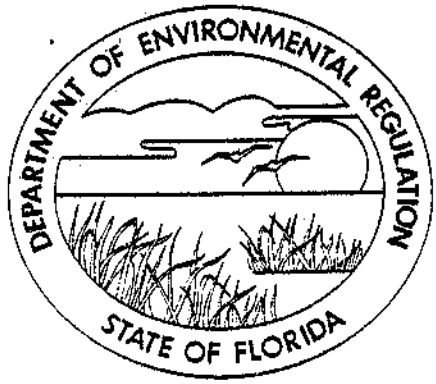

ENVIRONMENTAL STUDIES OF AN OIL-POLLUTED AREA of the ST. MARKS RIVER, FLORIDA

by

Lawrence A. Olsen, William J. Ihle, Landon T. Ross
Joseph D. Ryan, Steven Sheinbaum, and
Michael S. Zimmerman

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GENERAL INTRODUCTION

The operation of oil handling facilities at St. Marks, Florida, has resulted in numerous documented oil spills into the St. Marks River over the years. Flowing south through the port of St. Marks, the river converges with the Wakulla River to form the lower St. Marks River and subsequently empties into Apalachee Bay, a distance of approximately 4.5 miles. The most heavily oiled areas are those directly above this confluence, especially at the barge turning basin* (Fig.A1) west of the town. On July 12, 1978, an oil spill released approximately 10,000 gallons to the waters in the vicinity of the turning basin. Much of this oil coated the shoreline vegetation, docks, bulkheads and boats in the area, but apparently a great deal of it sank as a mat (possibly as a result of dispersants applied during cleanup operations) to the bottom. For months afterward, oil was churned up from the bottom by passing barges, coating the bottoms of boats at a local marina and generally giving the water an unsightly appearance. Consequently, a proposal was made to dredge this potentially hazardous material from the bottom in an effort to clean up the area and to improve the bottom habitats for various plants, benthic animals and fishes. Dredging would take place over a two-mile stretch in the immediate vicinity of the oil dock facilities and would remove approximately ~~1,000,000~~ STET cubic yards of oiled sediments (NOAA, 1979).

In a preliminary effort, the Biological Section of the Florida Department of Environmental Regulation received a Coastal Energy Impact

*The turning basin is an enlarged and deepened area of the river which enables barges to be turned around for their return journey down the river to the Gulf.

Program grant through the Florida Department of Community Affairs, to do a baseline survey of the immediately affected river area and areas above and below the oil unloading facilities. The existing biological conditions would then be documented in the event that the river is dredged. Any "recovery" of the affected area could then be seen in relation to the baseline data collected over the course of a year.

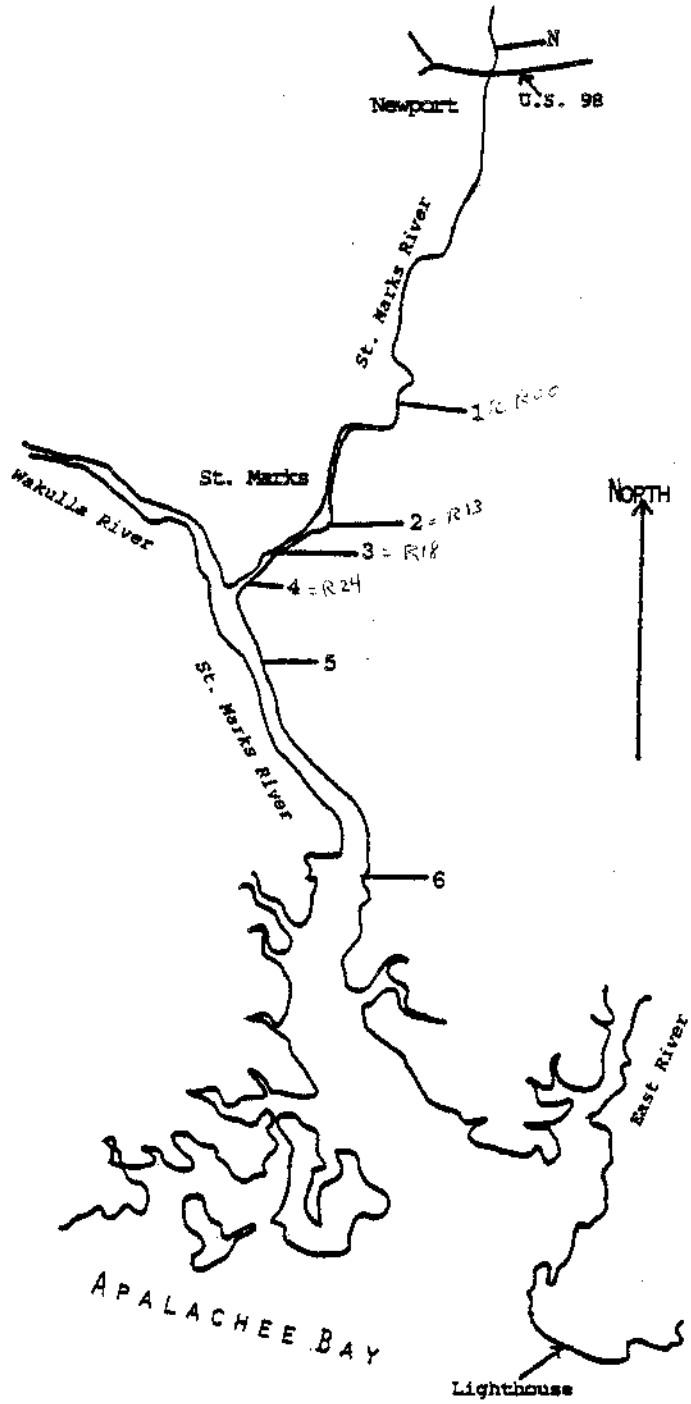
The major emphasis of the study was the structure of the plant and animal communities in the river. Other aspects of the general ecology were also studied, including detrital decomposition and periphyton community make-up at several stations. The study also considered aspects of the sediments (e.g., extent of the oiled area, percent oil in the sediments, general sediment composition, chemical characterization of the bottom oil), and various chemical and physical parameters of the water (temperature, salinity, and dissolved oxygen). Additionally, two significant portions of the study were sub-contracted and have been issued as separate reports. These are: 1) a year-long bacteriological survey of water column and sediment to establish the possible impact of oil on the bacterial populations in the river, and 2) an economic survey of the area to determine the economic impact of oil spills, oil spill clean-up and the cost-benefit ratio involved in the dredging of the oiled bottom sediments. The bacteriological study was conducted by Dr. Paul LaRock of the Florida State University Department of Oceanography and the economic study was conducted by Dr. Frederick Bell of the Florida State University Department of Economics.

Preliminary surveys of the area were done in the fall of 1979, and station locations were established on the basis of sediment oil information provided by NOAA (1979), on bottom samples examined for organisms and vegetation, and on the general morphometry and configuration of the river. Based on these data, it was decided to establish stations along transects

of the river just upstream of the oiled area, within the oiled area itself, far upstream at Newport, and far downstream in the lower St. Marks River. The northernmost transect is consistently fresh, while the most seaward transect is consistently estuarine. The middle transects are frequently subject to wedges of low salinity water (Fig.1.1).

In the following pages, the various sections of the study are presented. Attempts have been made after each section to draw conclusions about the data presented therein. It must be stressed, however, that these are baseline data, collected over one year of a natural seasonal cycle. An effort was made to correlate data to the impact of oil in the environment. However, the very nature of the area as an estuary, in which plant and animal distribution is a function not only of sediment type but also of salinity, precludes such an approach. Rather, the impact of oil must be seen in concert with those other factors.

FIGURE A.1 Sampling Locations for the St. Marks Studies



SECTION ONE: PHYSICAL AND CHEMICAL SAMPLING

Introduction

Since the interpretation of biological data requires information on the chemical and physical aspects of the environment which is to be sampled, certain parameters of the water column were measured during the course of the St. Marks study. These include: water temperature, salinity, conductivity and dissolved oxygen. It was known from previous studies of the river (Beck, 1955; NOAA, 1979) that a salinity wedge frequently travels upstream as far as, and even beyond, the city of St. Marks. It was, therefore, most important to document the existence and extent of saline water in relation to the distribution of the flora and fauna. For this reason, all of the parameters were measured at various depths in the water column, and physical-chemical monitoring was carried out on a monthly, rather than a quarterly, basis in order to provide a better description of the area. It was not always possible to sample at a particular point in the tidal cycle. Therefore, the data are indicative of, but not precisely descriptive of the regime. Station locations are shown in Figure A.1.

Materials and Methods

All of the data was gathered by remote-probes. Salinity, conductivity and temperature were measured by a Y.S.I. meter, model 33. Dissolved oxygen was also measured by a Y.S.I. meter, model 57. All of the instruments were standardized and calibrated in the laboratory before each sampling trip. In addition, pH measurements were taken in the field.

In the field, data was recorded at each station just below the surface of the water and at one-meter intervals until the bottom was reached. In this manner, a depth-parameter profile was possible for each station used in the biological sampling studies.

Results

The salinity and conductivity data are presented as Appendix Table 1. Temperature and dissolved oxygen are found in Appendix Table 2. Bottom salinity, temperature and dissolved oxygen data have been plotted for each station for each month, and are presented as Figure 1.1. The pH values are found in Appendix Table 3; however, data are suspect due to meter malfunction.

Discussion

It is apparent that the salinity wedge often reaches the area of the turning basin (station 2) and frequently also the station upriver, beyond the oil docks (station 1). The station at Newport (station N) never showed any bottom salinity, although the conductivity did vary somewhat. Beck (1955) refers to low saline water having reached as far upriver as Newport.

The water depth at the turning basin (5m) may be a reason for the fairly high bottom salinities at that station in that stratification can be seen in this more sluggish portion of the river.

The salinity values for the upper water column at station 2 are lower (Appendix Table 1) and stratification is apparent. The buck of dissolved oxygen near the bottom decrease at all stations during the summer months, as expected. The temperature, of course, is highest during this period.

FIGURE 1.1 Monthly Bottom Salinity, Temperature and Dissolved Oxygen at St. Marks Stations

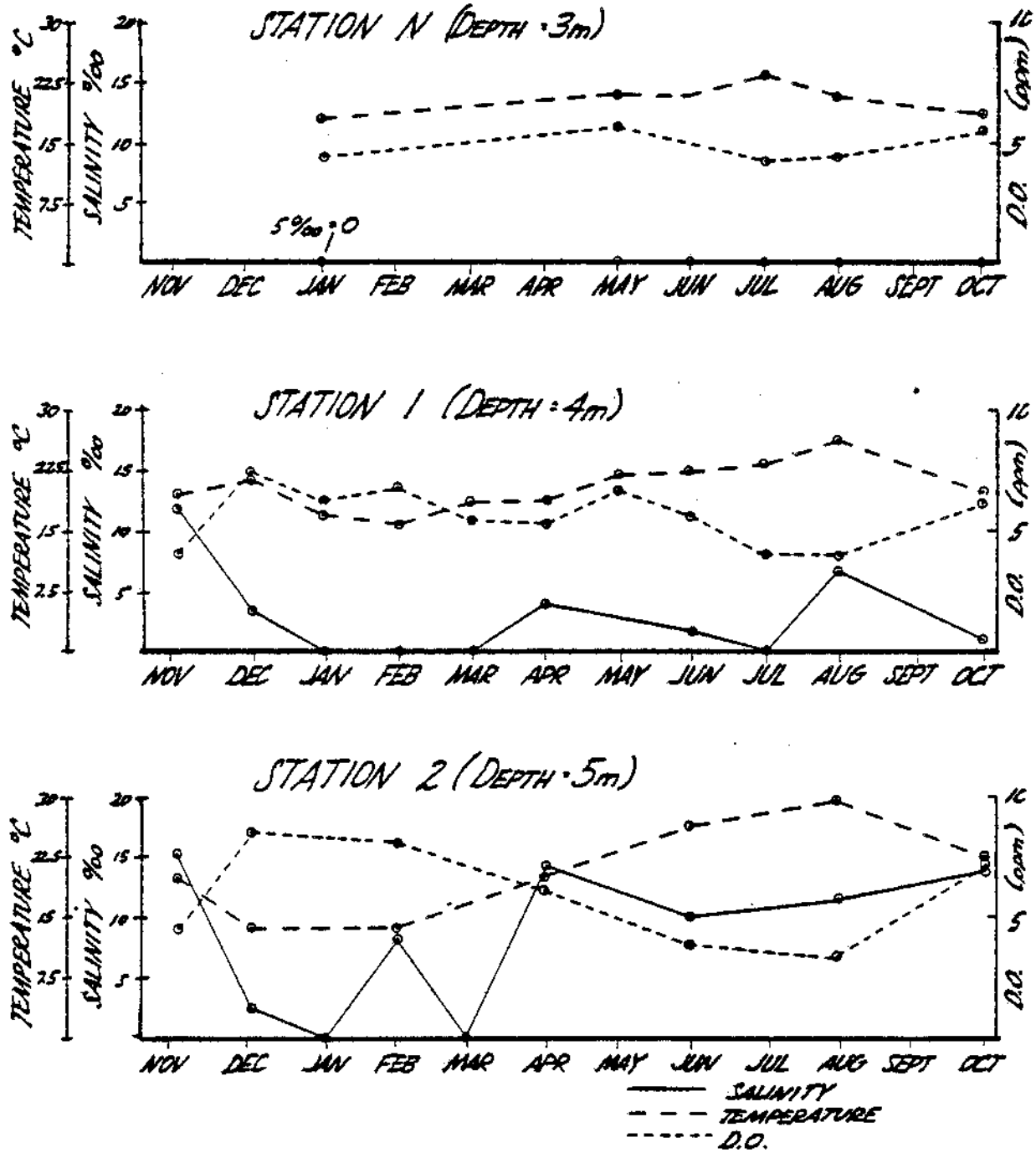


FIGURE 1.1 (continued)

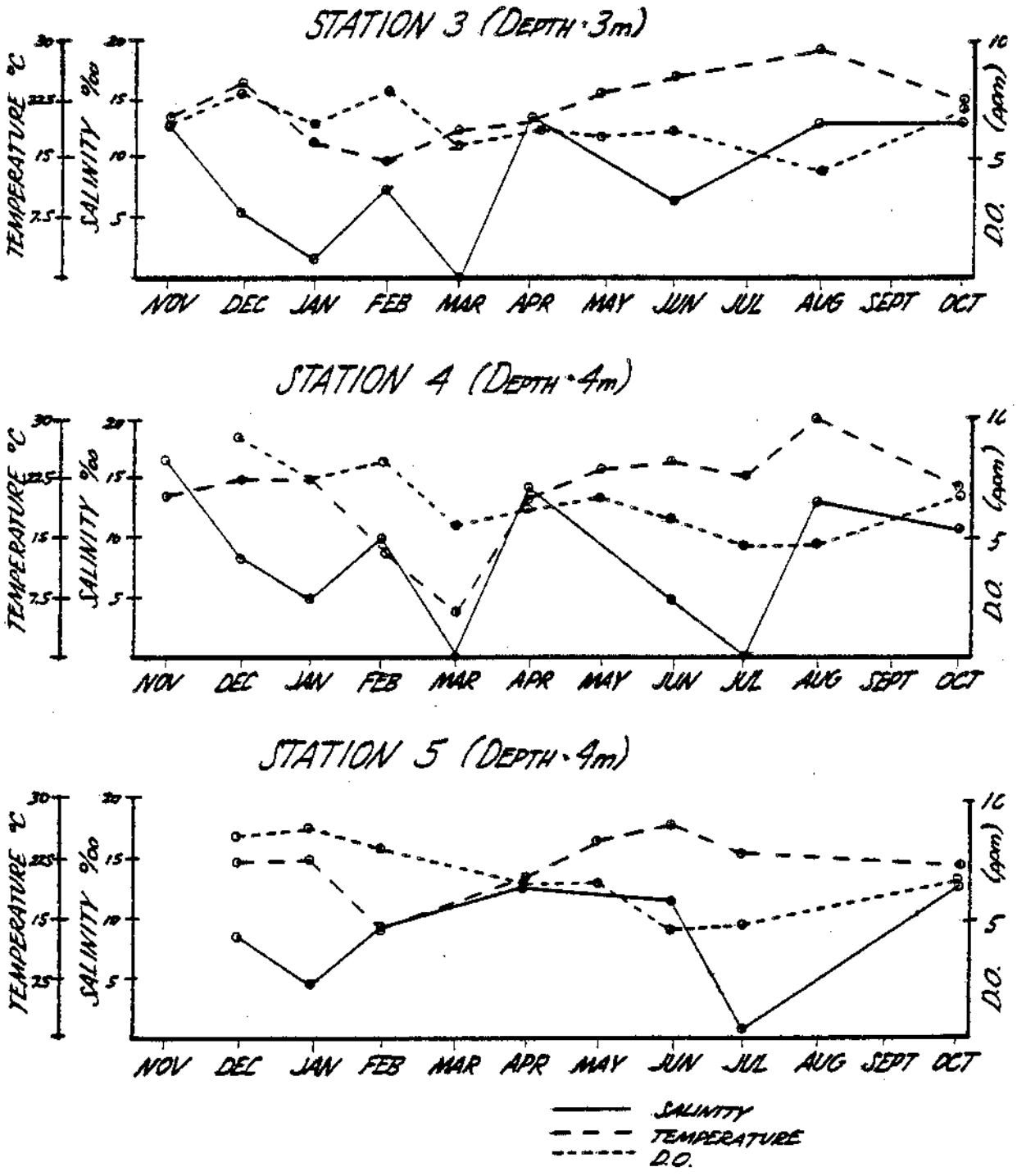
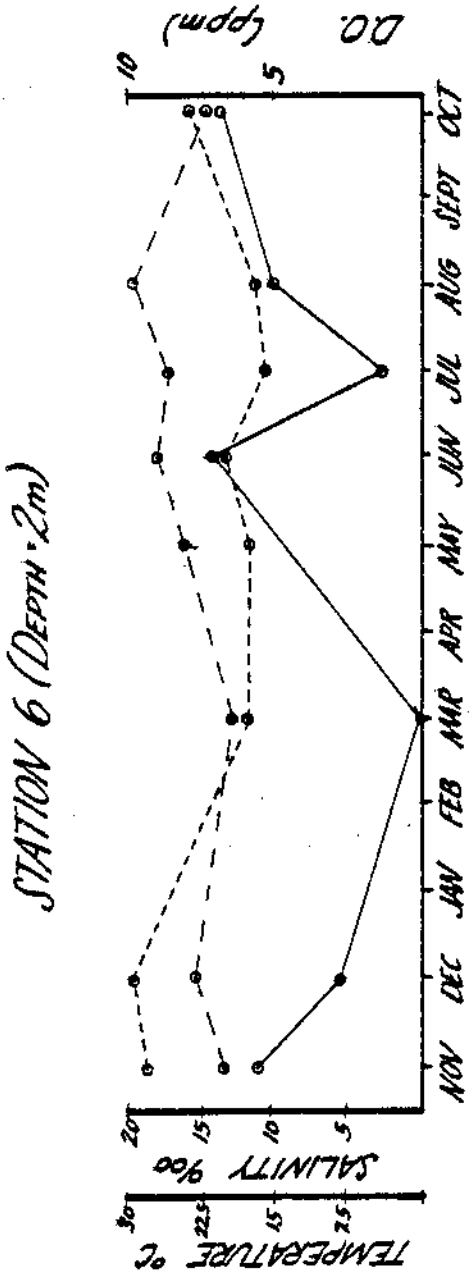


FIGURE 1.1 (Continued)



SECTION TWO: SEDIMENT ANALYSES

Introduction

Part of the problem in assessing the nature and extent of animal and plant communities is that there are a number of factors in the environment which inhibit or augment the distribution of the organisms. It has been established elsewhere in this report (See Section One) that one very important such factor is salinity. A wedge of saline water frequently moves up the river as far as transect 1, which is upstream from the town of St. Marks (Figure A.1). As a consequence, animals and plants distribute themselves along the bottom according to their salinity preferences. However, sediment type also changes along the course of the river bottom, and also influences distribution patterns. Further, some of that sediment is contaminated with oil from the many spills which have occurred near St. Marks.

In an effort to characterize the sediment, core samples were taken and analyses performed to determine the sediment particle size distribution, the percent water content, and the oil and grease content. Also, the oil in the most heavily contaminated area, the turning basin, was qualitatively characterized.

Material and Methods

Samples were taken for sediment particle size analyses in April, 1980, at all of the transects sampled in the faunal and plant surveys (transects N, 1, 2, 3, 4, 5 and 6; Figure A.1). The same coring device

which was used in the benthic sampling program (and described in that section of this report) was used to collect sediment samples. Duplicate samples were collected. One sample was for analysis; the other, frozen, as a back-up in case of accident. In the lab, the samples were processed according to the method of Buchanan and Kain (1971), in which the sediment is separated into silt-clay (<63μm) and other larger fractions (>63μm, 88μm, 125μm, 250μm, 2.0mm) via wet and dry sieving. The data derived were then analyzed according to Folk (1961) and categorized according to phi size and percent composition.

Samples for oil and grease analysis were taken with the coring device in June, 1980 (again Stations along transects N, 1, 2, 3, 4, 5 and 6), approximately one year after the NOAA study (1979). The latter study analyzed samples for oil and grease at similarly located transects. The corer was thoroughly cleaned with hexane, including two rinses, after each substrate sample was taken. Samples were placed in clean glass containers and sealed with screw caps. The samples were taken to the lab within six hours of collection and were frozen for later analyses.

The analytical procedure for oil and grease is a modification of a gravimetric method (Sediment Extraction Procedure, EPA S.E. W. Q. Lab, Method No. SP8/71). The modification involves the extraction of oils and grease with hexane. The complete method is given in Appendix Table 4. Percent oil and grease is calculated on a dry sediment weight basis. Preliminary sample extractions of four replicate samples of thoroughly mixed oiled sediment yielded a standard deviation of $\pm$ 14%.

Qualitative analysis for hydrocarbons in the most consistently heavily oiled region, the turning basin, was undertaken by the DER Chemistry Section. The subject sediment sample was extracted with organic solvent and the extract analyzed using infra-red spectroscopy, flame ionization gas chromatography, and gas chromatography/mass spectrometry.

Results

The sediment particle size distribution at St. Marks stations is listed in Table 2.1. It is noteworthy that the particle sizes at stations along transect 2 (the turning basin) are heavily skewed towards the fines (ϕ=5 and less) with about 21% silt-clay at Station 2E and 25% silt-clay at Station 2C. Station 3C has a very high silt-clay fraction-54% of the total. The only other substantial silt-clay fraction among the stations is at 5W, about 26%. A large percentage (39%) of the substrate at station 6E is within ϕ=2 to ϕ=-1 (medium sand) range. This station actually has a substantial amount of shell hash, which falls into the ϕ=2 and above size category.

The results of the oil and grease analyses appear as Table 2.2. The results vary widely, even within the same station, which indicates an uneven distribution of oil along the bottom. For that reason, no attempt has been made to average different values within a station, but rather, the data are presented individually. As expected, the stations at the turning basin transect (2E, 2C) all show consistent evidence of oil, as do the stations just downstream (3C, 3W). Stations above and below are quite patchy, yet some of the upstream stations still show oil. Station 1W, for example, varied from 0% to 1.41% oil and grease on a dry weight basis. Most surprising are the extreme upstream and downstream stations. Station 6E and 6W varied from 0.00 to 2.02% oil and grease while NW had 0.00 and 2.63%.

The composition of the hydrocarbons in the turning basin is quite complex. The IR spectra indicated a dominance of non-aromatic carbon-hydrogen absorption with a minor amount of aromatic C-H present. Detectable amounts of mixed carbonyl groups were present. No indication of other functional groups was detected. The over-all spectra were similar to what in the past has been observed with highly weathered petroleum products.

The FID-GC indicated a very complex mixture of high boiling components. Again, the GC pattern was quite similar to that of highly weathered petroleum products such as lubricating oils. However, separation of individual components was poor using the packed column in our routine analysis. It is most probable that to obtain adequate separation for more than about six of the major individual components in this mixture, a capillary column would be required. Because of this, no attempt was made to identify specific components by GC only.

Adequate separation of several major components was achieved on packed columns to provide mass spectra clean enough for tentative identification of the following compounds:

1. 2,6-Dimethyl-3-alklyl-decahydronaphthalene
2. 2,5-Dimethyl-Phenanthrene
3. 2,3-Dimethyl-Phenanthrene
4. 2,3,5-Trimethyl-Phenanthrene
5. 4-Methyl-Pyrene
6. Benz{a}anthracene

It should be emphasized that no authentic standards for these compounds were available and that tentative identification has been assigned on the

basis of the interpretation of their mass spectra and on the results of a computer assisted search of our NIH-EPA mass spectra library. It is estimated that the major components in this complex mixture constitute about 10-15% of the total mass of more than 50 individual chemical species.

Numerous other polyaromatic hydrocarbons were indicated. However, GC separation difficulties precluded specific identification or mass spectra interpretation of these components. The absence of chlorine isotope clusters indicated no major amounts of organochlorine compounds.

Discussion

The sorting and percent composition of the substrate varies widely along the river bottom and no doubt has a bearing upon the distribution of plants and animals at the sampling location. Correlations of this sort are quite expected in benthic ecological studies (Stanley, 1970; Cairns, 1971; Boesch, et al., 1974).

The percentages of oil and grease determined at various sampling stations confirm the findings of the NOAA report of a year earlier (NOAA, 1979). The latter were more comprehensive(i.e., more stations and at various sediment depths) and found widely varying amounts of oil. The NOAA study found 0.04% oil and grease just north of the turning basin near our station 1W, which in the present study was found to have 0.0, 0.06 and 1.41% oil and grease. Also, the NOAA study showed 1.19% oil and grease in an area just south of the Newport Bridge. Our station NW, which is just north of the bridge, yielded values of 0.0% and 2.63%. A

possible explanation for these unexpectedly high values so far north of the oil spill area (about 3 miles north) could be that sunken oil was carried upstream in a saline wedge. However, our salinity measurements never indicated any bottom salinity that far upstream, although it has been reported elsewhwere (Beck, 1955). A more likely possibility is that the small boatyard located near the bridge may have, over the years, contributed to some oiling of sediments in the area. The NOAA report also pointed out this possibility. It was not the purpose of either the NOAA study or the present study to investigate that possibility, however.

Finally, the qualitative oil and grease analyses tend to confirm the results of the 1979 NOAA report in that the sediment extracts contain a complex mixture of petroleum base hydrocarbons. The dominant species are polyaromatic hydrocarbons with little or no indication of individual high molecular weight aliphatic hydrocarbons that would be expected even in highly weathered petroleum distillate products such as diesel fuels or lubricating oils. The high polyaromatic hydrocarbon content as major components indicates petroleum refined distillate bottoms, such as asphalts, as a major source of this material, rather than either crude petroleum or refined distillate.

Table 2.1 Sediment Particle Size Distribution at St. Marks Stations

Percentages

	(granule & above) $\phi=-1$	(medium & coarse sand) $\phi=2$	(fine sand) $\phi=3$	$\phi=3.5$	(very fine sand) $\phi=4$	(silt/clay) $\phi=5$
NE	0.05	2.73	10.35	48.44	31.99	6.45
NW	0.13	3.55	15.19	54.85	19.32	7.00
1E	1.66	3.47	13.48	45.35	20.64	15.40
1W	5.26	4.74	15.34	45.39	19.68	9.59
2E	8.00	13.70	11.52	25.81	20.12	20.85
2C	7.12	10.03	13.55	26.29	17.99	25.02
2W	0.67	4.08	10.51	44.35	24.08	16.30
3E	2.99	17.40	12.56	26.55	20.70	19.80
3C	1.53	2.09	4.98	15.93	21.38	54.09
3W	10.62	11.89	9.46	35.83	12.23	19.96
4E	0.03	1.52	14.95	47.83	26.06	9.61
4C	0.58	4.10	15.65	47.24	22.39	10.03
5E	4.32	3.86	14.11	42.71	23.15	11.85
5W	0.05	6.89	10.11	32.06	24.92	25.98
6E	2.93	39.35	11.22	18.33	13.93	14.24
6W	0.00	5.96	24.97	36.92	18.54	13.60

$\phi=-1$ -- >2.0mm

$\phi=2$ --- >250 μm

$\phi=3$ --- >125 μm

$\phi=3.5$ ---> 88 μm

$\phi=4$ ---> 63 μm

$\phi=5$ ---< 63 μm

Table 2.2 Oil and Grease in St. Marks Sediments in June, 1980

Station	Percent Oil and Grease (Dry wt. Basis)
NW	0.00; 2.63
1W	0.00; 0.06; 1.41
2E	0.55; 0.82
2C	0.31; 2.29
3C	0.93
3W	0.77; 1.75
4E	1.06
5W	0.48
6E	0.00; 1.57
6W	0.00; 2.02

SECTION THREE: BENTHIC FAUNA

Introduction

While monitoring of chemical water quality parameters is often used to determine the indirect effects of oil pollution, alterations of the benthic invertebrate communities are much more indicative of direct environmental degradation. Studies of changes in species composition of these bottom-dwelling organisms have been widely employed to assess the impact of oil spills in numerous estuarine and marine habitats (Reish, 1965; Crapp, 1971; Boesch et al., 1974, Wharfe, 1975; Leppakoski and Lindstrom, 1978; Sanders et al., 1980). Since many of these animals reproduce rapidly and are either sedentary or move only small distances from their initial settling sites, short and long-term changes in faunal community composition are discernable by sampling those communities over a period of time.

The impact of an oil spill on benthic organisms is largely dependent upon the amount and type of petroleum spilled, and the degree to which it has been degraded by natural processes (Boesch et al., 1974; Sanders et al., 1980). Although oil is very complex, its constituent hydrocarbons fall into three classes: alkanes (also called parafins or saturates), alkenes (olefins), and aromatics (e.g., napthalene, phenanthrene). The alkane and aromatic hydrocarbons comprise the greatest proportion of petroleum products, whereas alkenes are found in refined hydrocarbons such as gasoline. In terms of toxicity, it is the low-boiling, highly water-soluble aromatic compounds which appear to be the most immediately toxic and pose the greatest

threat to the fauna (Blumer and Sass, 1972; Straughan, 1972; Boesch et al., 1974; Sanders et al., 1980). Alkenes are probably less toxic than aromatics but more so than alkanes. Each of these groups is composed of thousands of compounds which make up the oil products encountered in the environment.

Numerous studies have examined the effects of petroleum hydrocarbons on marine benthic communities (Colwell, 1970; Boesch et al., 1974; Leppakoski and Lindstrom, 1978; Tatum et al., 1978; Reish, 1979; Sanders et al., 1980). These and other studies (Murphy, 1970; Blumer and Sass, 1972; Mackie et al., 1978) have noted that, while fuel oil distillates initially kill numerous organisms in the water column as well as on the bottom (over a period of several weeks or months), the physical effects of an oil spill may persist indefinitely. These effects are particularly evident with crude and heavier oils (e.g., Bunker C) or highly weathered oils which can smother, abrade or remove and alter the substrate.

With the previously established community's demise, "open" areas become available to rapidly colonizing opportunistic species which may completely change the species composition of the habitat. As weathering and microbial activity proceed, the more toxic and volatile hydrocarbons may become degraded and the previous "established" fauna may recolonize if conditions return to the pre-spill status.

In this report, we provide a baseline survey of the benthic fauna at various locations (oil-polluted and unpolluted) along the St. Marks River. Since most benthic studies have dealt with those organisms inhabitating fresh, estuarine, or marine waters, it is difficult to assess the

impact that the oil spills have had on this biologically complex river system. That is, it is difficult to differentiate among natural gradients (biological, chemical, physical) along this river since many of the affected areas occur at the fresh and salt water transition zone (See Section One). Additionally, the exact composition of the oil in the sediment is difficult to analyze owing to the great diversity and quantity of oil being transported on the St. Marks River.* Rather than generating a predictive model, therefore, this section provides a description of the spatial and seasonal variability of benthic macroinvertebrates over a 7 mile segment of the St. Marks River.

Materials and Methods

Monthly benthic collections were taken at the seven previously discussed study sites along the St. Marks River, Florida (Fig. A1). A transect was established across each location so that east, west, and center habitats could be sampled (stratified random sampling). Unfortunately, hard limestone bottoms precluded center-station sampling at those sites above and below the port of St. Marks (i.e., for transects N and 1,4,5, and 6). Each of the sixteen stations along the seven transects differed substantially in biological, chemical and physical make-up. Shoreline stations (east and west) ranged from one meter to three meters in depth at transects 2 and 3, while center stations 2C, 3C, and 4C were situated at approximately four and a half meters depth.

*See Section Two of this report for sediment and oil discussion; also see F. Bell's economic assessment on the St. Marks area, which is part of this study.

With the exception of 6E, all benthic areas are of a mud-silt composition (Table 2.1). Substrates at 6E are composed largely of coarse sand and oyster rubble. Data on the emergent and submergent vegetation are discussed for each station in Section Four of this report. It appears that chronic oil spillage may have denuded the benthic macrophyte community in the area of barge turning basin (Transect 2).

Salinities were polyhaline at transects 4, 5, and 6, whereas upper study sites (N and 1) were characterized by salinities, of 0% and less than 5%, respectively. Middle transects 2 and 3 frequently reached 10% or higher. All physical and chemical river data are given in Appendix Tables 1 and 2. Conductivity, temperature, and salinity measurements were obtained with a portable Y.S.I. model 33 meter. Dissolved oxygen was determined with a portable Y.S.I. model 57 meter. Although the data are suspect because of repeated meter malfunctions, pH readings were made with a Fisher model 150 pH meter, and are listed in Appendix Table 3.

All benthic samples were taken with a 7.62cm diameter suction coring device (Stoner et al., 1981) and operated from the collecting boat. This device was constructed with long handles especially for this study and was capable of reaching a depth of over 5m. The top 10cm of sediment was removed, passed through a 0.5mm sieve (U.S. Standard Sieve #35), and washed into glass containers. Each core was then stained with rose bengal and preserved in a 10% buffered formalin solution. Sample size (i.e., number of cores needed for a reliable estimate of macrobenthos) was based on the rarefaction method described

by Simberloff (1978). Species-accumulation curves were determined from preliminary collections, and a total of eight core samples was determined to be sufficient to collect over 93% of the benthic organisms at each location. Therefore, eight cores were taken at each station. In some cases loss of a sample meant that only seven were available for identification.

Benthic samples were brought back to the FDER laboratory in Tallahassee, sorted under a 60X dissecting microscope, and stored in 70% ethanol for identification. All macrofaunal organisms were identified to the lowest possible taxonomic level under dissecting and/or compound microscopes and placed in vials for future reference. All of these samples are stored at the FDER biological laboratory (Tallahassee) and a type collection is maintained of all species found in the samples. Organisms such as copepods, which are usually considered to be part of the meiofauna, are not included in the identifications. Other organisms, such as ostracods, nematodes, etc. which may be larger than the 0.5mm sieve, but which are not normally included in benthic macroinvertebrate studies, were tentatively identified but not included in species diversity indices or in the total species present at a station. They were calculated into faunal density/m^2.

Time and manpower constraints prevented the analysis of continuous monthly data; therefore, only quarterly information is discussed in this report (i.e., fall, winter, spring, and summer). In this respect, the study follows the standard format of most seasonal benthic surveys.

The taxonomic references used in identifying organisms found in the samples are referenced in Appendix Table 5.

Results

Analyses of benthic data revealed that annelids dominated the fauna at most St. Marks study sites. Based on total abundance for all four quarters, a polychaete, *Hypaneola florida*, and numerous unidentified immature oligochaete tubificids made up the majority of animals appearing in core samples, with 24.1% and 14.9% total abundances, respectively (Table 3.1). *Hypaneola florida* plus four other annelids, an oligochaete, *Limnodrilus hoffmeisteri,* the polychaetes *Streblospio benedicti, Laeonereis culveri,* and *Aulodrilus piguetti* comprised over 30.9% of all benthic organisms taken.

The crustacean fauna was largely dominated by two amphipods, *Grandidierella bonnieroides* and *Hyalella azteca*, depending upon the salinity. The former was regularly found at those stations receiving salt water influence, whereas *Hyalella* appeared to be restricted to upper, freshwater stations. Together, they comprised 10% of the total number of organisms collected (Table 3.1). Two isopods, *Edotea* sp. and *Cyathura polita,* also appeared regularly in cores.

Only one mollusc, the snail, *Neritina reclivata,* occurred in large numbers in the samples, accounting for 3.3% of the total. The snail is ubiquitous, occurring at our most freshwater locations at N all the way downstream to our most saline locations at 6. It is most conspicuously absent from the turning basin stations and only occurs

in the winter quarter samples at the location near Shields Marina. Figures 3.1 through 3.26 indicate the most common species found at all stations during each of the four quarters sampled. However, since considerable variation in time and space was observed, the data are misleading unless they are analyzed within a spatio-temporal framework. Therefore, the following paragraphs attempt to break down the large numbers of organisms collected into more manageable and meaningful analyses, by considering seasonal variations as well as variations among the stations.

Spatial Variability

Greatest density (in numbers per m^2) of benthic organisms was recorded at those stations above (NE) and below (4C, 5W, 6E) the port of St. Marks (Table 3.2). Immature tubificids and *Hyalella azteca* dominated the macrofauna at NE, while tubificids, *Hypaneola florida*, and *Grandidierella bonnieroides* were most abundant in core samples from the latter stations. Transects 2 and 3 (the turning basin and Shields Marina areas, respectively) are almost entirely unvegetated and were characterized by the smallest mean faunal densities throughout the study. With the exception of station 3E, which is vegetated (See Section Four), the fewest number of species was taken at these sites.

The number of different taxa was consistently highest at the northern and southernmost stations (NE and 6E), with considerable seasonal fluctuation noted within each transect (Tables 3.3, 3.4, 3.5 and 3.6). Shannon-Weaver diversity indices (H') are also given in Tables 3.3 through 3.6. Transects 2 and 3, with the exception of Station 3E, consistently show low diversity indices.

Freshwater locations were dominated largely by species such as *Hyalella azteca, Aulodrilus pigueti,* and numerous immature tubificids, although species composition varied tremendously with season. At the polyhaline sites, the polychaetes *L. culveri* and *S. benedicti* became more numerous, and *G. bonnieroides* was the most abundant amphipod. These species were relatively unimportant, however, when compared with densities of *Hypaneola florida,* which was encountered regularly from transects 1 through 6. Although *G. bonnieroides* and *S. benedicti* were present throughout the freshwater-saltwater continuum, only *Hypaneola* and *Neritina reclivata* exhibited heavy population densities along this gradient. Examination of species composition at the most heavily oiled transects (2 and 3) revealed that *H. florida* consistently ranked first in terms of density in these areas. Only at the vegetated site (3E) was there an increase in species number. Tables 3.7-3.10 list all species and calculated densities (no./m^2) at each sampling station during the fall, winter, spring and summer collections.

Seasonal Variability

Numbers of taxa were significantly higher during the spring (Rank Sum Anova, $p \leq .05$; Gertz 1978) than in the other quarters, with the greatest number of species taken at stations NE, 3E, and 6E (Table 3.5). Insects and oligochaetes were most common (46 and 17 species, respectively) in spring collections after seasonal lows during fall and winter quarters. The lowest numbers of species were taken in winter and summer samples. A list of all 126 species collected over the year of sampling is found in Table 3.11.

Based on total numbers, faunal densities were greatest in the summer quarter (Table 3.6), and were largely dominated by immature

tubificids, *H. florida*, and *G. bonnieroides*. However, the highest number of organisms per m^2 in any quarter was in the fall, at Station 6E.

Seasonal trends were evident for all species. Trends for some of the most numerous species are given in Figures 3.27 - 3.30. For example, *Nertina reclivata* reached a high, in terms of numbers/m^2, in the winter (Fig. 3.29) as did the amphipods, *Grandidierella bonneroides and Gammarus mucronatus* (Fig. 3.28) and the polychaete, *Streblospio benedicti* (Fig. 3.30). With one exception, the other numerous species *Procladius subletti, Polypedilum halterale, Clinotanypus* sp., *Hyalella azteca, Edotea* sp., *Cyathura polita* and *Laeonereis culveri*, generally increased in numbers in the spring. The exception was *Hypaneola florida*, whose population steadily decreased from the fall through summer quarters, although the summer average of about 1.9×10^4 animals/m^2 was still substantial compared with the other fauna (Fig. 3.30).

Discussion

Results from this preliminary study indicate that three benthic macroinvertebrates made up over 70% of the total infauna collected at the most heavily oiled transects (2 and 3). They are: *Hypaneola florida, Grandidierella bonnieroides, Limnodrilus hoffmeisteri*. Within this area, only station 3E exhibits a significant increase in species numbers. The consistently large number of species taken at this site is probably due to the dense *Sagittaria* grassbeds which apparently have not been affected by the chronic oil spills on the St. Marks. Conversely, the smallest number of species was recorded on the west side of both transects 2 and 3 during fall and winter quarters. In addition, total faunal densities

(no./m^2) at these habitats were the lowest encountered at any of the 16 study sites along the river.

Because diversity indices have been strongly criticized (Pielou, 1977; Green, 1979) and since they do not reflect the extensive changes in habitat structure at the various stations, they are not emphasized in this report. Most emphasis is placed upon total number of species, individuals, and population structure of several conspicuous species. However, it is of note that the index of diversity is generally lowest at the stations along transects 2 and 3, with the aforementioned anomalous exception of station 3E. The anomolously low values of H' at station 4C are believed to be due to the large numbers of *H. florida* at that station, which is near the confluence of the St. Marks and the Wakulla Rivers and which is almost devoid of vegetation.

Examination of species composition data revealed that the domiculous (tube-building) polychaete, *Hypaneola florida,* made up 25% of the total number of organisms taken in the study and over half (51.6%) of the benthic infauna collected at stations 2 and 3. This species appears to be ubiquitous in the oligo- and mesohaline areas of the St. Marks. In a previous study of the lower portions of the river, Subramanyam et al., (1976) listed this species* as the fourth most abundant macroinvertebrate collected.

While *H. florida* has been recorded from Maine to Florida (Zottoli, 1974; Pettibone, 1977) in water ranging up to 21% salinity (G. Ray and B. Mahoney, personal communication; Sanders, 1965), relatively little is known about its life history. Zottoli (1974) found that spawning of this

*Although Subramanyam et al., refer to this as *Amphicteis gunneri,* this worm has been recently reclassified as *Hypaneola florida* by Pettibone (1977).

worm in Massachusetts occurs from May to early September, with larvae released directly into the adult tube. Juveniles then leave the tube at the 2-setiger stage and settle immediately on the bottom. Trophically, *H. florida* is a surface deposit feeder. It appears from this study that *H. florida* may be quite tolerant of oil pollution, since large percentages of the fauna at the oil-contaminated areas (2, 3 and 4) are *H. florida* throughout the year. Since *H. florida* is a surface deposit feeder, its presence at those sites is also correlated with the substrate type (i.e., the near absence of vegetation). Indeed, it is not a prominent species in vegetated areas.

Because the most heavily oiled sites are located in zones of transition in terms of both chemical and biological factors, the effects of chronic oil spills on the St. Marks are not easily interpretable. That is, salinity is strongly influenced by tidal cycle in this area and, as noted in Section Four of this report, plant communities also undergo a compositional change at these sites. Therefore, the observed faunal changes could be attributable to differential physiological tolerances of these organisms (i.e., salinity) or a response to changes in habitat availability (i.e., macrophytes), or both.

The presence of petroleum hydrocarbons in the sediments of transects 2 and 3 and others have been reported (See Section Two), but it is not clear whether these compounds directly kill the benthos or whether we are observing sub-lethal community alterations due to the oil spillages. It is difficult to establish exact levels of petroleum-hydrocarbons which kill estuarine organisms (Tatem et al., 1978) since oils are made up of thousands of hydrocarbons which differ in solubility and toxicity.

For example, napthalenes, as well as other bicyclic and polyclic aromatics which are extremely toxic and rapidly accumulated by estuarine invertebrates (Tatem et al., 1978; Rossi et al., 1976; Anderson, et al., 1974), are present in sediments at the turning basin and Shields Marina (See Section Two). These compounds can become even more toxic at higher temperatures, inducing even greater physiological stress during warmer months. It should be noted that the lowest number of individuals and species was recorded during the summer quarter at several of the stations at transects 2 and 3 (Table 3.6). There is evidence that incorporation of oil into fine-grained material results in gradual release of hydrocarbons over a period of years (Shaw and Wiggs, 1980).

Indirect effects resulting from oil spills additionally complicate the picture since scouring or smothering by sunken mats of oil may eliminate suitable hatitats (e.g., vegetation) and create a substrate which is favorable to only a few organisms. For example, Grassle and Grassle (1974) found that polychaetes possessing some sort of brood protection (e.g., *Hypaneola florida, Streblospio benedicti*), which allowed larvae to be released, immediately settle, and rapidly attain large population densities, were the most successful colonizers during the West Falmouth, Massachusetts spill. Indirect effects may be those such as loss of vegetation, which tends to support those organisms capable of deposit feeding. Interestingly, all three polycheates found at transects 2 and 3 are are deposit feeders.

It would appear that one or more of these parameters may be responsible for the observed differences in the turning basin-Shields

Marina areas, versus other sampled areas. Numbers of species are reduced at all stations along these two transects except station 3E, where a small but dense *Sagittaria* grassbed is present (See Section Four). At 3E, significant increases in numbers of all species were recorded with the exception of *H. florida* and *Streblospio benedicti;* it seems that the presence of these submerged macrophytes may be implicated.

These observations indicate the complexities of marsh-estuarine areas. With the additional influence of petroleum hydrocarbons spilled into these environments, the problems of interpretation become even more difficult. One major observation which has emerged in this study is the patchy distribution of both the benthic organisms and the oil which settles on the bottom. Therefore, it becomes crucial to adequately sample these patches in order to determine how these organisms are affected. Only by taking a large number of replicate benthic samples in such areas, as in this study, are such problems overcome.

In conclusion, the year-long benthic sampling program has established a data base on the faunal composition at 16 stations on the St. Marks River. The stations were located along seven transects which were upstream, within, and downstream of the heavily oiled area, which was delineated in previous sediment studies (NOAA, 1979). Our results showed the following:

1. Seasonal trends are apparent at all locations, with often dramatic species composition and population density changes from season to season.
2. The areas of transect 2 (the turning basin) and transect 3 (Shields Marina) were substantially lower with regard to the number of species present and population densities other than

transects. Calculated H' values are significantly lower than at most of the other stations. One exception was station 3E, which was consistently higher than nearby stations, probably because of the grassy habitat at that station. Station 4C also was consistently lower with regard to the species diversity index.

3. Although the presence of oil was detected at stations other than along transects 2, 3, and 4, any effects on the benthos at those stations were not detectable; i.e., the communities were considered to be balanced.

It appears that long-term effects of the St. Marks oil spills on benthic macroinvertebrates are localized within a stretch of the river which encompasses the turning basin and the Shields Marina area, and reaches to transect 4, a total of about 1.5 miles.

FIGURE 3.1 Dominant Fauna at Transect N, Fall Quarter, 1979
(percentages based on total number/m^2)

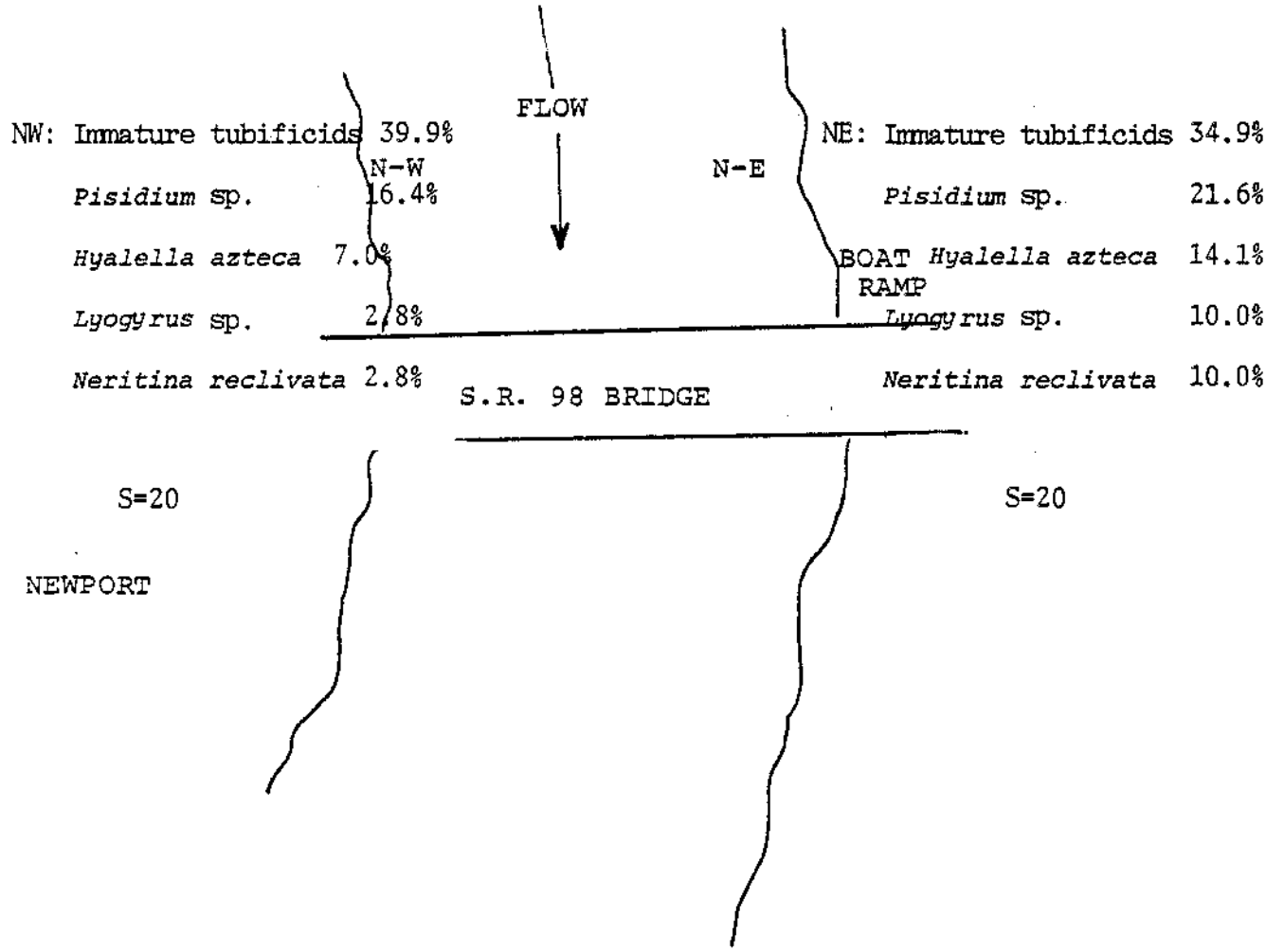


FIGURE 3.2 Dominant Fauna at Transect 1, Fall Quarter, 1979.
(Percentages based on total number/m^2)

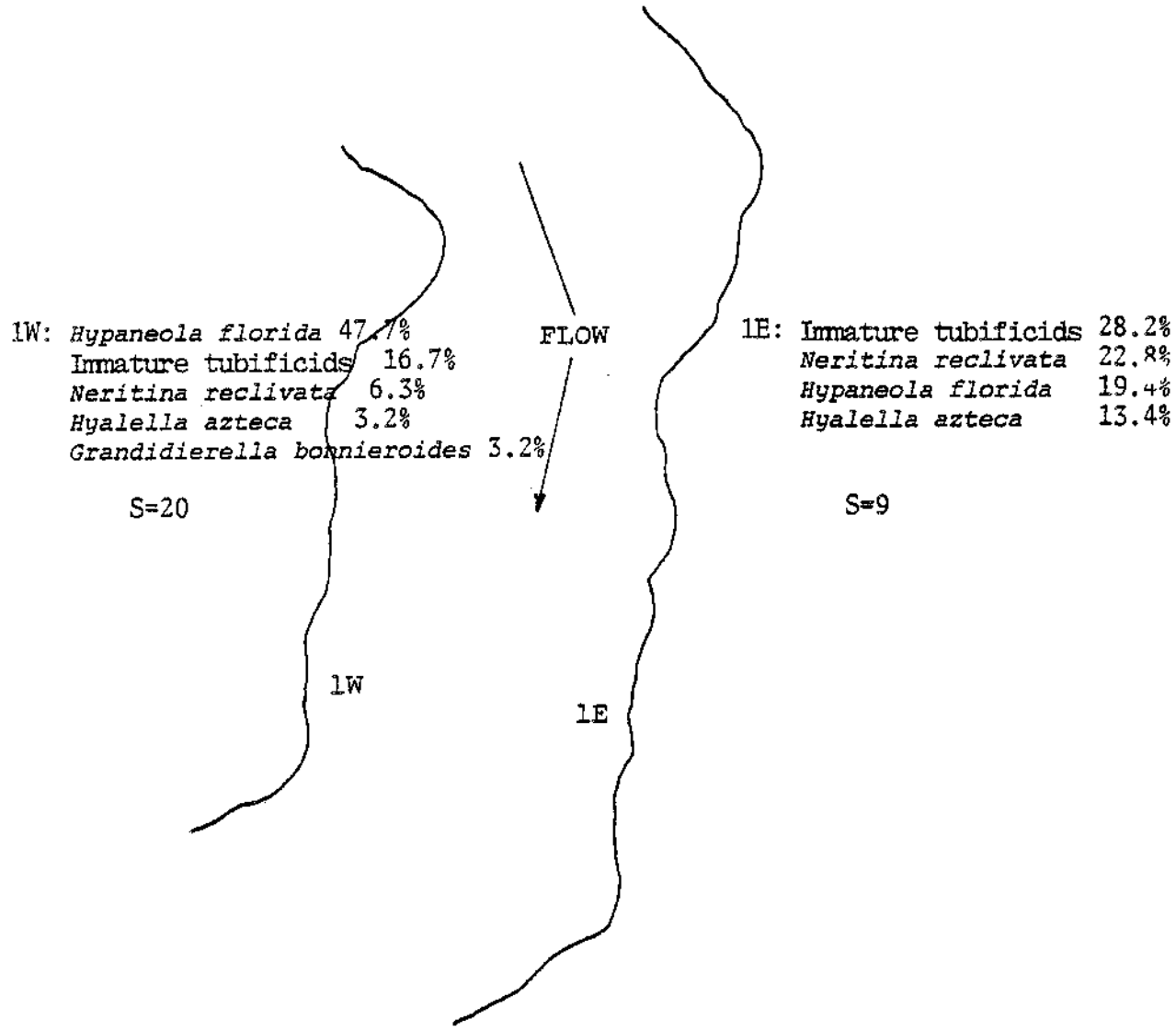


FIGURE 3.3 Dominant Fauna at Transect 2, Fall Quarter, 1979.
(Percentages based on total number/m^2)

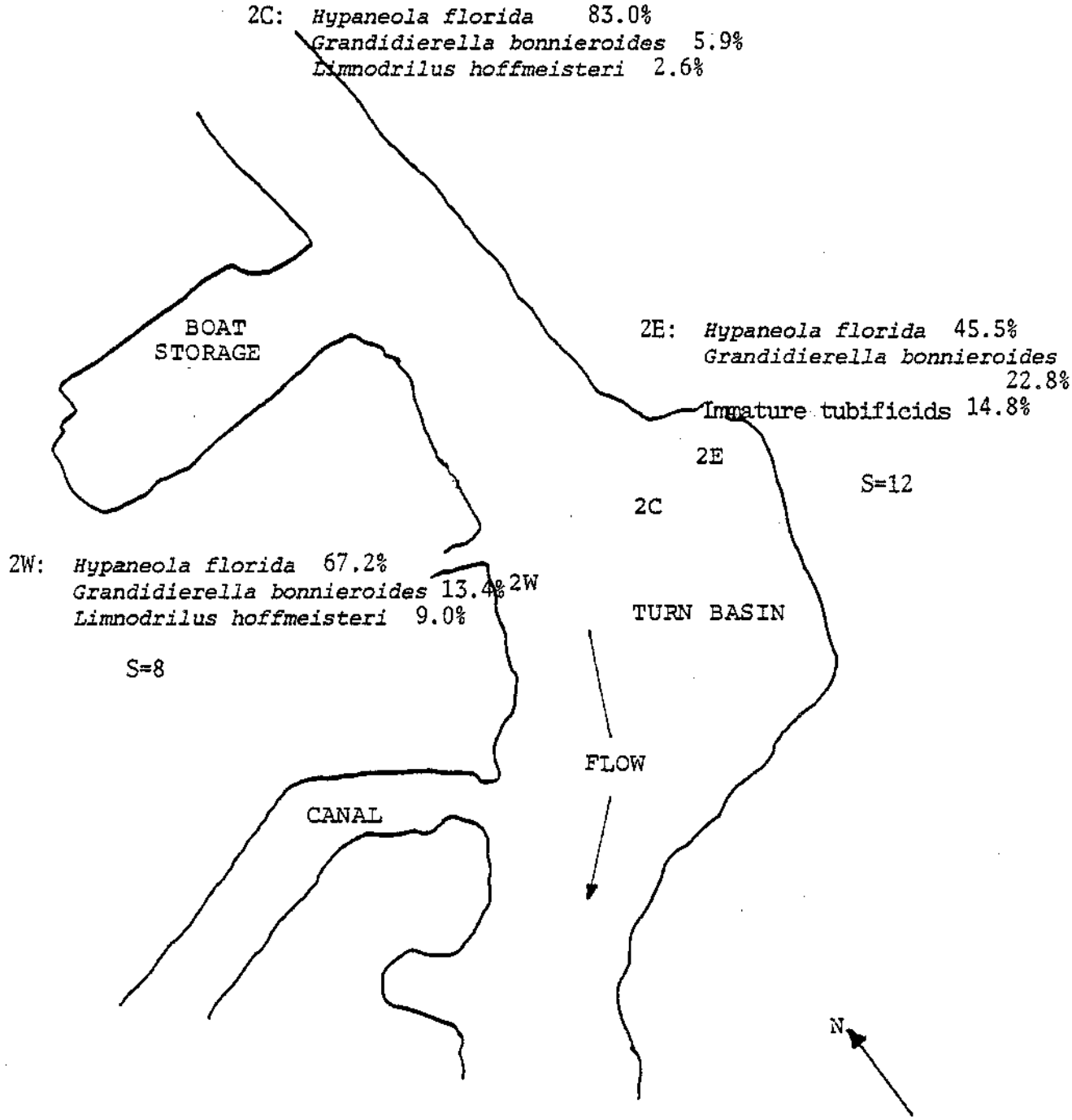


FIGURE 3.4 Dominant Fauna at Transect 3, Fall Quarter, 1979.
(Percentages based on total number/m^2)

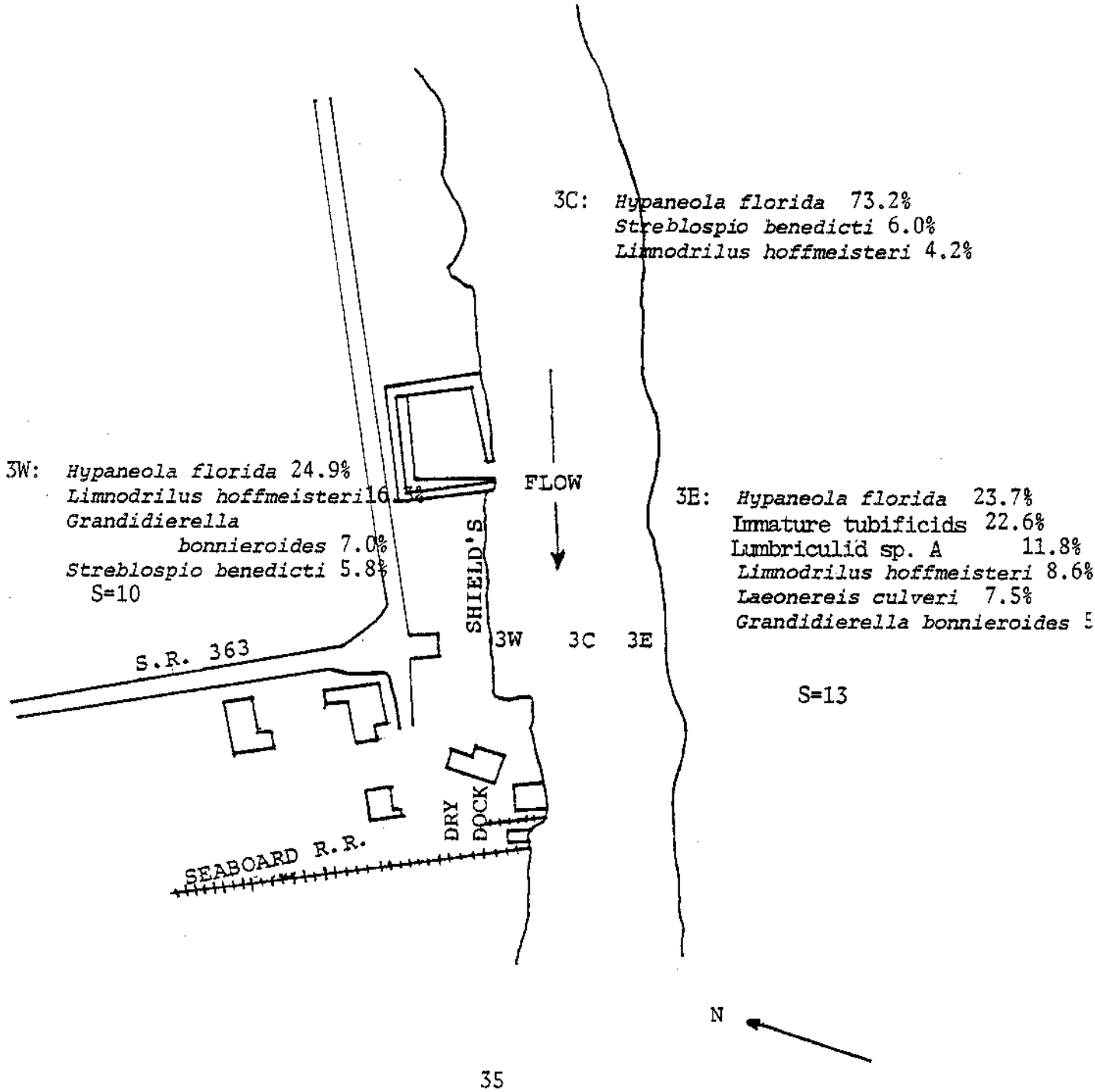


FIGURE 3.5 Dominant Fauna at Transect 4 Fall Quarter, 1979
(Percentages based on total number/m^2)

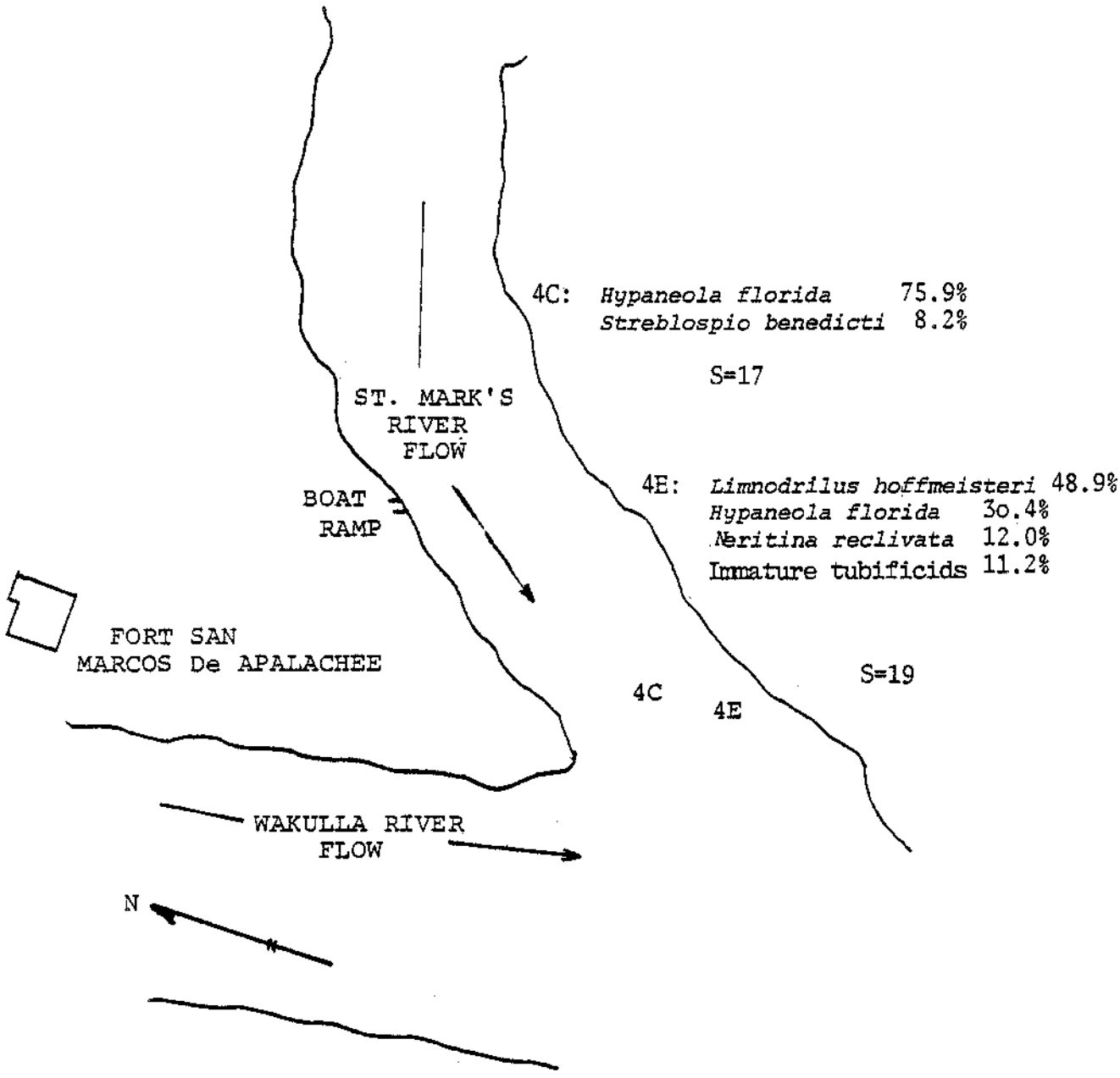


FIGURE 3.6 Dominant Fauna at Transect 5, Fall Quarter, 1979
(Percentages based on total number/m^2)

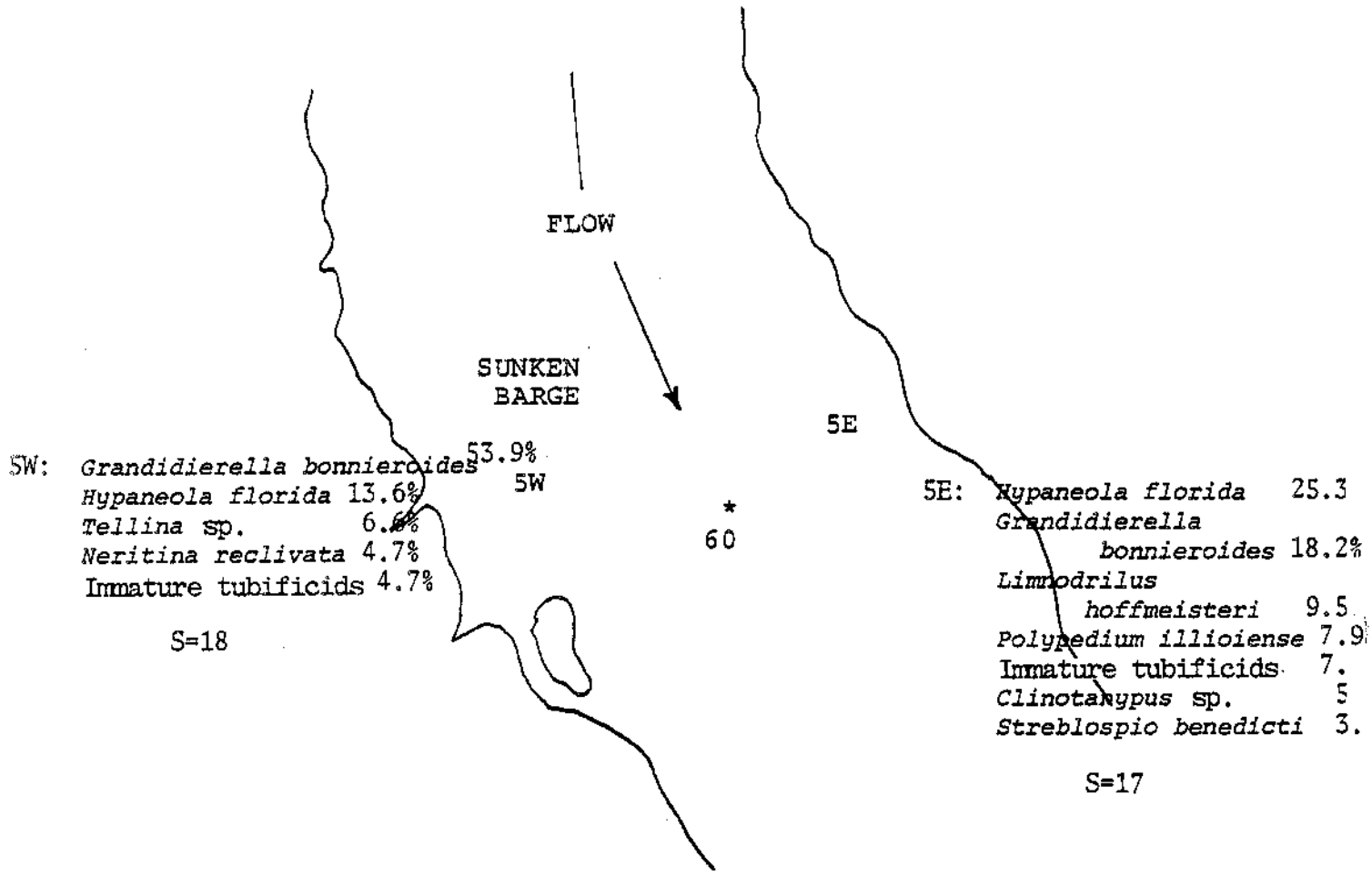


FIGURE 3.7 Dominant Fauna at Transect 6, Fall Quarter, 1979
(Percentages based on total number/m^2)

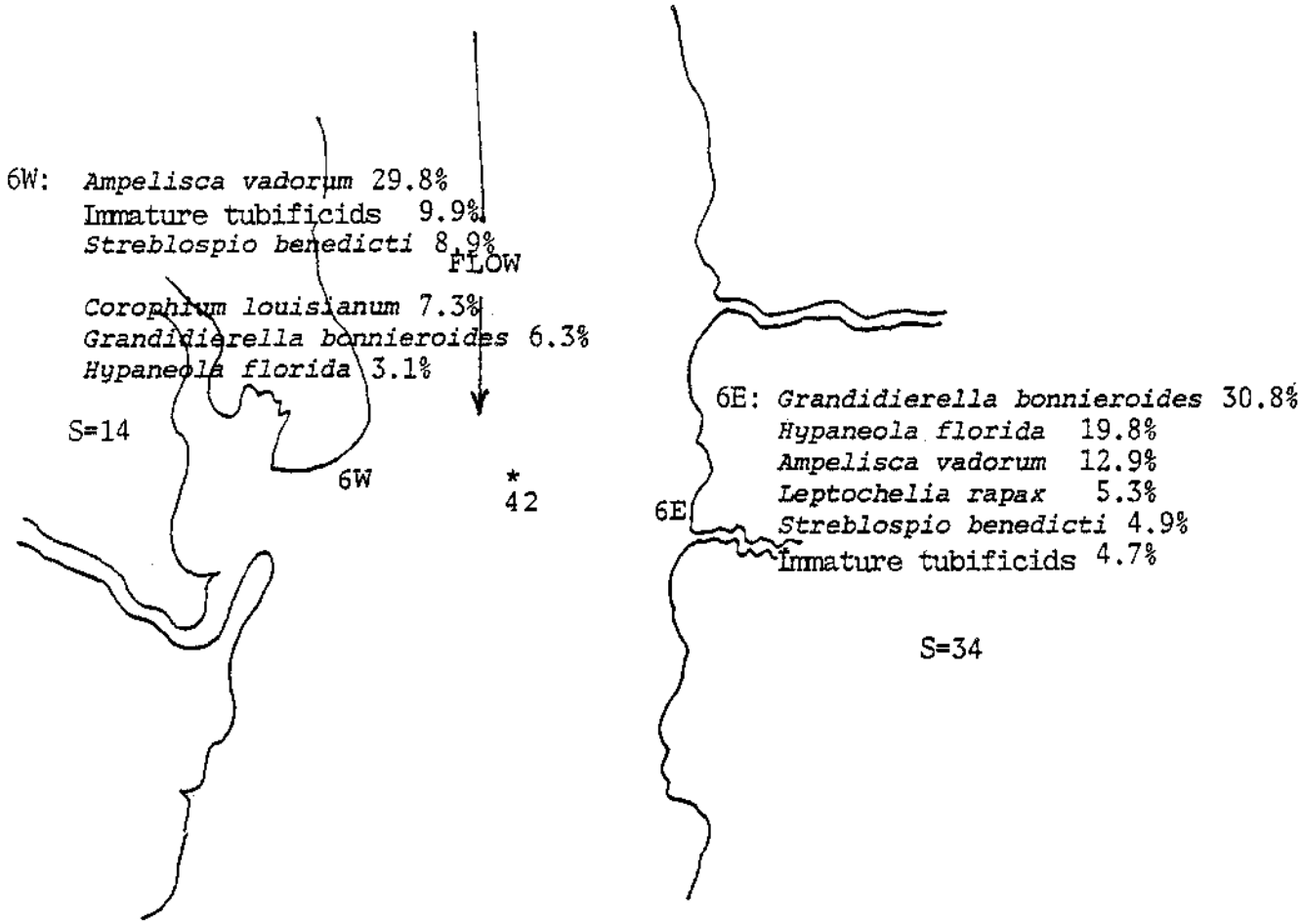


FIGURE 3.8 Dominant Fauna at Transect 1, Winter Quarter, 1980
(Percentage based on total number/m^2)

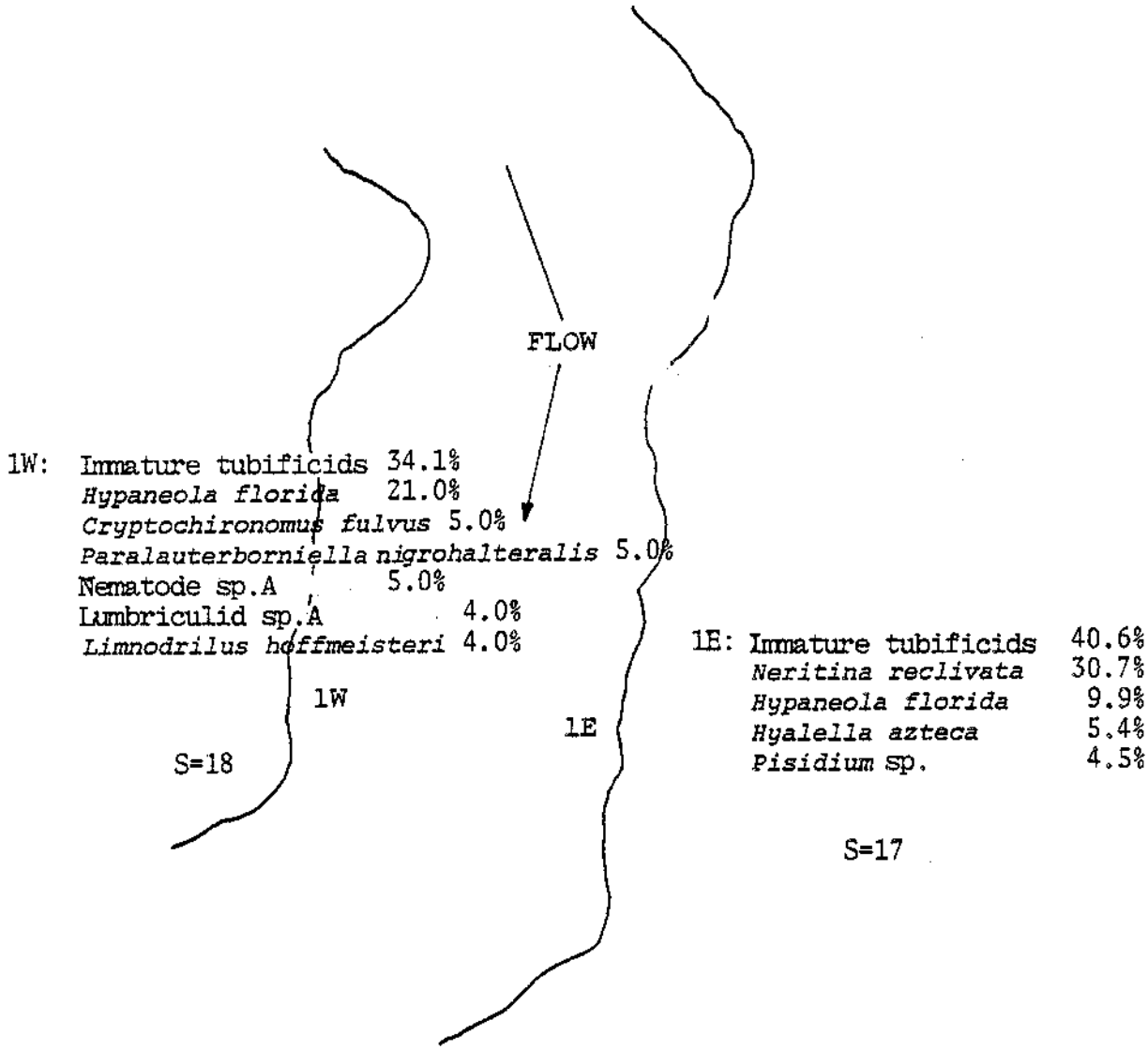


FIGURE 3.9 Dominant Fauna at Transect 2 Winter Quarter, 1980
(Percentages based on total number/m^2)

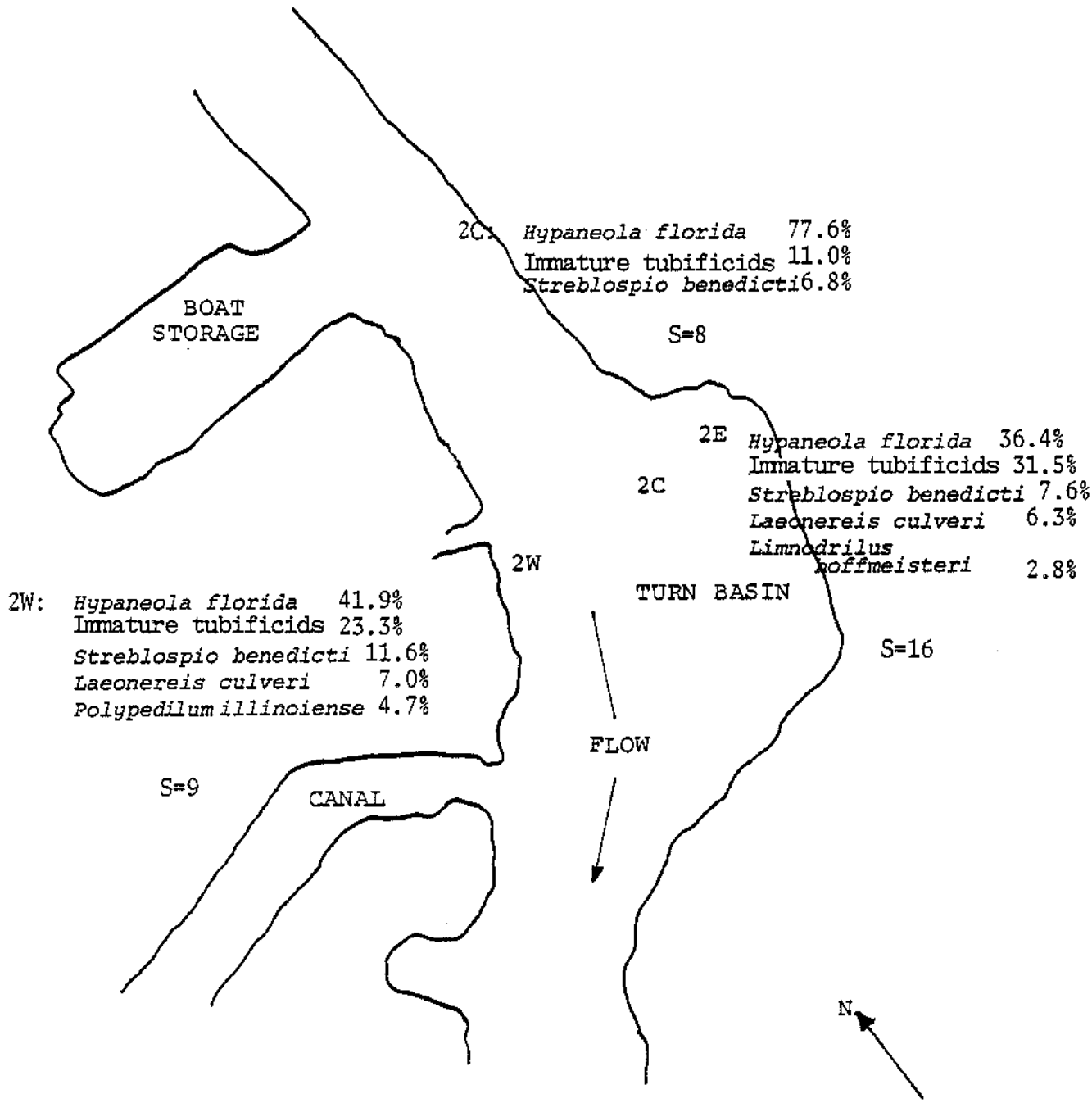


FIGURE 3.10 Dominant Fauna at Transect 3, Winter Quarter, 1980
(Percentages based on total number/m^2)

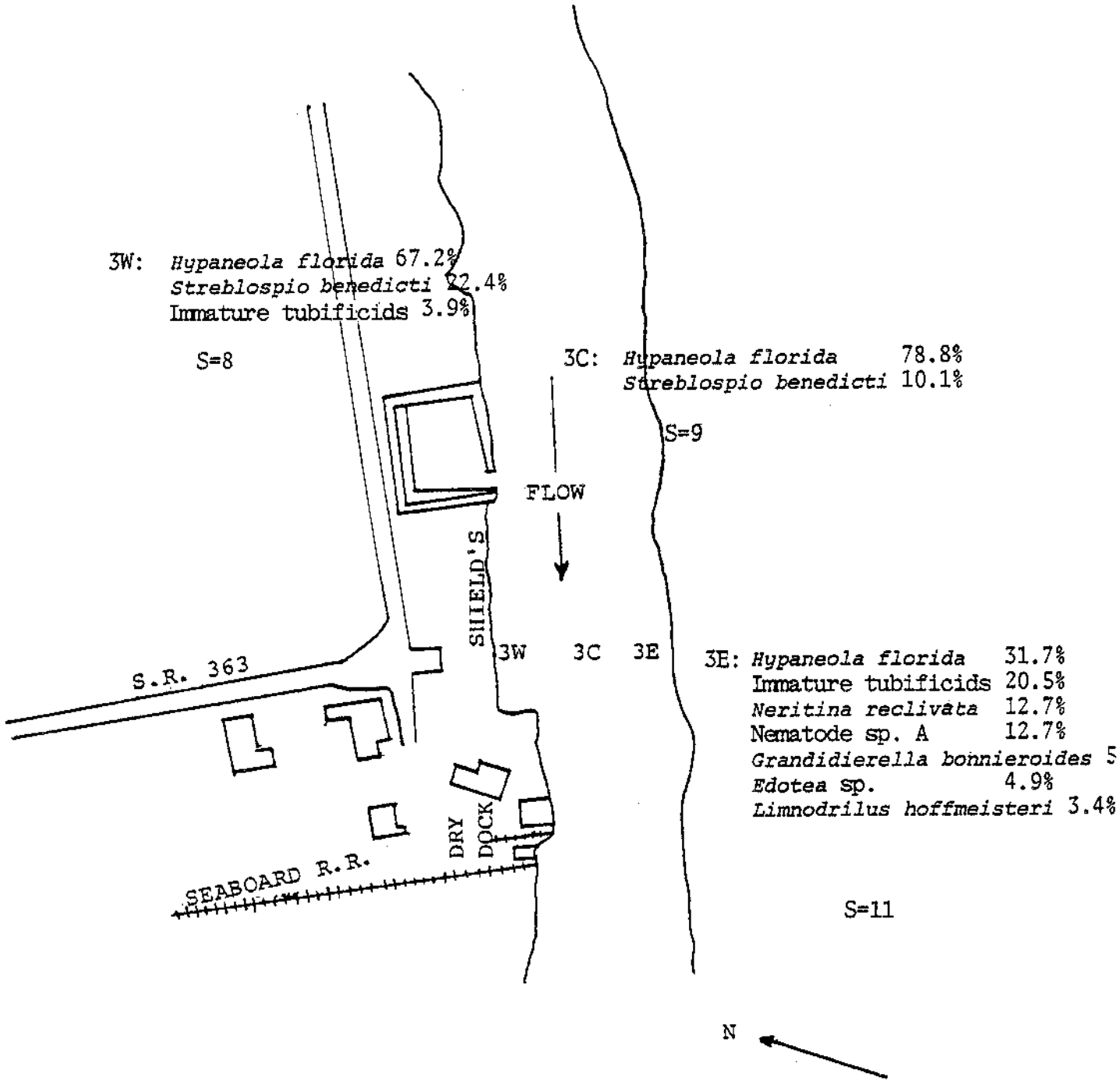


FIGURE 3.11 Dominant Fauna at Transect 4, Winter Quarter, 1980
(Percentages based on total number/m^2)

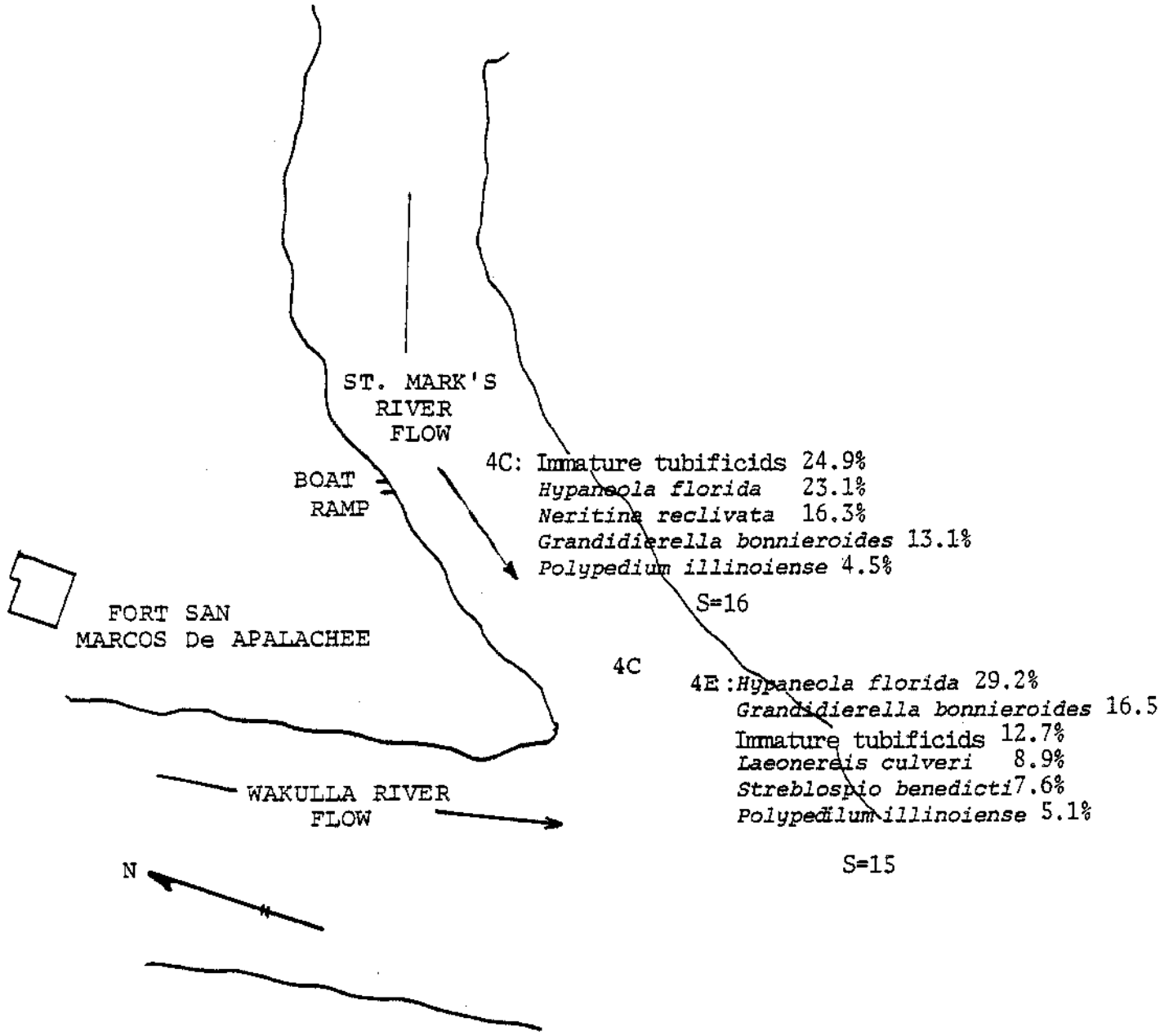


FIGURE 3.12 Dominant Fauna at Transect 5, Winter Quarter, 1980
(Percentages based on total number/m^2)

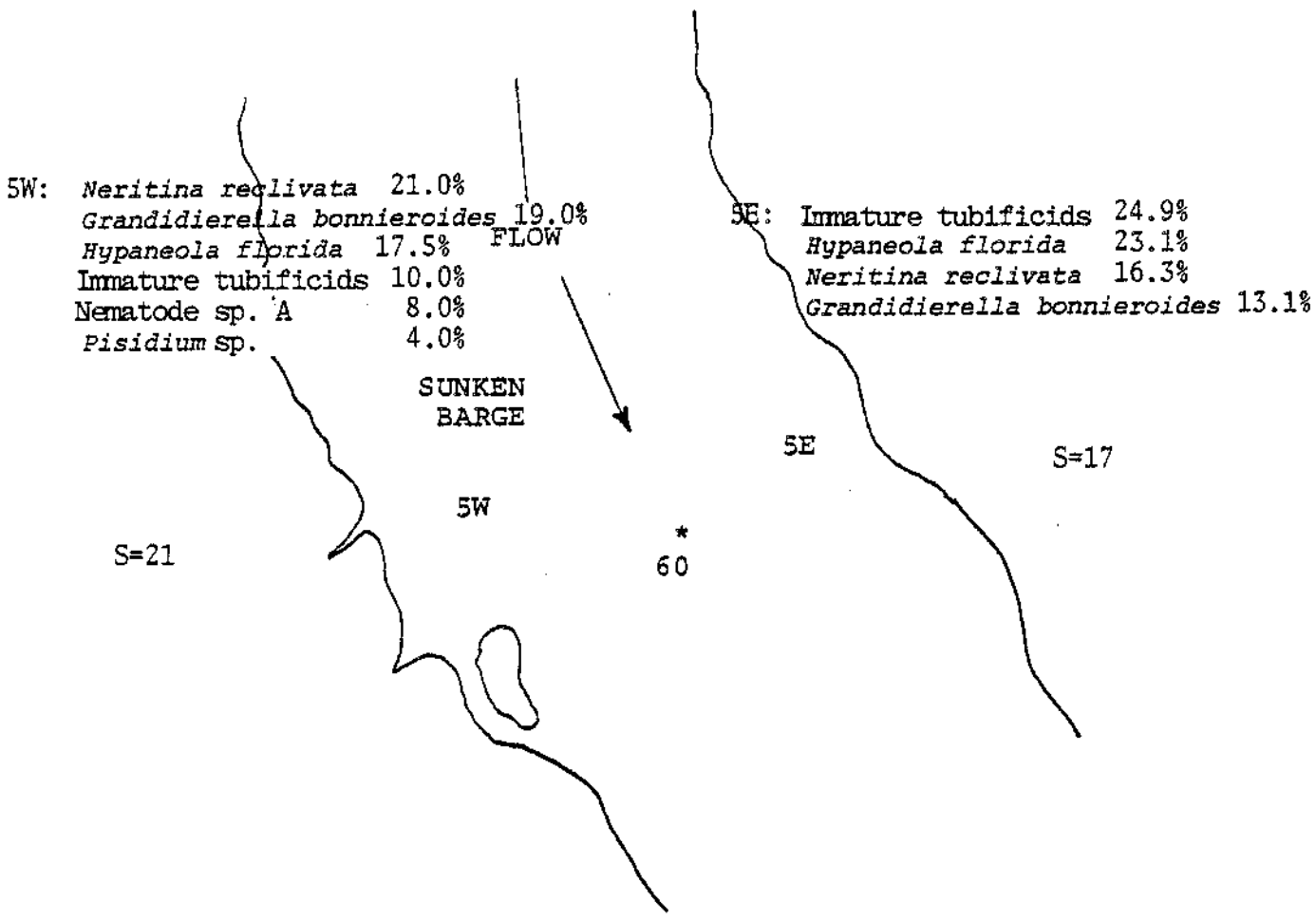


FIGURE 3.13 Dominant Fauna at Transect N, Spring Quarter, 1980
(Percentages based on total number/m^2)

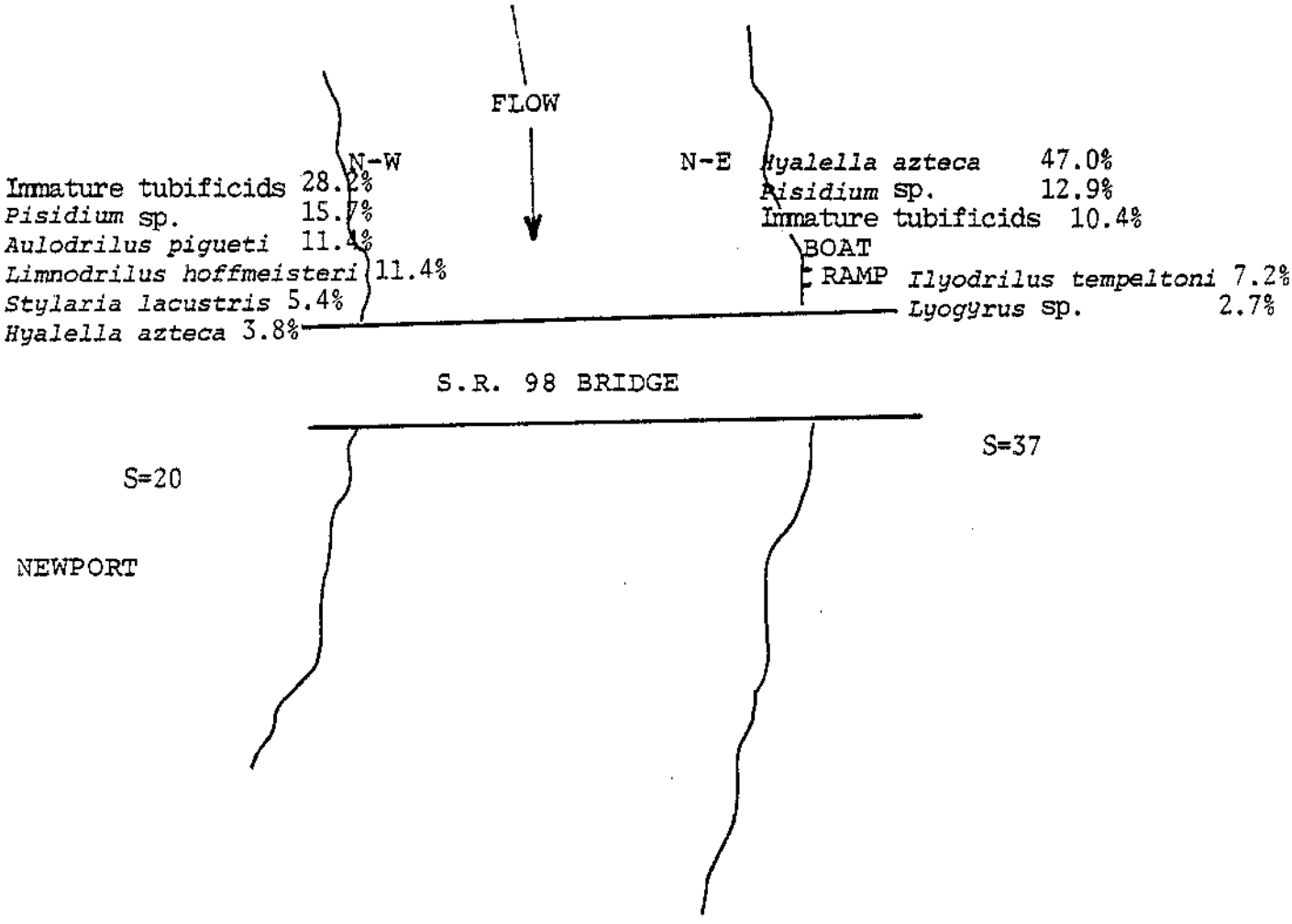


FIGURE 3.14 Dominant Fauna at Transect 1, Spring Quarter, 1980
(Percentage based on total number/m^2)

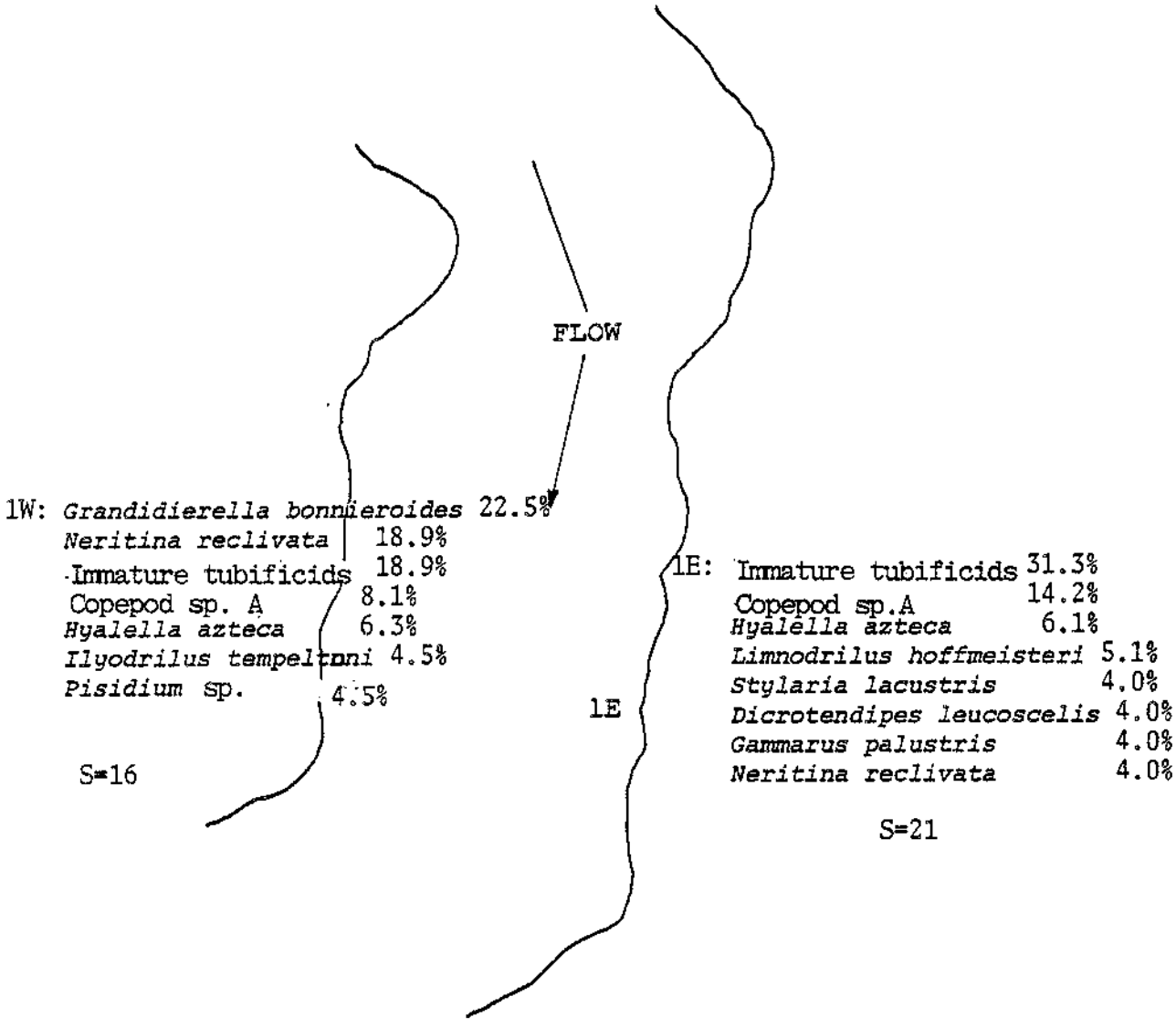


FIGURE 3.15 Dominant Fauna at Transect 2, Spring Quarter, 1980
(Percentages based on total number/m^2)

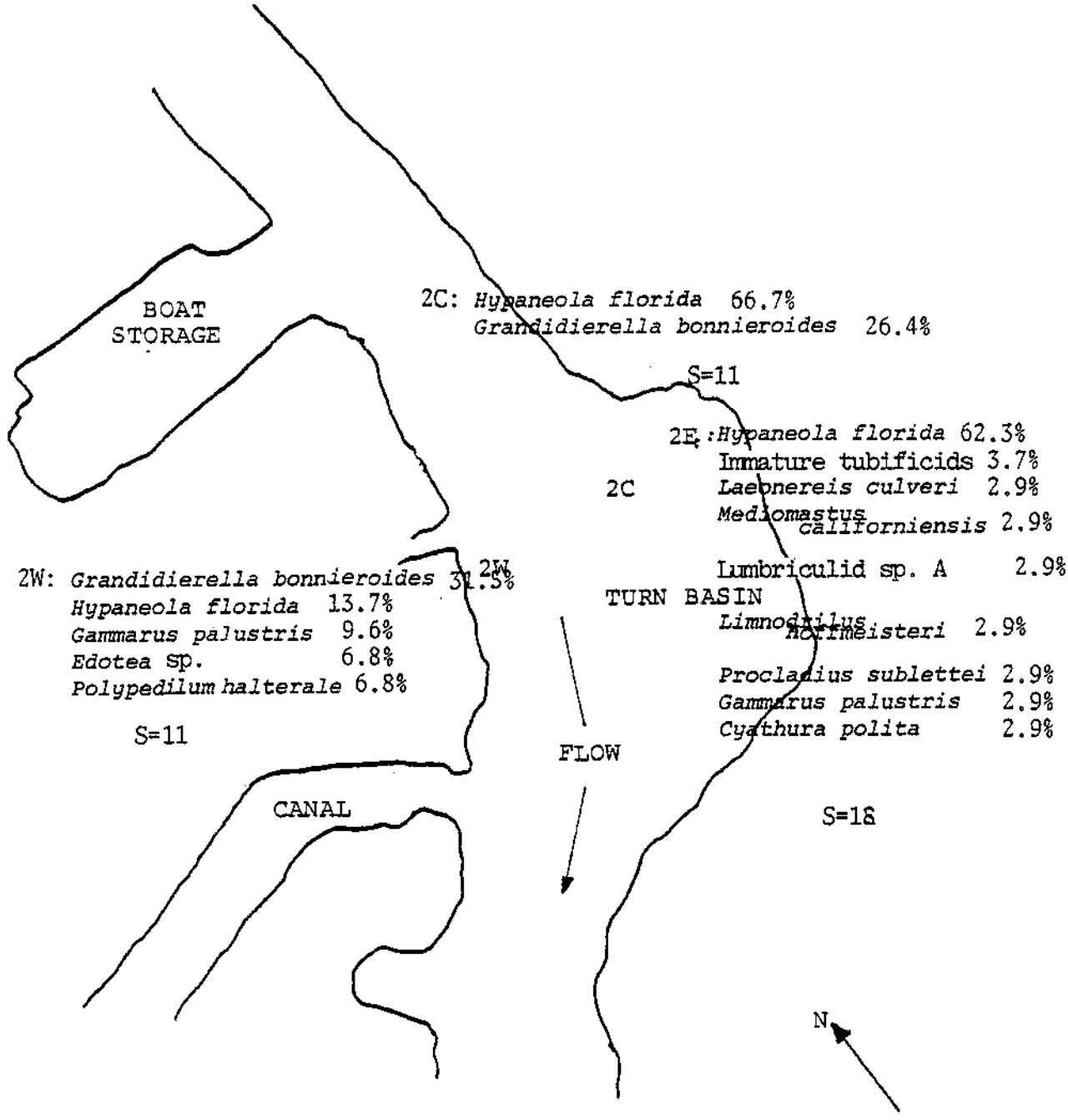


FIGURE 3.16 Dominant Fauna at Transect 3, Spring Quarter, 1980
(Percentages based on total number/m^2)

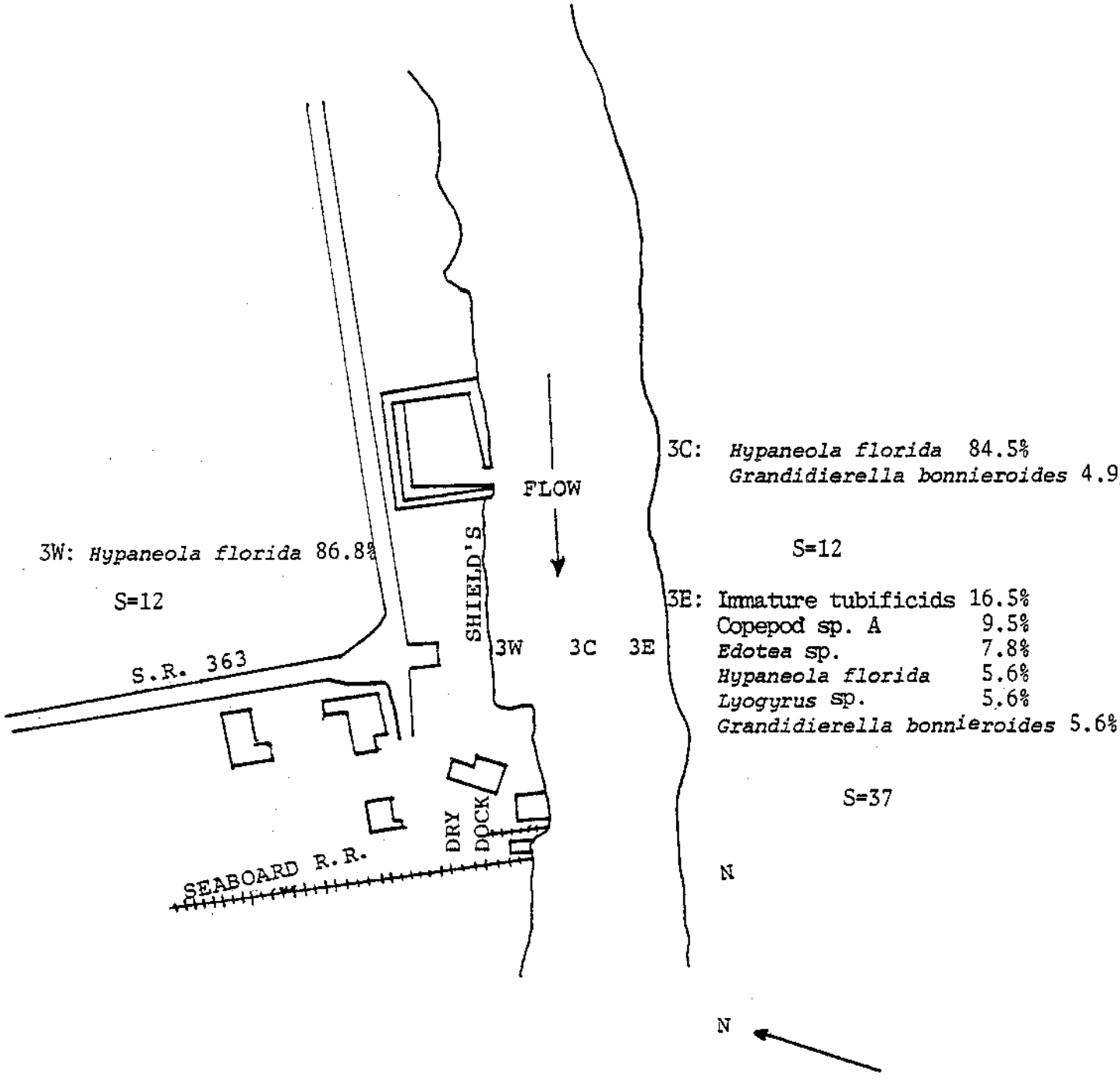


FIGURE 3.17 Dominant Fauna at Transect 4, Spring Quarter, 1980
(Percentages based on total number/m^2)

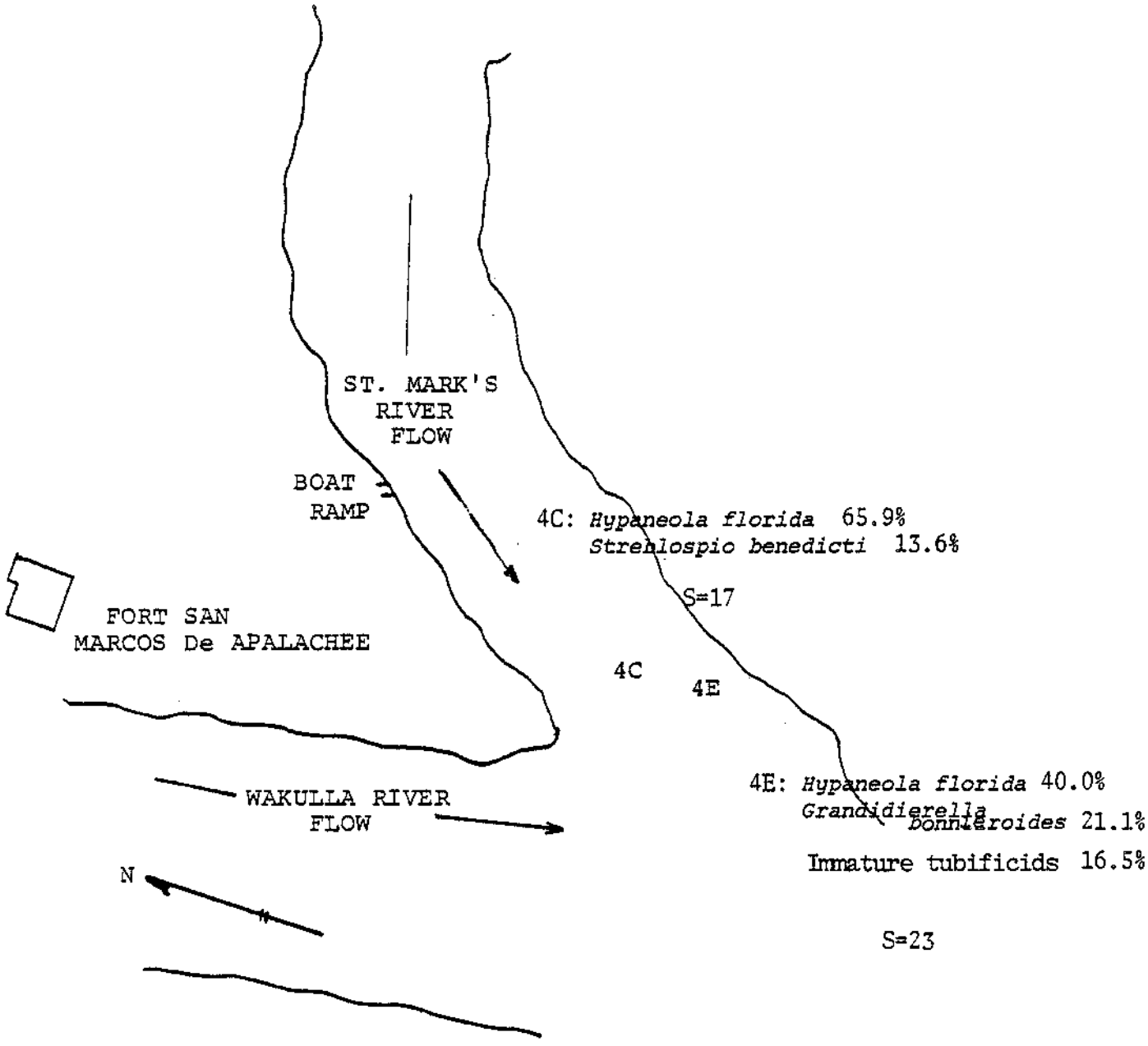


FIGURE 3.18 Dominant Fauna at Transect 5, Spring Quarter, 1980
(Percentages based on total number/m^2)

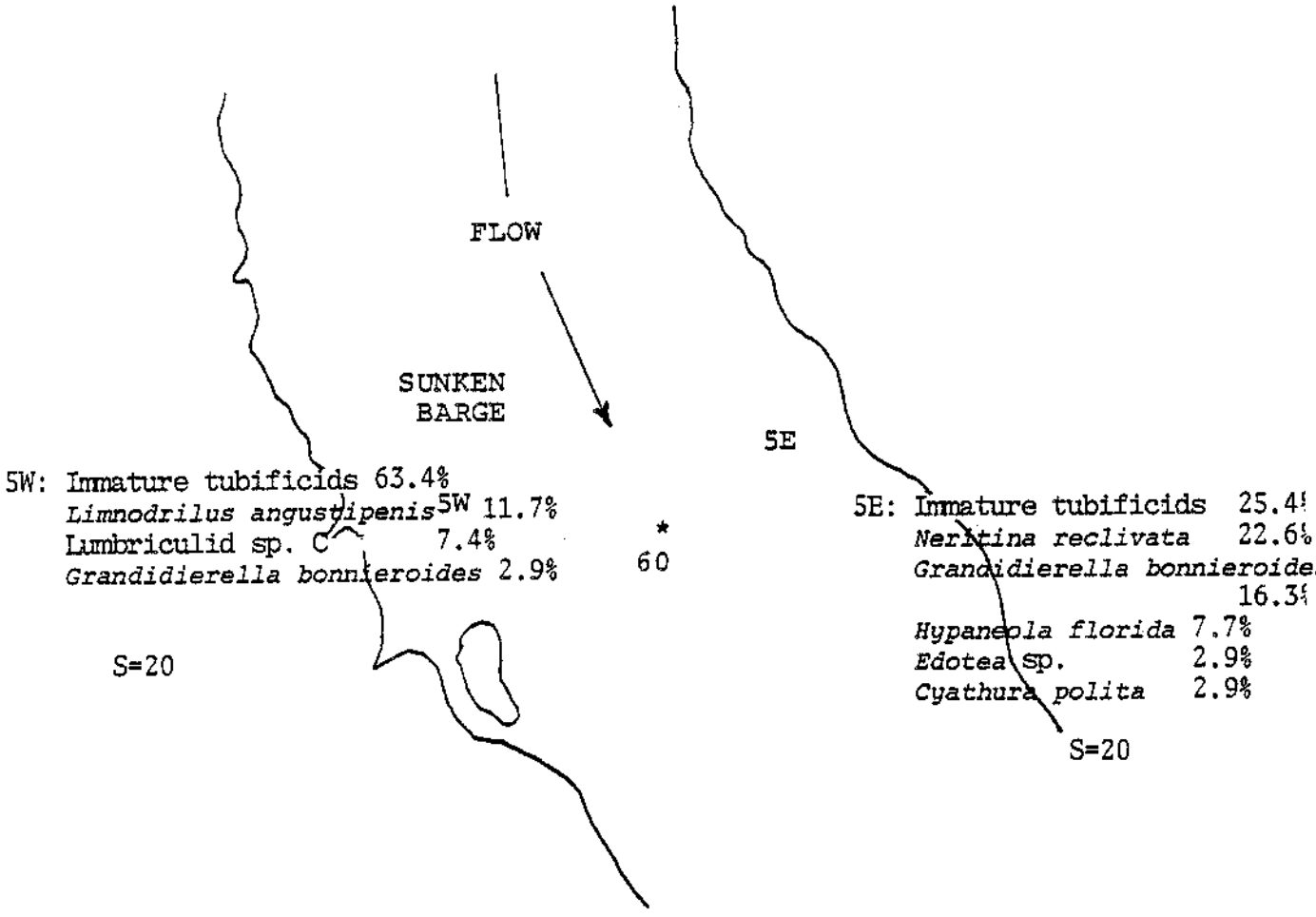


FIGURE 3.19 Dominant Fauna at Transect 6, Spring Quarter, 1980
(Percentages based on total number/m^2)

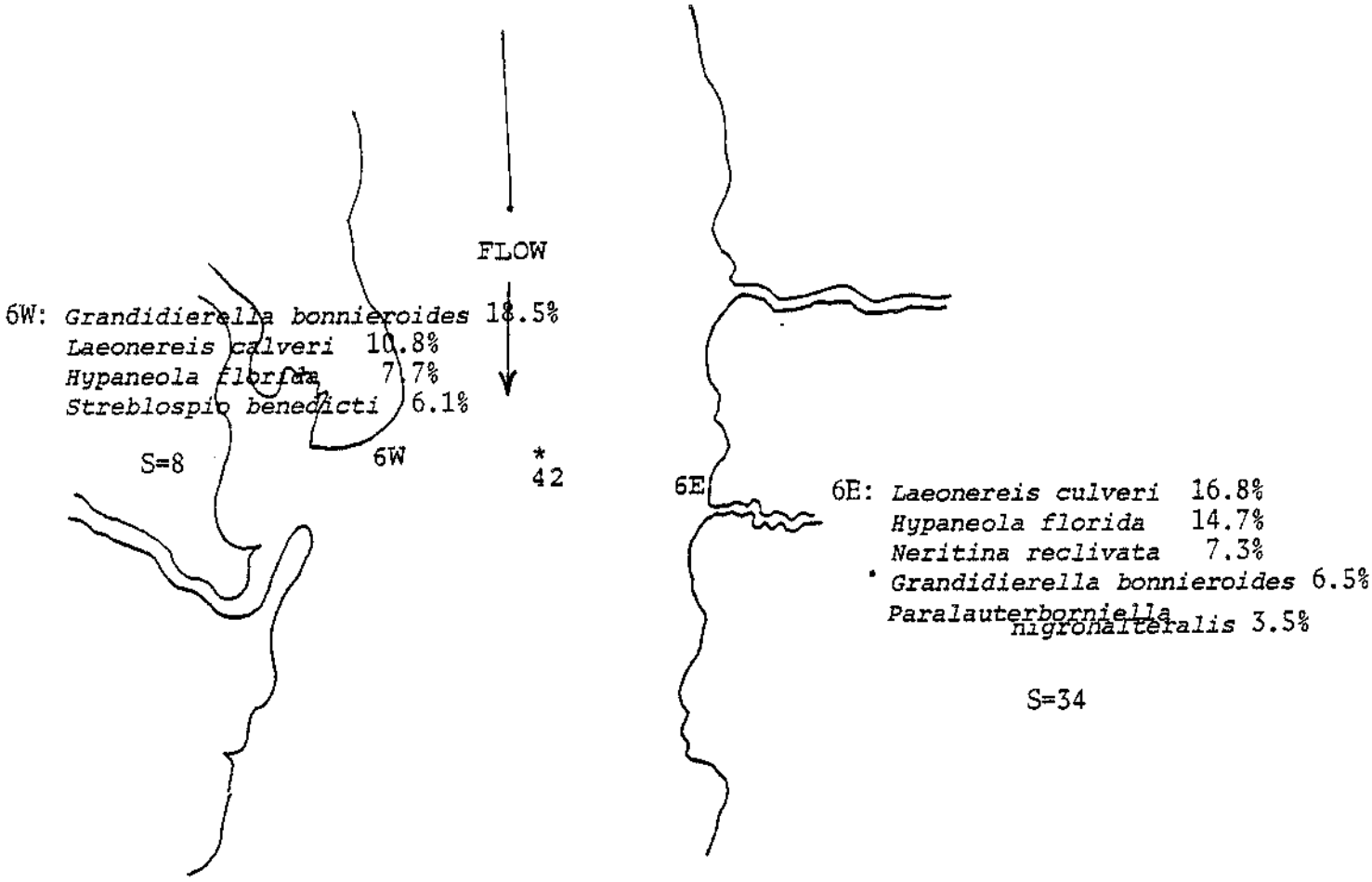


FIGURE 3.20 Dominant Fauna at Transect N, Summer Quarter 1980
(Percentages based on total number/m^2)

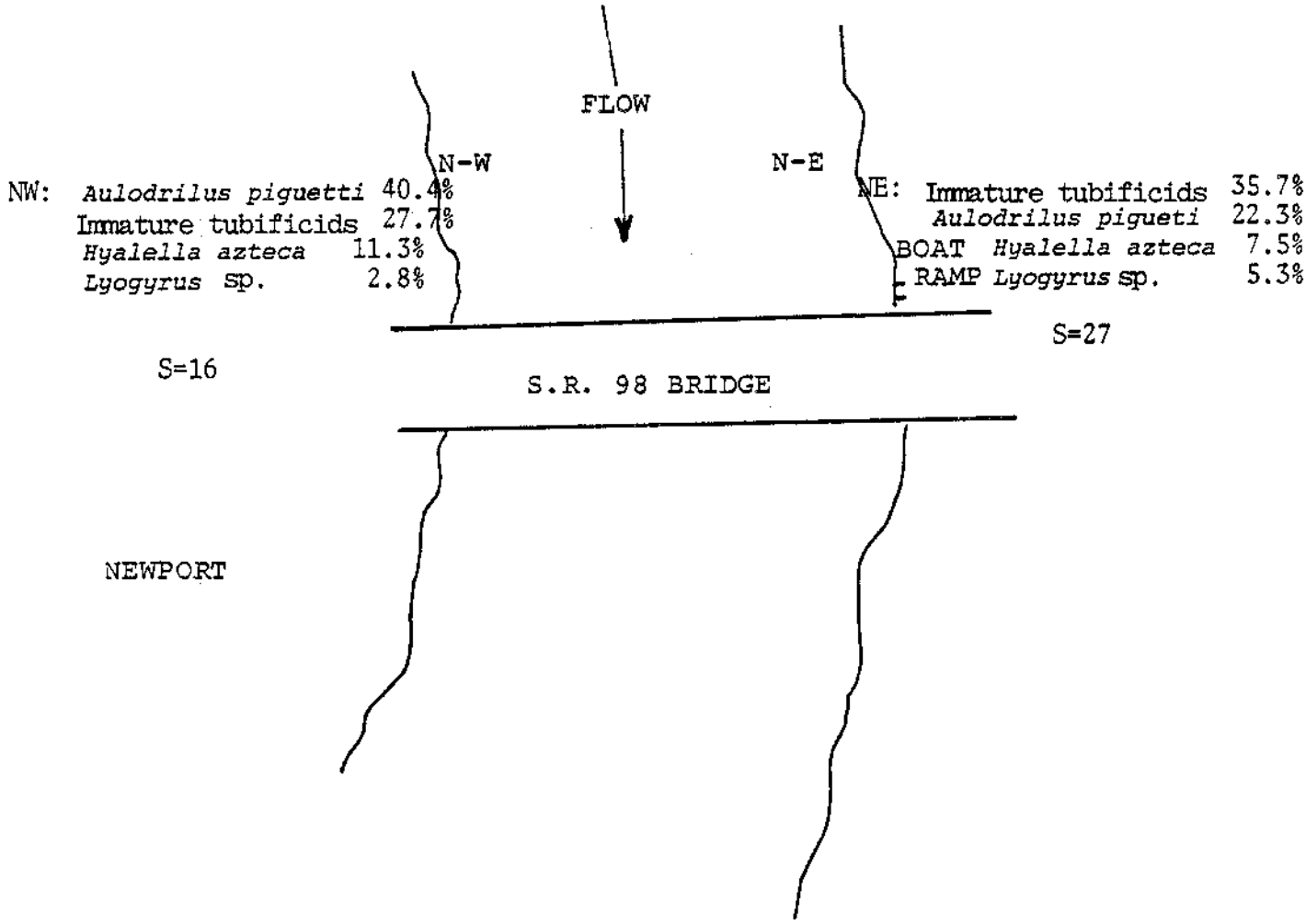
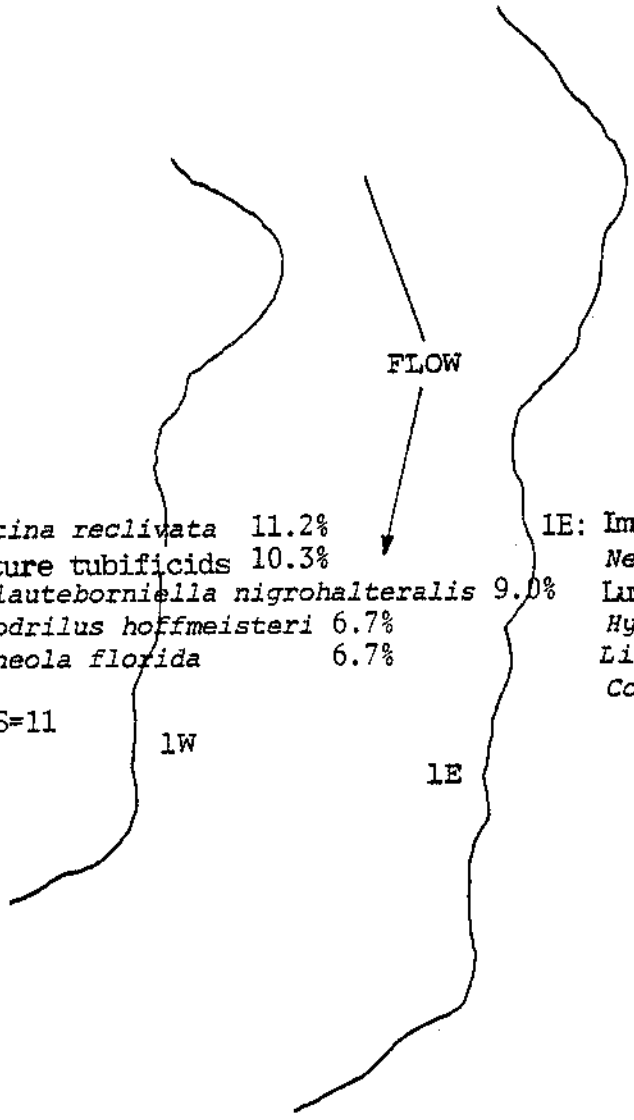


FIGURE 3.21 Dominant Fauna at Transect 1, Summer Quarter 1980
(Percentages based on total number/m^2)



1W: *Neritina reclivata* 11.2%
Immature tubificids 10.3%
Paralauteborniella nigrohalteralis 9.0%
Limnodrilus hoffmeisteri 6.7%
Hypaneola florida 6.7%

S=11

1E: Immature tubificids 46.4%
Neritina reclivata 12.0%
Lumbriculid sp. A 5.2%
Hypaneola florida 3.1%
Limnodrilus hoffmeisteri 2.9%
Coelotanypus concinnus 2.9%

S=18

FIGURE 3.22 Dominant fauna at Transect 2, Summer Quarter 1980
(Percentages based on total number/m^2)

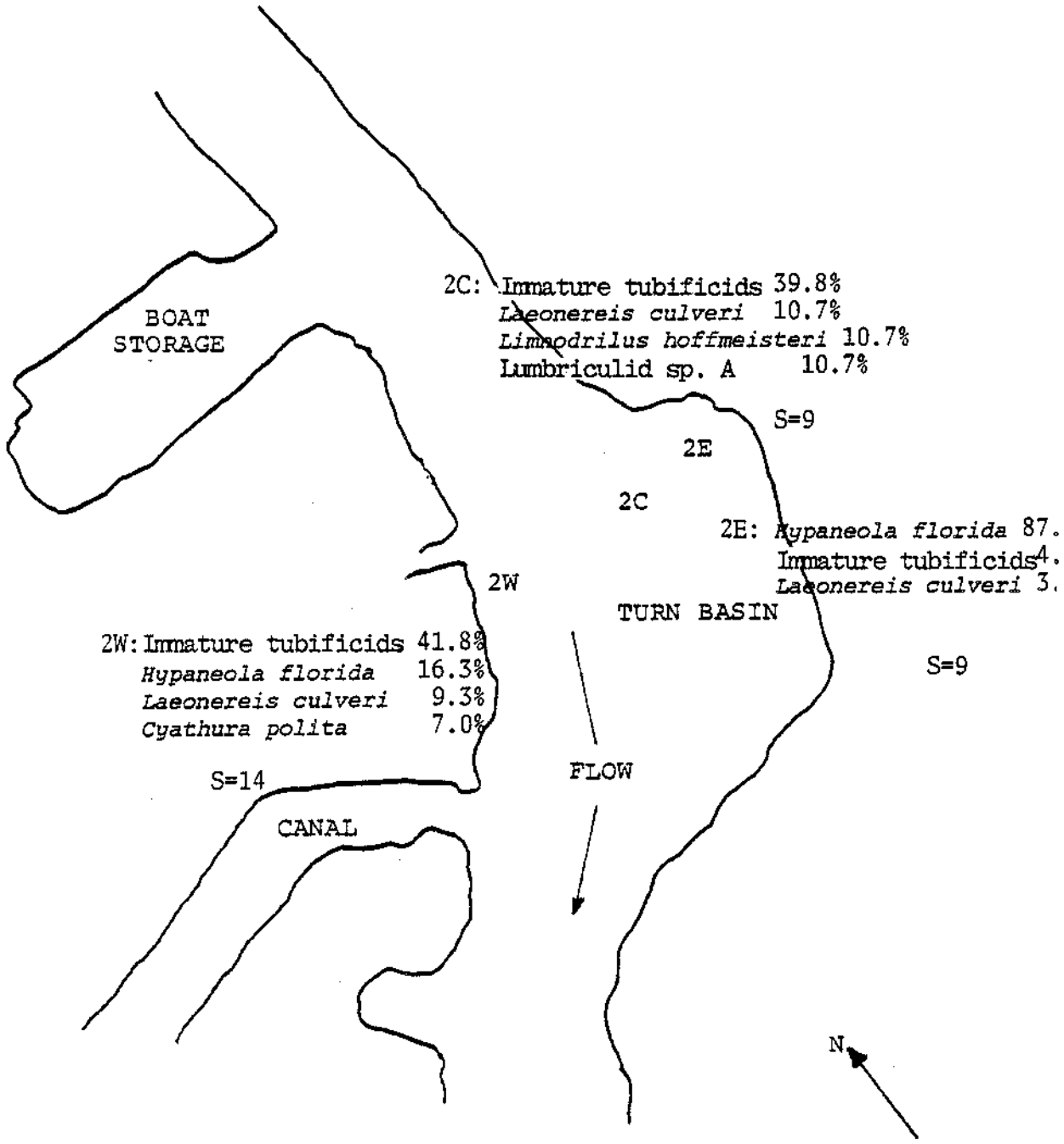


FIGURE 3.23 Dominant Fauna At Transect 3, Summer Quarter 1980
(Percentages based on total number/m^2)

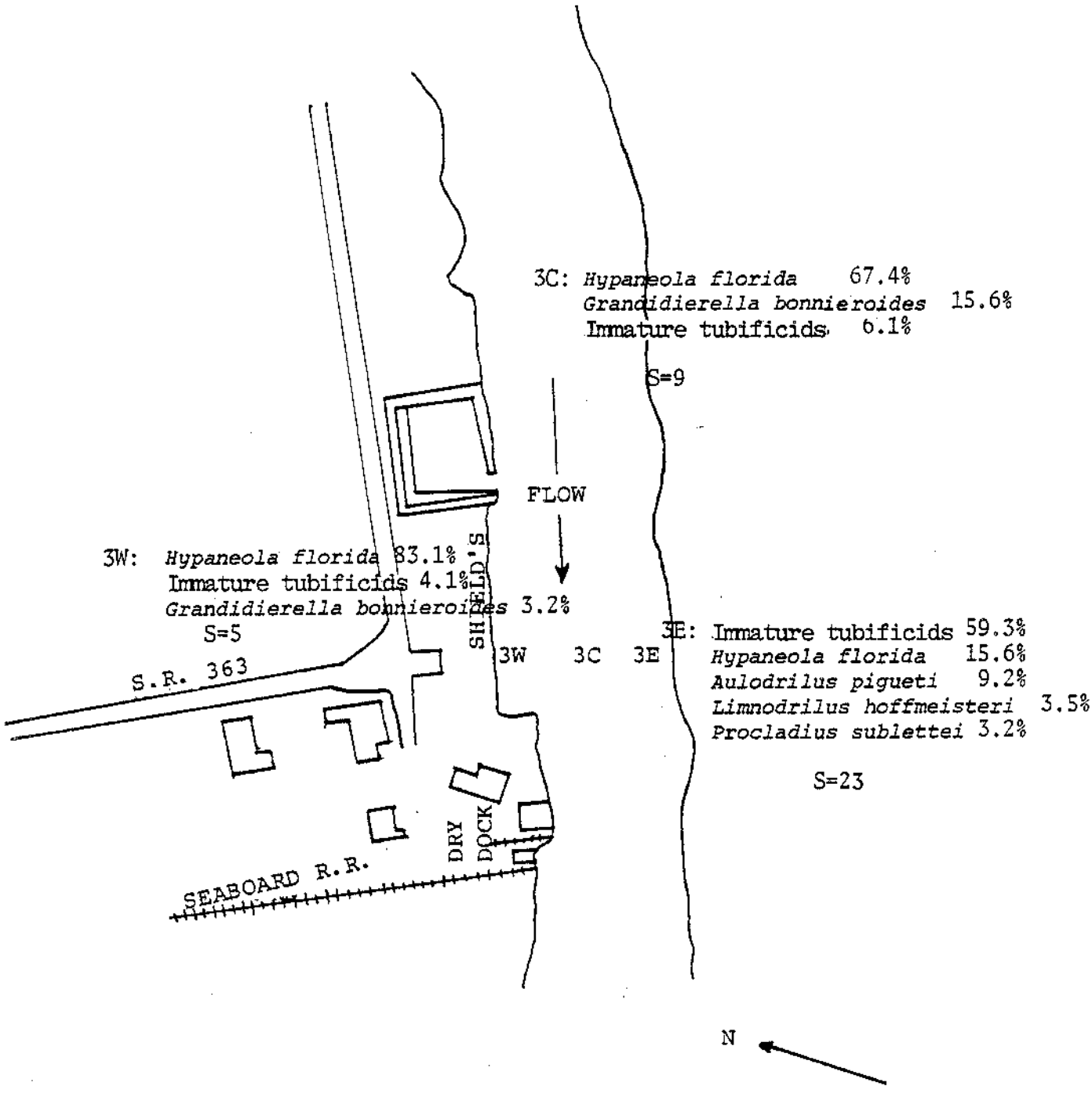


FIGURE 3.24 Dominant Fauna at Transect 4, Summer Quarter 1980
(Percentages based on total number/m^2)

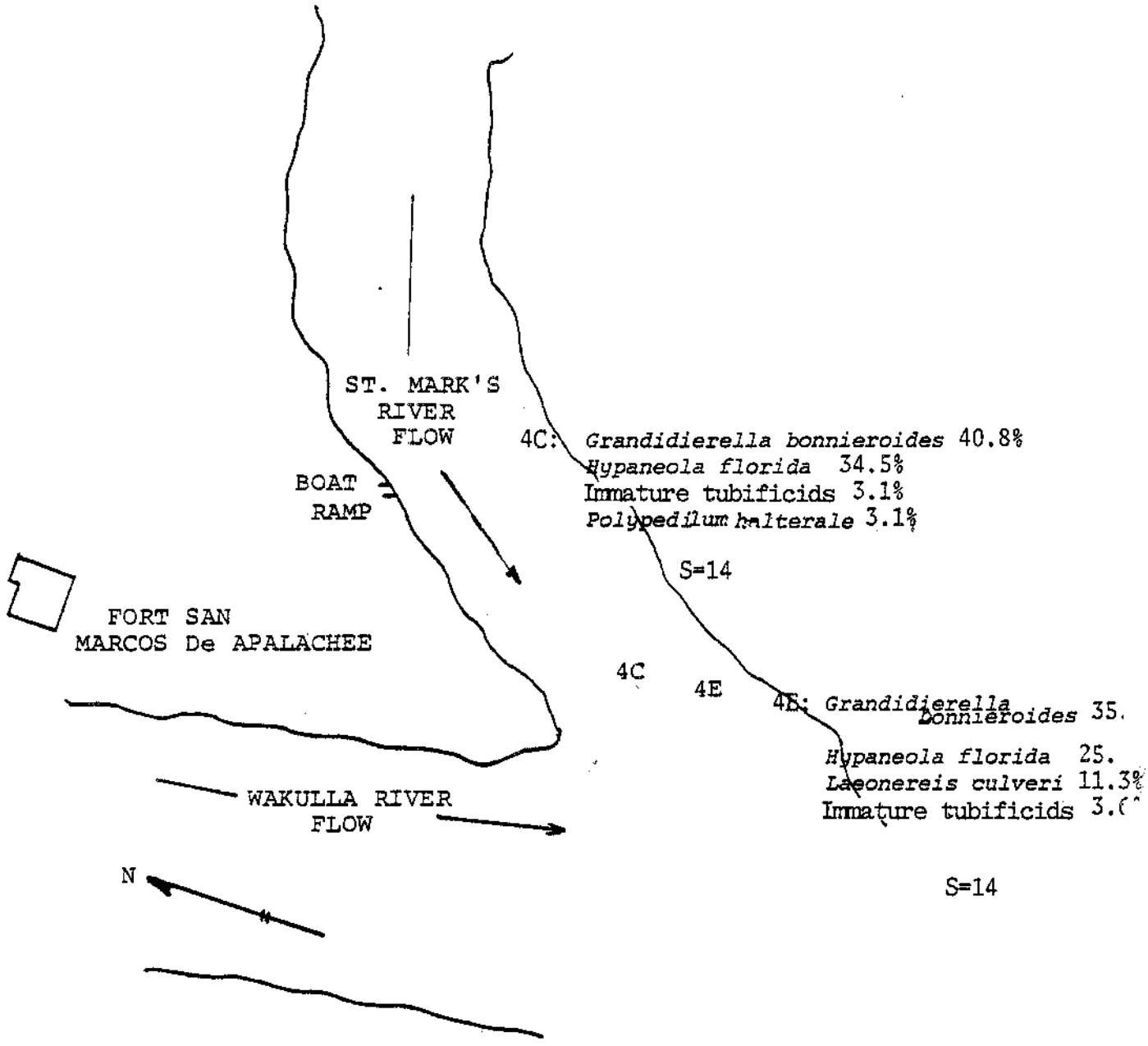


FIGURE 3.25 Dominant Fauna at Transect 5, Summer Quarter 1980
(Percentages based on total number/m^2)

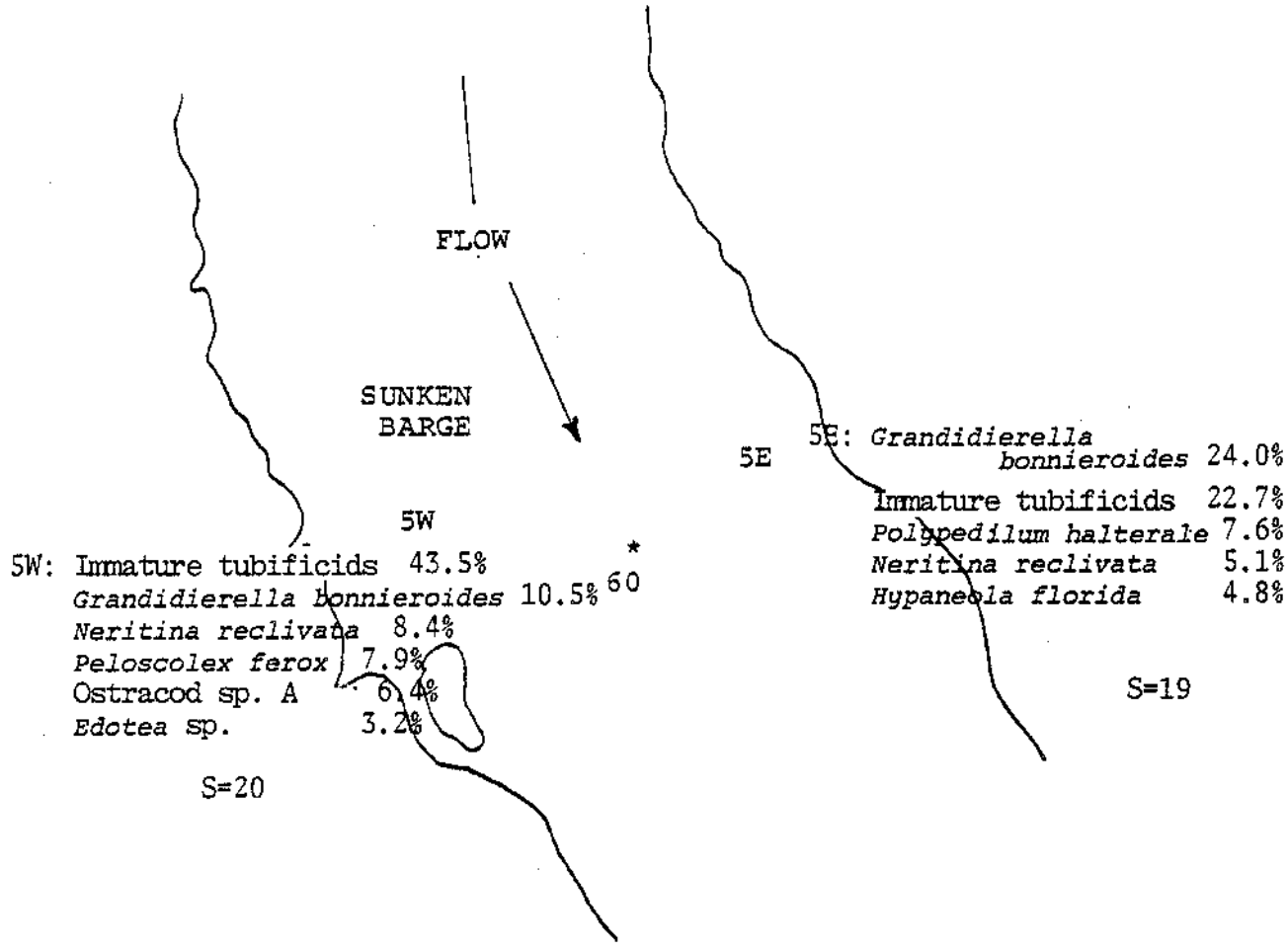


FIGURE 3.26 Dominant Fauna at Transect 6, Summer Quarter 1980
(Percentages based on total number/m^2)

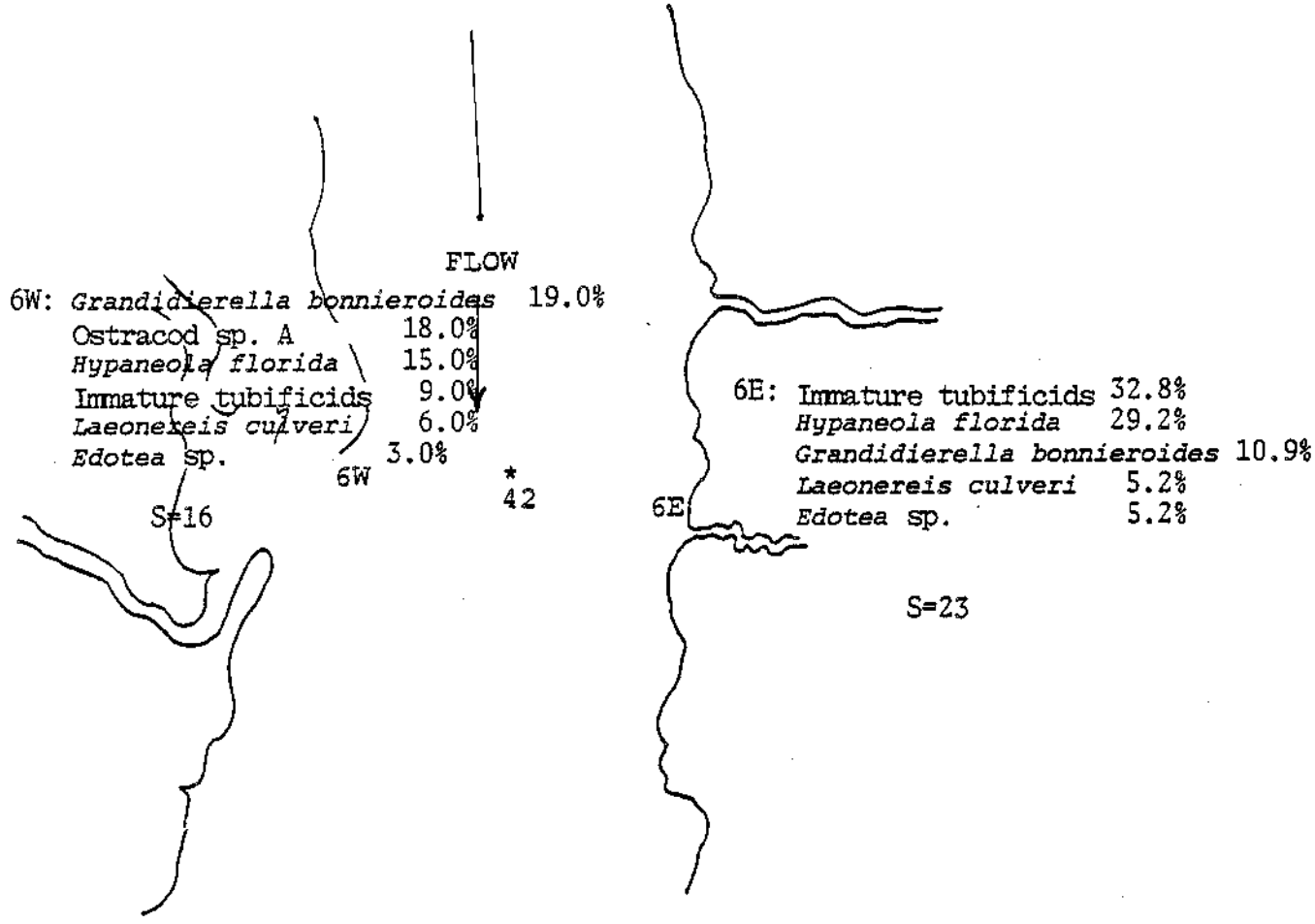


FIGURE 3.27 Seasonal Fluctuations in Total Numbers/m^2 (All Stations) of *Procladius sublettei*, *Polypedilum halterale* and *Clinotanypus* sp. A

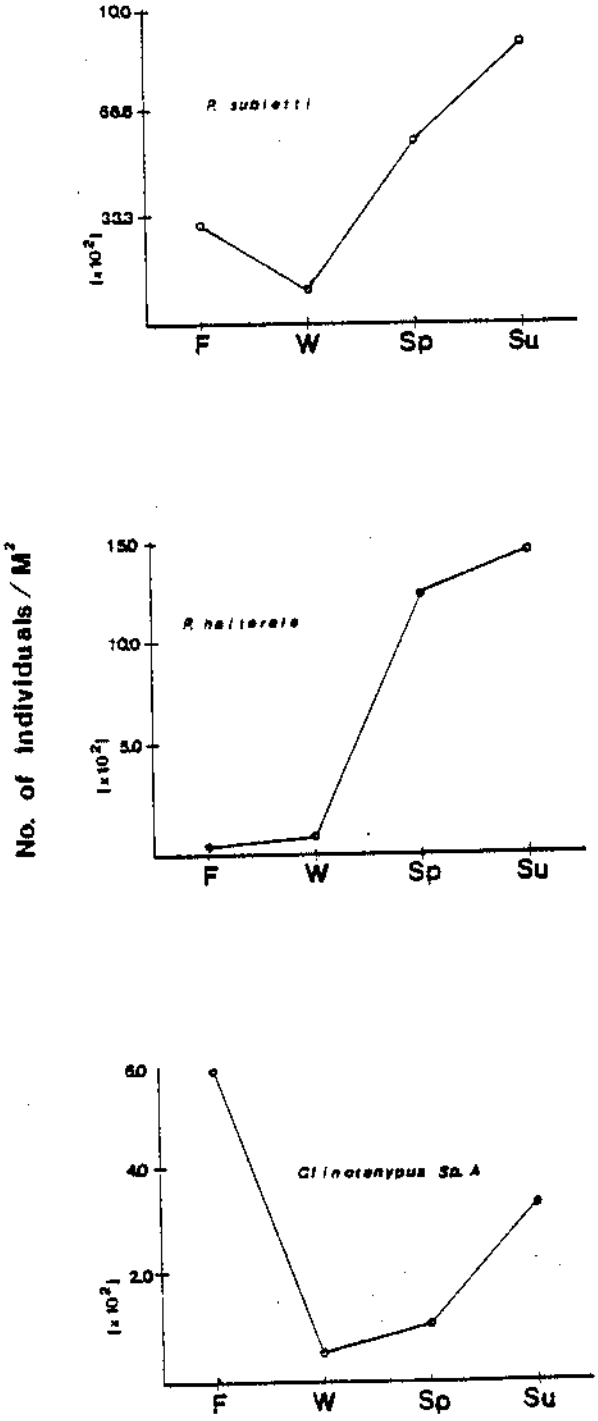


FIGURE 3.28 Seasonal Fluctuations in Total Numbers/m^2 (All Stations) of *Grandidierella bonnieroides, Gammarus mucronatus* and *Hyalella azteca*

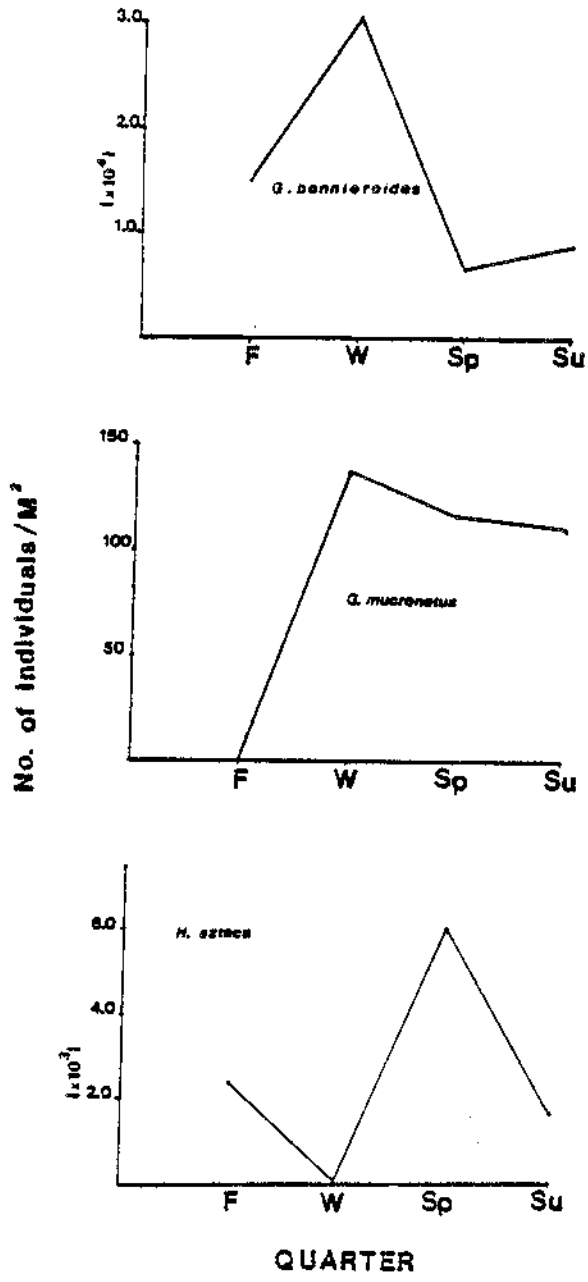


FIGURE 3.29 Seasonal Fluctuations in Total Numbers/m^2 (All Stations) of *Edotea sp.*, *Cyathura polita* and *Neritina reclivata*

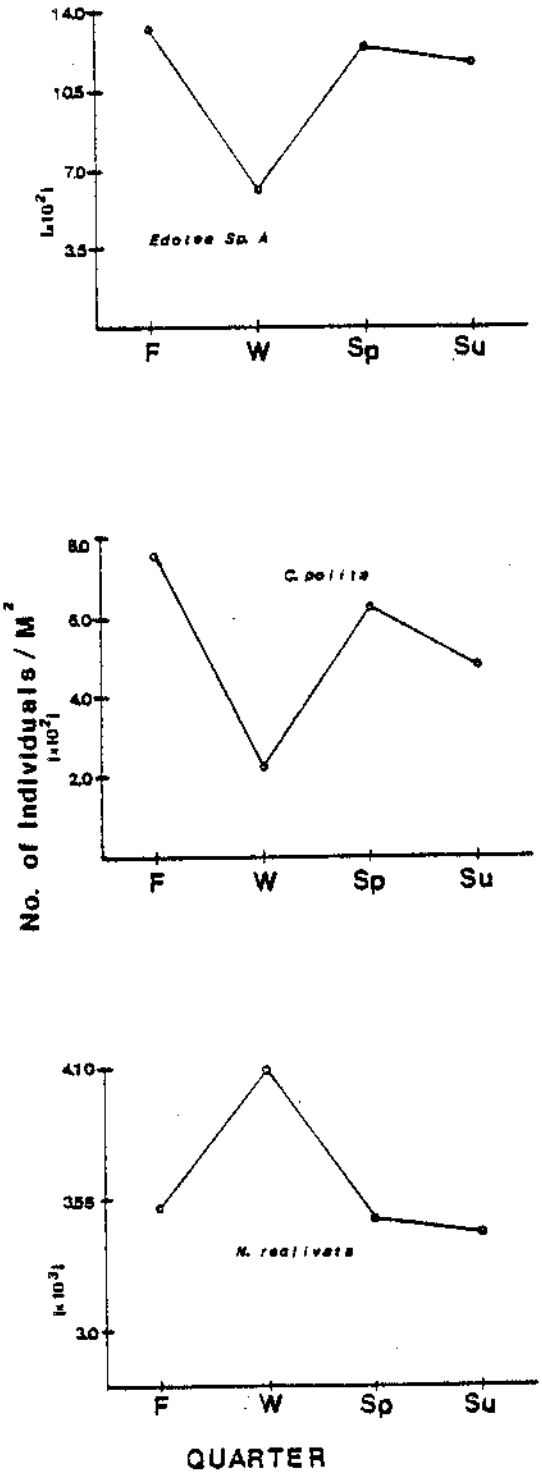


FIGURE 3.30 Seasonal Fluctuations in Total Numbers/m^2(All Stations) of *Hypaneola florida, Streblospio benedicti* and *Laeonereis culveri*

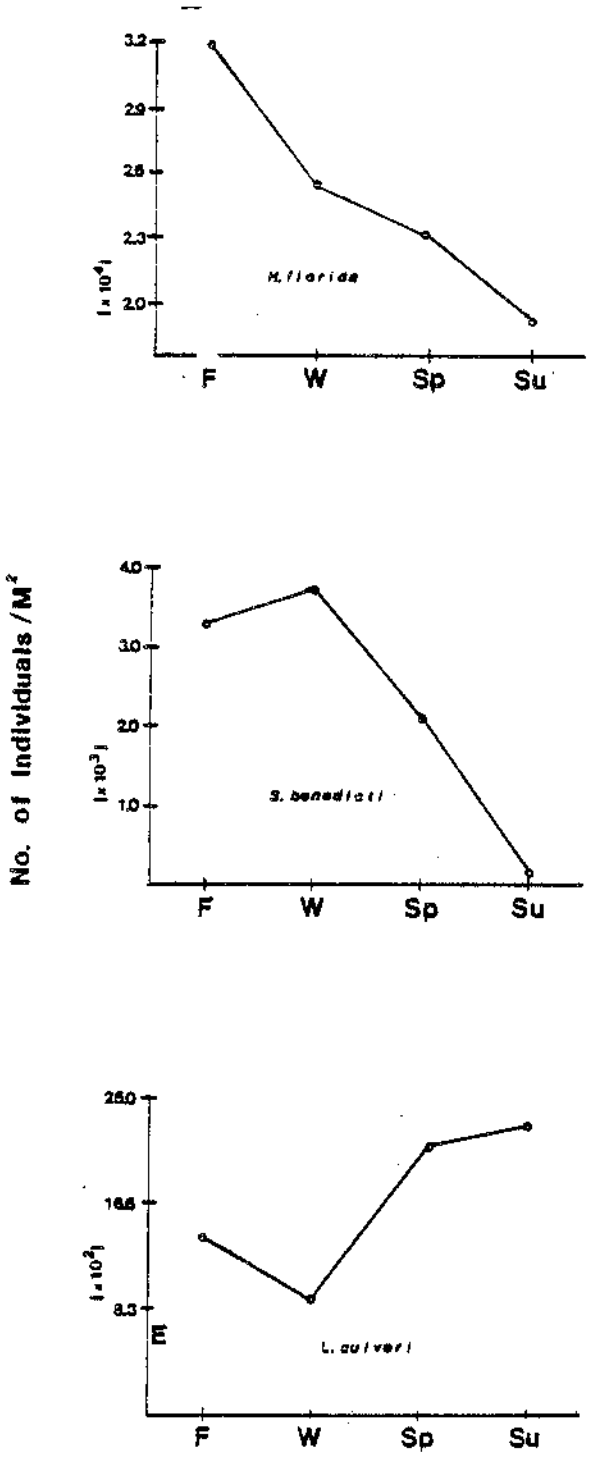


Table 3.1. No. of Individuals (Relative Abundance).

	Fall	Winter	Spring	Summer	TOTAL
Hypaneola florida	31.6%	47.7%	27.0%	11.3%	24.1%
Immature tubificids	11.4	15.0	17.8	15.3	14.9
Grandidierella bonnieroides	14.9	5.2	7.1	4.7	7.6
Neritina reclivata	3.5	7.0	3.7	1.8	3.3
Hyalella azeteca	2.4	0.3	6.6	0.9	2.4
Streblospio benedicti	3.3	6.4	2.2	0.1	2.1
Limnodrilus hoffmeisteri	3.5	1.2	1.1	1.0	1.6
Aulodrilus piguetti	0.3	0.1	0.9	3.0	1.6
Laeonereis culveri	1.4	1.6	2.2	1.2	1.5

Table 3.2. Summary: Numbers of Species and Faunal Densities

Station	S		No./m^2		
	(max)	(min)	(max)	$\bar{x}$	(min)
*NE	37 (Sp)	20 (F)	11,914 (Sp) 11,315 (Su)	9,949	6,619 (F)
*NW	20 (Sp) (F)	16 (Su)	5,847 (F) 5,077 (Sp)	4,932	3,872 (Su)
1E	21 (Sp)	9 (F)	9,549 (Su)	5,561	3,046 (W) 3,100 (S)
1W	20 (F)	11 (Su)	3,478 (Sp)	3,239	2,742 (W) 2,796 (Su)
2E	16 (W)	9 (Sp)	10,109 (Su)	4,461	1,057 (Sp)
2C	11 (Sp)	8 (W) 9 (F) (Su)	7,222 (W)	4,240	1,182 (Su)
2W	18 (Sp)	8 (F)	2,364 (Su)	1,911	1,178 (W)
3E	37 (Sp)	11 (W)	15,520 (Su)	8,148	5,105 (F) 5,630 (W)
3C	13 (F) 12 (Sp)	9 (W) (Su)	6,421 (F) 6,176 (Sp)	5,273	3,580 (Su)
3W	12 (Sp)	5 (Su)	4,145 (Sp)	2,727	1,984 (Su)
4E	23 (Sp)	14 (Su)	4,588 (Su)	3,839	2,167 (W)
4C	17 (F) (Sp)	14 (Su)	13,540 (Sp) 12,934 (W)	10,640	7,002 (Su)
5E	20 (Sp) 19 (Su)	17 (W) (F)	6,528 (Sp)	5,596	3,969 (F)
5W	21 (W) 20 (Sp) (Su)	18 (F)	14,085 (Sp)	10,330	5,489 (W)
*6E	34 (F) (Sp)	23 (Su)	20,926 (F)	8,331	6,031 (Su)
*6W	16 (Su) 14 (W)	8 (Sp)	5,983 (F)	3,591	2,036 (Sp)

* Based on 3 quarters of data only.

TABLE 3.3 Fall Quarter - Benthos

Station	#spp.	*Total #/m^2	Species Diversity (H')
NE	20	6619	2.94
NW	20	5847	3.26
1E	9	6510	2.45
1W	20	3940	2.65
2E	12	2756	2.08
2C	9	4191	1.09
2W	8	2098	1.66
3E	14	5105	3.03
3C	13	6421	1.50
3W	10	2694	1.99
4E	19	4437	2.80
4C	17	9087	1.62
5E	17	3969	3.17
5W	18	9935	2.37
6E	34	20,926	3.18
6W	14	5983	2.54

* No./m^2 includes immature tubificids, plus flatworms and nematodes which were not included in the number of species or in the H' calculation.

TABLE 3.4 Winter Quarter - Benthos

Station*	#spp	Total #/m^2	Species Diversity (H')
1E	17	3046	2.94
1W	18	2742	3.42
2E	16	3923	2.52
2C	8	7222	0.75
2W	9	1178	2.21
3E	11	5630	2.34
3C	9	4914	1.08
3W	8	2085	1.36
4E	15	2167	3.03
4C	16	12,934	1.59
5E	17	6924	2.91
5W	21	5489	2.92

*Stations N and 6 not done winter quarter.

TABLE 3.5 Spring Quarter - Benthos

Station	#spp.	Total #m/^{2}	Species Diversity (H')
NE	37	11,914	2.70
NW	20	5077	3.78
1E	21	3100	4.07
1W	16	3478	3.14
2E	11	1057	1.99
2C	11	4365	1.31
2W	18	2004	3.25
3E	37	6335	4.57
3C	12	6176	0.95
3W	12	4145	0.90
4E	23	4165	2.89
4C	17	13,540	1.80
5E	20	6528	2.97
5W	20	14,085	3.24
6E	34	6367	3.94
6W	8	2036	2.62

TABLE 3.6 Summer Quarter - Benthos

Station	#spp.	Total #/m^2	Species Diversity (H')
NE	27	11,315	3.43
NW	16	3872	2.53
1E	18	9589	3.44
1W	11	2796	3.20
2E	9	10,109	2.44
2C	9	1182	2.91
2W	14	2364	3.35
3E	23	15,520	3.67
3C	9	3580	1.46
3W	5	1984	1.19
4E	14	4588	2.68
4C	14	7002	2.08
5E	19	4966	3.33
5W	20	11,813	3.43
6E	23	6031	3.44
6W	16	2755	3.31

TABLE 3.7 Fall Quarter, 1979. Benthic Species and number per m^2 by Station.

Station →→	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Oligochaeta																
Aulodrilus limnobius	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Aulodrilus pigueti	27	324	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Illyodrilus templetoni	192	110	--	--	--	--	--	--	--	--	---	--	--	--	--	--
Limnodrilus hoffmeisteri	247	82	--	31	--	110	188	439	275	438	1316	--	376	--	55	--
Limnodrilus (c f.) udekemianus	82	27	--	--	--	--	--	---	--	--	--	--	--	--	--	--
Lumbriculid sp. A	27	55	--	--	--	--	--	604	27	63	--	--	31	--	--	--
Lumbriculid sp. B	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--
Specaria josinae	27	82	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Stylaria lacustris	192	--	440	94	--	--	--	--	--	--	--	--	--	--	--	--
Immature Tubificids*	2280	2335	1838	658	407	55	27	1154	55	31	302	--	313	470	989	595

TABLE 3.7 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA Polychaeta																
Capitella capitata	--	--	--	--	--	27	--	--	82	31	--	192	--	63	302	--
Chone sp.	--	--	--	--	--	--	--	--	--	--	31	--	--	--	220	--
Ilesionid sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Heteromastus filiformis	--	--	--	--	--	--	--	--	--	--	--	137	--	--	--	--
Hypaneola florida	55	--	1264	1880	1254	3479	1410	1208	4697	1598	1348	6895	1003	1348	4148	188
Laeonereis culveri	--	--	--	--	63	55	55	384	165	63	--	82	94	188	247	--
Loandalia americana	--	--	--	--	31	--	--	27	--	--	63	--	--	63	27	--
Mediomastus californiensis	--	--	--	--	--	--	--	--	110	--	31	137	--	--	165	--
Nereis sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Notomastus sp.	--	--	--	--	--	--	--	--	82	--	--	--	--	31	--	31
Pilargid sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	110	--
Polydora ligni	--	--	--	--	--	--	27	--	--	--	--	--	--	313	165	--
Serpulid sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Streblospio benedicti	--	--	--	31	63	110	--	--	385	157	93	741	125	63	1016	533

TABLE 3.7 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Diptera																
Clinotanypus sp.	--	55	165	94	--	--	--	--	--	--	--	--	219	--	55	--
Coelotanypus concinnus	82	82	165	125	--	--	--	--	--	--	--	--	--	--	--	--
Cryptochironomus blarina	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--
Cryptochironomus fulvus	--	--	--	--	--	--	--	--	--	--	--	--	--	--	82	31
Glyptotendipes sp.	--	--	--	--	--	--	--	--	--	--	31	--	--	--	--	--
Harnischia sp.	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Labrundinia neopilosella	--	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--
Paralauterborniella nigrohalteralis	27	--	--	--	--	--	--	--	--	--	--	--	--	--	27	31
Polypedilum convictum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polypedilum halterale	--	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--
Polypedilum illinoense	--	--	--	31	31	--	55	27	27	--	--	82	313	--	82	--
Procladius sublettei	55	55	--	--	31	27	--	27	--	--	63	27	--	31	--	--
Stichtochironomous devinctus	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--
Tanytarsus sp. A	--	--	--	31	--	--	--	--	--	--	31	--	31	--	55	--
Tanytarsus sp. B	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3.7 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Other Diptera																
Chironomid pupae sp. A	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--
Chironomus sp.	--	--	--	--	--	--	--	--	--	--	31	--	--	--	--	--
Diptera sp. A	--	--	--	--	31	--	--	--	--	--	--	--	31	--	--	--
Diptera sp. B	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Ephemeroptera																
Cloeon rubropictum	--	--	165	94	--	--	--	--	--	--	--	--	--	--	--	--
Lepidoptera																
Paraponyx sp.	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--
Pyralid sp.	--	--	--	63	--	--	--	--	--	--	31	--	--	--	--	--
Odonata																
Enallagma (c f.) traviatum	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3.7 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Eucarida																
Decapoda																
Cambarin sp.	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Palaeomon sp.	--	--	--	--	--	--	--	--	--	--	31	--	--	--	--	--
Rhithropanopeus harrisii	--	--	--	--	--	--	--	110	--	--	63	--	--	--	55	--
Pericarida																
Amphipoda																
Ampelisca vadorum	--	--	--	--	--	--	--	--	--	--	--	137	--	31	2692	1786
Ampelisca verilli	--	--	--	--	--	--	--	--	--	--	31	--	--	--	--	--
Cerapus benthophilus	--	--	--	--	--	--	--	--	55	--	--	55	--	--	55	63
Corophium louisianum	--	--	--	--	--	--	--	82	--	--	--	27	--	--	412	439
Gammarus macromucronatus	--	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--
Gammarus palustris	--	--	55	125	--	--	--	--	--	--	--	--	--	--	--	--
Grandidierella bonnieroides	--	--	--	125	627	247	282	302	105	188	--	165	721	5359	6455	376
Hyalella azteca	934	412	879	125	--	--	--	110	--	--	--	--	--	--	--	--

TABLE 3.7 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Pericarida																
Isopoda																
Asellus sp.	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cyathura polita	--	--	--	--	--	27	--	--	--	--	63	82	63	251	275	--
Edotea sp.	--	--	--	--	125	27	27	440	27	31	251	137	31	158	55	31
Mysidacea																
Mysidopsis almyra	27	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Taphromysis bowmani	--	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--
Taphromysis louisianum	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tanaidacea																
Leptochelia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	1099	63
Mollusca																
Bivalvia																
Pisidium sp.	1428	961	--	--	--	--	27	--	--	--	--	--	--	--	--	--
Tellina sp.	--	--	--	--	--	--	--	--	27	--	--	82	--	658	302	--

TABLE 3.7 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
MOLLUSCA																
Gastropoda																
Lyogyrus sp.	659	165	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Neritina reclivata	27	165	1483	247	--	--	--	137	--	--	533	--	431	470	27	--
Pyramidella sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	220	--
MISCELLANEOUS*=	5906	5491	6483	3909	2725	4164	2098	5105	6119	2600	4343	9240	3813	9841	20976	5797
Batracobdella phalera	27	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dugesia (c f.) tigrina	--	82	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hydrozoan sp.	27	27	--	--	--	27	--	--	302	94	31	27	--	63	247	93
Leucon sp.	--	--	--	31	31	--	--	--	--	--	63	--	125	31	192	--
Ostracod sp. A	--	--	--	--	--	--	--	--	--	--	--	--	31	--	192	93
Trematode sp.	659	165	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trinectes maculatus	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--
Turbellarian sp. A	--	55	--	--	--	--	--	--	--	--	--	--	--	--	137	--
Turbellarian sp. B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	82	--
	713	356	27	31	31	27	0	0	302	94	94	27	156	94	850	186

* Not used in calculation of diversity index, but included in density calculations

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TABLE 3.8 Winter Quarter, 1980. Benthic Species and Number per m^2 by Station.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Oligochaeta																
Aulodrilus pigueti	--	--	--	--	--	--	27	--	--	--	--	--	--	55	--	--
Limnodrilus (c f.) angustipenis	--	--	27	82	--	--	--	--	--	--	--	--	--	--	--	--
Limnodrilus hoffmeisteri	--	--	27	110	110	--	--	192	--	27	55	--	188	--	--	--
Lumbriculid sp. A	--	--	82	110	--	--	--	165	55	--	--	82	63	--	--	--
Tubifex tubifex	--	--	82	--	--	--	--	--	55	--	--	--	--	--	--	--
Immature Tubificids*	--	--	1236	934	1236	797	275	1154	110	82	275	357	1724	549	--	--
Polychaeta																
Capitella capitata	--	--	--	--	--	--	--	--	--	--	--	302	--	--	--	--
Chone sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Nesionid sp.	--	--	--	--	--	--	--	--	--	--	--	27	--	--	--	--
Heteromastus filiformis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hypaneola florida	--	--	302	577	1428	5604	494	1786	3873	1401	632	9120	1598	961	--	--
Laeonereis culveri	--	--	--	--	247	55	82	--	--	27	192	137	63	110	--	--

TABLE 3.8 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Polychaeta																
Loandalia americana	--	--	--	--	27	27	--	--	--	--	27	27	31	--	--	--
Mediomastus californiensis	--	--	--	--	55	27	--	--	55	--	55	440	125	--	--	--
Nereis sp.	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--	--
Polydora ligni	--	--	--	--	--	--	--	--	--	--	--	--	--	110	--	--
Streblospio benedicti	--	--	--	--	302	494	137	--	494	467	165	1456	188	27	--	--
ARTHROPODA																
Insecta																
Diptera																
Clinotanypus sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	55	--	--
Coelotanypus concinnus	--	--	--	55	27	--	--	27	--	--	--	--	--	27	--	--
Cryptochironomus fulvus	--	--	--	137	--	--	--	--	--	27	--	--	31	--	--	--
Dicrotendipes (c f.) leucoscelis	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--	--
Paralauterborniella nigrohalteralis	--	--	137	--	--	--	--	--	--	27	--	--	--	--	--	--
Polypedilum halterale	--	--	--	--	27	--	--	--	--	--	--	27	--	27	--	--

TABLE 3.8 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Diptera																
Polypedilum illinoense	--	--	--	27	27	--	55	55	--	27	110	137	313	82	--	--
Procladius sublettei	--	--	--	55	27	--	--	--	--	--	27	--	--	--	--	--
Rheotanytarsus sp. A	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--	--
Stichtochironomus devinctus	-	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--
Tanytarsus sp. A	--	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--
Other Diptera																
Ceratopogonid sp.	--	--	--	--	82	--	--	27	--	--	--	--	--	--	--	--
Odonata																
Enallagma (c f.) traviatum	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--	--
Pyralid (Nymphulinae)			--	--	27	--	--	--	--	--	--	--	--	27	--	--
Trianodes sp.	--	--	--	--	27	--	--	--	--	--	--	--	--	--	--	--
CRUSTACEA																
Eucarida																
Decapoda																
Rhithropanopeus harrisii	--	--	--	--	--	--	--	82	--	--	--	--	--	--	--	--

TABLE 3.8 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Pericarida																
Amphipoda																
Ampelisca vadorum	--	--	--	--	--	--	--	--	--	--	--	330	--	--	--	--
Cerapus benthophilus	--	--	--	--	--	--	--	--	--	--	--	55	--	--	--	--
Corophium louisianum	--	--	--	--	--	--	--	--	--	--	--	--	63	--	--	--
Gammarus macromucronatus	--	--	27	--	--	--	--	--	--	--	--	--	--	27	--	--
Gammarus mucronatus	--	--	--	--	--	--	--	--	--	--	27	--	--	110	--	--
Gammarus palustris	--	--	--	27	--	--	--	--	--	--	--	--	--	--	--	--
Grandidierella bonnieroides	-	--	--	55	82	55	27	302	27	--	357	192	909	1044	--	--
Hyalella azteca	--	--	165	--	--	--	--	--	--	--	--	--	--	--	--	--
Isopoda																
Cyathura polita	--	--	--	27	--	82	--	--	--	--	55	--	94	--	--	--
Edotea Sp.	--	--	--	--	--	--	27	275	27	--	--	--	63	220	--	--
Mysidacea																
Mysidopsis bigelowi	--	--	--	--	--	--	--	--	--	--	--	27	--	--	--	--

TABLE 3.8 Cont.

Station →→	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
MOLLUSCA																
Bivalvia																
Pisidium sp.	--	--	137	--	--	--	--	--	--	--	27	--	--	--	--	--
Polymesoda caroliniana	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--	--
Tellina sp.	--	--	--	--	27	--	--	--	27	--	27	27	94	220	--	--
Gastropoda																
Lymnaea sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--	--
Lyogyrus sp.	--	--	--	82	--	--	--	--	--	--	--	--	--	--	--	--
Neritina reclivata	--	--	934	55	27	27	--	714	--	--	55	--	1128	1154	--	--

TABLE 3.8 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
			3019	2578	3831	7195	1151	4204	4860	2085	2113	12525	6625	4967		
MISCELLANEOUS*																
Copepod sp. A	--	--	27	27	27	27	--	110	--	--	--	27	31	27	--	--
Copepod sp. C	--	--	--	--	--	--	--	--	--	--	27	--	--	--	--	--
Dugesia (c f.) tigrina	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--	--
Harpacticoid sp. A	--	--	--	--	--	--	--	--	27	--	--	27	--	--	--	--
Nematode sp. A	--	--	--	137	55	--	--	714	27	--	--	55	31	440	--	--
Nemertean sp. B	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--
Nemertean sp. C	--	--	--	--	--	--	--	--	--	--	27	--	31	--	--	--
Nemertean sp. C	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--
Ostracod sp. A	--	--	--	--	--	27	--	--	--	--	--	--	63	55	--	--
Turbellarian sp. A	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--
			27	164	92	27	27	824	54	0	54	109	249	522		

* Not included in calculation of diversity, but included in density calculations

TABLE 3.9 Spring Quarter, 1980. Benthic Species and Number per m^2 by Station.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Oligochaeta																
Aulodrilus pigueti	110	577	31	63	--	--	--	55	--	--	--	--	--	--	--	--
Ilyodrilus templetoni	852	522	63	157	--	--	31	--	--	--	--	--	--	--	--	--
Limnodrilus (c f.) angustipenis	--	--	--	--	--	--	--	--	--	--	--	--	--	1648 [1]	55	--
Limnodrilus hoffmeisteri	--	577	157	--	31	--	--	82	--	--	27	--	63	--	82	--
Limnodrilus (c f.) limnobius	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Lumbriculid sp. A	--	--	--	31	--	--	27	192	--	27	27	--	31	137 [1]	--	--
Lumbriculid sp. B	--	--	--	--	--	--	--	27	--	--	--	--	63	192 [1]	82	--
Lumbriculid sp. C	--	--	--	--	--	--	--	--	--	--	--	--	93	1044 [1]	82	--
Naidid sp.	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Nais variabilis	27	--	--	--	--	--	--	55	--	--	--	--	--	--	--	--
Peloscolex gabriellae	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Potamothrix moldaviensis	--	--	--	--	--	--	--	55	--	--	27	--	--	--	--	--
Pristina sima	--	--	--	--	--	--	--	220	--	--	82	--	31	632	--	--
Slavina appendiculata	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Specaria josinae	--	--	--	--	--	--	--	27	--	--	27	--	31	27	--	--

[1] subsample

TABLE 3.9 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Oligochaeta																
Stylaria lacustris	137	275	125	--	--	--	--	27	--	--	--	--	--	--	--	--
Tubifex tubifex	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Immature tubificids*	1236	1428	972	658	93	--	110	1044	110	--	687	220	1661	8296[1]	247	--
Polychaeta																
Capitella capitata	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Heteromastus filiformis	--	--	--	--	--	--	--	--	--	--	--	55	--	--	--	--
Hypaneola florida	--	--	--	63	658	2912	275	357	5219	3599	1456	8298	501	467	934	157
Laeonereis culveri	--	--	--	--	31	55	82	165	--	27	137	110	125	82	1071	219
Loandalia americana	--	--	--	--	--	--	--	--	--	--	27	--	--	22	--	--
Mediomastus californiensis	--	--	--	--	31	27	--	--	27	55	27	714	--	--	27	--
Notomastus sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	27	55	--
Polydora ligni	--	--	--	--	--	--	--	55	--	--	--	--	31	--	27	63
Serpulid sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Streblospio benedicti	--	--	--	--	--	--	--	--	82	--	--	1840	--	--	55	125

[1] Subsample

TABLE 3.9 Cont.

Station ↔	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Coleoptera																
Dubiraphia quadrinotata	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Diptera																
Ablabesmyia mallochi	55	--	--	--	--	--	--	82	--	--	--	--	--	--	--	--
Ablabesmyia parajanta	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ablabesmyia ornata	110	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Ablabesmyia tarella	55	--	--	31	--	--	--	27	--	--	--	--	--	--	--	--
Clinotanypus sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	110	--
Coelotanypus concinnus	27	27	31	--	--	--	--	27	--	--	--	--	--	--	--	--
Coelotanypus scapularis	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--	--
Cricotopus bicinctus	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Cryptochironomus fulvus	--	--	--	--	--	--	55	--	--	--	--	27	--	--	55	--
Dicrotendipes (c f.) leucoscelis	220	--	125	--	--	--	27	27	--	--	--	--	---	--	--	--
Dicrotendipes (c f.) lobus	27	--	--	63	--	--	--	--	--	--	--	--	--	--	--	31
Dicrotendipes neomodestus	55	--	--	31	--	--	--	55	27	--	--	--	--	--	--	--

TABLE 3.9 Cont.

Station →→	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Diptera																
Dicrotendipes (c f.) nervosus	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Labrundinia neopilosella	--	27	31	--	--	--	--	27	--	--	--	--	--	--	--	--
Orthocladiin sp.	--	27	--	--	--	---	--	--	---	--	--	--	--	--	--	--
Pagastiella sp.	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Paralauterborniella nigrohalteralis	--	27	31	--	31	--	27	--	--	--	--	--	--	--	247	--
Pentaneura inconspicua	--	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polypedilum halterale	--	82	--	--	--	27	137	192	192	82	82	275	--	31	110	--
Polypedilum illinoense	27	--	--	--	--	--	--	--	--	27	27	--	--	--	--	--
Procladius sublettei	55	--	31	--	31	27	55	137	27	27	110	--	--	82	--	--
Rheotenytarsus sp. A	--	--	--	--	--	--	--	27	--	--	--	--	--	--	27	--
Stichtochironomus devinctus	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Tanytarsus sp. A	247	55	--	--	--	27	27	--	--	--	82	--	--	--	--	--
Other Diptera																
Ceratopogonid sp. A	27	--	--	--	--	--	27	--	--	--	27	--	--	--	27	--
Chironomid pupae sp. A	82	--	--	--	--	--	--	110	--	--	82	--	--	--	27	--
Chironomid pupae sp. B	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--

TABLE 3.9 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Ephemeroptera																
Cloeon rubropictum	110	27	63	--	--	--	--	--	--	--	--	--	31	--	--	--
Tricorythodes albilineatus	27	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Odonata																
Enallagma (c f.) traviatum	--	--	--	--	--	--	27	55	--	--	--	--	--	--	--	--
Trichoptera																
Hydroptilid sp.	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Oxythira sp.	--	82	31	--	--	--	--	--	--	--	--	--	--	--	--	--
Polycentropid sp.	27	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Psychomiid sp.	--	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--
Triaenodes sp.	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--	--
CRUSTACEA																
Eucarida																
Decapoda																
Rhithropanopeus harrisii	--	--	--	--	--	--	---	27	--	--	--	--	31	--	--	--
Pericarida																
Amphipoda																
Ampelisca vadorum	--	--	--	--	--	--	--	--	--	--	--	82	--	--	27	251
Cerapus benthophilus	--	--	--	--	--	--	--	--	27	--	--	137	--	--	--	--

TABLE 3.9 Cont.

Station →→	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Pericarida																
Amphipoda																
Corophium louisianum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Gammarus macromucronatus	--	--	--	--	--	--	--	--	27	--	--	--	--	27	55	--
Gammarus mucronatus	--	--	--	31	--	--	--	--	--	--	27	--	31	27	--	--
Gammarus palustris	220	--	125	63	31	--	193	110	--	--	--	--	--	--	27	--
Grandidierella bonnieroides	--	--	--	784	--	1154	632	357	302	55	879	275	1066	412	412	376
Hyale sp.	--	--	--	--	--	27	--	302	--	--	--	--	--	--	--	--
Hyalella azteca	5604	192	188	219	--	--	--	--	--	--	--	--	--	--	--	--
Leptocheirus sp.	--	--	31	--	--	--	--	--	--	--	--	--	--	--	--	--
Isopoda																
Cassidinea ovalis	--	--	--	--	--	27	--	--	--	--	--	--	--	--	--	--
Cyathura polita	--	--	--	--	31	--	--	82	--	--	27	165	188	82	137	--
Edotea sp.	--	--	--	--	--	--	137	494	27	--	27	137	188	247	--	--
Mysidacea																
Mysidopsis almyra	--	--	--	--	--	27	--	--	--	27	--	--	--	27	--	--
Mysidopsis bigelowi	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Mysidopsis sp. (no telson/head)		--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Taphromysis bowmani	137	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--
Taphromysis louisianum	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--	--

TABLE 3.9 Cont.

Station ↔	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Pericarida																
Tanaidacea																
Apsudes sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27	--
Leptochelia sp.	--	--	--	--	--	--	--	--	--	--	27	55	--	27	82	31
MOLLUSCA																
Bivalvia																
Pisidium sp.	1538	797	63	157	27	--	82	--	--	--	--	27	--	--	--	--
Polymesoda caroliniana	--	--	--	--	--	--	--	--	--	55	--	220	31	110	--	--
Tellina sp.	--	--	--	--	--	--	--	27	--	55	--	27	--	--	55	--
Gastropoda																
Lyogyrus sp.	329	--	--	31	--	--	--	357	--	--	27	--	--	--	--	--
Neritina reclivata	--	--	125	658	--	--	27	165	82	--	82	27	1473	357	467	--
Physa sayi	--	--	--	31	--	--	--	--	--	--	-	--	--	--	--	--
Pyramidella sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	687	--

TABLE 3.9 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
	11558	4885	2567	3102	995	1145	1950	5183	6176	4036	4057	13318	5728	14003	5819	2005
MISCELLANEOUS *																
Batracobdella phalera	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Copepod sp. A	27	82	439	282	31	--	27	604	--	27	27	--	93	--	--	--
Copepod sp. B	--	--	--	--	--	--	--	82	--	--	--	--	110	--	--	--
Crab megalops	--	--	--	--	--	--	27	82	--	--	--	--	31	--	27	--
Crab zoea	--	--	--	--	--	--	--	--	--	--	--	--	31	82	--	31
Dugesia (c f.) tigrina	55	--	--	--	--	--	--	--	--	--	27	27	--	--	27	--
Harpacticoid sp. A	27	--	31	--	--	--	--	--	--	27	--	55	--	--	--	--
Harpacticoid sp. C	--	--	--	--	--	--	--	55	--	--	--	--	--	--	--	--
Helobdella elongata	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--
Hydrozoan sp.	27	--	--	--	--	--	--	--	--	--	--	--	--	--	55	--
Leucon sp.	--	--	--	--	--	--	--	55	--	55	27	110	63	--	192	--
Nematode sp. A	165	110	63	94	31	--	--	165	--	--	--	--	251	--	110	--
Nematode sp. B	--	--	--	--	--	--	--	--	--	--	--	--	63	--	27	--
Nematode sp. D	--	--	--	--	--	--	--	82	--	--	27	--	93	--	--	--
Nemertean sp. A	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
Nemertean sp. B	--	--	--	--	--	--	--	--	--	--	--	--	--	--	110	--
Nemertean sp. D	--	--	--	--	--	--	--	--	--	--	--	--	31	--	--	--
	354	192	533	376	62	0	54	1152	0	109	108	192	797	82	548	31

* Not included in calculation of diversity index, but included in density calculations

TABLE 3.10 Summer Quarter, 1980. Benthic Species and Number per m^2 by Station.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Oligochaeta																
Aulodrilus pigueti	2527	1566	55	--	--	--	55	1428	--	--	--	--	--	--	--	--
Limnodrilus (c f.) angustipenis	--	--	--	--	--	--	--	82	--	--	--	--	--	--	--	--
Limnodrilus hoffmeisteri	165	--	275	188	137	126	55	852	--	--	--	--	--	--	--	27
lumbriculid sp. A	55	--	494	--	--	63	--	137	--	--	--	--	--	--	--	27
lumbriculid sp. B	--	--	--	--	--	--	--	27	--	--	--	--	--	--	--	--
lumbriculid sp. C	--	--	--	--	--	31	--	549	--	--	--	--	126	659	--	--
Naidid sp.	--	--	--	--	--	--	--	165	--	--	--	--	--	220	--	--
Nais simplex	--	--	--	--	55	--	--	55	--	--	--	--	--	--	--	--
Peloscolex ferox	--	--	--	--	--	--	--	--	--	--	--	--	--	934	--	--
Pristina sima	165	82	--	--	--	--	--	--	--	--	--	--	126	220	--	--
Pristina sp.	494	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Specaria josinae	110	--	--	126	--	--	55	55	--	--	--	--	--	--	--	--
Tubifex tubifex	--	--	110	--	--	31	--	192	--	--	--	--	--	27	--	--
Wapsa immobilis	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Immature Tubificids*	4038	1071	4450	1037	412	471	989	9202	220	82	165	220	1131	5137	157	247

TABLE 3.10 Cont.

Station →→	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ANNELIDA																
Polychaeta																
Hesionid sp.	27	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Hypeneola florida	27	--	302	188	8845	--	385	715	2419	1648	1154	2417	565	659	1759	412
Laeonereis culveri	27	--	--	--	330	127	220	192	126	--	522	55	126	55	314	165
Loandalia americana	--	--	--	--	--	--	--	--	--	--	--	--	126	--	--	--
Mediomastus californiensis	--	--	--	--	--	--	--	--	--	--	82	82	63	--	--	27
Pilargid sp.	--	--	--	--	--	--	--	--	--	--	--	27	--	--	--	--
Polydora ligni	--	--	--	--	--	--	--	--	--	--	--	--	--	55	--	--
Streblospio benedicti	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	165
ARTHROPODA																
Insecta																
Coleoptera																
Dubiraphia quadrinotata	55	--	--	--	--	--	--	--	--	--	--	--	--	--	---	--
Dubiraphia quadrinotata (larvae)	165	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Dubiraphia sp. A	385	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3.10 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Diptera																
Ablabesmyia parajanta	--	--	--	--	--	--	--	--	--	--	--	--	--	55	--	--
Ablabesmyia tarella	--	27	55	63	--	--	--	--	--	27	--	27	---	--	--	--
Brillia sp.	--	--	--	--	--	--	--	--	--	--	--	55	--	--	--	--
Cladotanytarsus conversus	--	--	--	--	55	--	--	--	--	--	--	---	--	--	--	--
Clinotanypus sp.	27	--	--	63	--	--	55	--	--	--	--	--	--	165	--	27
Coelotanypus concinnus	27	--	275	63	--	27	--	--	--	--	--	27	--	55	--	--
Cricotopus bicinctus	--	--	--	--	--	--	--	31	--	--	--	--	--	--	--	--
Cryptochironomus fulvus	--	--	--	--	--	--	--	27	31	--	--	--	63	--	63	--
Dicrotendipes (c f.) leucoscelis	--	--	--	--	--	--	55	--	--	--	--	--	--	--	--	--
Harnischia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Labrundinia neopilosella	55	--	--	--	--	--	--	--	--	--	--	--	--	55	--	--
Parachironomus crinatus	--	--	--	--	--	--	--	--	--	--	--	--	63	--	--	--
Paralauterborniella nigrohalteralis	110	--	--	251	--	--	--	--	31	--	--	27	--	--	94	--
Polypedilum halterale	--	--	220	--	--	--	--	357	63	--	--	220	377	192	--	--
Procladius sublettei	55	--	110	--	55	--	--	494	94	--	27	--	63	--	--	--

TABLE 3.10 Cont.

Station ++	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
ARTHROPODA																
Insecta																
Diptera																
Rheotanytarsus sp. A	--	--	--	--	--	--	--	--	--	--	110	--	--	--	--	--
Rheotanytarsus sp. B	--	--	--	--	--	--	55	--	--	--	--	--	--	--	--	--
Tanypus neopunctipennis	--	--	--	--	--	--	--	82	--	--	--	--	--	--	--	--
Tanytarsus sp. A	82	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Other Diptera																
Ceratopogonid sp. A	---	--	--	63	--	--	55	--	--	--	--	--	63	--	--	--
Ceratopogonid sp. B	--	--	165	--	--	--	55	--	--	--	--	--	--	--	--	--
Chironomid pupae sp. B	--	--	--	--	55	--	--	--	--	--	--	--	63	--	63	--
Chironomid pupae sp. C	--	--	--	--	--	--	--	--	--	--	55	--	--	--	--	27
Ephemeroptera																
Tricorythodes albilineatus	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Odonata																
Enallagma (c f.) traviatum	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Trichoptera																
Hydroptila (c f.) wakulla	55	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Triaenodes sp.	--	55	55	--	--	--	--	--	--	--	--	--	--	--	--	--

TABLE 3.10 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Eucarida																
Decapoda																
Rhithropanopeus harrissi	--	--	--	--	--	--	--	55	--	--	55	--	63	--	--	--
CRUSTACEA																
Pericarida																
Amphipoda																
Ampelisca vadorum	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	27
Ampelisca verrilli	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	31
Ceraptis benthophilus	--	--	--	--	--	--	--	27	--	--	302	687	--	--	--	--
Gammarus macromucronatus	--	--	--	--	--	63	--	--	--	--	--	--	63	--	--	--
Gammarus mucronatus	--	--	--	--	--	--	--	--	--	--	--	55	--	55	--	--
Gammarus palustris	--	--	--	63	--	--	--	82	--	--	--	--	--	--	--	--
Grandidierella bonnieroides	--	--	--	--	55	--	55	55	565	64	1621	2857	1194	1236	660	522
Hyalella azteca	852	440	220	251	--	--	--	--	--	--	--	--	--	--	--	--
Isopoda																
Cyathura polita	--	--	55	--	--	--	165	--	--	--	110	--	63	55	94	--
Edotea sp.	55	--	--	--	55	31	55	--	--	--	--	137	63	385	314	82

TABLE 3.10 Cont.

Station ↔	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
CRUSTACEA																
Pericarida																
Mysidacea																
Mysidopsis almyra	--	--	--	--	--	--	--	--	--	--	--	--	--	--	188	--
Mysidopsis bigelowi	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	110
Taphromysis bowmani	110	55	--	--	--	--	--	--	--	--	--	--	--	--	--	220
Tanaidacea																
Leptochelia sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--	63
MOLLUSCA																
Bivalvia																
Pisidium sp.	220	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Polymesoda carolinfana	--	110	--	--	--	--	--	--	--	--	--	27	--	55	--	--
Tellina sp.		--	--		--	--	--	--		--	--	--	--	--	--	
Gastropoda																
Lyogyrus sp.	604	110	--	--	--	--	--	82	--	--	110	--	--	--	--	--
Neritina reclivata	--	--	1154	314	55	--	--	440	--	27	110	--	251	989	63	--
Planorbid sp.	110	27	110	--	--	--	--	--	--	--	--	--	--	--	--	--
Pyramidella sp.	--	--	--	--	--	--	--	--	--	--	--	--	--	--	94	27

TABLE 3.10 Cont.

Station →	NE	NW	1E	1W	2E	2C	2W	3E	3C	3W	4E	4C	5E	5W	6E	6W
	10,959	3872	8160	2733	10,054	1023	2309	15,415	3580	1936	4423	6920	4652	11,263	3813	2261
MISCELLANEOUS*																
Copepod sp. A	--	--	55	--	--	--	--	--	--	--	55	--	--	330	--	--
Copepod sp. B	--	--	--	--	--	--	--	55	--	--	--	--	--	--	--	--
Dugesia (c f.) tigrina	--	--	55	--	--	--	--	--	--	--	--	--	63	--	--	--
Harpacticoid sp. A	55	--	--	--	--	--	--	--	--	--	--	27	--	--	--	--
Helobdella elongata	110	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
Helobdella triserialis	--	--	55	--	--	--	--	--	--	--	--	--	--	--	--	--
Leucon sp.	--	--	--	--	55	--	--	--	--	--	--	55	--	--	126	--
Nematode sp. A	27	--	989	63	--	--	--	--	--	--	--	--	--	110	63	--
Nematode sp. B	--	--	275	--	--	157	55	--	--	27	--	--	--	--	--	--
Nematode sp. D	--	--	--	--	--	--	--	--	--	--	--	--	--	55	--	--
Nemertean sp. A	82	--	--	--	--	--	--	--	--	--	55	--	188	--	--	--
Nemertean sp. B	--	--	--	--	--	--	--	--	--	--	--	--	63	--	--	--
Nemertean sp. D	--	--	--	--	--	--	--	--	--	--	55	--	--	--	--	--
Ostracod sp. A	--	--	--	--	--	--	--	--	--	27	--	--	--	55	1979	494
Ostracod sp. B	82	--	--	--	--	--	--	--	--	--	--	--	--	--	--	--
	354	0	1429	63	55	157	55	55	0	54	165	82	314	550	2168	494

* Not included in calculation of diversity index, but included in density calculations

Table 3.11. Cumulative Species List for all Stations in all Sampling Periods

Ablabesmyia mallochi
Ablabesmyia ornata
Ablabesmyia parajanta
Ablabesmyia tarella
Ampelisca vadorum
Ampelisca verilli
Apsudes sp.
Asellus sp.
Aulodrilus limnobius
Aulodrilus pigueti

Brillia sp.

Cambarin sp.
Capitella capitata
Cassidinea ovalis
Cerapus benthophilus
Ceratopogonid sp. A
Ceratopogonid sp. B
Chironomid sp. A
Chironomid sp. B
Chironomid sp. C
Chironomus sp.
Chone sp.
Cladotanytarsus conversus
Clinotanypus sp.
Cloeon rubropictum
Coelotanypus concinnus
Coelotanypus scapularis
Corophium louisianum
Cricotopus bictinctus
Cryptochironomus blarina
Cryptochironomus fulvus
Cyathura polita

Dicrotendipes (cf.) leucoscelis
Dicrotendipes (cf.) lobus
Dicrotendipes neomodestus
Dicrotendipes (cf.) nervosus
Diptera sp. A
Diptera sp. B
Dubiraphia quadrinotata
Dubiraphia sp. A

Edotea sp.
Enellagma (cf.) traviatum

Gammarus macromucronatus
Gammarus mucronatus
Gammarus palustris
Glyptotendipes sp.
Grandidierella bonnieroides

Harnischia sp.
Hesionid sp.
Heteromastus filiformis
Hyale sp.
Hyalella azteca
Hydroptila (cf.) wakulla
Hydroptilid sp.
Hypaneola florida

Ilyodrilus tempeltoni

Labrundinia neopilosella
Laeonereis culveri
Leptocheirus sp.
Leptochelia sp.
Limnodrilus (cf.) angustipenis
Limnodrilus hoffmeisteri
Limnodrilus (cf.) limnobius
Limnodrilus (cf.) udekemianus
Loandalia americana
Lumbriculid sp. A
Lumbriculid sp. B
Lumbriculid sp. C
Lymnaea sp.
Lyogyrus sp.

Mediomastus californiensis
Mysidopsis almyra
Mysidopsis bigelowi
Mysidopsis sp.

Naidid sp.
Nais simplex
Nais variabilis
Nereis sp.
Neritina reclivata
Notomastus sp.

Orthocladiin sp.
Oxythira sp.

Pagastiella sp.
Palaeomon sp.
Parachironomus crinatus
Paralauterborniella nigrohalteralis
Paraponyx sp.
Peloscolex ferox
Peloscolex gabriellae
Pentaneura inconspicua
Physa sayi
Pilargid sp.
Pisidium sp.

Planorbid sp.

Polycentropid sp.
Polydora ligni
Polymesoda caroliniana
Polypedilum convictum
Polypedilum halterale
Polypedilum illinoense
Potamothrix moldaviensis
Pristina sima
Pristina sp.
Procladius sublettei
Psychomiid sp.
Pyralid sp.
Pyramidella sp.

Rheotanytarsus sp. A
Rheotanytarsus sp. B
Rhithropanopeus harrisii

Serpulid sp.
Slavina appendiculata
Specaria josinae
Stichtochironomus devinctus
Streblospio benedicti
Stylaria lacustris

Tanypus neopunctipennis
Tanytarsus sp. A
Tanytarsus sp. B
Taphromysis bowmani
Taphromysis louisianum
Tellina sp.
Triaenodes sp.
Tricorythodes alibilineatus
Tubifex tubifex

Wapsa immobilis

SECTION FOUR: MACROPHYTES

Introduction

Salt marshes dominate the coastal regions along the Atlantic seaboard and the north central coast of the Gulf of Mexico (Eleuterius, 1976). These areas are suitable habitats for a unique set of organisms, and temporary habitats for many economically important marine species (de la Cruz, 1973). The salt marsh along the St. Marks River is dominated by two species, *Juncus roemarianus* and *Cladium jamaicense*.

The St. Marks River over the last few years has had a number of oil spills (NOAA, 1979). Baker (1973) discussed the sensitivity of three species of salt marsh plants to long-term oil exposure. She found *Juncus roemerianus* to be less sensitive to oil than the other two, *Spartina* sp. and *Puccinellia* sp. It is the initial purpose of this study to determine the standing crop and productivity of the flora along the St. Marks River. If, in the future, any catastrophes (e.g., large oil spills) should occur, these baseline data will be available for comparison.

Materials and Methods

The seven transects previously discussed (Figure A.1) were used in the macrophyte study. One additional station on the Wakulla River was used as a comparison (i.e., an unaffected area) for primary production measurements (Figure 4.1). Each transect was subdivided into submerged and marsh vegetation types. Submerged vegetation as used here, means that

it was never exposed at low tide. If hardwoods or man-made structures were located at the river's edge, no samples were taken at that station along the transect. Included in the collections as macrophytes are some macroscopic algae which contributed significantly to the biomass at a station. Other occasional epiphytic algae growing on the vegetation were rinsed away along with the microscopic algae.

Standing crop biomass samples were taken at transects 1 through 6 and transect N in December 1979. Five quadrats (25cm X 25cm) were taken at each submerged area. Three quadrats were collected at each marsh site in this preliminary survey.

Because of time constraints, it was decided to reduce the sampling regime in subsequent quarters. First, the number of quadrats taken at the submerged sites during later sampling periods was reduced to three. Second, the number of transects sampled was reduced to four. Transects 1 and 5 were retained, as well as transects 2 and 3, which are believed to be close to the oil spill sources. Sampling was quarterly (December, March, June and September) at these four transects. The *Cladium* marsh at transect 2 was not sampled because it is very small (about a 2 ft. fringe) and repeated sampling might have substantially diminished the marsh.

The standing crop biomass samples were taken by randomly throwing a $25cm^2$ wire form. Aboveground and underground biomass samples were taken. Underground samples were excavated to a depth of approximately 20cm, washed in the field, and returned to the laboratory. At the laboratory, samples were separated into living and dead components, oven dried to a constant weight at $105^{o}C$ and weighed.

The paired plots method (Lominicki et al., 1968) of determining aboveground net primary production* was used at three marsh locations. The three sites are: 3 East, closest to the oil pollution sources and consisting of a mixture of *Cladium jamaicense* and *Juncus roemerianus;* 5 West, dominated by *Juncus roemerianus* and located further downstream from the oil pollution sources; and Wakulla West, an area dominated by *Juncus roemerianus* along the west side of the Wakulla River and generally untouched by oil pollution.

The net productivity measurements were started on March 27, 1980. For each species at each station, two plots (25cm X 25cm) with approximately the same stem counts were selected. At one plot (H) all dead material was removed at the start. At the other plot (B), all the dead and green material (i.e., the whole plant) was removed (b_o=0). After a known time interval (usually one month, possibly two) both the green and dead material was again removed (b_1) at plot B and the dead material was harvested (h_1) at plot H. The harvested material was returned to the laboratory, dried to a constant weight at 105°C, and weighed. The net primary productivity was then calculated according to the formula of Lominicki et al. (1968):

$Y_1 = h_1 + (b_1 - b_o)$, where b_o is always equal to zero, since plot B was, of course, harvested of all material each month. Net primary production of *Juncus roemerianus* was measured at all three locations. The net primary production of the *Cladium* marsh was measured at site 3.

*Net primary productivity is the rate of storage of organic matter in a plant's tissues beyond that used in respiration over a given amount of time (Odum, 1959).

Results

The vegetation of the St. Marks River system can be categorized into three main groups: (1) strictly freshwater species; (2) species able to exist in fresh and moderately brackish water; (3) estuarine species.

The exclusively freshwater species were collected primarily from transects N and 1. Major species collected were: *Sagittaria kurziana, Myriophyllum heterophyllum, Vaucheria* sp., *Isoetes flaccida, Eleocharis flavessens,* and *Ludwigia repens*. *Sagittaria kurziana* was the dominant macrophyte (75.2% of total biomass) at transect N but a small amount was also found at transect 3 in the Fall, 1980, quarter (5.2% of total biomass). *Myriophyllum heterophyllum* was collected only at transect 1 and was the dominant macrophyte there in the summer and fall quarters(63.9% and 39.3% of total biomass, respectively). *Vaucheria* sp. was epiphytic on *Myriophyllum* at station 1 but was found on other macrophytes at transect 3.

The second group of plants was found at both the freshwater sites N and 1, and the moderately brackish water site 5. Species belonging to this group are *Sagittaria subulata, Lilaeopsis chinensis, Vallisneria americana, Potamogeton perfoliatus, Saururus crenuus and Cladium jamaicense*. *Sagittaria subulata* is a component of the freshwater marsh at site N and the salt marsh at site 5. It is one of the most ubiquitous macrophytes along this river. At the upstream transects, it is the dominant macrophyte between the submerged plant zone and the flatwoods. At the lower transects, *Sagittaria subulata* dominates a zone contiguous

to the salt marsh. *Lilaeopsis chinensis* occurs, but in smaller numbers, in the same area. At site 5 there are extensive, shallow mud flats around a sunken barge. These mud flats are covered by *Vallisneria americana, Potamogeton perfoliatus* and *Ruppia maritima*. *Cladium jamaicense* and *Saururus cernuus* are found extensively in the marshes from transect 2 to transect 5.

There are only two species that exist in strongly brackish waters in the study area: *Juncus roemerianus* in the salt marshes and *Ruppia maritima* in submerged areas.

Table 4.1 is a complete list of all plants collected from the St. Marks River transects. It is composed of 24 species consisting of two algae and twenty-two higher plants. The two algae are *Vaucheria* and *Cladophora* which were found intertwined among submerged macrophytes. One marsh plant belonging to the family Asteraceae was collected. Since it was not in flower, no identification was possible.

December 1979 was the only month in which all transects (1-6,N) along the St. Marks River were sampled. Figure 4.2 summarizes the mean biomass of marsh and submerged vegetation at each of these locations. Marsh vegetation biomass is low at the upper river sites, i.e., less than $1000g/m^2$ at sites N, 1 and 2. Biomass is much higher at the down-river sites; i.e., greater than $2000g/m^2$. Station 6 has the maximum biomass of over $7500g/m^2$. Maximum biomass of submerged macrophytes (greater than $1500g/m^2$) is at site N. Biomass of submerged vegetation is significantly lower further down the river, reaching very low levels at transects 2 and 3 of less than $1.5g/m^2$. At transects 4, 5 and 6 the mean biomass is higher; 116, 340, and $61g/m^2$, respectively.

Table 4.2 presents percentage abundance of species collected at each transect in December 1979. *Sagittaria kurziana* was the most abundant submerged macrophyte at transect N. *Myriophyllum heterophyllum* was the most abundant submerged macrophyte at transect 1. *Sagittaria subulata* had the highest biomass in the marsh sites at transect N and 1; it was also found in the marsh and submerged sites at transect 5. *Cladium jamaicense,* a typically estuarine plant, was found from transect 2 to transect 5. The most upstream occurrence of *Juncus roemerianus* was at site 3, and it was the most abundant species at sites 3 through 6. *Ruppia maritima,* an important submerged macrophyte found in estuaries, was found at transects 4 through 6.

Table 4.2 lists the submerged and marsh plants present at all sites during the December, 1979, sampling effort. Tables 4.3, 4.4 and 4.5 list the plants and their percentages (by weight) at sites 1, 3 and 5 for the three subsequent quarterly sampling periods. It is evident from these tables that the biomass at the stations downstream of site 1 is concentrated in the marshes rather than the submerged vegetation. Also, the dominance by *Juncus* at sites 3 and 5 in the winter and spring (Tables 4.2 and 4.3) gives way to *Cladium* in the summer and fall (Tables 4.4 and 4.5). Station 6, the farthest downstream site, was only sampled in December, and it was also dominated by *Juncus* marsh (Table 4.2).

The submerged vegetation at transect 1 shows a strong trend for *Myriophyllum* to proliferate greatly in the summer (Table 4.4) and remain relatively equal in terms of its biomass to several other plants *(Vaucheria, Sagittaria, Valisneria)* during the other quarters of the year. The far upstream station, at Newport, showed that most of the biomass was tied up in *Sagittaria* spp. in December, 1979, the only time that it was sampled

(Table 4.2). Also sampled in December, 1979, was the turning basin, transect 2. The only submerged vegetation found was a small amount of *Lilaeopsis* in the eastern portion of the basin (Table 4.2). Most of the plant biomass at this station was in the small marsh at 2E, which is composed exclusively of *Cladium*.

The cumulative percent abundances of macrophytes at all stations are given in Figures 4.3 - 4.9. These figures illustrate the plant distribution along each transect from the most freshwater site, N, to the most saltwater site, 6. Of particular note is that station 3E is a relatively diverse area of submergent vegetation (Figure 4.6). This appears also to be the upstream limit of *Ruppia*, an important estuarine bottom grass.

Figures 4.10, 4.11 and 4.12 illustrate seasonal changes in biomass along three transects across the river. At transect 1 (Figure 4.10), the marsh site indicates little seasonal change. However, the submerged macrophytes there exhibit a definite seasonal trend with highest biomass values occurring in the summer. At transects 3 (Figure 4.11) and 5 (Figure 4.12) marsh biomass is much higher than submerged biomass unlike the upstream station. The marsh site at transect 3 shows no summer increase in biomass but the submerged vegetation biomass at 3E does increase seasonally, with a peak in the fall quarter. The two west sites at transect 5 (Figure 4.12) have a generally higher biomass than their eastside counterparts. At transect 5 (Figure 4.12) east marsh and east and west submerged macrophytes exhibit a definite seasonal trend in biomass, that is, increase in biomass with respect to increase in air temperature and day length. The west marsh, on the contrary, displays lowest biomass in the spring and summer samples. This follows the pattern of the marshes at transects 1 and 3.

Table 4.6 is a summary of net primary production values at three sites. At station 3, the *Juncus* site was consistently more productive than the *Cladium* site. Both species followed the same pattern: low productivity in April, increasing to a peak in June, decreasing in July, and increasing to a peak in September. *Juncus* had maximum productivity in June, while *Cladium* reached its maximum in September. The *Juncus* productivity at station 5 increased to a peak in June, decreased in July and reached a maximum in September. The *Juncus* marsh at station 5 was more productive than the *Juncus* site at station 3; i.e., 1507 g/m^2 as opposed to 1248 g/m^2 for the six month period. The *Juncus* marsh on the Wakulla River is the most productive of all, with a value of 2037 g/m^2. Because of high water, this station was not sampled in April and June. Productivity was constant during the first two sampling months (May and July) but reached its maximum in August before decreasing in September.

Discussion

With regard to marsh biomass studies, Kruczynski, et al. (1978) studied the *Juncus* marsh in the lower St. Marks River. Their sampling sites were located south of our station 6, between the lighthouse and the East River (Figure A.1). Their "low marsh" is equivalent to our marsh stations. Their standing crop during twelve months of study between 1972-74 was 1293 g/m^2. This is very close to the standing crop at station 6 of 1202 g/m^2 which was calculated from the December, 1979, data in the present study. Kruczynski, et al. also reported an underground biomass of approximately 6000 g/m^2 for December, 1974, which compares to our underground biomass of 5500 g/m^2 for December, 1979 at station 6.

While the standing crop and underground biomass figures from the present study are very similar to those of Kruczynski, et al. (1978), the values for net primary production of *Juncus roemerianus* are somewhat different. In the Kruczynski, et al. study, net primary productivity was measured for a full twelve months, whereas in the present study, productivity measurements were taken over a six month period. They found a net productivity of 1372 $g/m^2/yr$. This compares to our six month values of 2037 g/m^2 at the Wakulla site, 1507 g/m^2 at station 5W, and 1248 g/m^2 at station 3E. The six months sampled during the present study are the warmest of the year. Therefore, net productivity estimates for a whole year based upon spring-summer values would be artificially high, since the fall and winter slow growth period is excluded from the calculation. The main point here is that the more productive *Juncus* marshes appear to be correlated with the higher salinity regime downstream of the turning basin area.

The impact of oil on the marsh and submerged vegetation is difficult to determine from this study. It appears that the areas of heaviest oil concentration (transects 2 and 3) are transition zones. One transition is between salt marsh and hardwood forest. That is, the *Juncus* marsh is essentially at its habitat extreme in the area of Shields Marina (transect 3) and the hardwoods begin to exert more influence as one proceeds upstream. The submergent transition is between the exclusively freshwater macrophytes and moderately brackish water macrophytes. For example, at site 2 there is almost a complete lack of submerged macrophytes. Those which appear, such as *Lilaeopsis*, occur in very small numbers and do not occur further upstream. Likewise, *Ruppia* is found at station 3E, but not at site 2 or any of the other upstream stations.

One possible cause of the rather denuded state of the turning basin might be the activity of barges having a scouring effect on the bottom. This may affect plant growth directly or indirectly through high turbidity levels and, consequently, diminished light intensity. Another cause might be continued oil pollution; however, there is a fairly healthy macrophyte community just downstream at station 3E. Baker (1971, 1973) found oil to cause little long-term damage to perennial species of plants in salt marshes but severe damage to annuals. She also found that *Spartina* sp. was more sensitive to long-term exposure to oil than was *Juncus*. Thomas (1973) found massive destruction of *Spartina alterniflora* in lagoons and *Fucus spiralis* on rocky shores two years after an oil spill. DeLaune (1979) found that *Spartina alterniflora* can tolerate large amounts of oil without changes in aboveground biomass. Since *Spartina* is not present in the affected area (it doesn't occur at low salinities), it is most probable that the hardy *Juncus* marshes have simply withstood the various oil spills of the past without much long-term damage, as the literature suggests. The extremely diminished quantity and variety of submerged vegetation at transect 2 may have indeed been caused by the impact of oil. However, the effect appears to be quite localized over the long-term, with healthy plant communities, both submerged and marsh, upstream and downstream of transects 2 and 3.

FIGURE 4.1 Macrophyte Sampling Locations, Including an Additional Wakulla River Station for Marsh Primary Productivity Study

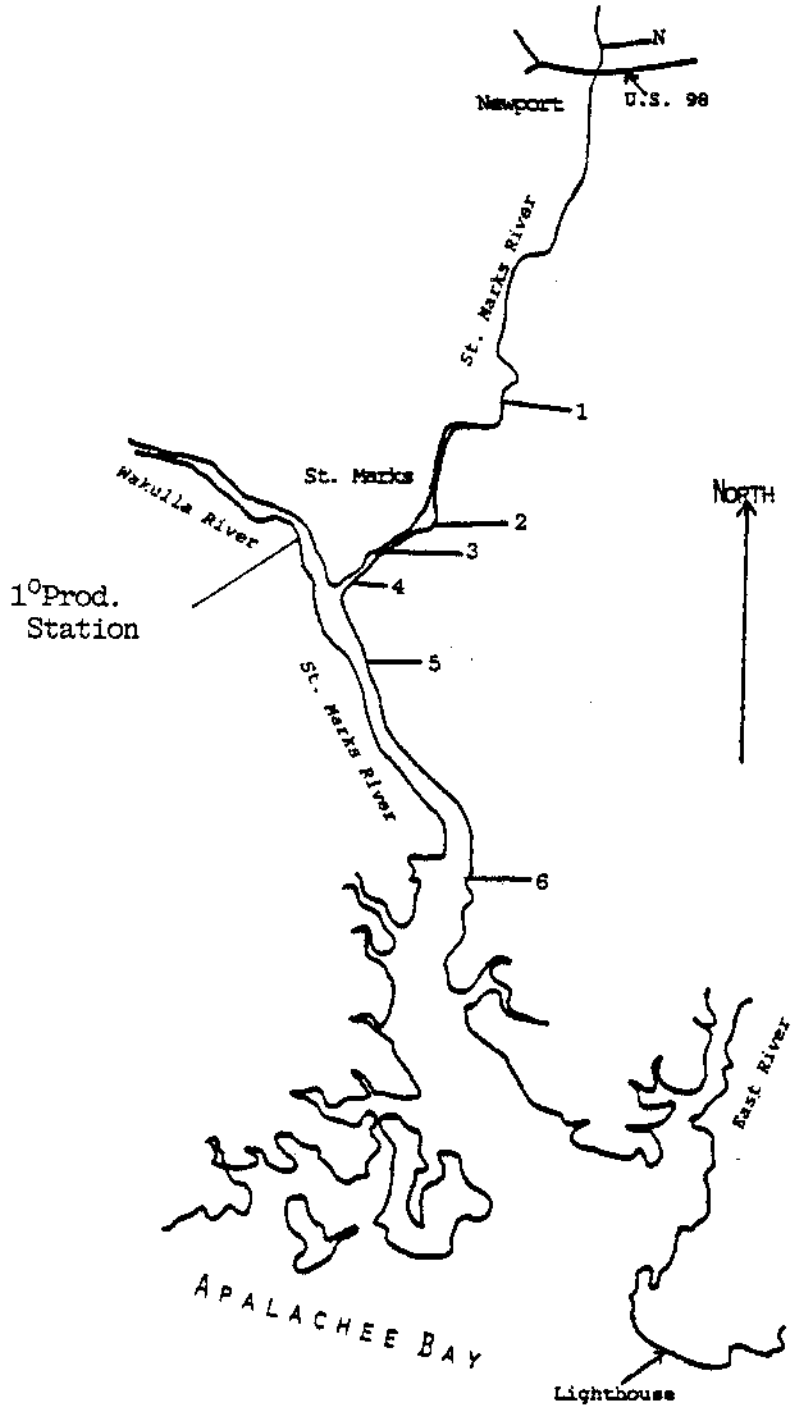


FIGURE 4.2 Mean Biomass of Marsh and Submerged Vegetation at All Transects in December 1979

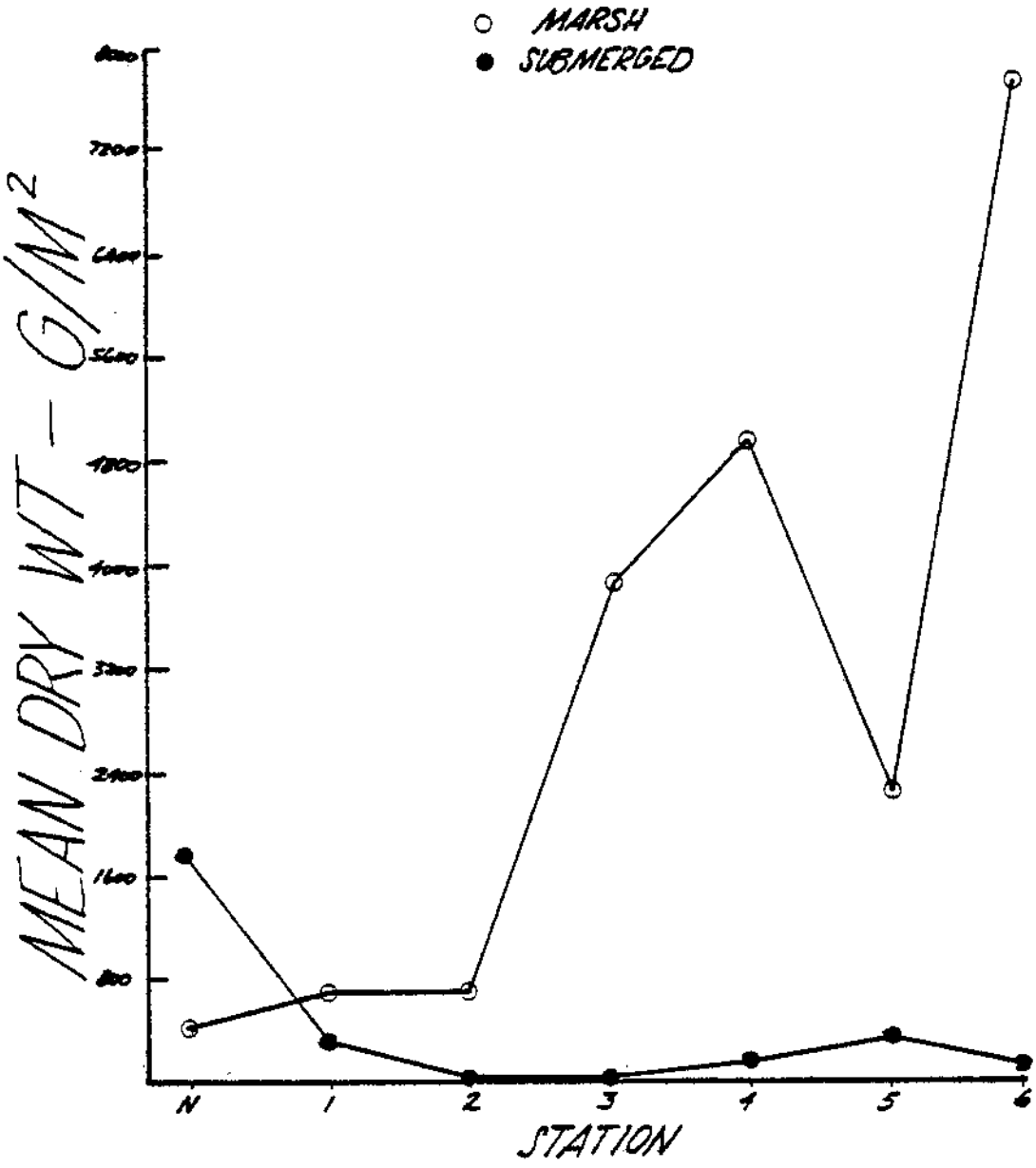
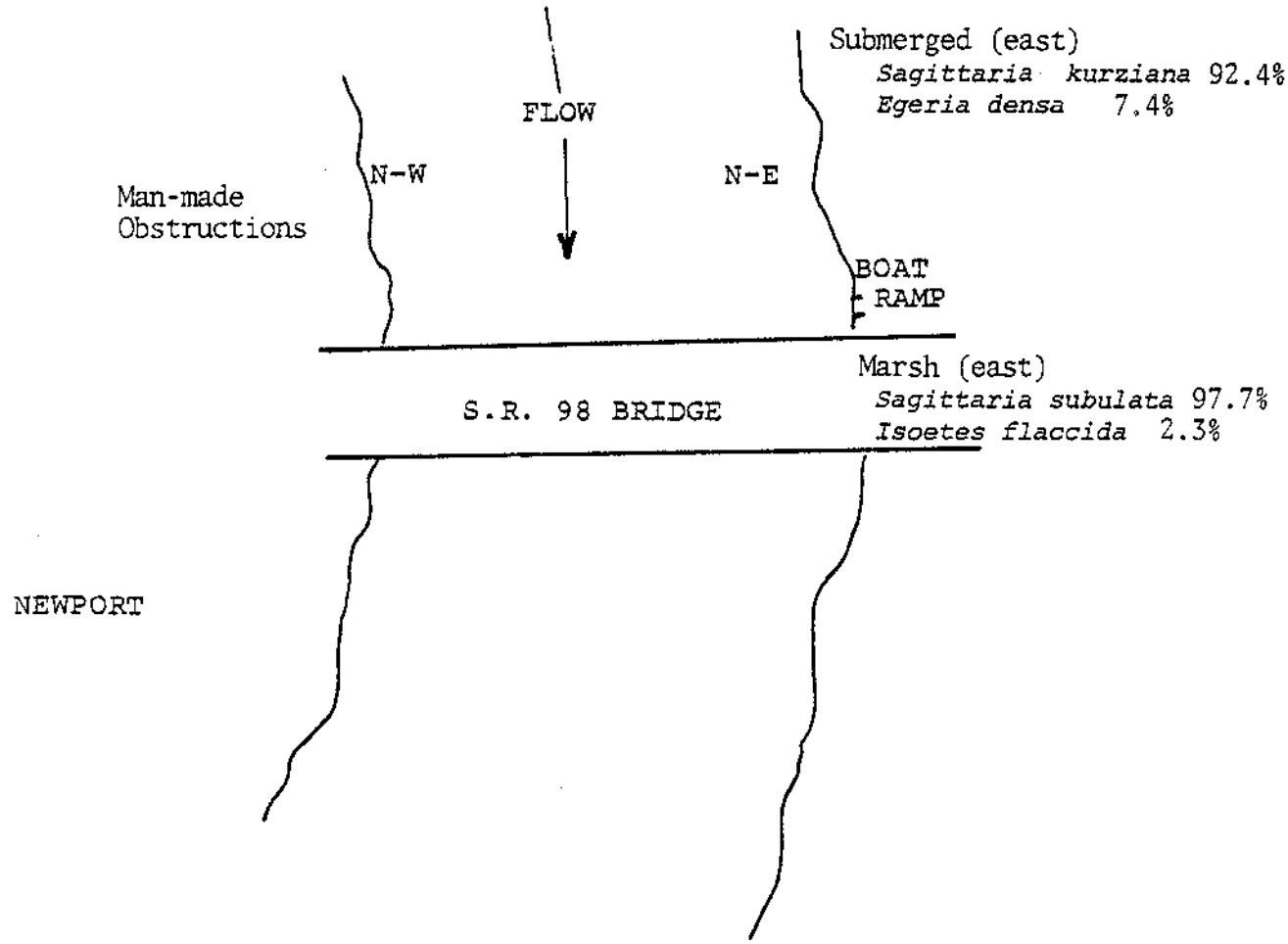
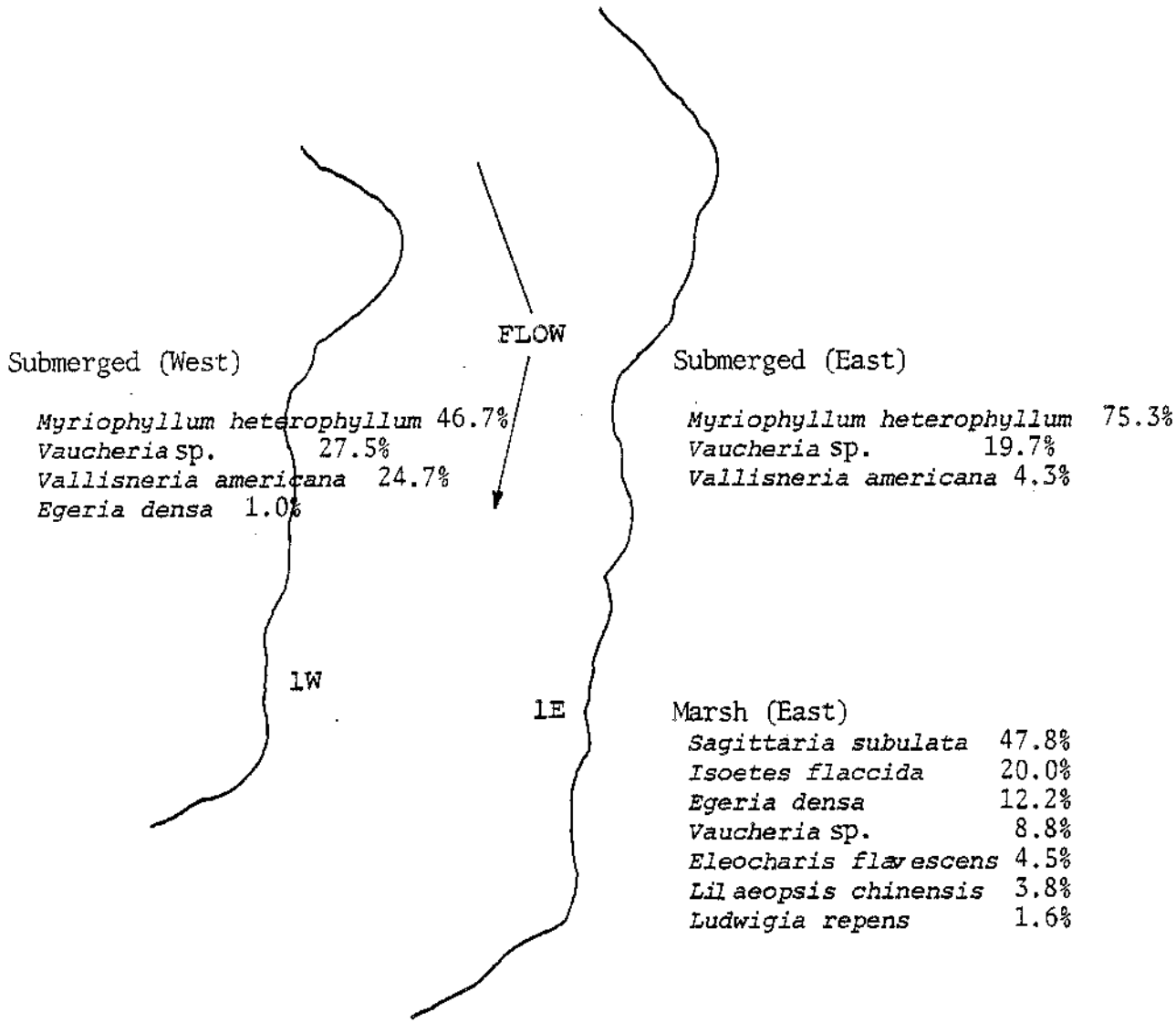


FIGURE 4.3
Abundance* of Macrophytes Collected December 1979 at Transect N



*Percent of Total Biomass

FIGURE 4.4
Abundance* of Macrophytes Collected from December 1979 to Sept 1980
at Transect 1



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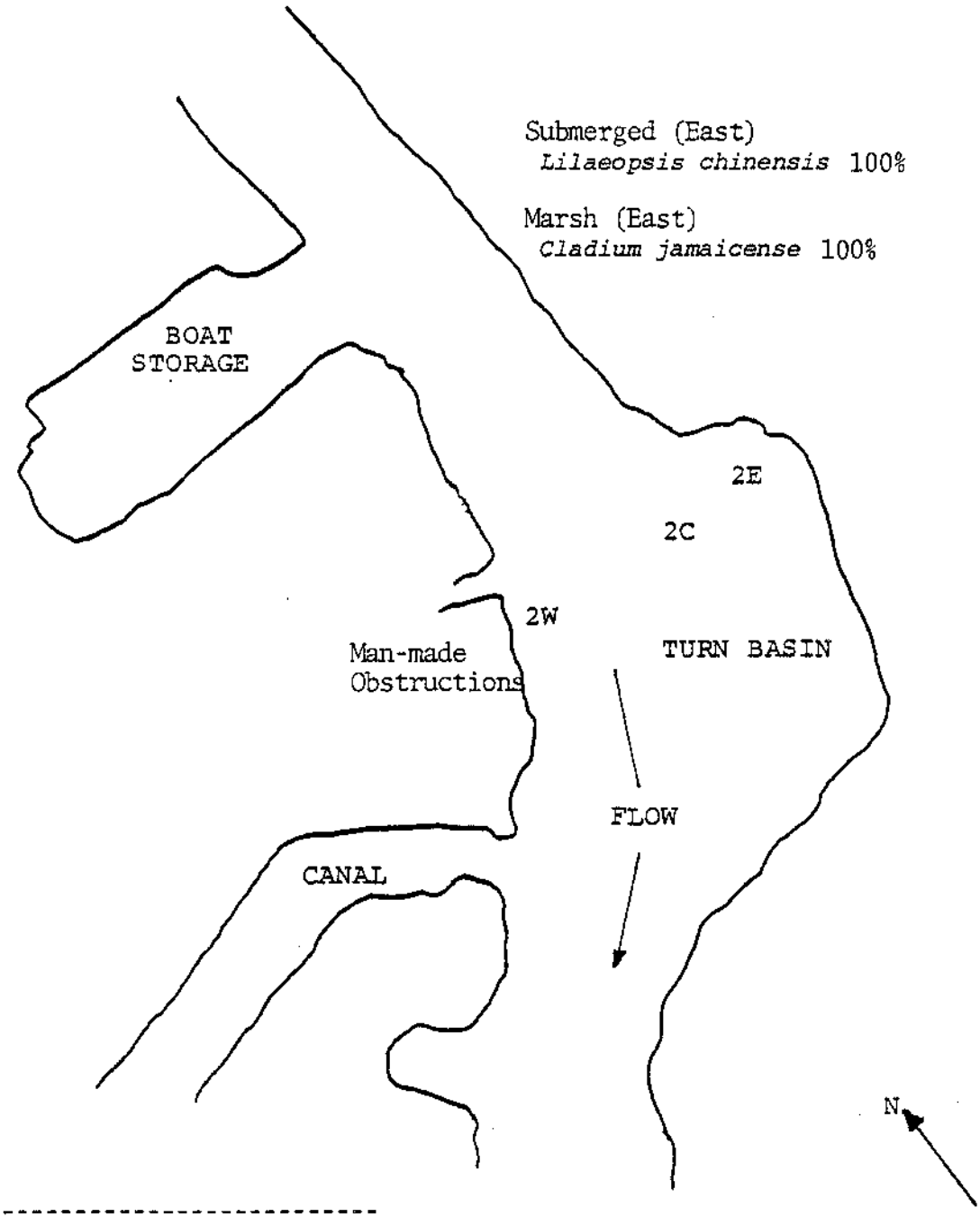
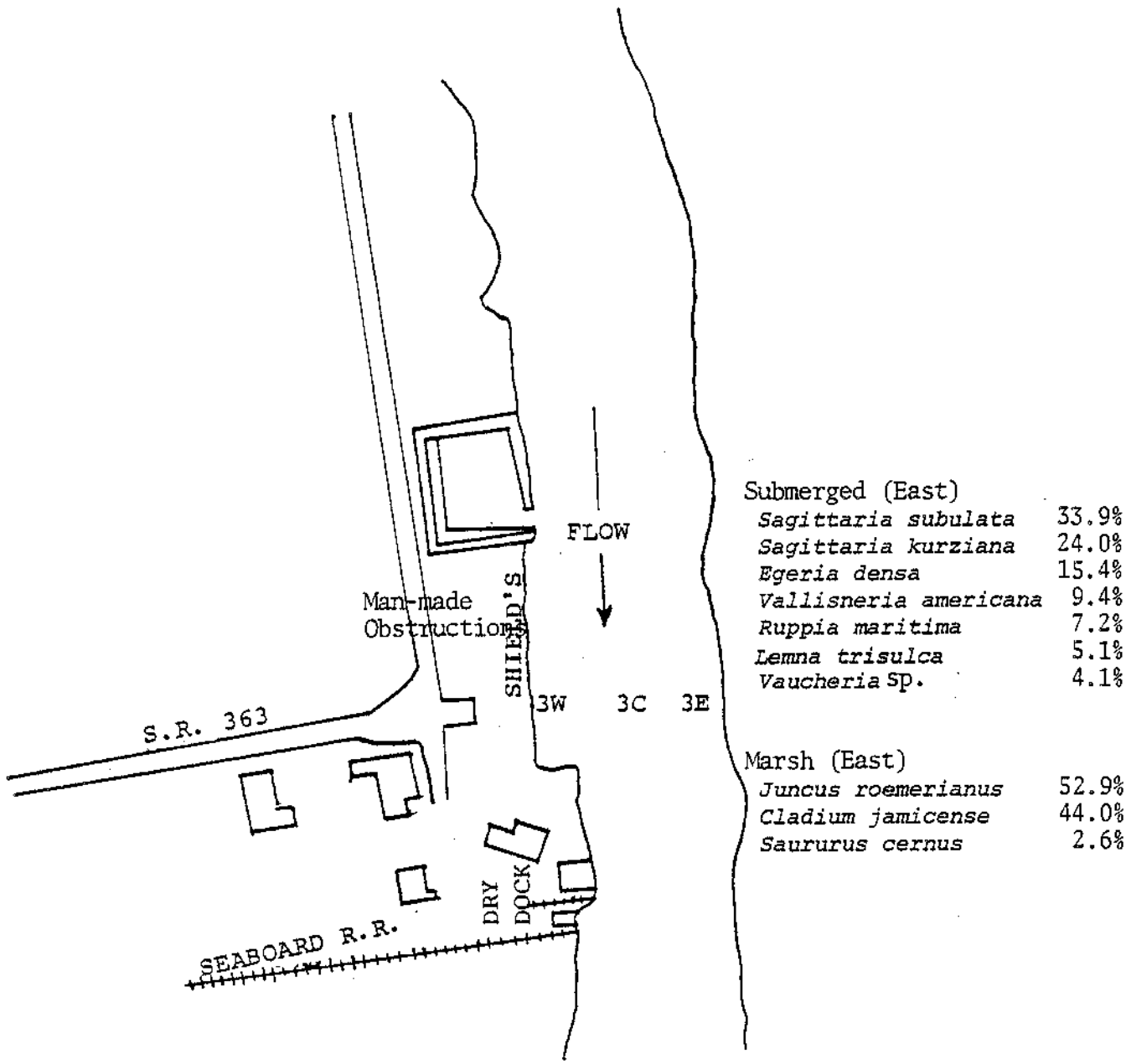
*Percent of Total Biomass

FIGURE 4.5
Abundance*of Macrophytes Collected from December 1979 to September 1980 at Transect 2



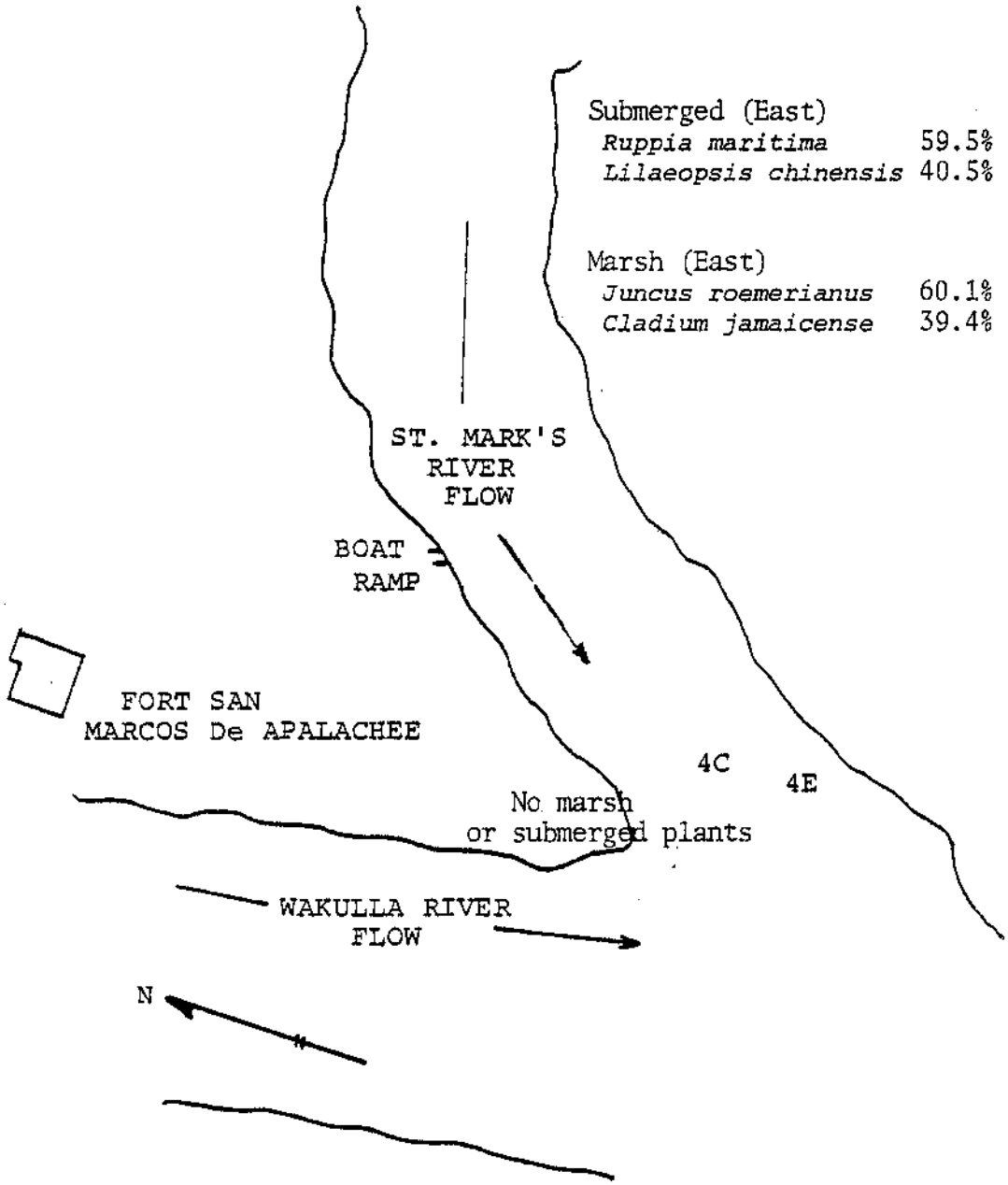
*Percent of Total Biomass

FIGURE 4.6 Abundance*of Macrophytes Collected from December 1979 to September 1980 at Transect 3



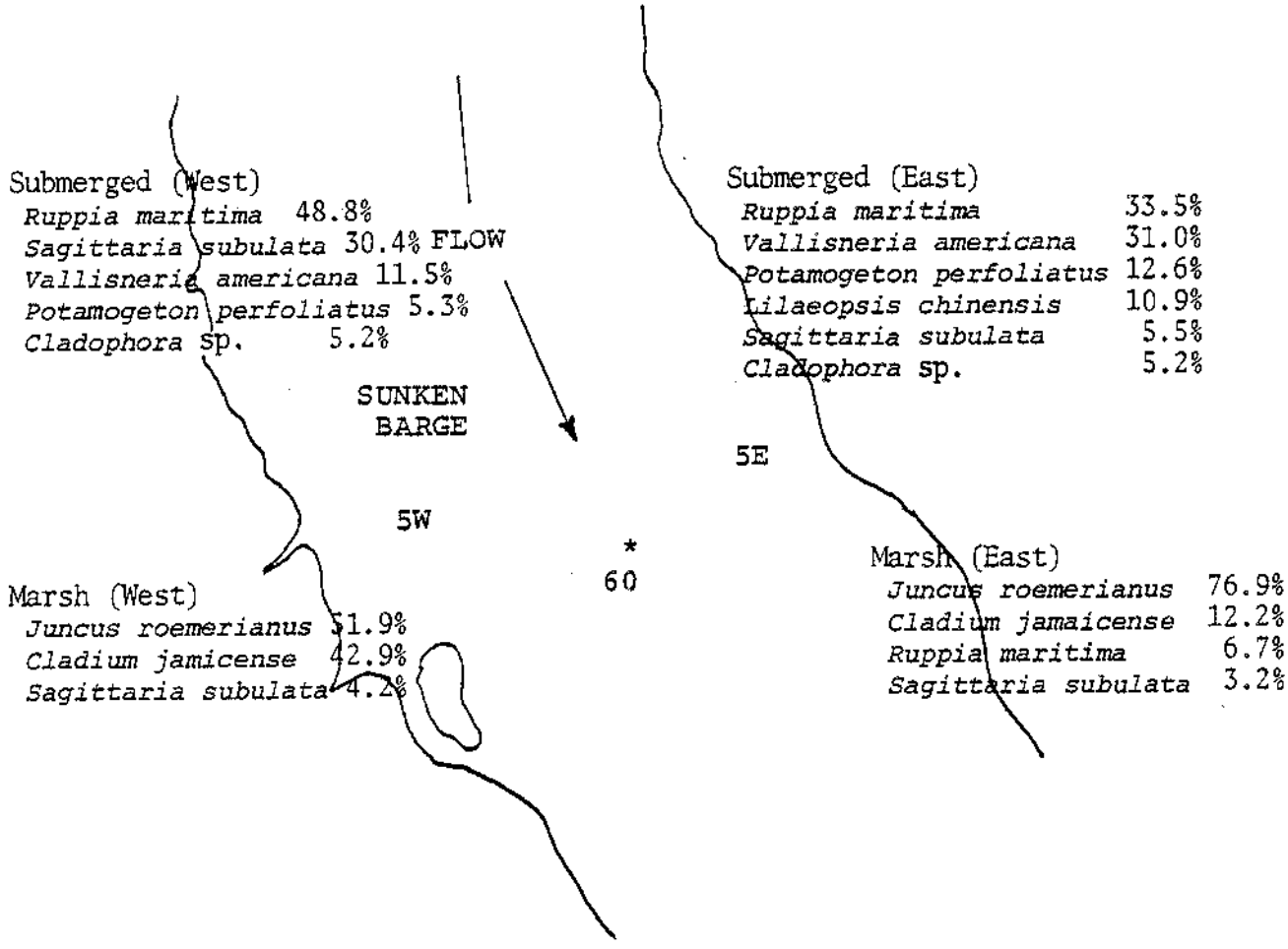
*Percent of Total Biomass

FIGURE 4.7 Abundance* of Macrophytes Collected December 1979 at Transect 4



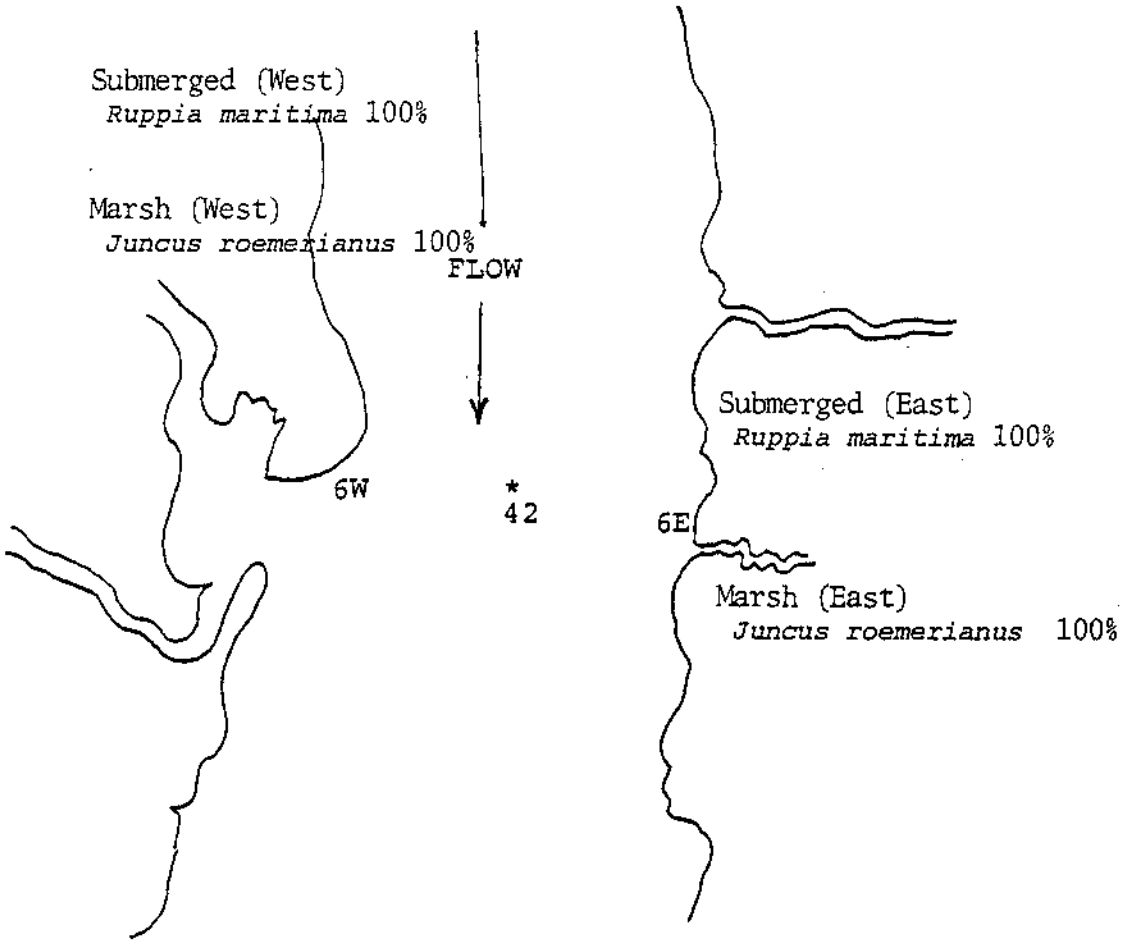
*Percent of Total Biomass

FIGURE 4.8 Abundance* of Macrophytes Collected from December 1979 to September 1980 at Transect 5



*Percent of Total Biomass

FIGURE 4.9 Abundance*of Dominant Macrophytes Collected December 1979 at Transect 6



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*Percent of Total Biomass

FIGURE 4.10 Seasonal Changes in Plant Biomass at Transect 1
(Mean Values Bracketed by Std. Error Bars;
N=3 samples except December, where submerged N=5)

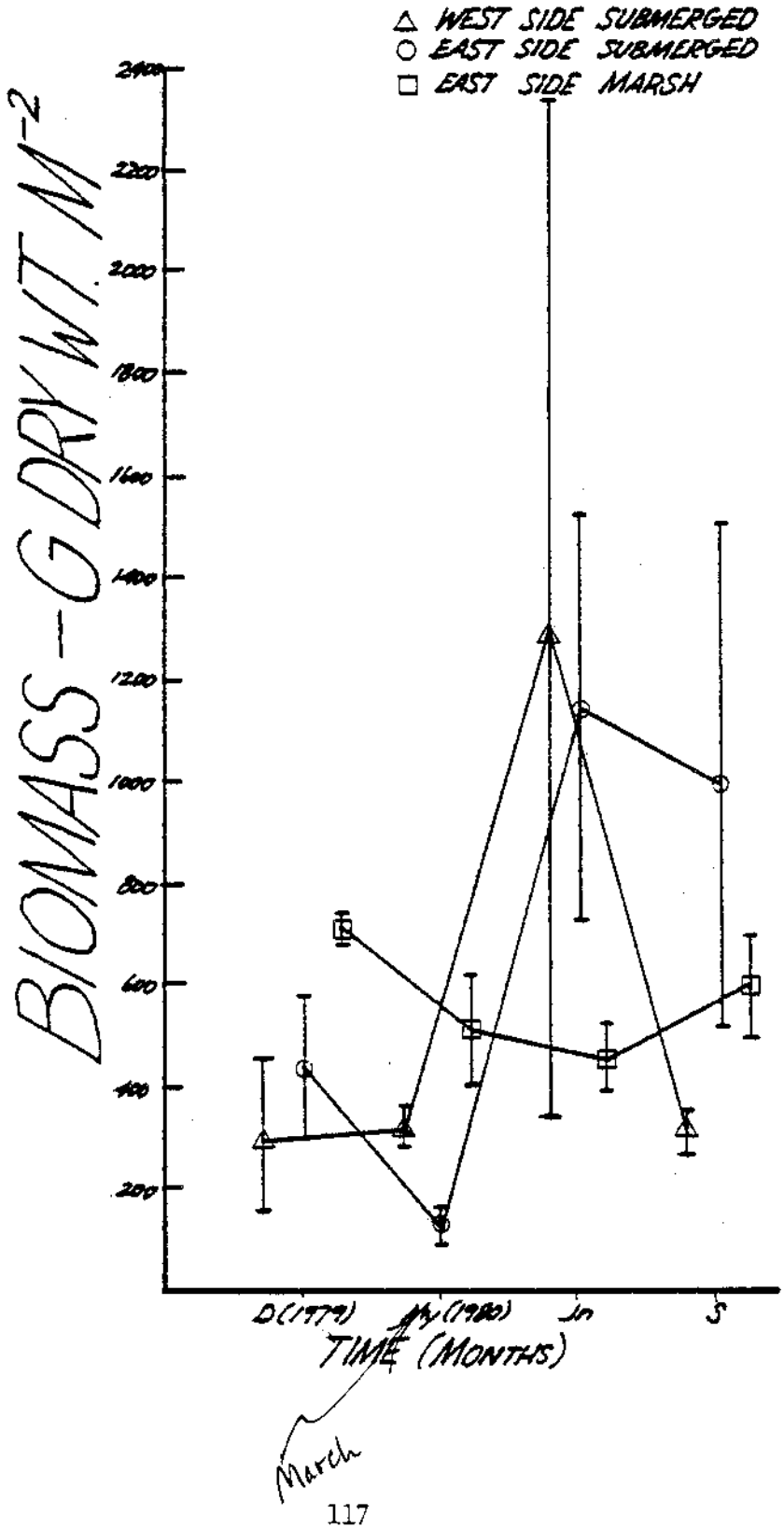


FIGURE 4.11 Seasonal Changes in Biomass at Transect 3. (Mean Values Bracketed by Std. Error Bars; N=3 samples)

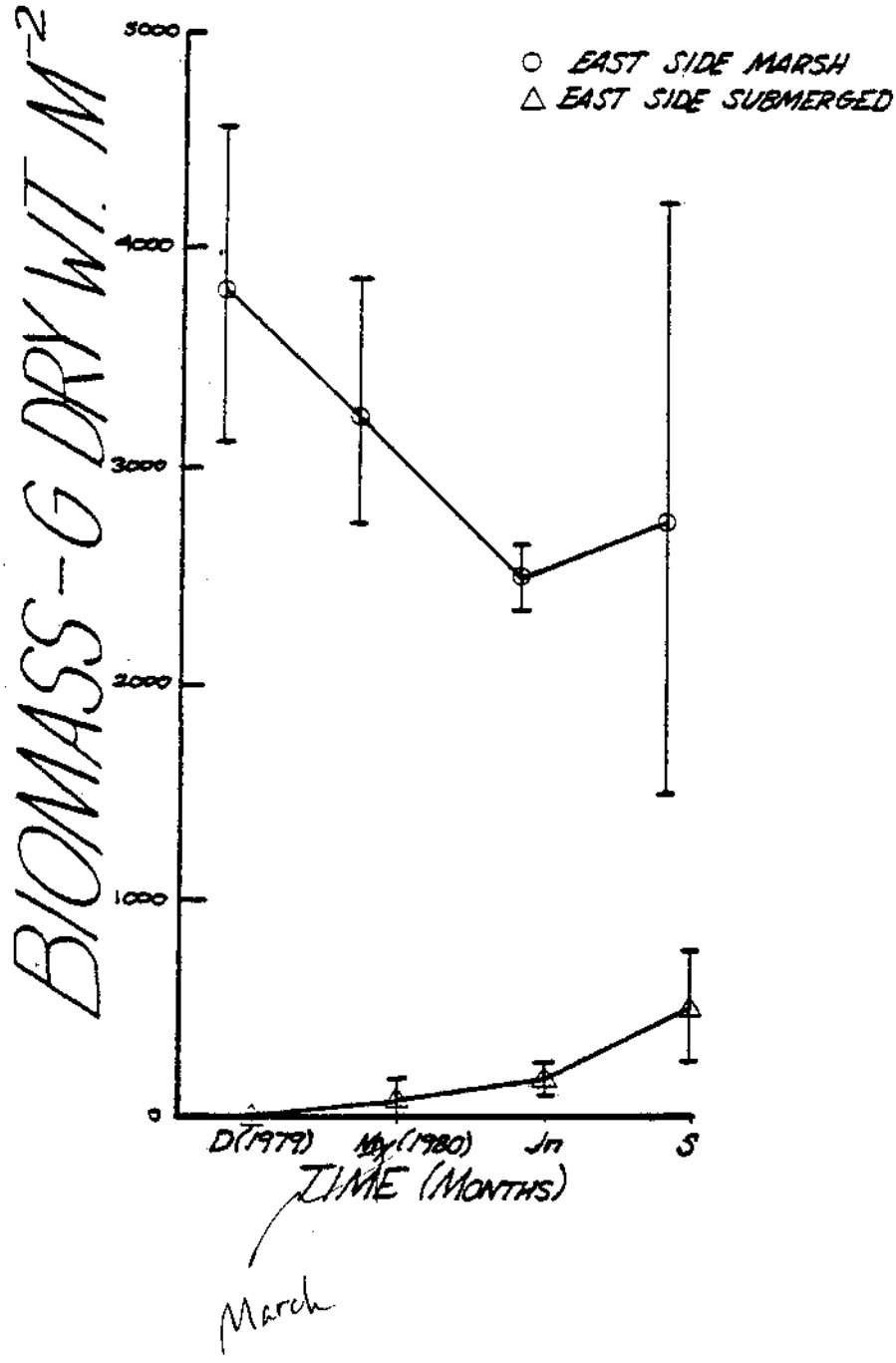


FIGURE 4.12 Seasonal Changes in Plant Biomass at Transect 5 (Mean Values Bracketed by Std. Error Bars; N=3 samples, except December, where submerged N=5)

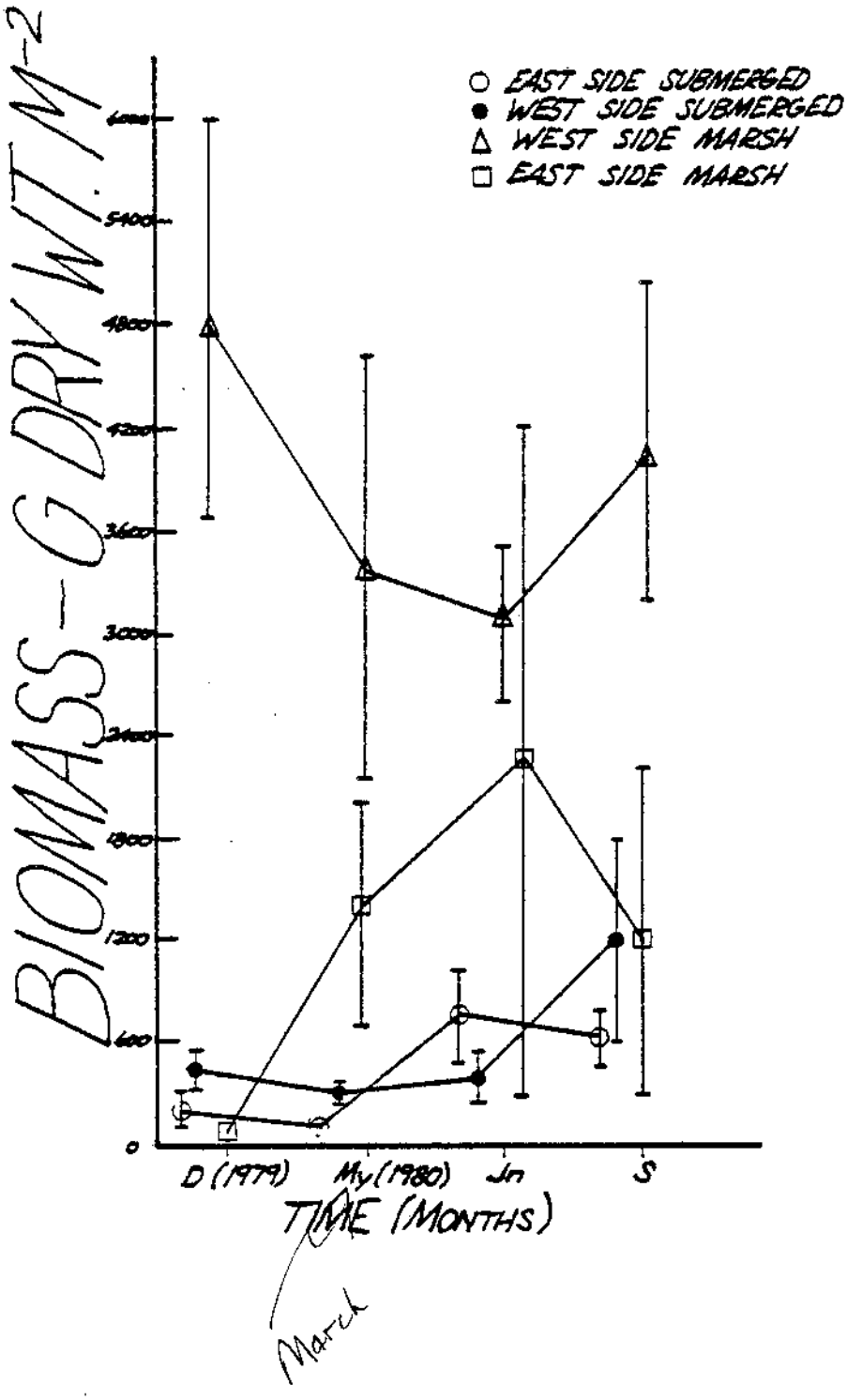


TABLE 4.1 Cumulative Plant Species List

Asteraceae sp.

Cabomba caroliniana

Ceratophyllum demersum

Cladium jamaicense

Cladophora sp.

Crinum americanum

Egeria densa

Eleocharis flavescens

Hydrochloa caroliniensis

Isoetes flaccida

Juncus roemerianus

Lemna trisulca

Lilaeopsis chinensis

Ludwigia repens

Myriophyllum heterophyllum

Najas guadalupensis

Potamogeton perfoliatus

Potamogeton pusillus

Ruppia maritima

Sagittaria kurziana

Sagittaria subulata

Saururus cernuus

Vallisneria americana

Vaucheria sp.

TABLE 4.2 Plant Species Abundance by Transect
(Percent of Total Biomass)

Winter Quarter (December 1979)

Transect N		Percent
	Sagittaria kurziana	75.2
	Sagittaria subulata	18.2
	Egeria densa	6.0
	Isoetes flaccida	.4
	Vaucheria sp.	.1
	Ceratophyllum demersum	<.1
Transect 1		
	Sagittaria subulata	25.8
	Myriophyllum heterophyllum	25.1
	Vaucheria sp.	24.7
	Egeria densa	17.3
	Vallisneria americana	6.4
	Isoetes flaccida	.6
Transect 2		
	Cladium jamaicense	99.8
	Lilaeopsis chinensis	.2
Transect 3		
	Juncus roemerianus	97.3
	Cladium jamaicense	2.5
	Saururus cernuus	.1
	Ceratophyllum demersum	<.1
Transect 4		
	Juncus roemerianus	57.9
	Cladium jamaicense	37.9
	Ruppia maritima	2.2
	Lilaeopsis chinensis	1.5
	Saururus cernuus	.4
	Sagittaria subulata	.1
Transect 5		
	Juncus roemerianus	82.1
	Sagittaria subulata	11.8
	Lilaeopsis chinensis	3.7
	Ruppia maritima	2.1
	Vallisneria americana	.3
	Potamogeton perfoliatus	.1
	Cladium jamaicense	<.1
Transect 6		
	Juncus roemerianus	98.7
	Ruppia maritima	1.3

TABLE 4.3 Plant Species Abundance by Transect
(Percent of Total Biomass)

Spring Quarter (March 1980)

Transect 1

	Percent
Vaucheria sp.	23.7
Sagittaria subulata	20.7
Isoetes flaccida	17.0
Vallisneria americana	16.7
Myriophyllum heterophyllum	13.6
Lilaeopsis chinensis	2.9
Eleocharis flavescens	2.2
Sagittaria kurziana	1.3
Crinum americanum	.7
Egeria densa	.6
Asteraceae sp.	.3
Ludwigia repens	.2
Potamogeton pusillus	.1
Ceratophyllum demersum	.1
Hydrochloa caroliniensis	.1

Transect 2

No Plants in Submerged Zone (Marsh not Sampled)

Transect 3

Juncus roemerianus	71.1
Cladium jamaicense	24.4
Saururus cernuus	2.6
Sagittaria subulata	1.8
Egeria densa	< .1
Najas guadalupensis	< .1

Transect 5

Juncus roemerianus	76.5
Cladium jamaicense	11.5
Vallisneria americana	3.7
Cladophora sp.	3.3
Sagittaria subulata	2.3
Ruppia maritima	1.8
Lilaeopsis chinensis	.6
Potamogeton perfoliatus	.3

TABLE 4.4 Plant Species Abundance by Transect
(Percent of Total Biomass)

Summer Quarter (June 1980)

Transect 1

	Percent
Myriophyllum heterophyllum	63.9
Vaucheria sp.	14.9
Vallisneria americana	7.9
Sagittaria subulata	5.2
Isoetes flaccida	4.4
Eleocharis flavescens	1.4
Lilaeopsis chinensis	1.0
Ludwigia repens	.6
Hydrochloa caroliniensis	.5
Egeria densa	<.1

Transect 2

Nc Plants in Submerged Zone (Marsh not Sampled)

Transect 3

Cladium jamaicense	69.6
Juncus roemerianus	14.2
Saururus cernuus	8.9
Sagittaria subulata	7.0
Ruppia maritima	.2
Vallisneria americana	.1

Transect 5

Cladium jamaicense	48.6
Juncus roemerianus	31.6
Ruppia maritima	11.0
Vallisneria americana	4.0
Sagittaria subulata	3.1
Cladophora sp.	1.4
Egeria densa	.2
Lilaeopsis chinensis	.1
Cabomba caroliniana	<.1

TABLE 4.5 Plant Species Abundance by Transect
(Percent of Total Biomass)

Fall Quarter (September 1980)

Transect 1

	Percent
Myriophyllum heterophyllum	39.3
Vaucheria sp.	17.6
Sagittaria subulata	16.9
Vallisneria americana	11.6
Isoetes flaccida	9.0
Eleocharis flavescens	2.2
Lilaeopsis chinensis	1.8
Ludwigia repens	.8
Saururus cernuus	.3
Egeria densa	.2
Lemna trisulca	.2

Transect 2

No Plants in Submerged Zone (Marsh not Sampled)

Transect 3

Cladium jamaicense	83.8
Sagittaria kurziana	5.2
Egeria densa	3.3
Vallisneria americana	2.0
Sagittaria subulata	1.8
Ruppia maritima	1.4
Lemna trisulca	1.1
Vaucheria sp.	.9
Saururus cernuus	.3
Ceratophyllum demersum	.2

Transect 5

Cladium jamaicense	50.2
Ruppia maritima	16.8
Juncus roemerianus	13.5
Sagittaria subulata	9.1
Vallisneria americana	5.2
Potamogeton perfoliatus	4.5
Cladophora sp.	.5
Potamogeton pusillus	.1
Ceratophyllum demersum	.1

TABLE 4.6 NET PRIMARY PRODUCTION

Station 3E *Juncus* Marsh

Month	Net Primary Production($g/m^2/day$)
April	2.37
May	3.54
June	12.90
July	3.36
August	8.74
September	10.18

Six Month Production $1248 g/m^2$

Cladium Marsh

Month	Net Primary Production($g/m^2/day$)
April	0.42
May	2.15
June	5.70
July	2.41
August	8.18
September	9.70

Six Month Production $870 g/m^2$

Station 5W *Juncus* Marsh

Month	Net Primary Production($g/m^2/day$)
April	2.67
May	3.65
June	8.00
July	2.61
August	14.11
September	18.53

Six Month Production $1507 g/m^2$

Wakulla Station *Juncus* Marsh

Month	Net Primary Production($g/m^2/day$)
April and May	5.09
June and July	5.26
August	27.42
September	18.53

Six Month Production $2037 g/m^2$

SECTION FIVE: DETRITUS

Introduction

The decomposition of organic matter in aquatic systems is dependent upon the action of both detrivores (ciliates, microcrustacea, small chewing insects, etc.) and bacteria. Numerous studies on the rate of breakdown of leaf and grass litter have been undertaken in estuarine and salt marsh areas (Teal, 1962; Odum and de la Cruz, 1967; Haines, 1977, de la Cruz, 1979.) The downstream coastal area of the St. Marks estuary was studied by Krucynski, et al. (1978) and included litter bag detrital breakdown analyses. For the purposes of the present study, three areas of the St. Marks river-- about five miles above the mouth --were chosen for a litter bag detrital breakdown study. The first site is in mostly freshwater above the oil unloading docks. The second site is in the turning basin, which is just downstream from the oil docks and is occasionally visited by low salinity water. The third site is a point just above the confluence of the St. Marks and the Wakulla Rivers where the salinity frequently reaches eight to ten parts per thousand. The object of the study was to determine the rates of decay of litter placed in bags at these various stations in the river. The stations are approximately equidistant from each other.

Materials and Methods

Two prevalent plants were chosen as sources of litter for the decomposition experiments: leaves of the sweet bay tree (*Magnolia virginica*) and stalks of the needlerush (*Juncus roemerianus*). The sweet bay is

prominent along the river banks in the area, particularly at the two upstream stations. *Juncus* is found as stands of fringing marsh all along the river up to about the area of station 1.*

Fresh bay leaves were harvested, rinsed with fresh water in the laboratory, and dried in a constant temperature room (22 °C) for 24 hours. *Juncus* stalks were cut from the marsh, returned to the laboratory where dead stems were separated and discarded. The washing and drying procedures were the same as for the bay leaves.

Bags of supple nylon netting of approximately 4 mm mesh were constructed with inner dimensions of 20 X 20 cm. The leaves or stalks were placed inside of the bag along with a durable label and the bag was sewn shut. The bags were also marked with identification numbers using indelible ink. Approximately 5 gram samples (to the nearest 0.01 g) of leaves or stalks were placed in a bag. The *Juncus* was cut into 15 cm lengths and bundled with rubber bands before being placed in the bag to prevent talks from sliding through the mesh. Altogether there were 126 bags, with 21 of each type placed at each of the three stations. The bags were tied to a rope which was attached to a cement block on the bottom and a styrofoam float at the top so that the bags were suspended in the water column independent of water level. Seven of each plant type were tied to each of three blocks at each station. The blocks were within a 2 m radius of one another. This arrangement was to minimize losses due to vandalism or accident. All bags were set out on March 27, 1980, and the first collection was made after two weeks, the second after four weeks, and thereafter at monthly

*Station numbers are labeled 1, 2 and 4 as one proceeds downstream, and correspond to station locations for the macrophyte and benthic portions of the study (Fig. 1).

intervals. A bag of each species was retrieved at random from each block at each station and brought back to the lab for processing.

In the laboratory, the bags were rinsed with fresh water to remove any debris which would pass through the bag. The unopened bags were next allowed to air dry for two weeks at constant temperature (22 ^{o}C) while suspended in the air on nylon screening. After two weeks, the bags were opened and their contents weighed to the nearest 0.01 g. The resulting loss of material due to decomposition was determined by subtracting these weights from the known weights at the beginning of the experiment. The percent weight loss was then calculated.

Results

All of the bags on all three blocks at station 4 were missing after the third month. A line leading from the blocks to the shore marker had been severed. Likewise, several of the ropes and bags from the upstream stations were taken during the course of the experiment. Therefore, it was not always possible to collect replicates at each station. A total of 33 of the original 126 bags were lost during this experiment.

The results of the decomposition experiments are found in figures 5.1 and 5.2. The initial rate of decay of the bay leaves was much greater than that of *Juncus*. Within the first month, the bay leaves had already lost an average of 35% of their original weight, while the *Juncus* lost from 14% to 23%. This trend continued throughout the course of the experiment, with virtually nothing left of the bay leaves by the September termination date. On the other hand, the *Juncus* lost no more than 38% of the initial weight during the six month period. Further, it is readily apparent that

there is little or no difference in the decay rates of *Juncus* among the stations. There is an apparent difference in bay leaf decay in that the decay rate at the turning basin appeared to level off in the summer period, whereas the rate of decay upstream continued to approach zero more rapidly. A t-test, however, demonstrated no significant difference in percent weight loss during this period (Table 5.1). The downstream data are not available so that further comparison is not possible.

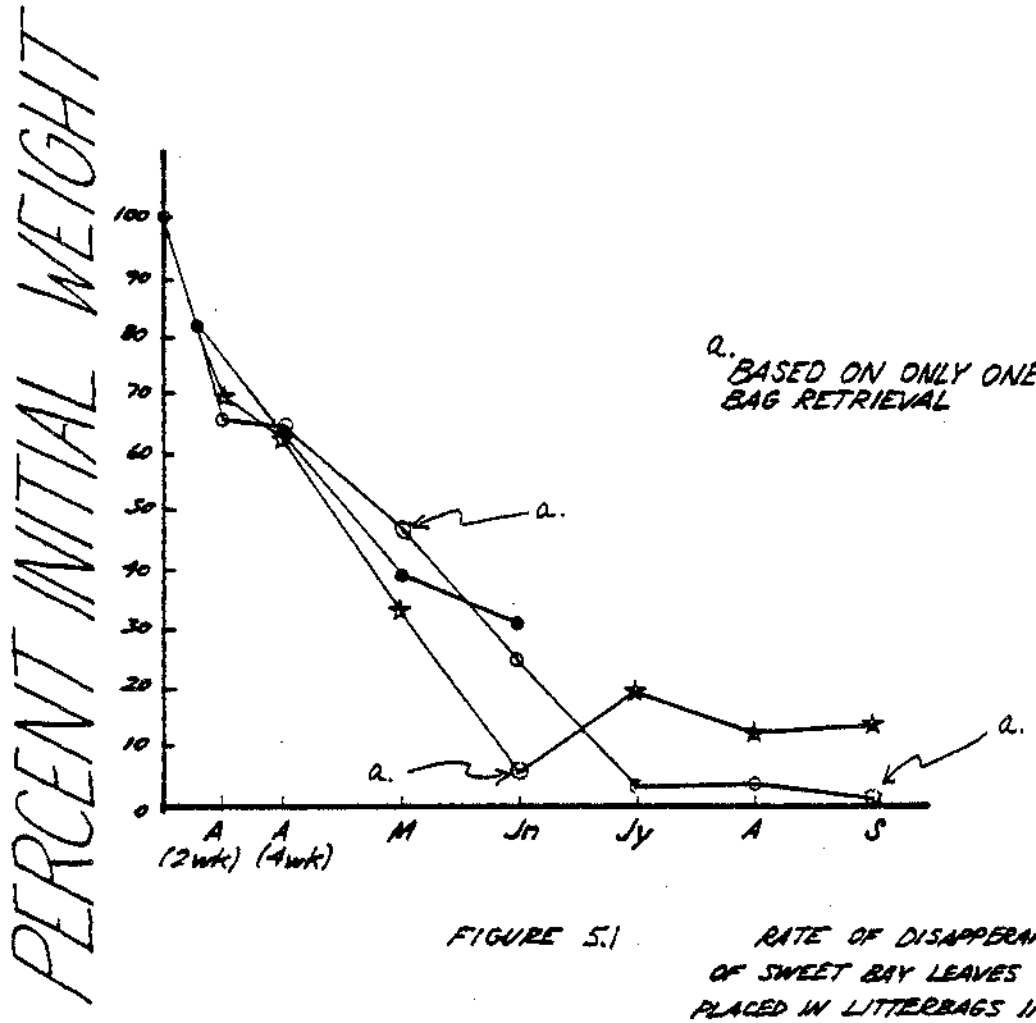
Discussion

The difference in decay rates between the two materials, bay leaves and *Juncus*, is not unexpected, since the latter is somewhat more woody in texture. Kruczynski, et al. (1978) found that *Juncus* decomposed at a slower rate than the less woody *Spartina* at a site in the East River, which runs into the lower St. Marks River near its mouth. In fact, after a year, the *Spartina* log suspended in the water column had lost about 95% of its initial weight, while the *Juncus* had lost-only about 65% of its initial weight (Kruczynski, et al., 1978). Recent work by Haines and Hanson (1979) suggests that maximum rates of degredation of estuarine marsh plants occur at the sediment-air or sediment-water interface; that detritus suspended in estuarine water may not obtain enough external nitrogen and buried detritus not enough exygen to facilitate decomposition. In the present study, the prospect of vandalism of sample bags precluded such an approach.

The process of the breakdown of plant material into detritus is complex, involving weathering, leaching, bacterial and fungal action and decomposer animals (de la Cruz, 1979). It is quite probable that one or

more of the processes involved in the decomposition of litter may be interrupted or modified by the presence of oil. Hydrocarbons are toxic in small concentrations to à large number or aquatic organisms, particularly to larval and juvenile stages (EPA, 1976). Oils may also inhibit the osmoregulatory functions of organisms (Anderson and Anderson, 1975) as well as interfere with the ability of animals to find food through olfactory detection. For example, small quantities of a soluble fraction of kerosene (4µg/l) interfere with the chemically mediated attraction to food of the marine snail *Nassarius obsoletus* (Jacobson, 1973). Atema and Stein (1974) found that small concentrations of Maine crude oil in the water column interfered with the ability of the lobster, *Homerus americanus*, to detect its food. Such physiological interferences could also affect simpler organisms such as bacteria or some of the microcrustacea and insects which utilize litter and thus help to break it down.

It appears from our data on the decomposition of bay leaves and *Juncus* that there are no differences among the stations and hence no perceived inhibitory effects due to oil pollution. It might be that such effects are short-term (i.e., just after a spill) when the toxic aromatic fractions are present. Since these volatilize rapidly (Sanders, et al., 1980), the inhibition of decomposer organixmx may last only a matter of days or weeks. As the chemical analysis of the oiled sediment shows (Fig. _), the oil on the St. Marks bottom is weathered, and is not replete with aromatic hydrocarbons.



a. BASED ON ONLY ONE BAG RETRIEVAL

FIGURE 5.1 RATE OF DISAPPEARANCE OF SWEET BAY LEAVES PLACED IN LITTERBAGS IN THE WATER COLUMN AT THREE STATIONS (STA. 1 = OPEN CIRCLES; STA. 2 = STARS; STA. 4 = CLOSED CIRCLES). ALL BAGS LOST AT STA. 4 AFTER JUNE.

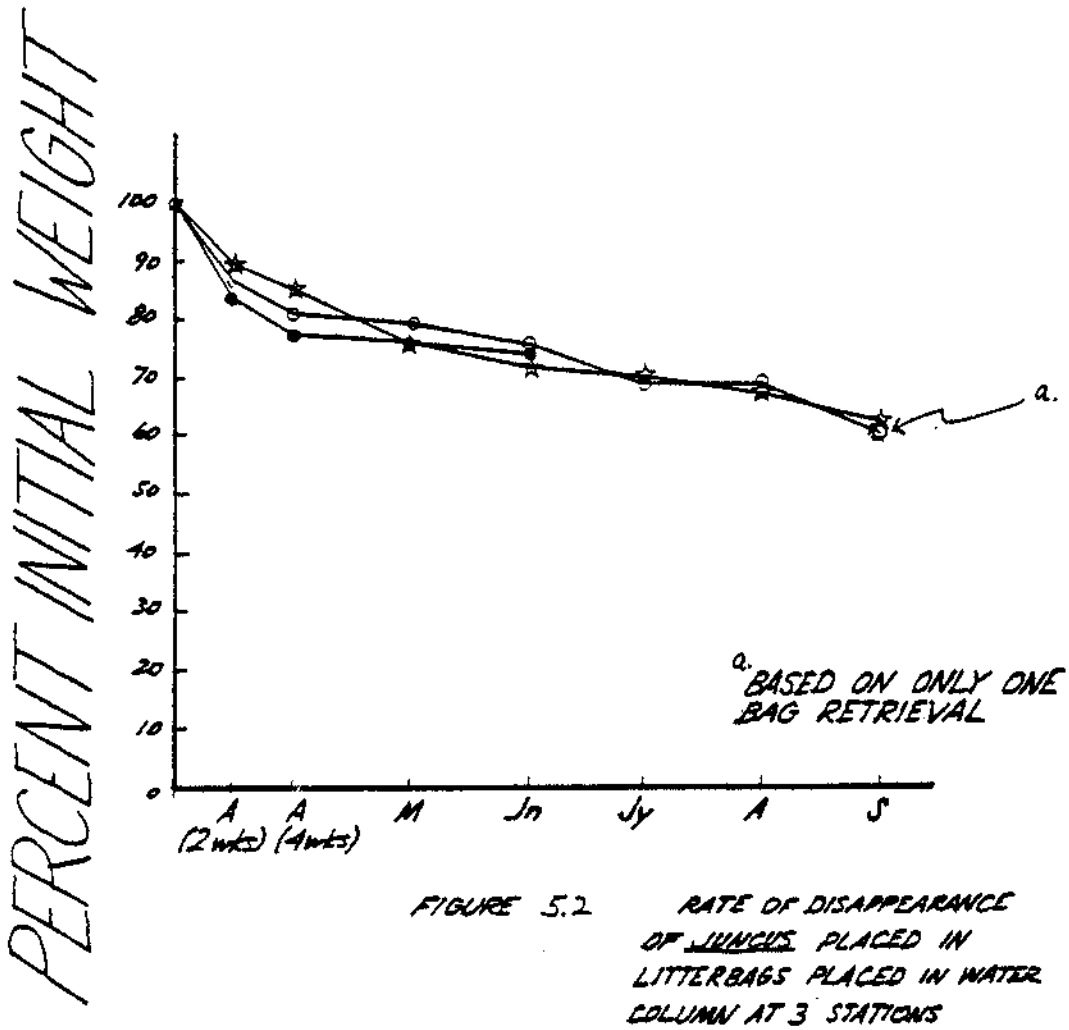


FIGURE 5.2 RATE OF DISAPPEARANCE OF JUNCUS PLACED IN LITTERBAGS PLACED IN WATER COLUMN AT 3 STATIONS (STA. 1 = OPEN CIRCLES; STA. 2 = STARS; STA. 4 = CLOSED CIRCLES). ALL BAGS LOST AT STA. 4 AFTER JUNE.

TABLE 51 Student's t-Test for Difference in Weight Loss of Sweet Bay Leaf Bags During Summer (July, August, September) at Stations 1 and 2

Percent Weight Loss

Station 1: 95.6, 99.8, 98.0, 95.8, 100.0

Station 2: 73.3, 89.7, 72.2, 92.5, 98.3, 71.2, 77.7, 100.0, 98.5

1.) Where $n_1 \neq n_2$, $t = \dfrac{\bar{X}_1 - \bar{X}_2}{\sqrt{\dfrac{\Sigma x_1^2 + \Sigma x_1^2}{n_1 + n_2 - 2}\,(1/n_1 + 1/n_2)}}$

2.) $t = 2.11$

3.) $t = \pm 2.18$ for 2-tailed test at $p < 0.05$

$t = \pm 3.06$ for 2-tailed test at $p < 0.01$

4.) No significant difference at either the 95% or the 99% confidence level.

SECTION SIX: PERIPHYTON

Introduction

The periphyton* community is recognized as an important component of aquatic communities as well as an excellent indicator of water quality (U.S.E.P.A., 1973). For these reasons, a short-term baseline study of the St. Marks River periphyton community was initiated in conjunction with the benthic and macrophytic studies. Attempts were made to characterize the periphyton algal communities of three separate stations along the St. Marks River by: 1) determination of the proportional distribution of periphyton phyla and 2) determination of the biomass distribution as measured by ash-free dry weights.

Study Site Description

Sites 1E, 2E and 4E of the benthic and macrophytic studies were used as sites for placement of the periphyton racks (Figure A-1; in particular, stations 1E, 2E and 4E). These three stations were chosen because data could be gathered regarding: 1) the growth of periphyton in an area disturbed by oil pollution and frequent disturbances by oil barges (station 2) and 2) periphyton growth in two relatively unoiled areas (stations 1 and 4) located approximately equidistant upriver and downriver from the turning basin station. It should be noted that stations 1 and 4 are not true "control" stations in that the salinity regimes differ among all three stations.

*Periphyton are those algal organisms which are neither rooted to the bottom nor free-floating, but, rather, adhere to other surfaces such as leaves, stalks, etc.

See Section Two for physical and chemical descriptions of the station locations. Further, station 4 is also subject to frequent barge traffic, although not to the extent that the turning basin experiences the barges as they are maneuvered by tugs. However, the turning basin is in the most consistently heavily oiled section of the river (see Section Three for sediment oil and grease discussion) and one would expect to see inhibitory effects in the periphyton community here, if at all.

Materials and Methods

Sample apparatus for periphyton collection were set out in the field at the three stations and left in place for four weeks (22 July 1980 to 23 August 1980). As a check on the results, a second group was set out in the same locations for four more weeks (23 August 1980 to 25 September 1980).

Samples for qualitative and quantitative analyses were collected by the "glass slide" method (Sladacek and Slodeckova, 1964). Four racks of eight slides (25mm X 75mm cleaned microscope slides) each were set out at all three locations. Slides were oriented vertically in the water column. Two of the stainless steel racks were suspended 31cm from the surface and two at 62cm from the surface by anchored floats (U.S.E.P.A., 1973). Four of the slides in each rack were used for dry weight determination and the other four were used in counting and partitioning into phyla. After four weeks, the racks were collected and slides from each rack were put into glass jars containing a buffered formalin solution in the field. In the laboratory in Tallahassee, the slides were scraped with razor blades to remove the periphyton from the glass surfaces. The edges of the slides were not scraped.

Ash-free dry weights were determined by scraping four slides from each of two replicate racks into a crucible. The volume was brought to 100 ml with distilled water and the samples were dried overnight at 105 ^{o}C. The samples were removed, brought to room temperature in a desiccator and then weighed. The dried samples were then placed into a muffle furnace at 550 ^{o}C for one hour. After ashing, they were rehydrated anq placed back into the drying oven overnight. Finally, the samples were allowed to reach room temperature in a desiccator and were again weighed. The net organic weight was determined by the following formula: Ash-free dry weight = Dry weight - Ash weight.

Periphyton obtained for population analysis was placed into glass jars containing 5% formalin solution and the volume was brought up to 100 ml with distilled water. The samples were then stored at 4 ^{o}C until ready to be analyzed. Microscopic analysis was performed at 400X using a Sedgwich-Rafter cell and a Whipple grid. Ten random fields were counted following E.P.A. guidelines (U.S.E.P.A., 1973). A simplified procedure was followed in which organisms were categorized into the Cyanophyta (the blue-green algae), the Chlorophyta (the green algae), the Bacillariophyta (the diatoms) or the Euglenophyta (the euglenoid organisms). Members of other phyla were not observed. The data were converted to number of organisms per ml by knowing both the volume of the ten fields examined and the dilution of the aliquot used and putting these into a standard formula.(U.S.E.P.A. 1973.) Dilutions were based on obtaining a manageable number (seventy to one hundred fifty or so) of organisms in the ten random fields.

Results

The data for top and bottom racks at each station were similar, except

that the top racks usually had more organisms per ml. This was expected because of the greater amount of light near the surface. Therefore, the data from top and bottom racks have been combined at each location.

These data strongly suggest that the dominant phylum at station 2 is Bacillariophyta, the diatoms (Figures 6-1 and 6-2). Stations 1 and 4, upriver and downriver, respectively, from station 2, show changes in dominant group from the first sampling period to the second (Figures 6-1 and 6-2). In terms of percentages, combined results for the two sampling periods show cyanophytes dominant at station 1, bacillariophytes dominant at station 2 and chlorophytes dominant at station 4 (Figure 6-3). Also, a few euglenoids were found in the top racks at station 1, but these accounted for less than 1.5% of the total.

The comparative differences in the general algal make-up of the periphyton communities at the three stations can be seen in the actual numbers of organisms per ml (Figures 6-4, 6-5 and 6-6). Here it can be seen that the numbers of organisms, particularly the diatoms, are much greater at stations two and four than at station 1, the upriver station. Dry weight data (Figures 6-7 and 6-8) show similar trends, with the mass of the periphyton increasing from station 1 to station 2 and then becoming much greater at station 4. The large difference between top and bottom ash-free dry weights at station 4 in the second sampling period is unexplained, since the no./ml data for the same replicates indicated no difference.

Discussion

It is apparent from the percent composition data at the three stations that there are at least two and possibly three habitats involved. However,

the data do not show that there is inhibition of periphyton growth at station 2, which is the most heavily oiled site. Inhibition of algal photosynthesis or growth due to petroleum hydrocarbons has been demonstrated by many investigators (Vandermeulen and Ahern, 1976). Photosynthetic inhibition in marine algae by various whole oils has been observed by Gordon and Prouse (1973) and in marine diatoms by Pulich, et al. (1974). Various water soluble fractions of crude and refined oils have been found to inhibit photosynthesis in marine algae at very low levels in the water column (Armstrong and Calder, 1978). Other experiments have demonstrated that components of weathered oils, such as naphthalene, can inhibit the rate of photosynthesis in algae (Vandermuelen and Ahern, 1976). Naphthalene, for example, has been positively identified as one of the components of the sediment at the turning basin (see Section 2). Any effects due to naphthalene, or any inhibitory effects caused by oil, however, are not apparent at the turning basin. Rather, it is more likely that other factors are influencing the abundance and distribution of the periphyton at the three sites.

Differing chemical and physical factors may contribute to the existence of differing habitats, and hence different community make-ups. One such factor is flow rate and turbulence. Station 4 is located near the confluence of the St. Marks and the Wakulla Rivers and therefore received more tidal flushing than the other two stations. Also, turbulence caused by eddy currents due to the convergence of the two rivers most likely affects station 4. Then, too, there is the barge traffic. Both stations 2 and 4 are affected by prop wash and wave action of many barges (approximately 300) each year. Station 1, however, received little of this. The importance of water flow to periphyton community make-up has been demonstrated by Biedermann, et al. (1979).

Another factor is salinity. There is a definite wedge of saline water which reaches up the St. Marks River (see Section Two). Stations 4 and 2 received more salt water influence then the upriver station and probably support different algal flora than the latter station. This is certainly true of the macrophytes (Section Four) and station 2 seems to be a transition zone for those plants. Had the periphyton analysis been to species rather than to general category, the transitional nature of the turning basin area could probably be seen more clearly.

One final factor is nutrient loading to each station. Station 4 is close to extensive marshes and several tidal creeks. The marshes thin out upriver, until only a small marsh remains at station 2. There is no fringing marsh at station 1. Since marshes are well-known producers of particulate detritus as well as inorganic nutrients and dissolved material (del la Cruz, 1979), it might well be that the periphyton populations at the two downstream stations are able to utilize these dissolved nutrients for growth. Further experiments would be necessary to confirm this hypothesis.

To conclude, it is more likely that factors such as salinity, flow rate, and nutrient loading have influenced the periphyton populations at the three stations, rather than oil. It is more plausible that the oiled sediment has had a greater effect on the bottom-dwelling plants, as observed by the paucity of macrophytes in the turning basin and nearby sites, than on those free-floating and attached algae in the water column above those sediments. This is also a function of algal population dynamics. Not only is the recovery time for unicellular algae far less than for rooted aquatic plants, but also the microalgae respond quickly to chemical changes in the water column (Patrick, 1972).

FIGURE 6.1 Periphyton Percent Composition by Phylum at St. Marks Stations, July-August 1979

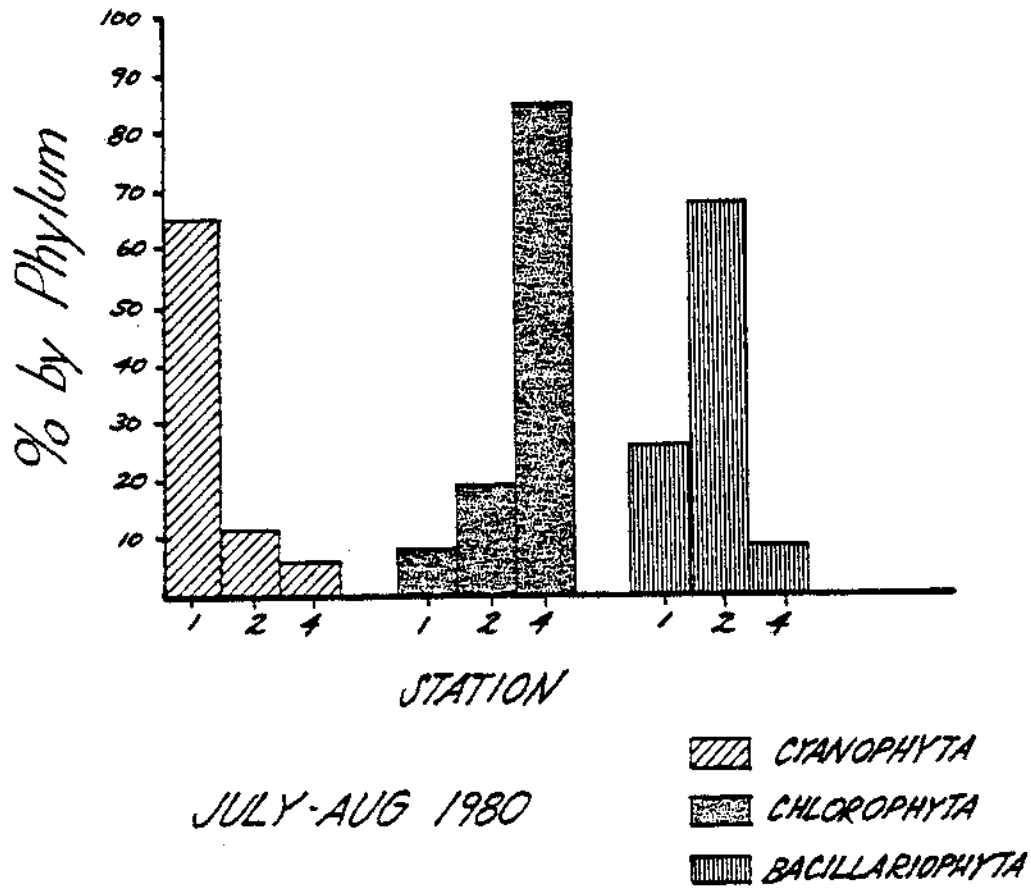


FIGURE 6.2 Periphyton Percent Composition by Phylum at St. Marks Stations, August-September, 1980.

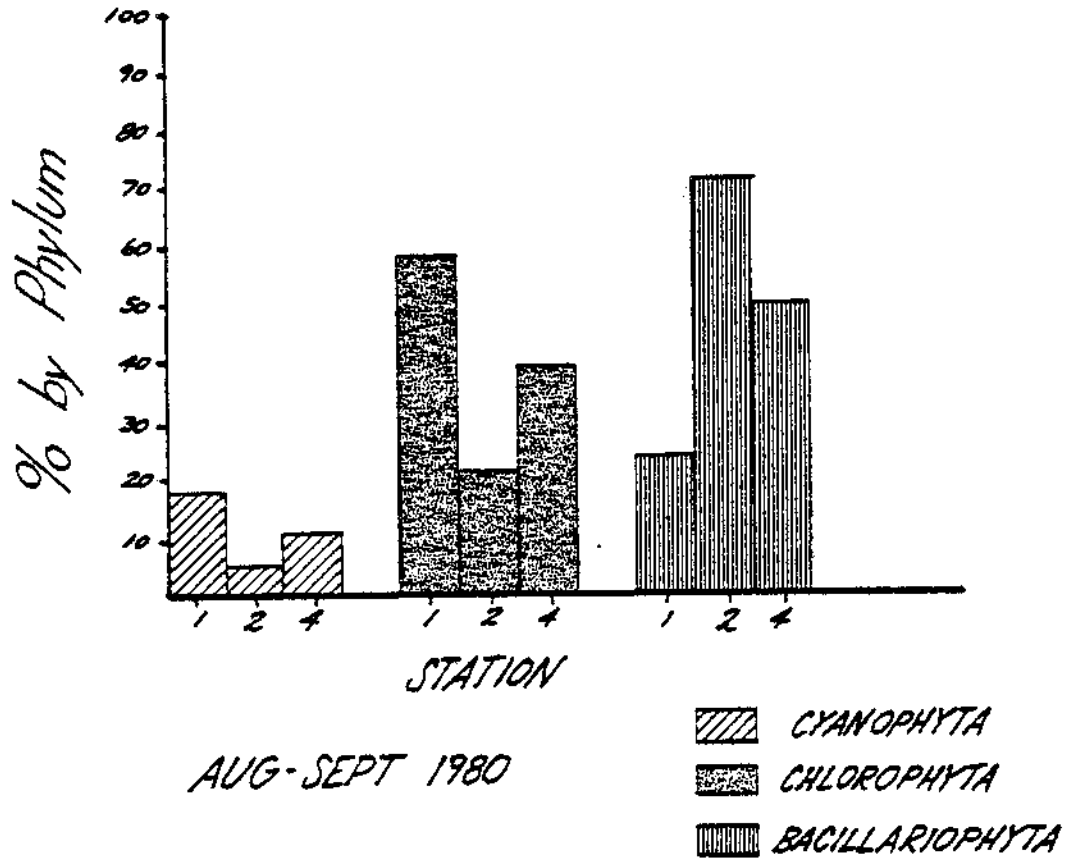


FIGURE 6.3 Periphyton Percent Composition by Phylum at St. Marks Stations. Combined Periods July-August and August-September 1980.

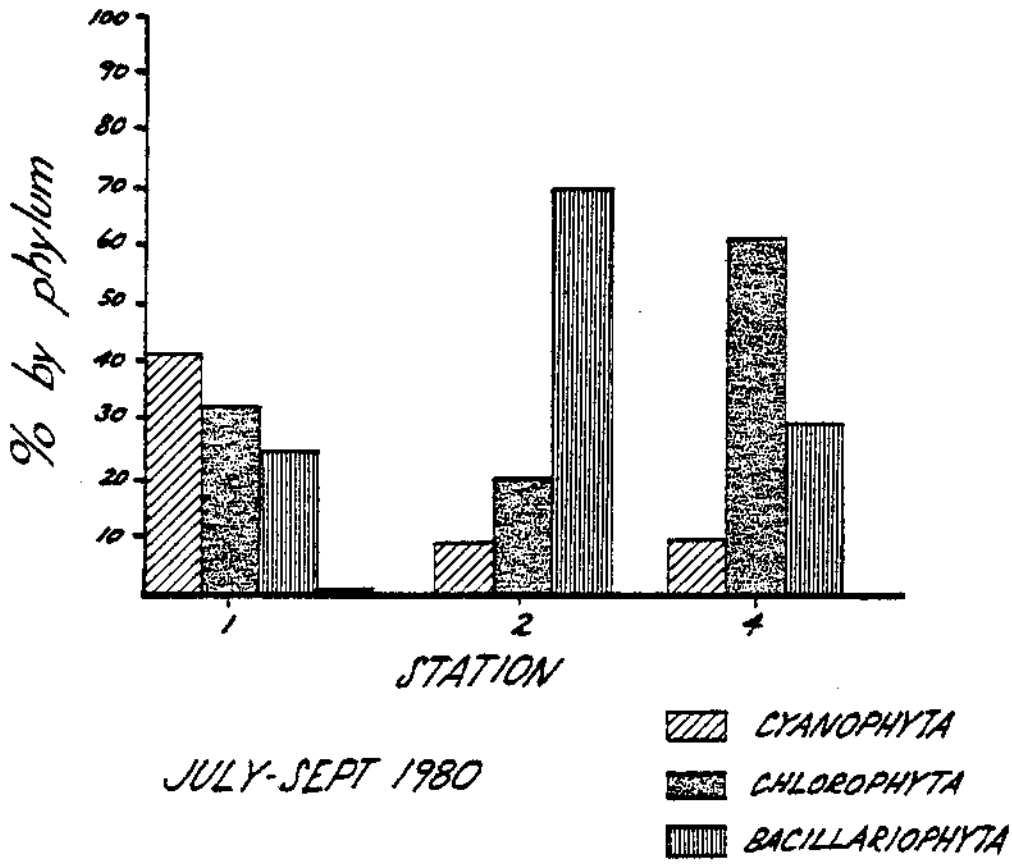


FIGURE 6.4 Mean Periphyton Counts at St. Marks Stations July-August, 1980 (Std. Errors shown by vertical lines; N=4)

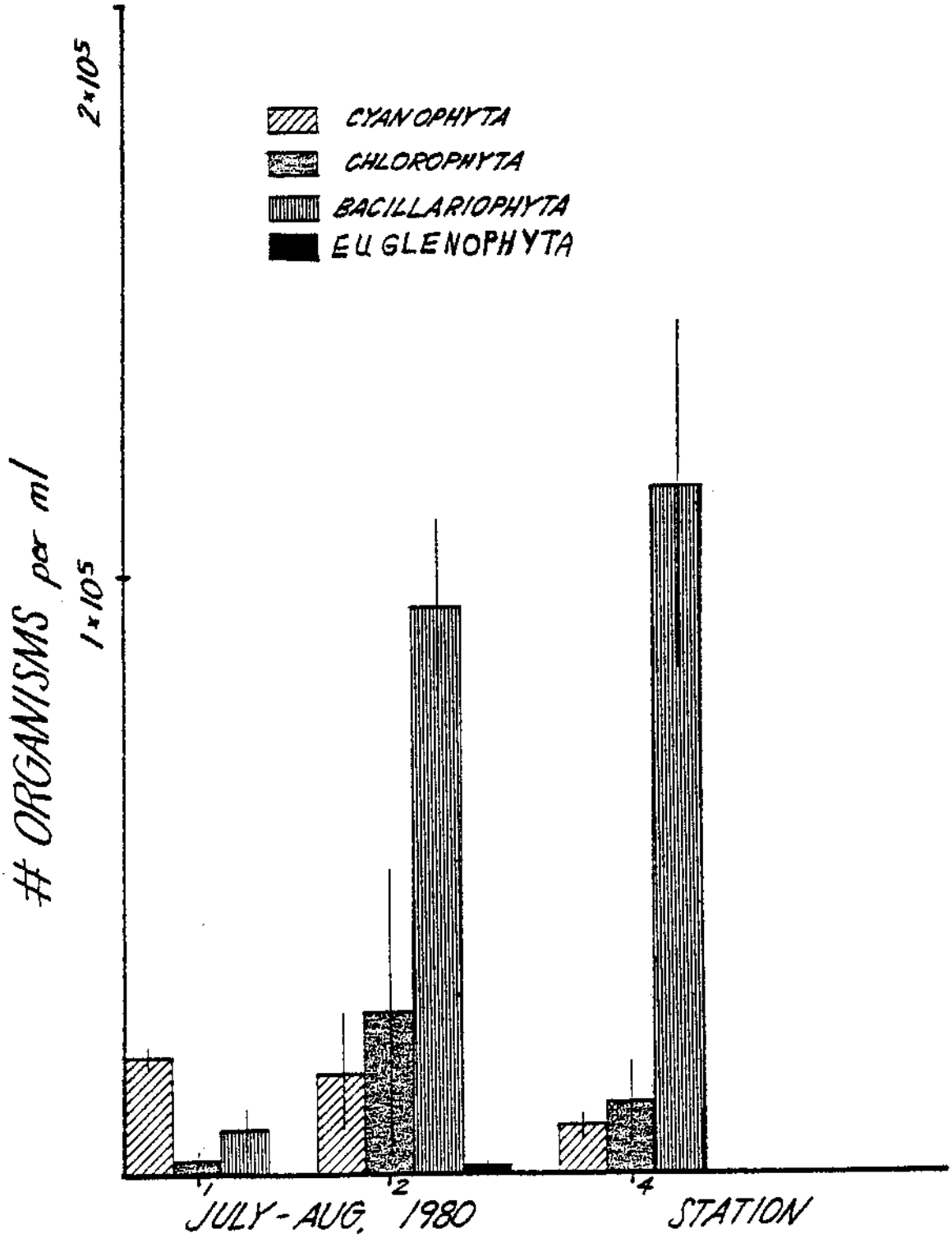


FIGURE 6.5 Mean Periphyton Counts at St. Marks Stations August-September 1980 (Std. errors shown by vertical lines; N=4)

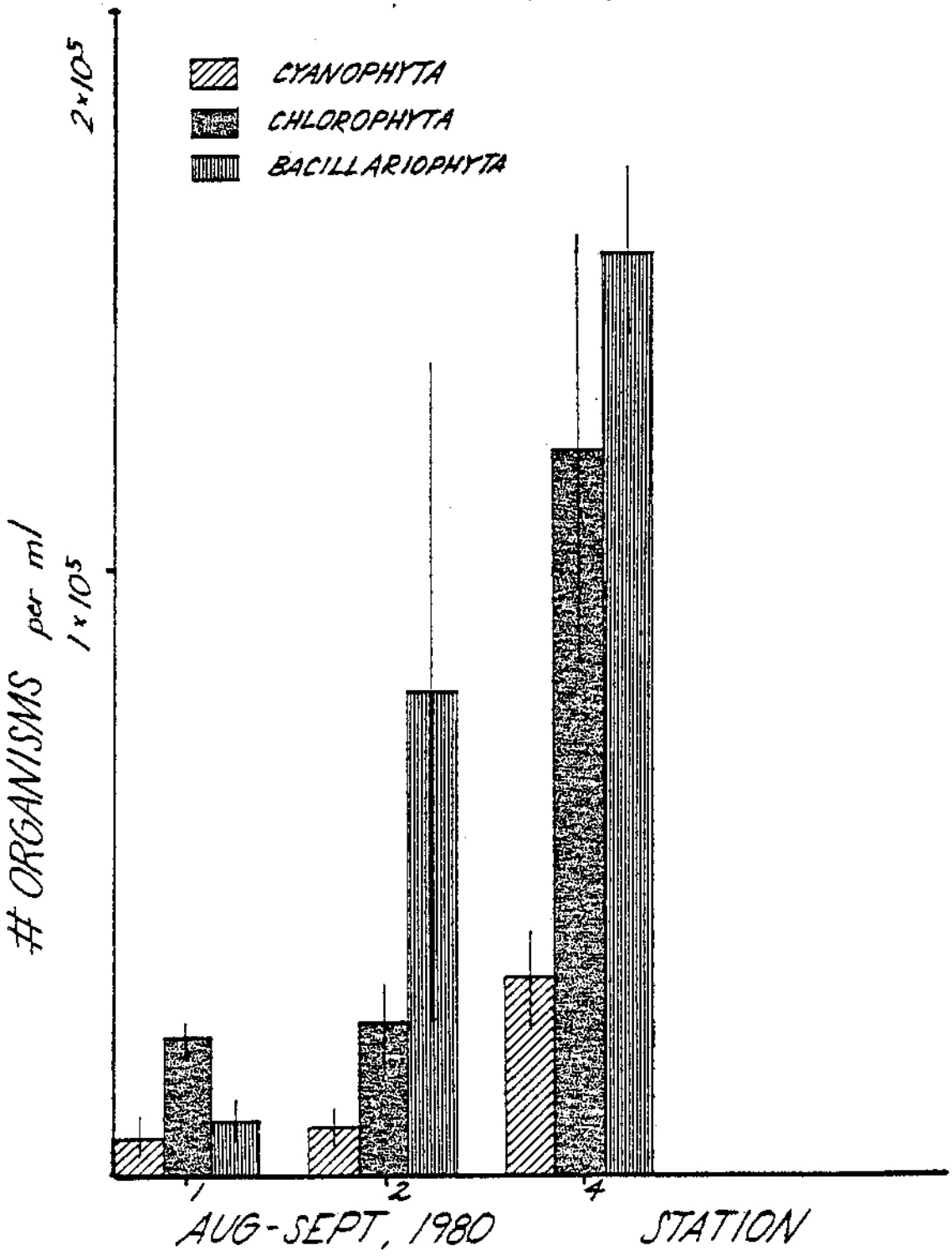


FIGURE 6.6 Mean Periphyton Counts at St. Marks Stations Combined Periods July-August and August-September 1980 (Std. errors shown by vertical lines; n=8)

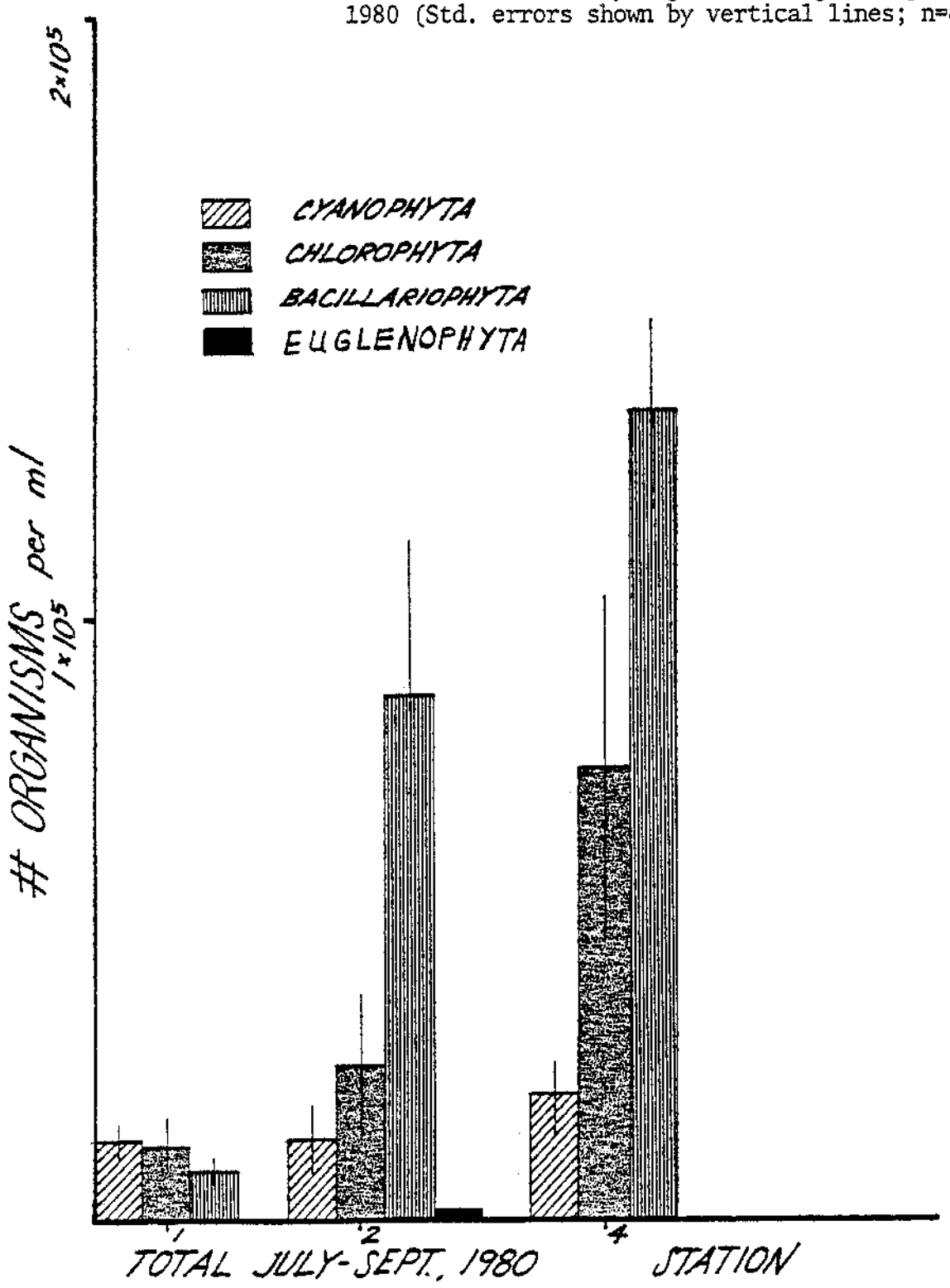


FIGURE 6.7 Periphyton Ash-Free Dry Weights, July-August 1980 (Top = 31cm below water surface; Bottom = 62 cm below water surface)

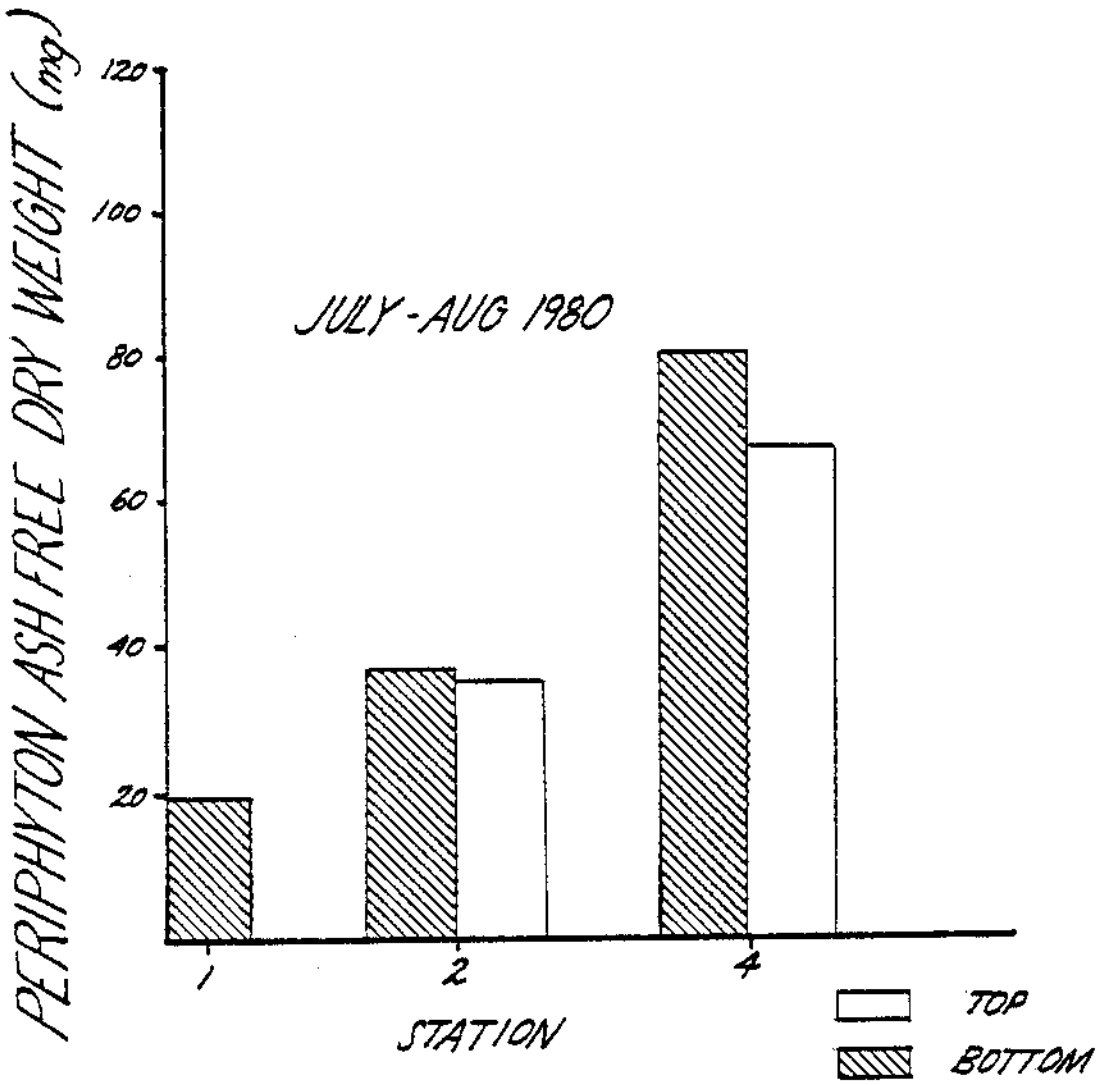
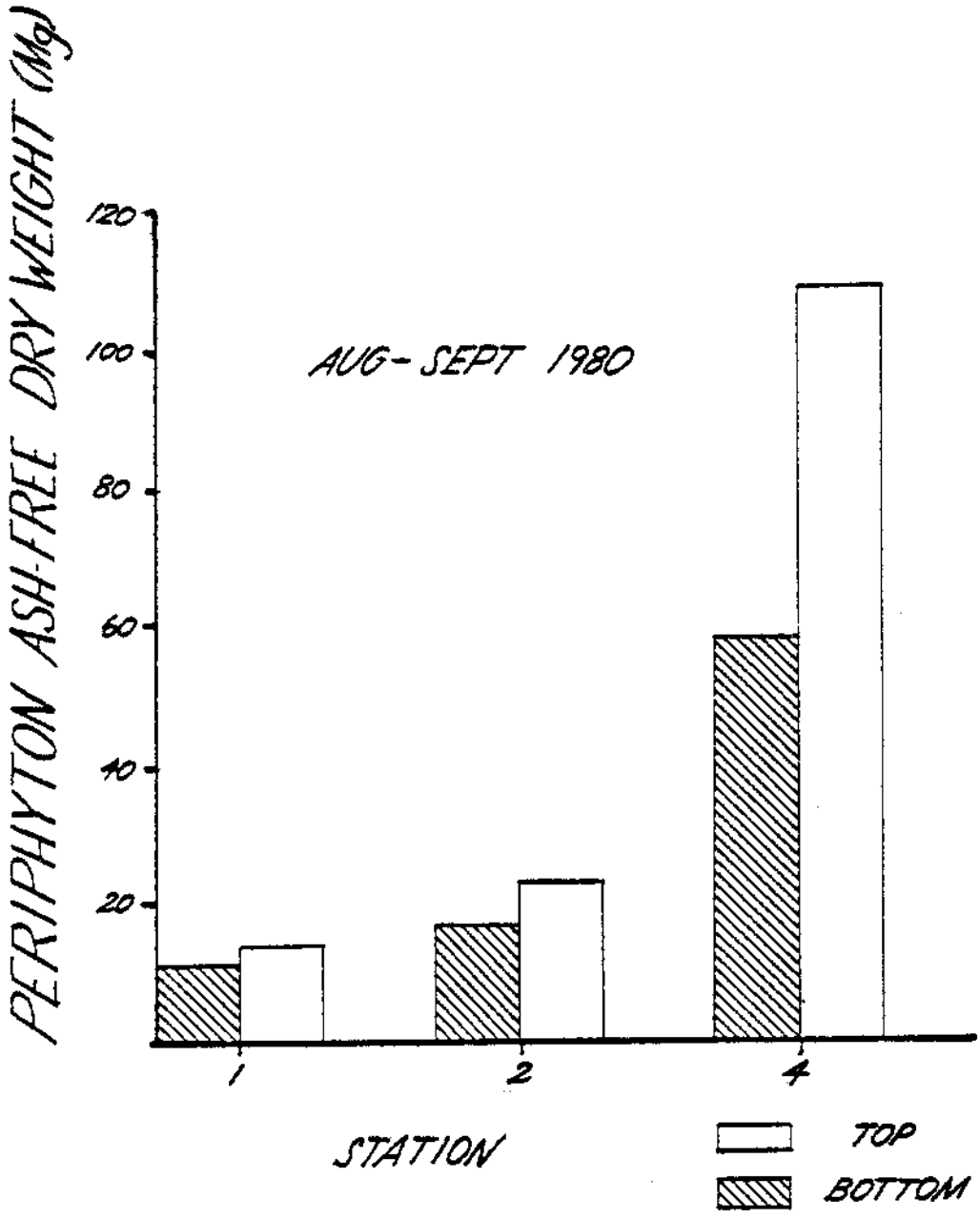


FIGURE 6.8 Periphyton Ash-Free Dry Weights, August-September 1980 (top = 31cm below water surface; bottom = 62cm below water surface)



GENERAL SUMMARY

The investigation of the biology of an area of the St. Marks River which was assumed to be adversely affected by oil pollution began in November of 1979 and ended in September, 1980. The studies involved detrital decomposition, periphyton growth, macrophyte composition and distribution. The latter two investigations covered all four seasons during the year of study. In addition, chemical and physical data were collected on the nature of the sediments, including oil and grease. Collateral studies were subcontracted to determine bacteriological impacts of oil on the bottom and to assess the economic condition of the St. Marks area.

The results of these studies provided no striking revelations with regard to the ecological health of the system. That is, it appears that the bottom area somewhat north and south of the turning basin has been adversely affected by oil. The area of impact is not really evident farther downstream than the confluence of the St. Marks and the Wakulla Rivers, even though the presence of oil in the sediment was detected by the 1979 NOAA survey as well as in the present study far downstream of the confluence.

Our benthic data confirm the original estimate by NOAA that about 1.5 miles of river bottom have been adversely affected by spilled oil.* Our macrophyte data also tend to confirm this. The other studies showed little or no differences among stations within and outside of

* NOAA suggested dredging about 2 miles of the river bottom.

the oiled area. Since these studies (periphyton and suspended detrital bags) dealt with the effects of the water column, it may be assumed that either the methodology was too gross in these studies to detect any differences, or that water column effects probably are very small or non-existent. Our conclusions are that the latter is probably the case; i.e., oil is probably tied up in sediment at this time and has a limited range of effects (i.e., benthic plants and animals in the immediate vicinity of the oiled sediment). This view is further reinforced by the existence of healthy plant and animal communities very near to the oiled sediment in the most adversely affected area.

Though it was difficult to sort out some of the overlying external independent variables such as salinity gradients and barge traffic, it is possible to look at the plant and animal data and to see definite changes in population structure and density in the heavily oiled zone as opposed to areas upstream and downstream. Anomalously low values of species numbers, density, diversity indices, etc., occur in this area.

The bacteriological report also indicates that the turning basin area is different than upstream and downstream areas. For instance, while the general trend for bacterial biomass was to increase in the more estuarine areas near the confluence, the turning basin sediment shows anomalously high biomass numbers. This was also true of other bacteriolgoical indicators: large numbers of hydrocarbon utilizers in the turning basin area as well as higher heterotrophic activity values than either directly north or sourth of the oiled areas.

These plant, animal and bacterial results, when viewed in conjunction with the oil and grease data from both the present study and the NOAA study of a year earlier, demonstrate the rather uniform distribution (through non-uniform quantities) of oil in this area of the river. That is, while oil and grease were detected upstream and downstream of the Turning Basin - Shields Marina area, the bacterial data, the plant data and the benthic macroinvertebrate data do not reflect a uniform oil distribution; rather they reflect patches of oil, which apparently have a minor effect on the bottom communities as a whole.

It is important to see these biological studies as they were intended to be seen: as baseline information on various aspects of the river.

Should a decision be made to dredge the material, these baseline data are available for future comparison with regard to possible recovery of plant and animal communities in the heavily oiled areas. That decision to dredge, of course, is beyond the scope of the biological studies. However, the economic report done as part of the St. Marks study suggests that cost-benefit ratios would favor dredging if nearby spoil sites can be obtained. Tentative sites are available on Seminole Asphalt property. Also, the economic report focuses on certain pragmatic aspects, such as prevention of future spills and containment of unloading facilities in a proposed barge slip.

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Appendix Table 1

Salinity and Conductivity at St. Marks Stations, 1979-1980

Station N

Salinity (0/00)

Date	0m	1m	2m	3m	4m
1-21-80	0	0	0	0	0
3-18-80	0	0	0	0	0
6-23-80	0	0	0	0	0
7-28-80	0	0	0	0	0
8-20-80	0	0	0	0	0
10-08-80	0	0	0	0	0

Conductivity (μmhos)

1-21-80	195	190	195	190	---
3-18-80	132	135	135	---	---
6-23-80	235	235	235	235	235
7-28-80	135	135	135	138	140
8-20-80	220	225	220	225	225
10-08-80	250	245	238	238	238

Appendix Table 1 (continued)

STATION #1

Salinity (0/00)

Date	surface	1m	2m	3m	4m	5m	6m
11-27-79	0.5	1.1	1.5	2.5	12.0	13.2	--
12-18-79	0.0	0.0	0.0	0.5	3.5	5.5	5.9
1-21-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2-19-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0
3-18-80	0.0	0.0	0.0	0.0	0.0	0.0	--
4-22-80	0.0	0.0	0.0	0.0	4.0	--	--
6-23-80	0.5	1.0	1.0	1.0	1.5	--	--
7-28-80	0.0	0.0	0.0	0.0	0.0	0.0	0.0
8-20-80	0.0	0.0	0.0	5.0	6.5	8.5	8.5
10-08-80	0.0	0.0	0.0	0.0	0.5	5.5	8.2

Conductivity (μmhos)

11-27-79	1010	1100	2050	4450	10,600	20,500	--
12-18-79	182	189	238	780	5400	7800	9000
1-21-80	235	238	205	200	204	210	215
2-19-80	205	198	195	198	198	198	--
3-18-80	135	135	138	138	138	138	--
4-22-80	250	350	440	435	8500	---	--
6-23-80	1350	1450	1500	1600	1850	---	--
7-28-80	136	140	140	140	140	140	--
8-20-80	270	370	450	9000	11,500	16,000	16,000
10-08-80	280	275	280	330	1050	9200	12,800

Appendix Table 1 (continued)

STATION #2

Salinity (ppt)

Date	0m	1m	2m	3m	4m	5m
11-27-79	1.6	1.8	2.0	11.0	14.6	15.5
12-19-79	3.9	3.0	2.5	3.8	2.3	2.5
1-22-80	0.0	0.0	0.0	0.0	0.0	0.0
2-19-80	0.0	0.5	2.1	4.0	7.4	8.4
3-18-80	0.0	0.0	0.0	0.0	0.0	0.0
4-22-80	1.0	1.0	3.5	8.2	13.5	14.1
6-23-80	3.0	3.0	4.0	6.5	7.0	10.0
7-28-80						
8-20-80	0.0	0.5	4.0	9.0	11.0	11.5
10-08-80	1.0	2.0	4.2	11.0	13.0	14.0

Conductivity (μmhos)

11-17-79	2450	2680	3310	16,800	22,000	23,000
12-19-79	4500	3500	4000	6000	4500	4300
1-22-80	251	290	355	400	700	--
2-19-80	360	1050	3950	5500	11,000	12,000
3-18-80	140	140	140	140	140	--
4-22-80	1300	1900	3000	12,500	20,500	21,500
6-23-80	4400	4800	6500	11,000	14,000	16,900
7-28-80						
8-20-80	1000	1800	7000	18,000	21,000	22,000
10-08-80	1700	3000	5000	18,000	20,000	15,000

Appendix Table 1 (continued)

STATION #3

Salinity (0/00)

Date	0m	1m	2m	3m	4m	5m	6m
11-28-79	2.5	5.5	8.5	10.8	12.9	14.7	--
12-19-79	0.5	0.5	1.0	3.5	5.5	5.0	--
1-22-80	0.0	0.0	0.0	1.0	1.5	--	--
2-19-80	0.4	0.4	0.5	2.0	7.8	8.5	--
3-18-80	0.0	0.0	0.0	0.0	0.0	--	--
4-22-80	1.0	2.0	3.0	8.5	13.8	14.0	--
6-23-80	3.0	3.5	3.5	4.5	6.5	--	--
7-28-80							
8-20-80	0.5	4.0	10.0	12.5	13.0	13.0	--
10-08-80	1.0	1.8	3.0	12.5	13.0	13.2	12.8

Conductivity (μmhos)

11-28-79	3890	9100	12,800	16,900	19,800	21,900	--
12-19-79	920	1050	1450	4250	8900	8300	--
1-22-80	400	450	580	1150	3000	---	--
2-19-80	950	1050	1200	3500	11,500	12,800	--
3-18-80	135	139	140	140	140	--	--
4-22-80	1600	2600	4300	12,800	21,000	20,000	--
6-23-80	6000	6500	6500	8500	16,000	--	--
7-28-80							
8-20-80	1980	7800	17,200	21,900	22,400	22,200	--
10-08-80	2200	2600	5000	19,000	21,000	21,000	20,000

Appendix Table 1 (continued)

STATION #4

Salinity (0/00)

Date	surface	1m	2m	3m	4m	5m	6m
11-26-79	1.4	2.0	12.5	16.5	16.5	16.5	---
12-18-79	1.4	2.0	4.5	6.6	8.5	9.5	--
1-21-80	2.0	2.0	3.0	4.8	4.9	7.8	8.0
2-19-80	1.5	2.0	4.0	5.8	10.0	10.1	---
3-18-80	0.0	0.0	0.0	0.0	0.0	---	---
4-22-80	0.5	1.2	4.0	8.9	14.0	---	---
6-23-80	3.5	3.5	3.5	5.0	5.0	---	---
7-28-80	0.0	0.0	0.0	0.0	0.0	0.0	---
8-20-80	1.0	3.0	8.0	12.0	13.0	---	---
10-08-80	3.0	4.0	8.2	9.4	11.1	12.0	12.0

Conductivity (µmhos)

11-26-79	2400	3200	19,100	25,000	25,000	25,000	---
12-18-79	1880	2460	7200	10,200	13,500	15,100	---
1-21-80	2800	3050	4400	5500	7600	12,000	11,100
2-19-80	2750	3600	6200	8500	13,200	14,100	---
3-18-80	140	140	140	140	140	---	---
4-22-80	1000	2000	7000	14,500	21,300	---	---
6-23-80	7000	7000	7500	8500	9000	---	---
7-28-80	185	185	200	275	370	380	---
8-20-80	2450	6900	14,000	20,300	22,800	---	---
10-08-80	5000	8000	13,500	15,000	17,200	20,000	21,000

Appendix Table 1 (continued)

STATION #5

Salinity (0/00)

Date	surface	1m	2m	3m	4m	5m	6m
11-26-79	2.1	2.8	3.3	13.1	--	--	--
12-18-79	1.5	1.5	2.9	8.3	8.6	--	--
1-21-80	2.0	2.1	2.1	3.5	4.5	5.4	9.6
2-19-80	2.5	2.5	3.5	5.0	9.2	11.2	12.0
3-18-80	0.0	0.0	0.0	0.0	--	--	--
4-22-80	1.0	1.5	4.5	9.5	12.9	14.0	--
6-23-80	2.0	2.5	7.5	9.0	11.5	12.1	--
7-28-80	0.0	0.5	0.5	0.5	0.5	0.5	--
8-20-80	2.0	2.0	3.5	6.5	--	--	--
10-08-80	3.9	5.8	9.0	13.0	13.0	14.0	--

Conductivity (μmhos)

11-26-79	3810	4500	5800	20,300	--	--	--
12-18-79	2150	2230	4250	13,000	12,300	--	--
1-21-80	3020	3100	3500	5500	7500	8000	15,000
2-19-80	3490	4000	5100	7200	13,500	16,200	17,000
3-18-80	351	375	370	365	--	--	--
4-22-80	1200	2300	7500	14,500	20,000	22,500	--
6-23-80	3110	3850	12,500	15,500	19,000	20,000	--
7-28-80	340	330	300	300	300	305	--
8-20-80	3800	3959	7000	13,000	--	--	--
10-08-80	600	900	15,000	20,000	20,000	21,000	--

Appendix Table 1 (continued)

STATION #6

Salinity (0/00)

Date	0m	1m	2m	3m	4m
11-26-79	4.8	5.1	11.1	--	--
12-18-79	3.3	3.9	5.4	7.1	7.1
3-18-80	0.0	0.0	0.0	0.0	0.0
6-23-80	3.0	5.0	7.1	10.0	--
7-28-80	2.0	2.5	2.5	6.0	--
8-20-80	3.0	5.0	10.0	--	--
10-08-80	7.2	9.0	13.5	--	--

Conductivity (μmhos)

11-26-79	7800	8200	17,900	--	--
12-18-79	5400	5900	8800	11,000	11,000
3-18-80	230	232	233	240	232
6-23-80	5800	8100	13,000	17,000	--
7-28-80	3100	3700	4300	10,000	40,000
8-20-80	6500	10,500	18,800	--	--
10-08-80	11,500	14,000	20,800	--	--

Appendix Table 2

Temperature and Dissolved Oxygen at St. Marks Stations, 1979-1980

Station N

Temperature (^{o}C)

Date	0m	1m	2m	3m	4m
1-21-80	18.1	18.2	17.8	18.0	--
3-18-80	17.4	17.8	17.8	--	--
5-28-80	21.2	21.2	21.2	21.2	21.2
6-23-80	20.8	21.0	20.9	21.0	21.0
7-28-80	23.0	23.5	23.5	23.5	23.5
8-20-80	21.0	21.0	21.0	21.0	21.0
10-08-80	18.8	18.8	18.8	18.8	18.8

Dissolved Oxygen (ppm)

1-21-80	5.9	6.3	6.25	4.5	--
3-18-80	5.4	5.3	5.3	--	--
5-28-80	5.5	5.7	5.0	5.8	5.8
6-23-80	5.4	5.8	5.9	5.6	5.0
7-28-80	4.4	4.3	4.3	4.4	4.3
8-20-80	4.9	4.5	4.4	4.4	4.4
10-08-80	6.0	5.6	5.6	5.6	5.6

Appendix Table 2 (continued)

Station #1

Temperature (°C)

Date	Surface	1m	2m	3m	4m	5m	6m
11-27-79	20.4	19.5	19.1	18.9	19.5	20.1	--
12-18-79	21.8	21.8	21.8	21.9	21.5	21.1	21.2
1-21-80	19.0	18.1	18.0	17.5	17.2	17.1	17.4
2-19-80	17.9	17.5	16.8	16.2	16.0	16.1	--
3-18-80	17.5	18.0	18.0	18.1	18.3	18.5	--
4-22-80	19.5	18.5	18.5	18.5	19.0	--	--
5-28-80	24.0	23.0	22.3	22.0	21.9	21.8	21.8
6-23-80	22.0	22.1	22.1	22.5	22.5	--	--
7-28-80	24.0	23.7	23.5	23.5	23.2	23.2	--
8-20-80	23.5	23.0	23.0	25.0	26.0	27.0	27.0
10-08-80	20.5	20.5	20.0	20.0	20.0	21.0	22.0

Dissolved Oxygen (ppm)

11-27-79	6.0	5.5	5.0	4.4	4.1	--	--
12-18-79	7.9	7.65	7.15	7.15	7.2	6.9	6.85
1-21-80	5.7	5.75	7.15	6.7	6.2	--	--
2-19-80	7.25	7.05	6.95	6.9	6.8	6.6	--
3-18-80	5.4	5.4	5.4	5.4	5.5	5.5	--
4-22-80	4.9	4.9	5.3	5.4	5.3	--	--
5-28-80	6.4	6.8	7.1	7.0	6.7	6.5	6.1
6-23-80	6.7	6.4	6.2	5.5	5.7	--	--
7-28-80	4.1	3.9	3.9	4.0	4.0	3.9	--
8-20-80	6.2	6.1	6.1	4.3	4.0	3.5	3.2
10-08-80	7.0	7.0	6.5	6.5	6.2	6.6	5.7

Appendix Table 2 (continued)

Station #2

Temperature (°C)

Date	0m	1m	2m	3m	4m	5m
11-27-79	20.0	20.0	19.5	19.8	20.1	20.3
12-19-79	15.9	15.5	15.2	14.9	14.1	13.9
1-22-80	17.5	17.6	17.8	17.8	17.2	--
2-19-80	17.1	15.9	15.5	15.0	14.2	13.5
3-18-80	18.0	18.0	18.5	18.5	18.5	--
4-22-80	21.0	21.0	21.0	20.0	20.0	20.0
5-28-80	27.4	26.0	23.8	24.0	24.86	--
6-23-80	25.0	25.0	25.0	25.5	26.5	26.5
8-20-80	24.8	25.0	27.0	29.0	29.0	29.5
10-08-80	22.2	21.0	21.0	22.2	22.2	22.2

Dissolved Oxygen (ppm)

11-27-79	5.25	5.25	5.05	5.25	6.15	4.65
12-19-79	7.8	7.7	7.8	8.0	8.1	8.6
1-22-80	7.3	7.7	8.3	8.1	7.1	--
2-19-80	7.55	7.3	6.75	7.0	7.8	8.1
3-18-80	5.7	5.6	5.5	5.6	5.9	--
4-22-80	5.7	6.0	6.2	6.2	6.2	6.2
5-28-80	6.2	6.6	6.8	6.8	5.76	--
6-23-80	6.1	6.2	6.2	5.5	4.9	3.9
8-20-80	5.4	5.1	5.0	3.8	3.2	3.4
10-08-80	7.2	7.3	7.3	7.0	7.0	7.2

Appendix Table 2 (continued)

Station #3

Temperature (°C)

Date	Surface	1m	2m	3m	4m	5m	6m
11-28-79	20.4	19.8	19.8	19.8	19.8	19.9	--
12-19-79	22.1	20.1	18.8	26.9	24.5	22.1	--
1-22-80	17.0	17.1	17.1	17.1	17.0	--	--
2-19-80	17.0	16.9	16.1	15.0	14.8	13.5	--
3-18-80	17.2	18.0	18.0	18.5	18.5	--	--
4-22-80	21.5	21.5	21.0	20.0	20.0	20.0	--
5-28-80	23.8	23.1	23.0	23.0	23.8	24.1	24.0
6-23-80	26.0	25.0	25.0	25.0	25.5	--	--
8-20-80	26.0	27.0	29.0	29.0	29.0	29.0	29.0
10-08-80	22.0	21.4	22.6	22.2	22.2	22.1	22.0

Dissolved Oxygen (ppm)

11-28-79	7.2	7.4	7.7	8.0	6.4	8.6	--
12-19-79	8.2	7.7	7.2	7.4	7.8	8.2	--
1-22-80	6.8	7.2	7.7	7.9	6.4	--	--
2-19-80	7.7	7.55	7.6	7.8	7.8	7.95	--
3-18-80	5.4	5.3	5.6	5.6	5.6	--	--
4-22-80	5.8	5.8	6.1	6.3	6.4	5.9	--
5-28-80	5.7	6.2	6.6	6.6	6.0	5.6	5.5
6-23-80	6.1	6.5	6.6	6.5	6.2	--	--
8-20-80	6.2	5.4	5.0	4.7	4.5	3.8	--
10-08-80	7.2	7.2	7.4	7.2	7.1	7.0	6.5

Appendix Table 2 (continued)

Station #4

Temperature (°C)

Date	Surface	1m	2m	3m	4m	5m	6m
11-26-79	20.2	20.1	20.1	20.4	20.6	20.6	--
12-18-79	21.5	21.8	22.1	22.5	22.5	22.5	--
1-21-80	22.8	22.2	22.1	22.4	22.5	22.8	23.0
2-19-80	15.9	16.0	15.1	14.2	13.5	13.1	--
3-18-80	17.1	18.0	18.0	18.5	18.5	--	--
4-22-80	21.2	20.5	20.5	20.0	20.0	--	--
5-28-80	25.5	25.0	24.5	24.0	24.0	--	--
6-23-80	24.5	25.0	25.0	25.0	25.0,	--	--
7-28-80	25.0	25.0	24.3	23.5	23.0	23.0	--
8-20-80	27.0	26.8	29.0	30.0	30.2	--	--
10-08-80	22.0	22.0	21.9	21.9	22.0	22.0	22.0

Dissolved Oxygen (ppm)

11-26-79	--	--	--	--	--	--	--
12-18-79	9.0	8.8	8.9	8.9	9.25	9.0	--
1-21-80	7.4	7.6	7.7	7.7	7.5	7.5	7.4
2-19-80	8.2	8.4	8.1	8.25	8.35	8.35	--
3-18-80	5.5	5.5	5.7	5.7	5.7	--	--
4-22-80	6.1	6.3	6.5	6.4	6.3	--	--
5-28-80	6.2	6.7	6.8	6.8	6.8	--	--
6-23-80	5.8	6.2	6.3	6.0	5.8	--	--
7-28-80	5.3	5.0	4.9	4.6	4.8	4.2	--
8-20-80	6.2	5.7	5.3	5.2	4.8	--	--
10-08-80	7.3	7.3	7.4	7.2	6.9	6.8	6.8

Appendix Table 2 (continued)

Station #5

Temperature (°C)

Date	Surface	1m	2m	3m	4m	5m	6m
11-26-79	21.5	20.2	20.2	20.2	--	--	--
12-18-79	22.9	22.8	22.5	22.3	22.5	--	--
1-21-80	24.4	22.0	22.0	22.2	22.5	22.8	23.0
2-19-80	14.5	16.0	15.5	14.5	14.0	12.9	12.5
3-18-80	18.2	18.5	18.9	18.9	--	--	--
4-22-80	23.0	20.5	20.5	20.0	20.0	20.0	--
5-28-80	24.0	23.2	23.2	23.9	25.0	--	--
6-23-80	25.5	25.0	24.2	24.0	23.8	23.5	--
7-28-80	25.5	25.0	24.2	24.0	23.8	23.5	--
8-20-80	26.0	25.8	25.5	25.5	--	--	--
10-08-80	23.0	22.2	22.0	22.0	22.2	22.2	--

Dissolved Oxygen (ppm)

11-26-79	7.0	5.4	5.35	5.6	--	--	--
12-18-79	8.8	8.75	8.5	8.9	8.45	--	--
1-21-80	7.7	8.6	9.0	9.15	8.9	8.7	--
2-19-80	7.95	8.25	8.0	8.05	8.0	7.9	8.0
3-18-80	5.9	5.7	5.9	5.6	--	--	--
4-22-80	6.4	6.8	6.8	6.8	6.4	6.5	6.3
5-28-80	5.9	6.5	6.5	6.7	6.5	--	--
6-23-80	6.4	6.7	5.9	5.5	4.5	4.5	--
7-28-80	5.1	5.1	4.8	4.8	4.8	4.7	--
8-20-80	5.2	5.0	4.4	4.1	--	--	--
10-08-80	84.	7.5	7.2	6.9	6.6	6.3	--

Appendix Table 2 (continued)

Station #6

Temperature (°C)

Date	0m	1m	2m	3m	4m
11-26-79	20.2	20.2	20.5	--	--
12-18-79	23.0	22.9	22.9	22.9	22.8
3-18-80	19.0	19.0	19.1	19.1	19.0
5-28-80	24.0	24.0	24.1	25.8	26.0
5-28-80		$\left(\frac{5m}{26.1}\right)$	$\left(\frac{6m}{26.1}\right)$		
6-23-80	26.5	26.5	27.0	28.0	--
7-28-80	27.0	27.0	26.0	26.0	27.0
8-20-80	28.5	28.5	29.5	--	--
10-08-80	22.0	21.8	22.0	--	--

Dissolved Oxygen (ppm)

11-26-79	12.2	11.7	9.4	--	--
12-28-79	10.1	9.9	9.8	9.8	9.3
3-18-80	5.9	5.8	5.8	5.8	5.8
5-28-80	5.7	6.0	5.9	6.2	6.4
		$\frac{5m}{6.5\ 0/000}$	$\frac{6m}{6.4\ 0/000}$		
6-23-80	6.7	7.4	6.7	6.2	--
7-28-80	5.5	5.4	5.2	4.9	5.4
8-20-80	7.0	6.3	5.6	--	--
10-08-80	7.8	8.0	7.9	--	--

Appendix Table 3 Water Column pH at St. Marks Stations

Date	Station 1	Station 2	Station 3	Station 4	Station 5	Station 6	Station 7
November	7.03	7.51	7.33	7.49	7.66	7.42	--
December	---------- NO DATA ----------						
January	6.98	7.32	8.07	7.7	7.6	--	7.19
February	7.8	7.7	7.6	7.75	8.1	--	--
March	7.7	8.3	8.3	8.2	8.0	8.6	7.7
April	8.4	--	8.5	7.9	7.8	--	--

APPENDIX 4

Method for Extracting Hydrocarbons from Sediment Samples

1. Collect 300-400g of sample from each site (2 samples per site). These may be stored in the freezer after water is decanted.

2. a. Drain off any water that may have collected at the top of the sample.
   b. Grind sample with mortar and pestle.
   c. Mix sediment to obtain a homogeneous sample.

3. Place sediment on paper towels and allow to air-dry at room temperature for at least two hours (overnight is acceptable).

4. a. Weigh 10-20g of sediment into pre-weighed culture tube.
   b. Weigh another 10-20g of sediment and place into a pre-weighed aluminum pan and dry at 105 ^{o}C, for 24 hours (or constant weight).

5. Add 20-30 ml acetone to the sediment in the culture tube and shake; let settle and then decant through a pre-weighed filter paper into a tared 250 ml beaker.

6. Add 20-30 ml hexane to culture tube and shake for one minute; let settle and decant into the tared beaker. Repeat several times (at least 3-4X) until all hydrocarbons have been extracted (no yellow color remains).

7. Filter sediment onto pre-weighed filter paper; rinse culture tube with approximately 25 mls of hexane (rinse with hexane 3-4 times).

8. Place filter paper/sediment into pre-weighed Aluminum dishes, and put under hood for approximately 45 minutes. Then place into 110 ^{o}C oven for 24 hours (or constant weight).

9. Calculate (on a dry weight basis) percent oil and grease using the following formula:

$$\% \text{ oil and grease} = \frac{(\text{actual sed. wt. loss} - \text{expected loss})}{(\text{wet wt})(\% \text{ solids})} \times 100$$

Appendix 5
Taxonomic References Used in Benthic Macoinvertebrate Identification

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