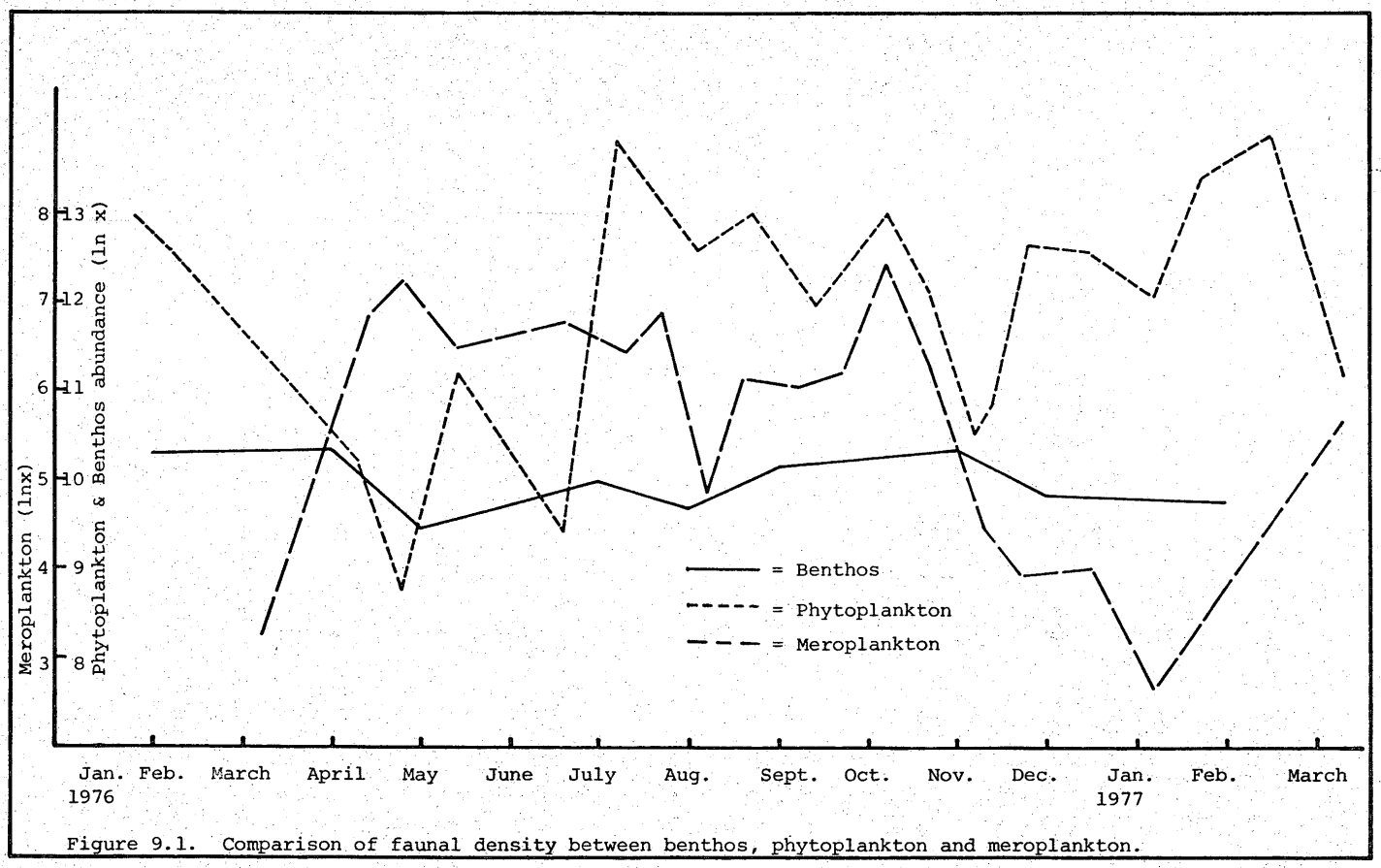

Figure 9.1. Comparison of faunal density between benthos, phytoplankton and meroplankton.

greater abundance in the fall and spring months.

Abundance of benthos and phytoplankton were relatively high when compared to the meroplankton.

Biomass

Biomass was estimated only for the benthos and phytoplankton (total seston). A comparative graph is presented in Figure 9.2. Both thermal and non-thermal areas are compared for the two components. Peaks in the biomass of the phytoplankton are matched with similar peaks for the benthos. An apparent lag appears to occur for the benthos suggesting a belated increase in biomass of benthos after the increase in the phytoplankton. Generally, no differences in biomass existed between the thermal and non-thermal areas for both components.

Species Richness

A comparative analysis of species richness for the three components is shown in Figure 9.3 (for thermal areas) and Figure 9.4 (for non-thermal areas). The benthic component was far more diverse than the planktonic components. While species richness was similar in both thermal and non-thermal areas for the planktonic components, the thermal areas exhibited a slight depression in species richness for the benthos.

Higher species richness was encountered for all three components during the fall months. Phytoplankton and benthos exhibited a higher species richness in the winter also. Mero-

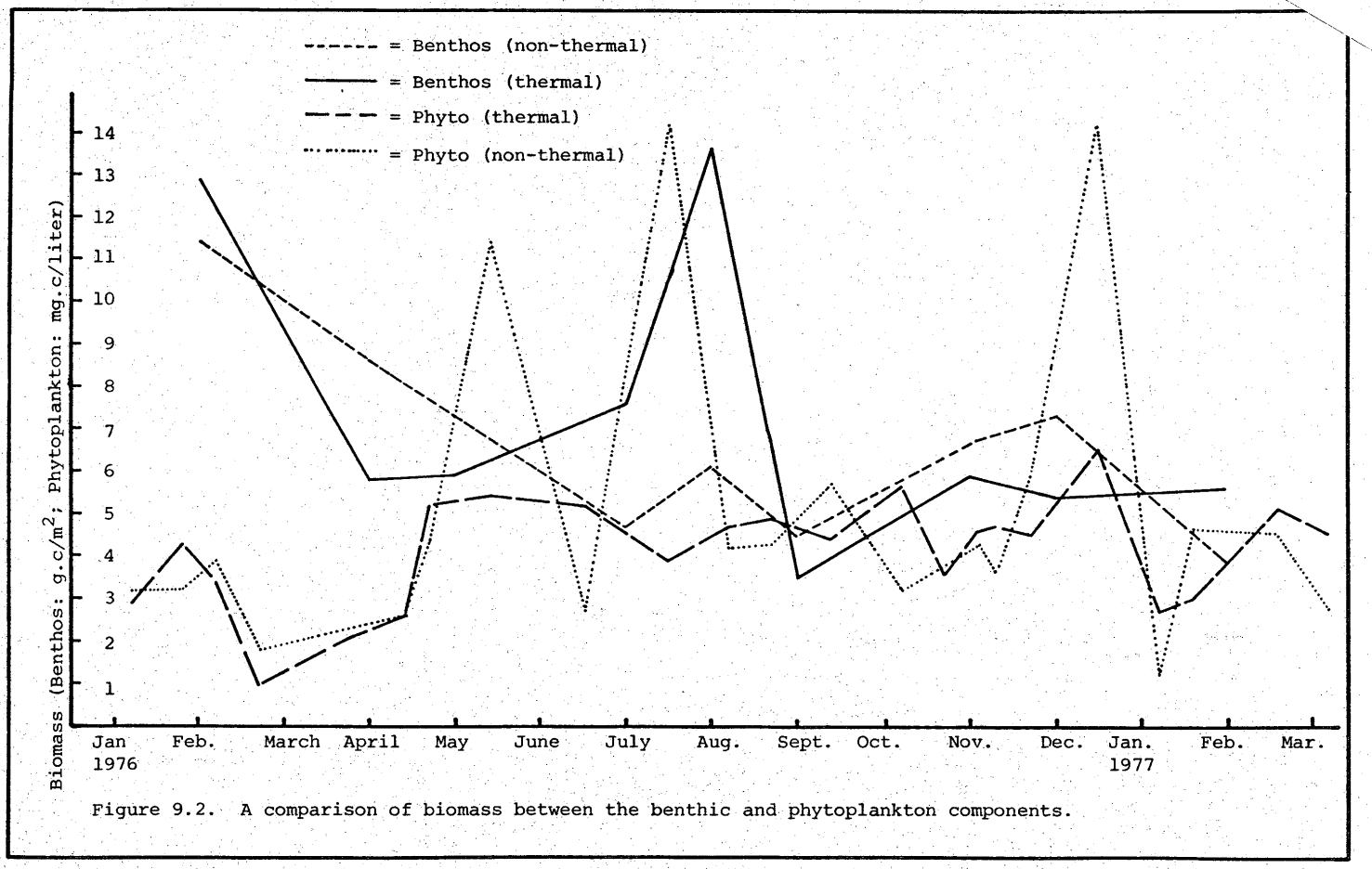

Figure 9.2. A comparison of biomass between the benthic and phytoplankton components.

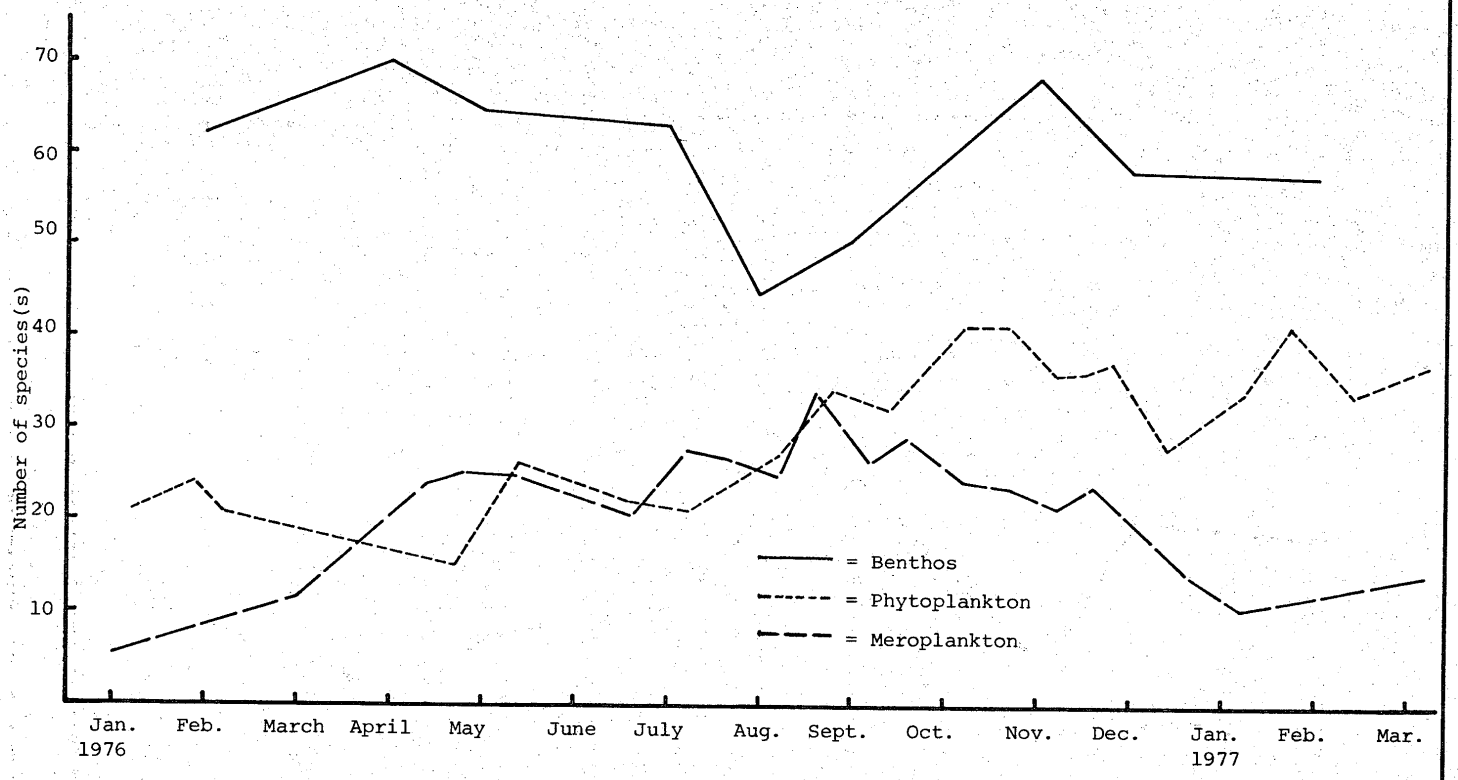

Figure 9.3. Species richness of benthic, phytoplankton and meroplankton components in thermal areas of Big Bend.

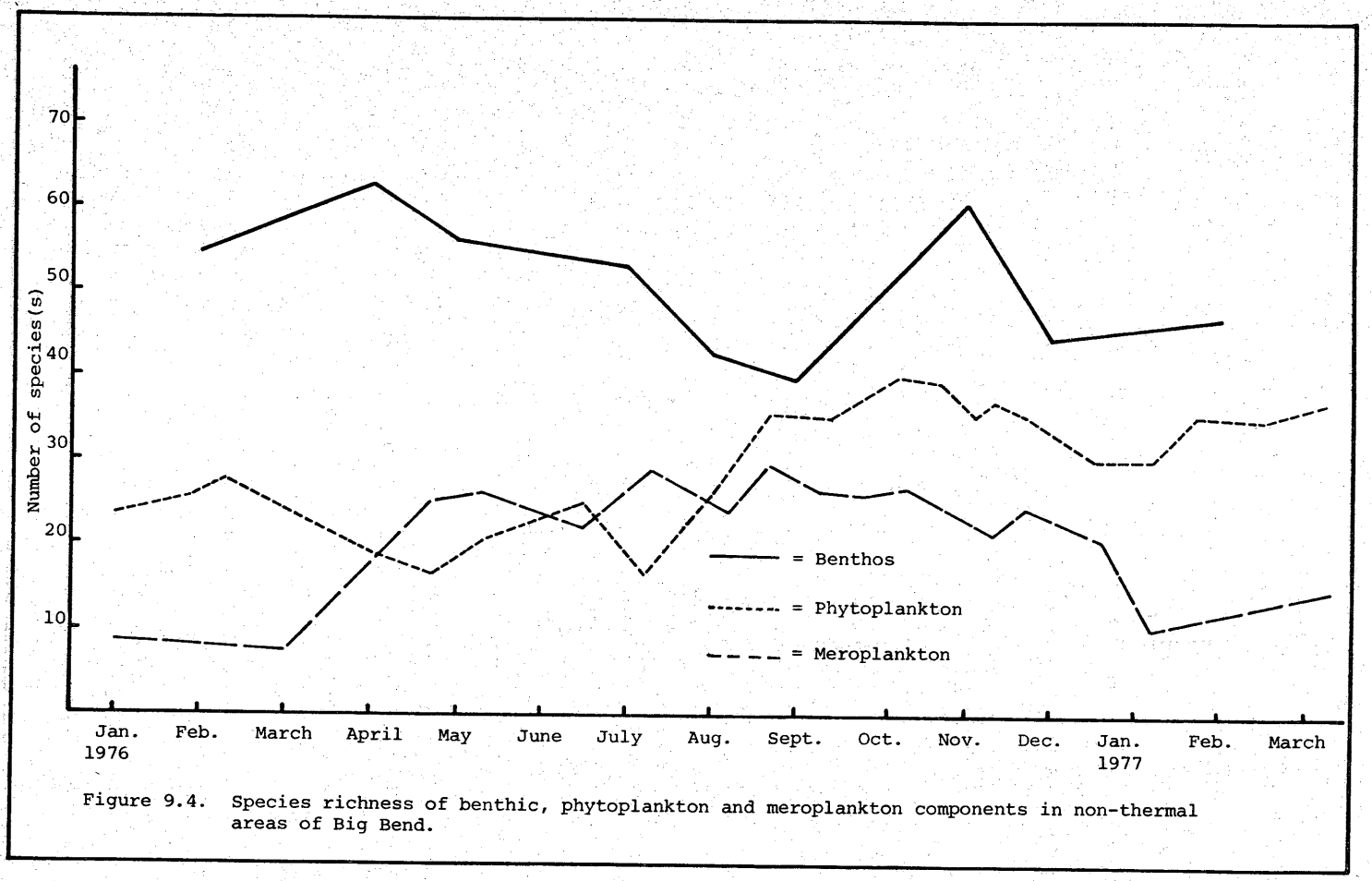

Figure 9.4. Species richness of benthic, phytoplankton and meroplankton components in non-thermal areas of Big Bend.

plankton contained a greater number of species during spring and summer months. Seasonal fluctuations in species numbers were more pronounced in the planktonic components.

General Considerations

In general, the planktonic components showed more extensive seasonal variations in density, biomass and diversity than the benthic component. This would be expected because of the short life spans (phytoplankton) or residing time (meroplankton) of the planktonic components. Overall, the Big Bend area appears to contain a diverse and dense benthic faunal assemblage but an oligomictic and physically controlled (controlled by hydrographic variations in the water column) planktonic community. This characterization would typically fit an estuarine system where benthic stability (and the abundance of niches) and water column fluctuations dominate (or control).

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