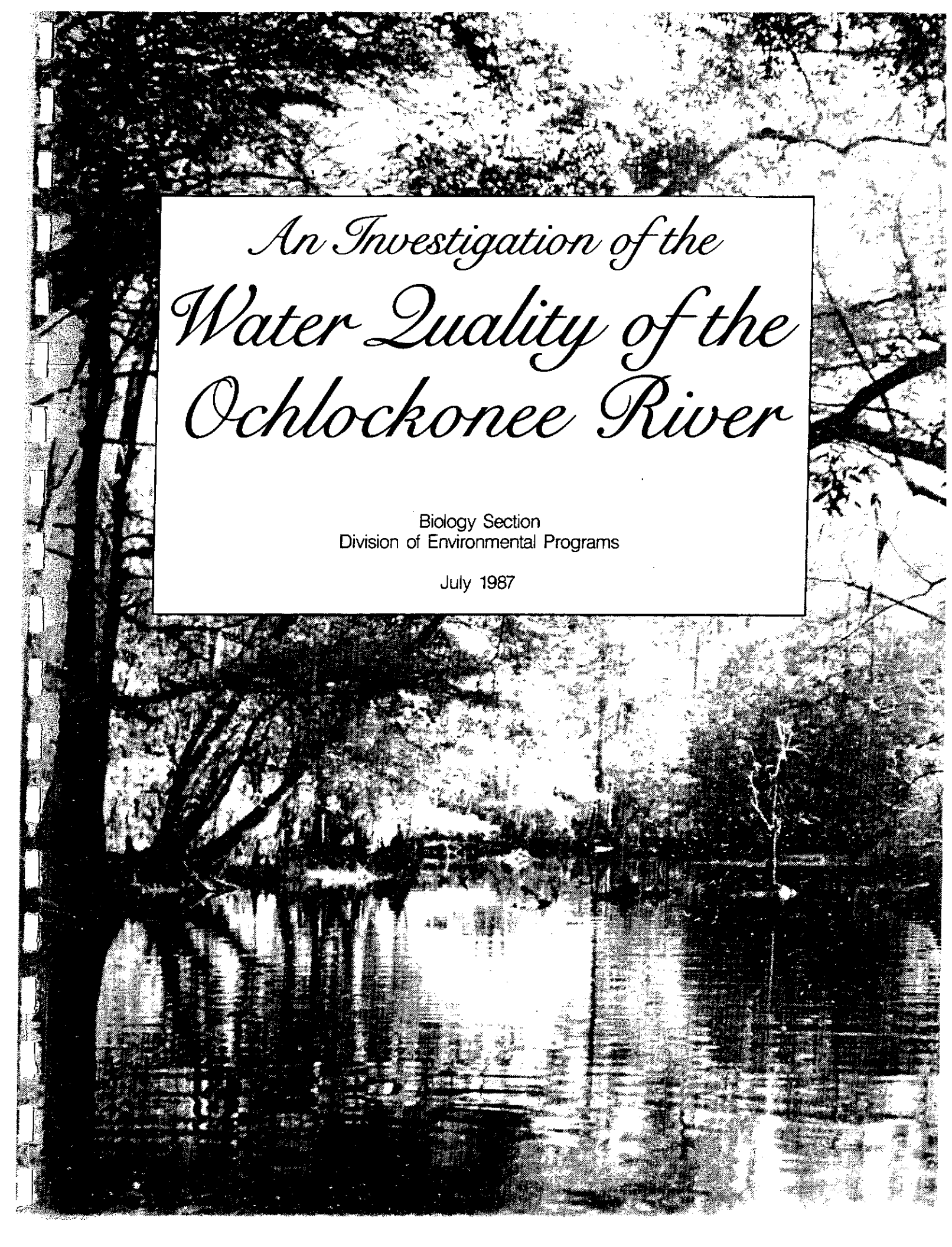
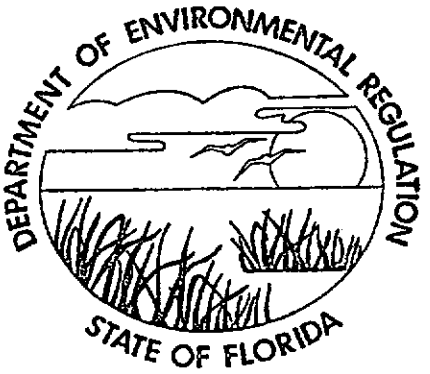


An Investigation of the Water Quality of the Ochlockonee River

Biology Section
Division of Environmental Programs

July 1987



AN INVESTIGATION OF THE WATER QUALITY OF THE OCHLOCKONEE RIVER

JULY 1987

Biology Section
Division of Environmental Programs

CONTENTS

Executive Summary....iv
Introduction....iv
Pollution Sources....iv
Physiography, Geology, Land Use and Erosion....v
Sediments....v
Physical and Chemical Water Quality....v
Toxicity....v
Algal Growth Potential and Limiting Nutrients....vi
Bacteria....vi
Periphyton and Chlorophyll....vi
Benthic Macroinvertebrates....vii
Fishery Resources....vii
Introduction....1
General Methodology....1
Station Locations and Descriptions....4
Primary Stations....4
Secondary Stations....5
Personnel....8
Acknowledgements....8
Pollution Sources....10
Physiography, Geology, Land Use and Erosion....14
Physiography and Geology....14
Land Use....17
Erosion....17
Conclusions....19
Sediments....21
Introduction....21
Methods and Materials....21
Results....22
Discussion....29
Conclusions....30
Physical and Chemical Water Quality....31
Methods....31
Results....31
pH....35
Alkalinity....35
Conductivity....35
Hardness....35
Turbidity....40
Total Suspended Solids....40
Temperature....40
Dissolved Oxygen....52
Phosphorus....52
Nitrogen....58
Discussion....65
pH....65
Alkalinity....65
Conductivity....66

Hardness....67
Turbidity....67
Total Suspended Solids....68
Temperature....70
Dissolved Oxygen....70
Phosphorus....71
Nitrogen....72
Multivariate Techniques....76
Historical Data....84
Conclusions....90
Chronic Toxicity Bioassays....91
Introduction....91
Methods....91
Results....96
Discussion....106
Oquina Creek....106
Tired Creek....107
Barnetts Creek....107
Other Stations....108
Conclusions....108
Algal Growth Potential and Limiting Nutrient Assays....109
Introduction....109
Methods and Materials....109
Results....111
River Stations....111
Tributary Stations....116
Discussion....116
Algal Growth Potential....116
Limiting Nutrients....119
Flow....120
Conclusions....120
Bacteria....126
Introduction....126
Methods and Materials....126
Results....127
Total Aerobic Bacteria....127
Total Coliform Bacteria....131
Fecal Coliform Bacteria....135
Fecal Streptococci Bacteria....135
Discussion....141
Conclusions....147
Periphyton and Chlorophyll....148
Introduction....148
Methods and Materials....148
Results....151
General Overview....151
Seasonal and Flow Regime Effects....169
Multivariate Techniques....178
Discussion....191
Conclusions....194

Benthic Macroinvertebrates.....195
Introduction.....195
Methods.....195
Results.....196
Discussion.....226
Historical Benthic Data.....230
Conclusions.....231
Fishery Resources.....233
Introduction.....233
Methods.....233
Results.....233
Discussion.....235
Conclusions.....237
Literature Cited.....238
Appendix.....254

EXECUTIVE SUMMARY

Introduction

This report documents the results of a study of the Ochlockonee River made from October, 1985, to October, 1986. The goals of the study were to determine 1) the existing conditions of the river and 2) the effects of point-source and nonpoint-source discharges with regard to present and future regulatory concerns. To accomplish these goals, 17 stations were established along the course of the river and in various tributaries (see station location map, Figure 2). The stations were monitored for a wide array of chemical and biological parameters with samples taken at monthly intervals.

Pollution Sources

Point-source discharges to the upper Ochlockonee River include seven municipal wastewater treatment facilities and three industrial facilities. Two of the industrial dischargers are food processors and one is a mining operation.

Nonpoint-source pollution consists primarily of agricultural and urban run-off. Run-off from agricultural activities may include eroded soils with adsorbed pesticides and nutrients. Urban run-off may contain sediments, oils and chemicals associated with stormwater from roads, parking lots, and buildings in populated areas.

Physiography, Geology, Land Use and Erosion

The Ochlockonee River Basin drains approximately 5,957 km^2 of southeastern Georgia and the panhandle of Florida east of the Apalachicola River. Originating in Worth County, Georgia, the river flows a total of 257 km through three physiographic provinces, the Tifton Upland District in Georgia, the Tallahassee Hills, and the Gulf Coastal Lowlands, where it empties into Ochlockonee Bay. The average gradient is 0.47 m/km and average discharge of the river is 45.7 m^3/s.

Generally, sediments underlying the Ochlockonee River Basin consist of clays, sand, and limestone. The upper reaches of the river are dominated by thick Miocene clays which hinder local ground-water movement and recharge. Erosion has, however, removed these thick clays in the lower river and exposed marine sands and limestone.

In southwest Georgia, forest land has been extensively converted to croplands since the 1940's, accelerating during the early 1970's. The decline in forest lands and wetlands bordering streams in southwest Georgia has exacerbated the problem of erosional surface run-off and sedimentation from croplands. Of the five counties comprising the Georgia portion of the Ochlockonee River Basin, 40% of the land is currently used for agricultural purposes. Eight percent of the land in Leon and Gadsden Counties, Florida, is under cultivation. Approximately 1.5 million metric

tons/year and 160,000 metric tons/year of soil is eroding from cropland in certain portions of Georgia and Florida, respectively, which possibly may be related to sediment problems observed at Station 6.

Sediments

Tributary sediment analyses generally reflected land use patterns in proximity to the streams which were sampled. Large deposits of fine particulates and a portion of the phosphorus additions which were found are mostly likely associated with agricultural and mining operations. Analyses indicate that two of the stations may be suffering from sediment-related problems. Sediments at Station 3 had elevated nutrient concentrations, most likely due to point source inputs from Oquina Creek. Sediments at Station 6 had the highest organic and silt/clay fraction as well as the highest nutrient concentrations. This observation, as well as a trend for turbidities to decrease in this vicinity, suggests that allochthonous materials (eroded soils) originating farther upstream were transferred from the water column to the sediments in this area.

Physical and Chemical Water Quality

Selected physico-chemical parameters seemed to reflect point and non-point source inputs which may have influenced the distribution of the biota of the river. Dissolved oxygen (D.O.) concentrations were occasionally depressed (below 4.0 mg/l) in the tributaries downstream of certain point sources. Although D.O. values never fell below 4.0 mg/l in the river, they sometimes approached this level at Stations 1, 2, 3, and 8. Phosphorus concentrations peaked at Station 3, probably as a result of point source inputs from Oquina Creek. Although tributary phosphorus and conductivity values were highest in the Tired Creek system, no phosphorus enrichment and only a slight increase in conductivity was observed at Station 5, downstream of that system. Nitrate enrichment was, however, observed at both Stations 3 and 5, probably as a result of inputs from Oquina Creek and Tired Creek, respectively.

Multivariate techniques isolated turbidity as the physical element accounting for the majority of variation among stations. In the Florida portion of the Ochlockonee River, extremely high turbidity values, particularly during high flow conditions, appeared to be the major water chemistry problem. Time series analysis of flow-corrected historical solids data indicated a significant increase in the solids content of the river since the 1960's. This corresponded with noteworthy increases in agricultural activities and, consequently, erosion in the basin during the same time period.

Toxicity

The results of 65 bioassays using the water flea, Ceriodaphnia dubia, isolated the presence of acutely and/or chronically toxic discharges in certain tributaries of the Ochlockonee River. The Thomasville Water Pollution Control Plant, Sunnyland Foods, Inc., and stormwater run-off

were responsible for the acute and chronic toxicity observed in Oquina Creek and at Station 3. Toxic effects, however, were not noted further downstream, at Station 4. Sources of toxicity in the Tired Creek watershed are discharges from the Cairo Water Pollution Control Plant, discharging into Parkers Mill Creek, and the W. B. Roddenberry Company, discharging into Little Tired Creek. Bioassays conducted on Stations 13, 14, and 16 showed toxicity from these sources. However, no effect was seen at Station 5, downstream of all these sources. Chronic toxicity was also observed in Horse Creek at Station 9, downstream of the Thor mine. No toxic effects were noted at Station 12, which is downstream of Station 9.

Algal Growth Potential and Limiting Nutrients

Generally, algal growth potential (AGP) increased to a peak at Station 5 and decreased thereafter to Station 8, where AGP was similar to levels measured at the two most upstream stations. AGP was highly correlated with total soluble inorganic nitrogen. The decrease in AGP at Station 6 corresponded to reductions in nutrient concentrations. The most significant increases in AGP occurred downstream of point source discharges. Nitrogen was determined to be the primary limiting nutrient during the period of low flow, and phosphorus was limiting during flood conditions.

Bacteria

The highest densities of all categories of bacteria were associated with tributary stations, especially stations with domestic and industrial discharges such as in the Thomasville and Cairo areas. Downstream impacts in Florida waters from upstream Georgia waters only occurred during flood conditions. Excessively high levels of fecal coliform bacteria originating in Georgia (predominately from Bryants Mill Creek, Station 17) resulted in Florida water quality violations at Station 6 during periods of high river flow. Mean total coliform bacteria were consistently greater than 2400 organisms/100 ml throughout the river system. Florida Stations 6, 7, and 8 were therefore in violation of State water quality standards for this parameter.

Periphyton and Chlorophyll

Periphyton, the attached algal community, was highly influenced by seasonal and water level fluctuations. Abundance, chlorophyll *a*, diversity, and species richness were all substantially reduced when the river was in flood stage, which occurred during winter and spring.

Abrupt longitudinal changes in community characteristics were apparent at Stations 3 and 6. These changes were manifested by a decreased proportion of diatoms accompanied by an increase in blue-green algae and severe reductions in abundance and chlorophyll *a*. A decrease in species richness was noted at Station 3.

Benthic Macroinvertebrates

Benthic macroinvertebrate communities are sensitive pollution indicators and are an important food source for sport and commercial fish. Macroinvertebrate mean abundance and species richness values were abnormally low at the first three stations and at Station 6. These parameters at Stations 4, 5, 7, and 8 were suggestive of normal to healthy conditions. Additionally, taxonomic group and species level data indicated that pollution intolerant taxa were often conspicuously rare or absent from Stations 1, 2, 3, and 6, but generally present to abundant at the remaining stations. Acutely toxic discharges from Oquina Creek were probably responsible for the reductions in the benthic community observed at Station 3. Episodes of low dissolved oxygen concentrations observed at the first three stations also may have stressed the benthic communities inhabiting the upper river.

Although discharges from the Thor Mine, Roddenberry Company, and the Cairo Water Pollution Control Plant may affect the receiving tributaries, they seem to have no negative effect on the macroinvertebrates in the Ochlockonee River. The reductions in benthic community parameters observed at Station 6 appear to be the result of siltation effects caused primarily by nonpoint-source (agricultural) run-off in Georgia.

Fishery Resources

Fisheries data are quite limited and should be viewed only as preliminary. Results from a single sampling event suggest that the Ochlockonee River in the vicinity of Station 6 had less biomass of rough fish and sport/commercial fish than other stations sampled. The number of individuals belonging to these groups of fish at Station 6 however, were comparable to other stations sampled. Station 6 had the second highest miscellaneous fish population (both by number and weight). If these preliminary results do accurately reflect actual conditions, a reduction in fish biomass at Station 6 may be related to the lack of benthic macroinvertebrate food sources found there, or may be due to unsuccessful fish reproduction in this area. Both these phenomena may be caused by the settling of fine silt/clay particles which probably originate from Georgia agricultural areas. The Florida Game and Freshwater Fish Commission is presently involved in further investigation of the Ochlockonee River fishery resources.

INTRODUCTION

Concerned about reported reductions in the sport fisheries of the upper Ochlockonee River, the Florida Legislature appropriated funds for the Florida Department of Environmental Regulation to conduct a water quality study of the river to determine if man-made pollution sources are responsible. Past studies, other historical information, and the observations of local residents suggest that the primary point and non-point source discharges to the upper portion of the Ochlockonee River basin above Lake Talquin originate in Georgia (Figure 1). These sources include industrial discharges (mining, food processing), domestic discharges (municipal sewage treatment plants) and agricultural runoff.

To determine what effects these sources had on downstream resources, we conducted a study of the physical, chemical, and biological properties of the river at 17 sites in the Ochlockonee Drainage Basin (Figure 2). Since it appeared that the most significant fishery problems in the Florida portion of the Ochlockonee (based on citizen complaints) existed in the portion of the river from the state line to Lake Talquin, we concentrated our efforts in the upper Ochlockonee Basin. Mining discharges to the Little River in Florida which affect Lake Talquin were not investigated in this study. The effects of these discharges are downstream of the upper river and are being evaluated through another investigation by the Florida Game and Freshwater Fish Commission.

The goals for this study were to: 1) determine the existing conditions in the river by obtaining appropriate biological data, and 2) determine the biological effects of both point-source and nonpoint-source discharges with regard to present and future regulatory concerns.

General Methodology

Biological sample collections began in October, 1985, and were made every four weeks at the eight primary stations (Table 1). The biological samples consisted of: 1) subsurface water grab samples for algal growth potential and limiting nutrient tests; 2) retrieval of periphyton samples that were incubated for four weeks; 3) retrieval of macroinvertebrate artificial substrate samplers that were also incubated for four weeks.

At both the primary and secondary stations, subsurface water grab samples were taken and transported to the City of Tallahassee Water Quality Laboratory, for analysis of nutrients and suspended solids (Table 1). Additional subsurface water samples were collected for certain physical-chemical parameters as well as for microbiological analyses. Selected stations were periodically sampled for acute and chronic toxicity. Water temperature, dissolved oxygen, and light penetration (Secchi disc) measurements were made *in situ* at each station. Fish populations were sampled by the Florida Game and Freshwater Fish Commission at two stations on the Ochlockonee River in the fall of 1983, and four stations in the fall of 1984. No fishery samples were taken in 1985 or 1986.

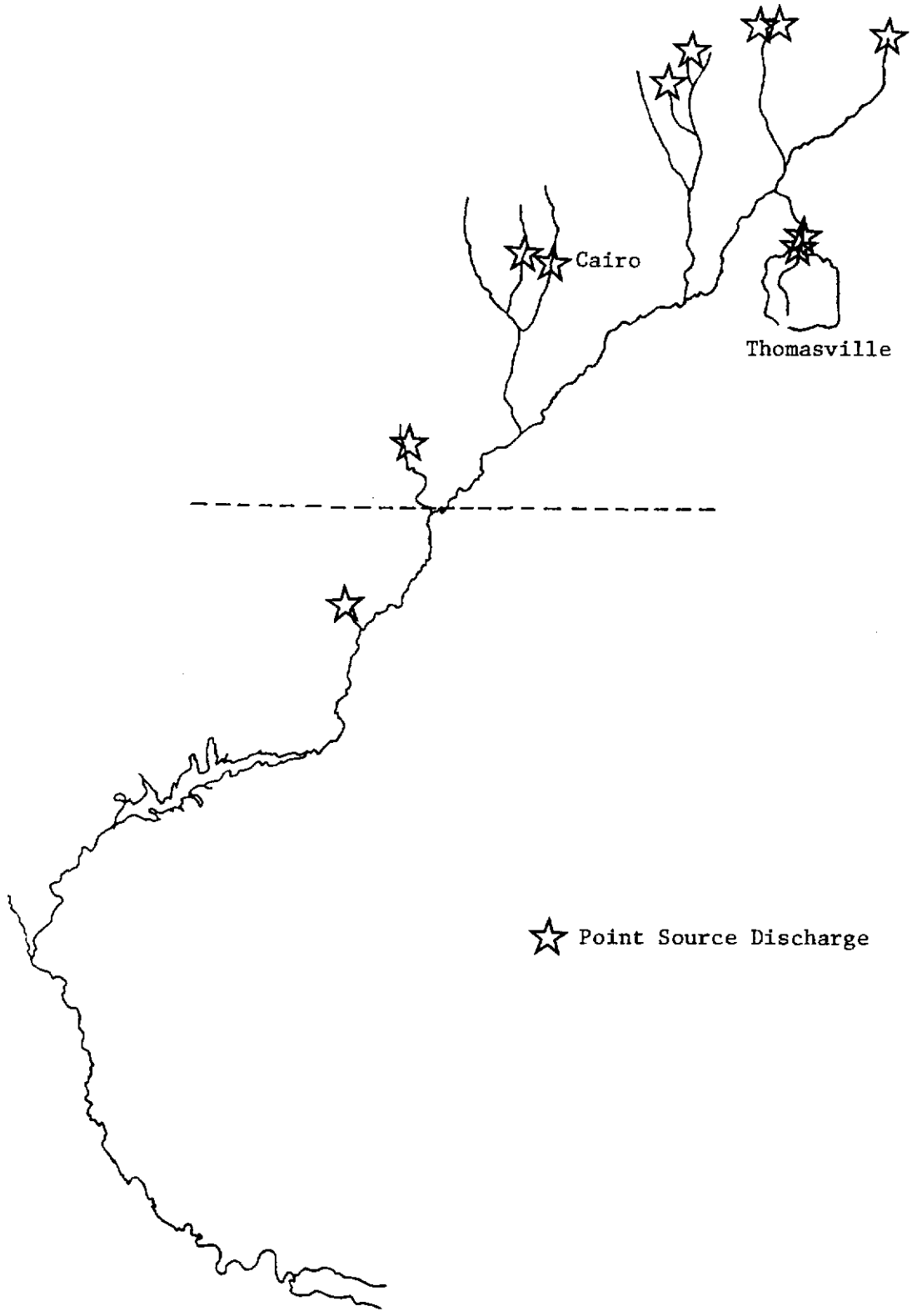


Figure 1. Point source discharges to the Ochlockonee River (discharges to Lake Talquin not shown).

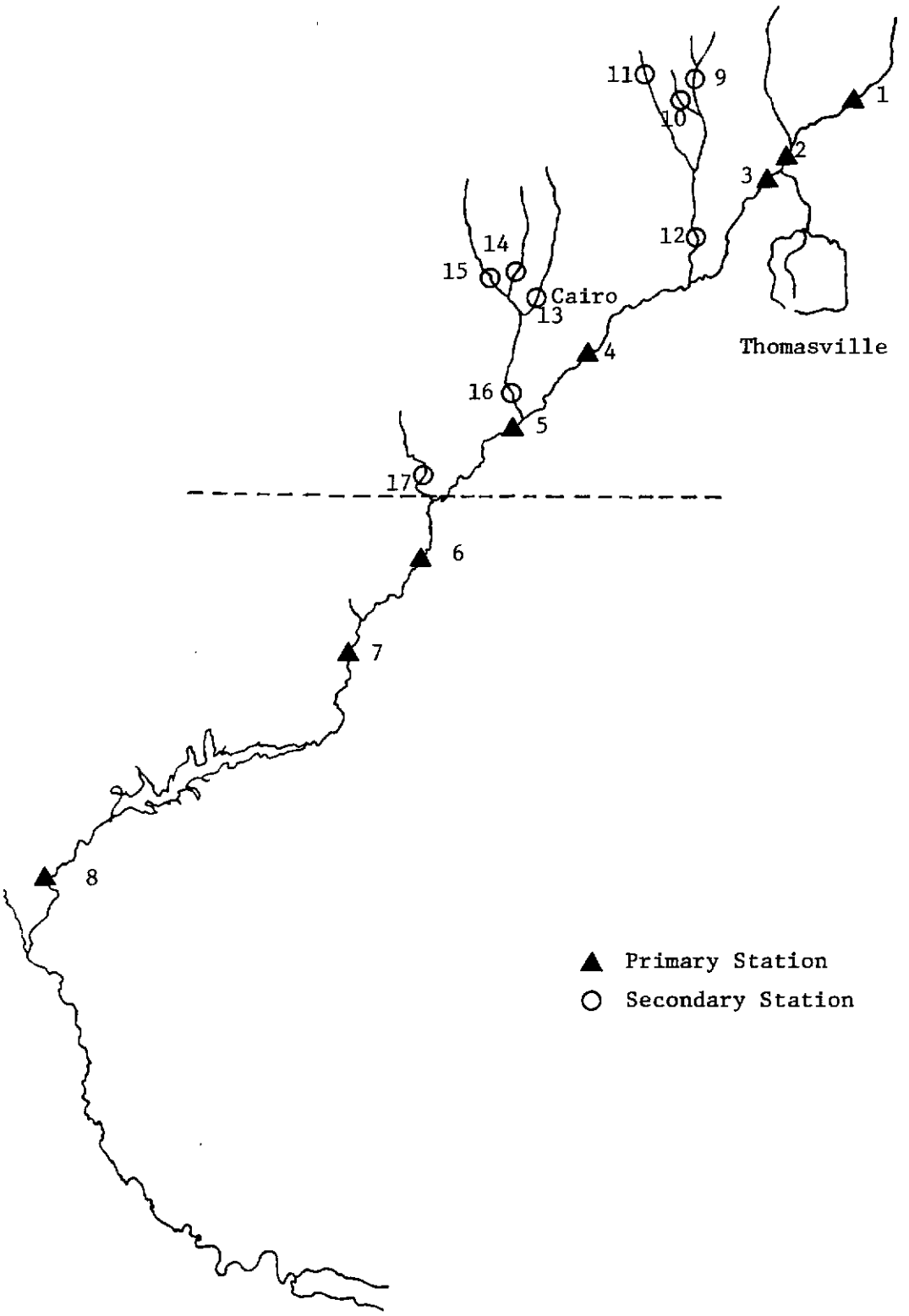


Figure 2. Station locations.

The remainder of our report will address details of the individual portions of the Ochlockonee study, i.e., pollution sources, physiography, geology, land use, erosion, physical/chemical analyses of sediment and water, toxicity tests, algal growth potential experiments, and characterizations of the bacterial, periphyton, benthic macroinvertebrate, and fish communities.

Station Locations and Descriptions

Our study sites were located throughout the upper Ochlockonee Basin so that the variety of potential sources noted earlier could be evaluated. The site locations also helped us examine the effect various land use patterns may have on the water quality of the river.

The study sites consisted of primary and secondary stations. At the eight primary stations (those located in the Ochlockonee River) an extensive array of biological, physical, and chemical analyses were performed (Table 1). For the purpose of graphical display of primary station data, Station 1 was considered the zero kilometer mark, and the remaining stations were assigned a kilometer distance as measured down the river channel from this point. At the nine secondary stations (major tributaries to the Ochlockonee River) several of the more labor-intensive biological analyses (macroinvertebrates, periphyton) were eliminated, but all physical-chemical analyses, as well as free water chlorophyll *a* determination and algal growth potential, were performed.

Primary Stations

River Kilometer		
0.0	Station 1	Ochlockonee River, approximately 100m upstream of Georgia Hwy. 202 bridge, 9.6 km north of Thomasville.
3.7	Station 2	Ochlockonee River, approximately 500m upstream of U.S. 19 bridge, 6.4 km north of Thomasville.
6.1	Station 3	Ochlockonee River, approximately 100m upstream of Georgia Hwy. 3 bridge, 4.8 km north of Thomasville. Oquina Ck., into which the City of Thomasville's sewage treatment plant discharges, enters the river just upstream of this station.
24.8	Station 4	Ochlockonee River, approximately 100m upstream of Georgia Hwy. 93 bridge, 8.8 km southwest of Cairo. Barnetts Ck. (Stations 9, 10, 11, 12) enters the river above this station.

River Kilometer

33.5	Station 5	Ochlockonee River, approximately 100m upstream of bridge on unnamed road, 13.5 km south of Cairo. This station is located below the confluence of the river and Little Tired Ck. (Stations 13, 14, 15, 16) which receives treated wastewater from the Cairo sewage treatment plant and the Roddenberry Company, also located in Cairo.
47.8	Station 6	Ochlockonee River, at dock on Col. Lester's property, 4.8 km south of Florida Hwy. 12 bridge. Bryants Mill Ck. (Station 17) enters the river above this station.
59.1	Station 7	Ochlockonee River, approximately 500m upstream of Tower Road boat landing, 3.2 km south of U.S. 27 bridge.
91.3	Station 8	Ochlockonee River, approximately 500m upstream of Stoutemire Landing, 4.8 km below Florida Hwy. 20 and the Lake Talquin dam.

Secondary Stations

Station 9 Horse Ck. at Georgia Hwy. 188 bridge, 1.6 km west of Ochlocknee. Thor Mining Co. discharges periodically into this creek.

Station 10 Branch of Barnetts Ck. at Georgia Hwy. 188 bridge, 2.8 km west of Ochlocknee.

Station 11 Barnetts Ck. at Georgia Hwy. 188 bridge, 4.8 km west of Ochlocknee.

Station 12 Barnetts Ck. below the confluence of Stations 9, 10, and 11, at Georgia Hwy. 38 bridge, 6.4 km west of Thomasville.

Station 13 Little Tired Ck. at Georgia Hwy. 93 bridge, 4.8 km south of Cairo. The Roddenberry Company discharges to this creek, approximately 4 km upstream of this station.

Station 14 Parkers Mill Ck. at Georgia Hwy. S-1715 bridge, 2.4 km south of Cairo. The City of Cairo sewage treatment plant discharges to this creek, approximately 2.5 km upstream of this station.

Station 15 Tired Ck. at Georgia Hwy. 111 bridge, 4.0 km south of Cairo.

Station 16 Tired Ck. at bridge on unnamed road, 10.4 km south of Cairo. This station is located below the confluence of Stations 13, 14, and 15.

Station 17 Bryants Mill Ck. at bridge on unnamed road, 7.2 km south of Reno.

TABLE 1. Study parameters for the Ochlockonee River Project.

Biology(1)	Physical-Chemical
benthic macroinvertebrates (1)(3)	pH (1)
periphyton (1)(3)	dissolved oxygen (1)
algal assay (algal growth potental and limiting nutrients) (1)	conductivity (1)
	alkalinity (1)
	hardness (1)
chlorophyll *a* (free water and periphyton) (1)	light penetration (Secchi disc) (1)
	turbidity (1)
chronic toxicity (1)(5)	nitrite + nitrate (2)(4)
	ammonia (2)(4)
	total Kjeldahl (2)(4)
	ortho phosphorus (2)(4)
	total phosphorus (2)(4)
	suspended solids (2)
	sediment analysis (particle size) (1)

(1) Analyses performed at DER Biology Laboratory
(2) Analyses performed at City of Tallahassee Water Quality Laboratory
(3) Analyses performed only at primary stations
(4) Analyses performed on both filtered and unfiltered samples
(5) Selected stations only

Personnel

The following individuals were responsible for the successful completion of this report, with major contributions specified. All are or were associated with the Department of Environmental Regulation, Biology Section.

Marcella J. Drawdy - land use and erosion, physiography and geology, toxicity, graphics

Craig W. Dye - field and laboratory direction, chironomid identifications, daily turbidity and flow, editing

J. Marshall Faircloth - algal assay, microbiological laboratory procedures

Mark O. Friedemann - physical/chemical water quality, sediments, chlorophyll analysis, graphics

Russel B. Frydenborg - project design, benthic macroinvertebrates, fishery resources

Kathleen M. Lurding - periphyton, editing, report organization

Frances D. Moore - manuscript preparation

Landon T. Ross - planning, editing

Leslee A. Williams - bacteria

Loretta E. Wolfe - statistics, computer programming

Acknowledgements

The Biology Section is appreciative of the following individuals for their help with this study:

1. Mr. Gray Bass, Mr. Dan Dobbins (Florida Game and Freshwater Fish Commission) and staff - for providing information on the Ochlockonee fish populations.

2. Mr. Jerrell Daigle (Florida Department of Environmental Regulation) for assistance with macroinvertebrate identifications.

3. Mr. Jack C. Dozier (Georgia Department of Natural Resources) for providing biological and chemical data from Georgia studies and for reviewing the draft manuscript.

4. Mr. Don Foose, Mr. Marvin Franklin, Mr. Paul Meadows, and Mr. Roger McFarland (United States Geological Survey) for providing hydrologic and water quality data.

5. Mr. Ralph Leonard (United State Department of Agriculture) for land use and erosion data.

6. Mr. Bill Leseman (City of Tallahassee Water Quality Laboratory) and staff - nutrient analyses.

7. Col. Nick Lester - for taking daily turbidity samples, and for general information about the river's history.

8. Mr. Tony Murray (Savannah Laboratories) for sediment nutrient analysis consultation.

9. Dr. Manuel Pescador (Florida Agricultural and Mechanical University) for assistance in macroinvertebrate verifications.

10. Mr. David Word (Georgia Department of Natural Resources) for providing NPDES permit information.

POLLUTION SOURCES

The Ochlockonee River receives discharges from point-sources, such as sewage treatment plants and industrial facilities, and nonpoint-sources, such as urban and agricultural areas.

Point-source discharges which may have significant effects on the upper Ochlockonee include seven municipal wastewater treatment facilities and three industrial facilities (Figure 3). These are currently permitted by the State of Georgia through the National Pollution Discharge Elimination System (NPDES) under jurisdiction of the U.S. EPA (Table 2). Possible environmental consequences of municipal wastewater discharges and food processing effluents include increased loads of organic mattter and nutrients, depressed dissolved oxygen levels, and elevated bacterial populations. Mining effluents may elevate turbidity and nutrient values in the receiving water. The most upstream point-source discharge to the Ochlockonee is the City of Doerun Water Pollution Control Plant (WPCP) which enters near the headwaters of the river via Mill Creek. Next, a larger WPCP in Moultrie discharges directly to the river five miles above Station 1. During periods of low water, the discharge from this facility constitutes the majority of flow in this section of the river (GEPD 1973). Municipal treatment facilities of two cities, Meigs and Pelham, discharge to the Ochlockonee River via the Little Ochlockonee River, which is less than one mile above Station 2. Discharges from the City of Thomasville WPCP and from Sunnyland Foods enter the river immediately above Station 3 via Oquina Creek. Thor Mining discharges to Horse Creek which enters the Ochlockonee between Stations 3 and 4 via Barnett's Creek. The Cairo WPCP and the Roddenberry Company discharge to Parkers Mill Creek and Little Tired Creek, respectively. These creeks are tributaries of Tired Creek, which enters the Ochlockonee 1.8 miles above Station 5. Floridin Mining, which is not currently operating, at one time discharged to the Ochlockonee above Station 6 via Bryant's Mill Creek. The City of Havana's Sewage Treatment Plant intermittently discharges to the Ochlockonee above Station 7 via Womack Mill Creek.

Although four other point-source discharges exist in the Ochlockonee Basin, they have no bearing on water quality in the upper Ochlockonee since they discharge through various tributaries to Lake Talquin. The effects of these dischargers on the biota of Lake Talquin are being evaluated through another investigation by the Florida Game and Freshwater Fish Commission. Permit information for all these dischargers is presented in Table 2.

Nonpoint-source pollution has recently been recognized as a serious threat to water quality throughout the United States. The deleterious effects of agricultural and urban run-off on aquatic systems are often difficult to determine quantitatively, but in some cases may be worse than point-source discharges (U.S. EPA 1984). Sediment loading from croplands is considered among the most pervasive potential causes of water pollution in the nation, especially the Southeast and Delta States (U.S. EPA 1984).

Figure 3. Pollution sources in the Ochlockonee River Basin.

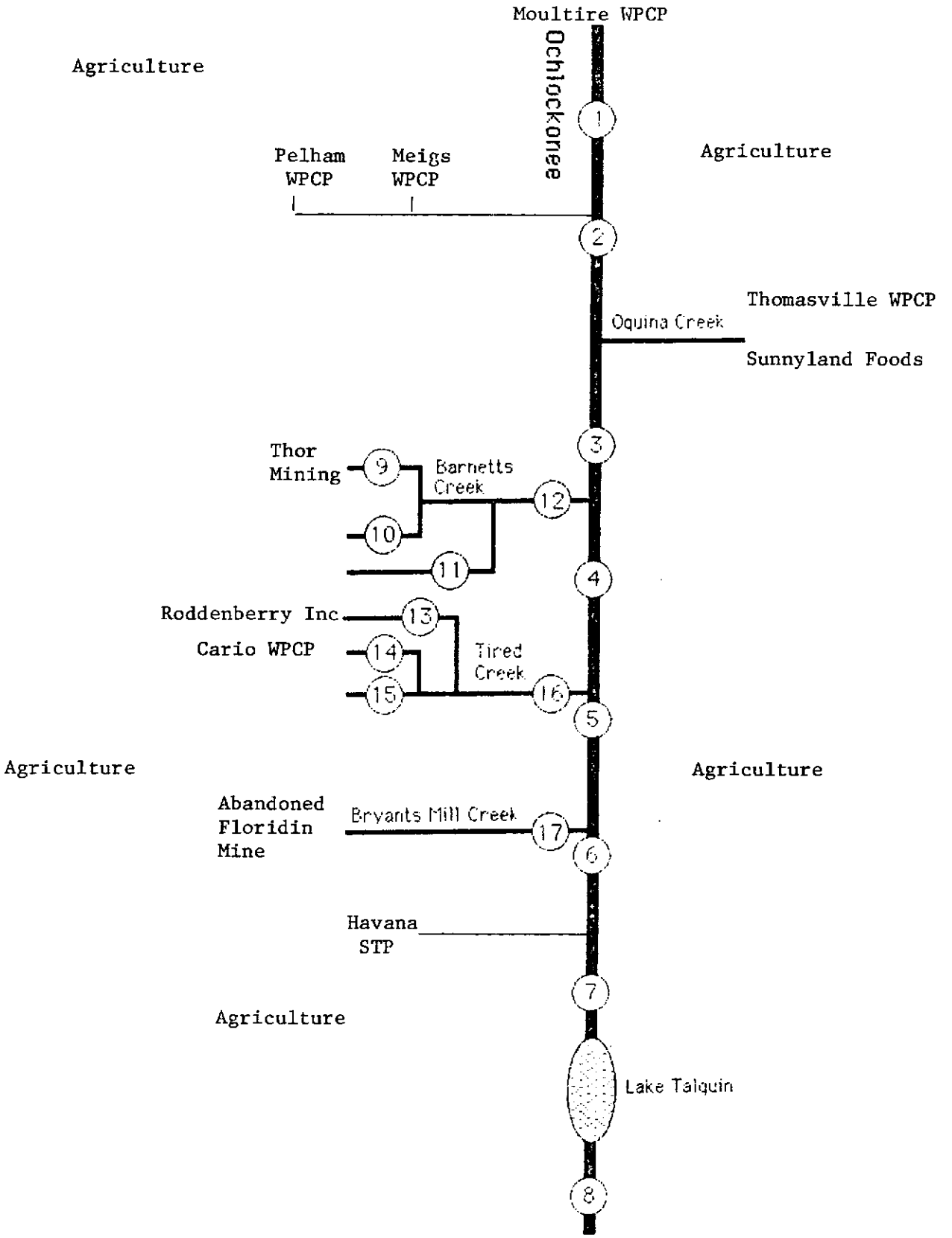


TABLE 2. Permitted Discharges into the Ochlockonee River and its Tributaries.

Facility	Receiving Waters	FLOW MGD	BOD_5 mg/l	NH_3N mg/l	Minimum DO mg/l	Fecal Coliform MPN	Suspended solids mg/l	pH range SU	Oil and Grease (mg/l)	Turbidity NTU	Specific Conductance umhos/cm	TKN mg/l	Possible Environmental Effects
City of Moultrie	Ochlockonee River	4.0	10	2.0	6.0	200/100 ml	30	6.0 - 9.0					Increased nutrients, Increased bacterial pop. Oxygen depletion
City of Meigs	Oaky Woods Creek	.15	15	3.0	5.0		30	6.0 - 9.0					"
City of Doerun	Mill Creek	.15	30			200/100 ml	90	6.0 - 9.0					"
City of Pelham	Big Creek	.75	30		5.0	200/100 ml	30	6.0 - 9.0					"
City of Thomasville	Oquina Creek	6.5	Seasonal 10.0- 30.0	Seasonal 2.0- 10.0	Seasonal 6.0 5.0	200/100 ml	30	6.0 - 9.0					"
City of Cairo	Parkers Mill Creek	2.0	30			200/100 ml	30	6.0 - 9.0					"
Sunnyland Foods	Steam Mill Branch		125 lbs/day	25 lbs/day	6.0	400/100 ml	125 lbs/day	6.0 - 9.0	10				Increased bacterial pop. Oxygen depletion
W. B. Roddenberry	Little Tired Creek		30,159 lbs/year		6.0		55,672 lbs/yr	6.0 - 9.0					Oxygen depletion Increased conductivity Increased bacterial pop.
Englehard Minerals	Little Attapulgus Creek		Seasonal 125,167 lbs/day	Seasonal 208-290 lbs/day	6.0		90	6.0 - 9.0		45 [daily average]			Increased turbidity increased nutrients
City of Quincy	Quincy Creek		20	7.0	5.0	200/100 ml	20	6.0 - 8.5					Increased nutrients Increased bacterial pop. Oxygen depletion
City of Havana	Womack Mill Creek		20		5.0	200/100 ml	50	6.0 - 8.5				28	"
Hopkins Generating Station	Ochlockonee River						30	6.0- 9.0	5.0				Increased temperature
Reichold Chemicals	Stokes Branch to Teolgia Creek		20	.48	6.0		57 lbs/day	6.0- 7.6	5.0		200 at 25°C		Increased conductivity Increased nutrients Oxygen depletion
Floridin Co. Thor Mine	Tributary to Horse Creek							5.0- 9.0		75 [daily average]			Increased turbidity Increased nutrients
Floridin Co. *Butler-Powell Mine	Bryant Mill Creek							5.0- 9.0		75 [daily average]			"

Permit information was obtained from individual permit files.

-Georgia Department of Natural Resources, Division of Pollution Control.

-Florida Department of Environmental Regulation, Division of Environmental Permitting.

* Mine is no longer in operation.

Both the states of Georgia and Florida recognize the need to curb soil erosion rates of agricultural lands currently under conventional tilling practices. These methods, which exacerbate wind and water related soil erosion, combined with fertilizer and pesticide use, contribute to water quality deterioration in lakes and streams. Soil Conservation Services in both states are currently implementing area-wide conservation plans promoting no-till farming and contour cultivation.

Increasing at significant rates are urban areas requiring run-off control. Sediments and stormwater from unpaved roads and urban land, often polluted by associated oil and chemicals, have direct access to streams through storm drains.

PHYSIOGRAPHY, GEOLOGY, LAND USE AND EROSION

Physiography and Geology

The Ochlockonee River Basin drains approximately 5,957 km^2 of southeastern Georgia and the panhandle of Florida east of the Apalachicola River. Originating in Worth County, Georgia, the river flows a total of 257 km through three physiographic provinces, the Tifton Upland District in Georgia (77 km), and the Tallahassee Hills and the Gulf Coastal Lowlands in Florida (180 km), where it empties into Ochlockonee Bay. The average gradient is 0.47 m/km and average discharge of the river is 45.7 m^3/s (State of Florida 1966). A major impoundment on the river is Lake Talquin, a 3,584 hectare reservoir bordering Leon and Gadsden counties in Florida (State of Florida 1983).

The Tifton Upland District is characterized by low rolling hills (elevation 38-143 m MSL) with a dendritic drainage pattern of generally sluggish streams with poorly defined channels flowing through broad, swampy bottomlands. Subsurface formations are composed of Neogene sediments dominated almost exclusively by the Hawthorn formation, which consists of marine sands, clays, marls, and sandy limestones. Surface formations are Miocene and Pliocene sands (2-26 million years old), which form the six major soil resource groups of the watershed and basin (U.S.D.A. 1982).

The Ochlockonee River flows south through the Tallahassee Hills, which are characterized by moderately steep clay and sand slopes. This region extends eastward 62 km from the Apalachicola River and south approximately 13 km. The region is characterized by level, poorly drained plateaus with steep sloping sides at elevations of 21-94m MSL. In contrast to the rugged and steep topography of the western region draining into the Apalachicola River, tributaries to the Ochlockonee River have carved a gentle, though moderately steep terrain through underlying clay soils (Pascale and Wagner 1982). In this region the Ochlockonee River Basin remains in the confines of the Hawthorn formation but is bordered closely on both sides by the underlying Miccosukee formation, a group of late Miocene deltaic sediments.

Dividing the Tallahassee Hills from the Gulf Coastal Lowlands is the Cody Scarp, an erosional remnant of an ancient marine scarp extending across most of Florida (Pascale and Wagner 1982, Puri and Vernon 1964). The Coastal Lowlands are composed of recent and Pleistocene series estuarine deposits and constituents from the Jackson Bluff formation, a group of carbonaceous sands and sandy shell marls. Distinguishing topographic features are typical of poorly drained coastal floodplains (elevation 0-21m MSL). Peat, muck, sand, and clay soils are associated with slow, shallow, sluggish streams, channels, and swamps. Average width of the floodplain is 1 km, including the Sopchoppy River Basin (Pascale and Wagner 1982).

Generally, sediments underlying the Ochlockonee River Basin consist of clays, sand, and limestone (Table 3). The upper reaches of the river are dominated by thick Miocene clays which hinder local ground-water movement and recharge. The forces of erosion have, however, removed these thick clays in the lower river and exposed marine sands and limestone.

TABLE 3. Stratigraphic units and their water-bearing properties in the Ochlockonee River area.

SYSTEM	SERIES	STRATIGRAPHIC UNIT	THICKNESS (feet)	LITHOLOGY	HYDROGEOLOGIC UNIT		WATER-BEARING PROPERTIES
QUATERNARY	HOLOCENE and PLEISTOCENE	SURFACE SANDS and TERRACE DEPOSITS	0–60	Unconsolidated sand, silt, clay, peat and muck.	SURFICIAL AQUIFER		Sand beds yield small supplies to mostly rural domestic dug wells; generally poor quality-high coliform counts.
TERTIARY	PLIOCENE	JACKSON BLUFF FORMATION	0–25	Clay and clayey sand, greenish-gray and brown; abundant marine fossils.	UPPER CONFINING UNIT		Not used as a source for water supplies due to low permeability.
	MIOCENE	MICCOSUKEE FORMATION	0–70	Clay and sandy clay, yellowish- to reddish-brown; some gravel lenses; limonite; crossbedding; iron staining; marine fossils absent.			
		HAWTHORN FORMATION	10–325	Clay, greenish-gray to yellowish-brown; sand, fine to coarse; clays become calcareous with depth; includes fuller's earth units; phosphorite prominent throughout but less extensive in the southern part of the study area.			
				Clay, sand, and phosphorite as above; limestone, soft to well-consolidated, sandy, generally low to moderate porosity, low permeability; thinly bedded dolomitic limestones common in northern part of study area.		WATER-BEARING ZONE	Yields small to moderate quantities of water, 5–70 gal/min; good quality.
				Clay, greenish-gray, calcareous, laminated.			Low permeability.
		TAMPA LIMESTONE	50–275	Limestone, various shades of gray, soft to well-consolidated, sandy, crystalline to granular, highly recrystallized; low to moderate porosity, moderate permeability; becoming dolomitic with depth; sand; clay, calcareous; foraminifera—not common; fossil molds and casts abundant; shell beds common in southern part of study area.	FLORIDAN AQUIFER		Yields moderate quantities of water, 10–200 gal/min; good quality; variable permeability; discontinuous clay units tend to retard vertical movement.
	OLIGOCENE	SUWANNEE LIMESTONE	70–280	Limestone, very pale orange to yellowish-brown, crystalline to granular, highly dolomitic; clay, dolomitic; sand less extensive than above; moderate to high porosity and permeability; foraminifera and other fossils abundant.			Yields moderate to large quantities of water, 50–4500 gal/min; water quality ranges from good to poor.
	EOCENE	OCALA LIMESTONE of JACKSON AGE	225–490	Limestone, white to light-gray, highly fossiliferous; moderate to high porosity and permeability; upper portion highly dolomitized; dolomite; chert; glauconite; clay, sparse; gypsum.			Yields large quantities of water; generally poor quality water; high chloride and sulfate concentrations.
		UNNAMED ROCKS of CLAIBORNE AGE	965–1230	Limestone, fossiliferous, glauconitic, argillaceous, cherty, sandy; shale, calcareous, laminated; dolomite; sandstone, glauconitic and calcareous; gypsum; glauconite increases with depth.			
		UNNAMED ROCKS of WILCOX AGE	305–565	Dolomite; limestone, sandy, argillaceous, fossiliferous; sandstone, calcareous; shale, laminated, micaceous; chert; glauconitic throughout.	?–?–? LOWER CONFINING UNIT		Generally not used as a source for water supplies. A few water wells penetrate the upper Claiborne rocks. Contains saline water.
	PALEOCENE	UNNAMED ROCKS of MIDWAY AGE	235–415	Shale, calcareous, laminated, glauconitic; sandstone, calcareous, argillaceous; limestone, fossiliferous, argillaceous, cherty, sandy.			
CRETACEOUS and older				Limestone, chalky and shale, calcareous, laminated.			Low or extremely low permeability. Contains saline water.

Source: Pascale, C.A. and J.R. Wagner. 1982. Water resources of the Ochlockonee River area, Northwest Florida. U.S. Geological Survey, Open File Report 81-1121. p. 13.

Land Use

Land use in the Southeastern United States has changed dramatically since the advancement of the railroad in the 1870's, when the native upland longleaf pine forests were logged and cleared. The lands were converted to cropland and primarily farmed in cotton until the 1920's when the boll weevil devastated the industry. Primary cash crops then changed to peanuts and tobacco (Lowrance et al. 1986). Land conversion trends from forest land to cropland have continued since the 1940's, increasing during the 1970's when economic conditions created a profitable situation for farmers to convert these lands (White et al. 1981). The Southwest Georgia area is considered the "breadbasket" of the state with approximately 50% of land area classified as prime farmland (State of Georgia 1982). Recent and projected trends are toward greater continuous acreage, more intensively cultivated and irrigated. From 1967 to 1979, approximately 26,000 hectares in the counties bordering the Ochlockonee River were converted to agricultural use (State of Georgia 1980a, 1980b). Currently, 40% of land in these Georgia Counties along the Ochlockonee River is utilized for agricultural purposes.

After considerable investigation, it was determined that past land use or planted crop information was not readily available for areas surrounding portions of the Ochlockonee River in Florida. It is known, however, that 8% of the total land in both Leon and Gadsden Counties is currently under tillage for crops (Table 4). Land use patterns for Georgia and Florida counties in the basin are also presented in Table 4.

In the Southwest Georgia Counties surrounding the Ochlockonee River 27,578 hectares of forest lands were converted in the 1970's to other uses, primarily agricultural (State of Georgia 1980a, 1980b). Presently, forests comprise 47% and 68% of the total land area in the Georgia and Florida counties bordering the Ochlockonee River, respectively (Table 4).

Associated with the decline in forest lands in Southwest Georgia is the decline in wetland areas, not considered a problem until recently, since most converted lands were upland pine forest areas. Since 1953, 81,000 wetland hectares have been converted to other land uses. The areas most affected are small ponds and blackwater branches or creek swamps (U.S.D.A. 1982). The degree of loss of wetland areas in Florida which could affect the Ochlockonee Basin is unknown.

Erosion

The acceleration of land conversion from bordering forest land and wetlands to cropland which occurred in Southwest Georgia particularly during the early 1970's has magnified the problem of nonpoint-source pollution, specifically erosional surface run-off and sedimentation from croplands. Similar erosional problems have occurred in the Florida section of the Ochlockonee River Basin, but to a far lesser extent since the total cropland involved is considerably smaller.

TABLE 4. Current land use in selected counties bordering the Ochlockonee River. All values in hectares.

Crops	Georgia[a]	Florida[b]
Corn	61,539	6,973
Cotton	12,063	Negligible
Peanuts	35,392	191
Sorghum	4,291	378
Soybeans	65,384	6,264
Tomatoes	Negligible	668
Wheat	18,299	Negligible
Other	82,633	9,813
Total Crops	279,602 (40%)	24,287 (8%)
Pasture	53,432 (8%)	16,184 (5%)
Forest	324,488 (47%)	210,332 (68%)
Other	31,538 (5%)	51,243 (17%)
Total Land Area	689,080	309,374

Adapted from:

U.S.D.A. 1984 Erosion Report Leon County
U.S.D.A. 1985 Erosion Report Gadsden County
State of Georgia 1985, Georgia Agricultural Facts

[a] Includes Worth, Mitchell, Colquitt, Thomas, and Grady Counties.

[b] Includes Leon and Gadsden Counties.

Sediment is considered by Georgia's Nonpoint Source Program (State of Georgia 1978) as "the largest potential pollution problem by volume and weight". Adsorbed to the sediment particles are nutrients such as phosphorus and nitrogen (White et al. 1981). Other agricultural chemicals possibly adsorbed include pesticides, fungicides, and herbicides (State of Georgia 1978).

An erosion rate of greater than 4.5 metric tons/hectare/year is considered excessive in terms of soil conservation (U.S.D.A. 1982). However, it should be noted that not all of this eroding soil reaches a watercourse. The most significant factor in determining sediment contributions to streams is the amount of vegetative buffer between the erosion source (cropland) and the watercourse (Candace Trimble, U.S.D.A. Soil Conservation Service, personal communication). Unpaved roads, with negligible vegetative buffers, may also be responsible for delivering large quantities of sediments to streams.

In the counties bordering the Ochlockonee River in Georgia, 102,017 hectares are eroding at a rate greater than 4.5 metric tons/hectare/year (U.S.D.A. 1982). A very conservative estimate of the total quantity of eroded soil from this area is approximately 1.5 million metric tons/year (U.S.D.A. 1982). However, important techniques for erosion rate estimates, such as field by field erosion analysis and ephemeral gully erosion quantifications, were not used in these calculations, and depending on the influence of other factors such as slope and rainfall intensity, substantial underestimation of the actual erosion rates may have resulted (Candace Trimble, U.S.D.A. Soil Conservation Service, personal communication). These newer techniques were used in similar erosion studies in Florida, for Leon and Gadsden counties, where 21,941 hectares were calculated to be eroding at greater than 4.5 metric tons/hectare/year. It should be noted that the majority of land in Leon and Gadsden counties is downstream of Station 6, the area in the Ochlockonee River which was determined to be most affected by sedimentation. Therefore, the quantity of eroded soils from areas in Florida which could conceivably contribute to the sediment load observed at Station 6 was calculated, and this turned out to be about 160,000 metric tons/year (from U.S.D.A. 1984, 1985). Erosion is presently less of a problem in the Florida portion of the Ochlockonee River Basin. In the last few years for example, pine trees have been planted in many fields once used for corn production, thereby reducing erosion from those areas (Darryl Johnson, U.S.D.A. Soil Conservation Service, personal communication).

Conclusions

In Southwest Georgia, land conversion trends from forest land to cropland have continued since the 1940's, accelerating during the early to mid 1970's and are expected to continue throughout the 1980's. Most lands converted were bordering forest lands already owned by farmers with the most critical of these forest lands being wetlands bordering streams. Wetlands are considered effective in controlling erosion from the cropland base. Without this buffer, the capacity to ameliorate the effects of erosion are lost.

No past land-use information for Leon and Gadsden Counties, Florida, was available for this report but current statistics show that 8% of the land in the two-county region as compared to approximately 40% of the area of Southwest Georgia, is currently in croplands.

The problem of erosional surface run-off and sedimentation from croplands is a critical resource problem of the upper Ochlockonee River Basin, and is most apparent at Station 6.

A conservative estimate of approximately 1.5 million metric tons/year of soil is eroded from 280,000 hectares of cropland in the Georgia portion of the Ochlockonee River Basin. Florida's sediment contribution to the Ochlockonee River at Station 6 is probably an order of magnitude less, as 160,000 metric tons/year of soil is eroding from 7355 hectares of cropland in the area.

SEDIMENTS

Introduction

Substrate composition has been shown to be an influential component in determining the hydrological and ecological quality of freshwater systems (Odum 1971). Evidence presented by several investigators (Golterman 1966, Welch 1977, Jacoby et al. 1982) suggests that internal loading and subsequent regeneration of sediment-bound nutrients may produce effects which directly hinder the progress of measures taken to alleviate eutrophic conditions. Furthermore, the distribution and abundance of macroinvertebrate populations is linked to sediment particle size and organic content (Linduska 1942, McLachan 1969, deMarch 1976).

The transportation of large loads of sediment has been shown to have an adverse effect on biota since the introduction of massive sediment loads can eliminate important spawning habitats, alter community structure in macroinvertebrate populations, and smother beds of aquatic vegetation. All these effects could eventually be detrimental to both the ecological and economic viability of an area (Duda 1985).

Methods and Materials

Samples for sediment analysis were collected on 4 February, 1986 during high flow, and on 19 June, 1986, during a low flow period. Four core samples were taken at each of the 17 stations using a 3.5 cm diameter acrylic coring device. All cores collected were approximately 10 cm in depth (Ford 1962). The contents of each core were emptied into a single Whirlpak® bag, labeled, and frozen upon return to the laboratory. Prior to analysis, core samples were thawed, dried, and weighed. Weighed samples were then ashed at 550°C in ceramic crucibles for 4 hours in a Thermolyne™ muffle furnace (Barnes 1959), rehydrated, dried, and re-weighed to ascertain the loss of organic content on ignition (FDER 1982).

Sediment grain size analysis was performed on samples from both high and low flow periods, using procedures outlined in FDER (1982). Seven size classifications were used in determining sediment grain size. Sieve screen sizes ranged from 2 mm to 62 um.

Sediment nutrient analysis was performed using a Technicon® Autoanalyzer®. Phosphorus and nitrogen samples were prepared by acid digestion using a Technicon® BD-40 block digestor. Adjustments were made to the sample volume when the range limits of the test were exceeded. Both phosphorus and nitrogen sediment concentrations were determined using colorimetric methods outlined in the Technicon® technical manual (1978) and A.P.H.A. et al. (1985).

Results

The organic content of the sediment samples ranged from 0.1 to 8% during low flow (< 1000 cfs) and from 0.1 to 9.2% during the high flow period (Figures 4-7). The highest organic content of the sediments in the river during both the low and the high flow episodes was noted at Stations 6 and 3. At low flow, sediments from Station 3 contained 2.9% organics while at high flow sediment organic content was measured at 1.3%. Significantly greater quantities of organic material were found at Station 6, which is located approximately 40 km downstream of Station 3. Organics at this station contributed 8% of the total weight of the sediment sample during low flow conditions while 7.1% of the total weight was attributed to organics during high flow conditions.

Sediment cores from several tributary streams contained large amounts of organic material though samples from Stations 9 and 10 were particularly noteworthy. Sediment samples from both these stations exhibited elevated organic content as well as elevated levels of silt and clay. Organic contents during low and high flow conditions were 7.3 and 9.2% at Station 9 and 6.7 and 5.3% at Station 10, respectively. Silt and clay at low flow conditions accounted for 29% of the total sediment weight at Station 9 and 20.4% at Station 10. During high flow conditions the silt and clay fraction decreased slightly, to 22.5% at Station 9 and 13.4% at Station 10.

In the river, the silt/clay fraction was highest at Station 6 during the time of both low and high flow conditions. Silt and clay accounted for 20.7% of the total sediment weight during low flow and 24.7% during high flow conditions. The next highest values in the river were dramatically lower, with silt and clay accounting for 10.6% at Station 2 during low flow and 5.8% at Station 5 during the high flow period of the study. The silt/clay fraction of the sediment samples during low and high flow episodes for all stations varied from .02 to 29% and from .05 to 24.7%, respectively (Figures 4-7).

Sediment nutrient concentrations for phosphorus and nitrogen in the river paralleled the observed accumulations of silts and organics. The highest concentrations of phosphorus and nitrogen were consistently noted at Station 6, regardless of water level. Sediment phosphorus and nitrogen concentrations were also elevated at Station 3 during low flow conditions and Stations 4 and 3 during high flow conditions. Stations 1, 2, 7, and 8 had the lowest sediment nutrient concentrations. Phosphorus concentrations in sediment samples taken from the river ranged from 28.7 to 502.7 mg/kg while nitrogen varied from 42.7 to 1334.4 mg/kg (Figures 10 and 11).

Sediment nutrient concentrations in the tributary streams ranged from 49.5 mg/kg to 320.1 mg/kg phosphorus and from 55.1 to 1643.5 mg/kg nitrogen (Figures 8 and 9). Elevated sediment nutrient concentrations were observed at several tributary stations. The concentrations, however, varied greatly between low and high flow. The highest levels of sediment

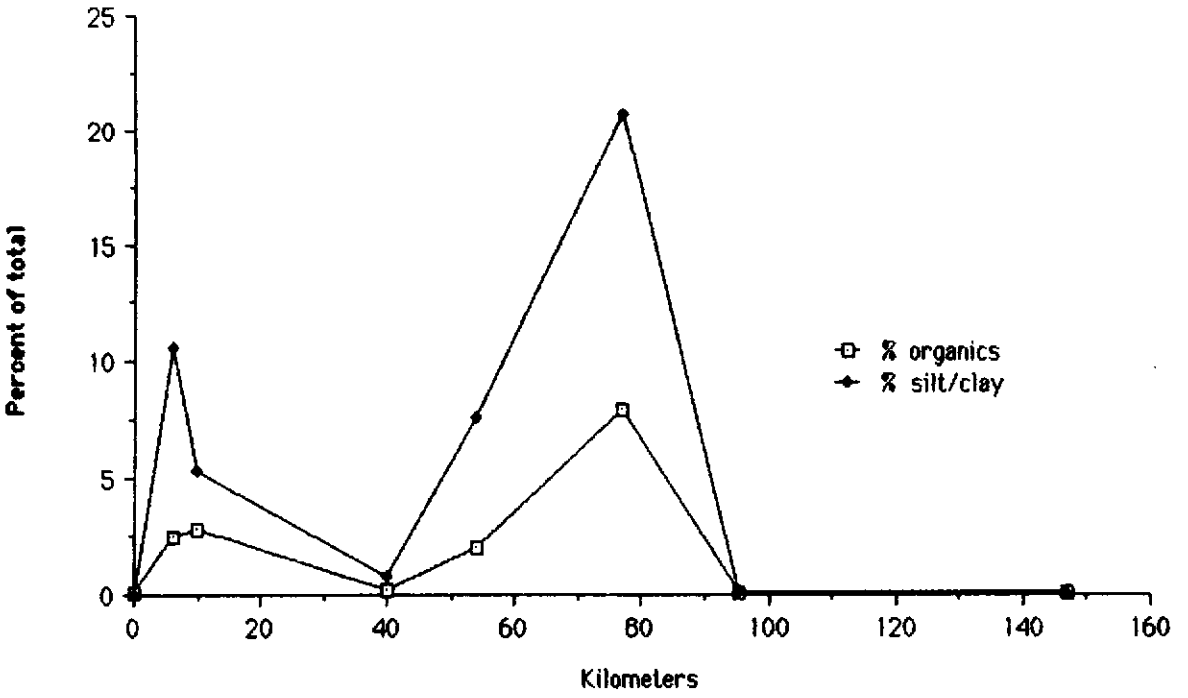


Figure 4. Sediment organic and silt/clay content during low flow.

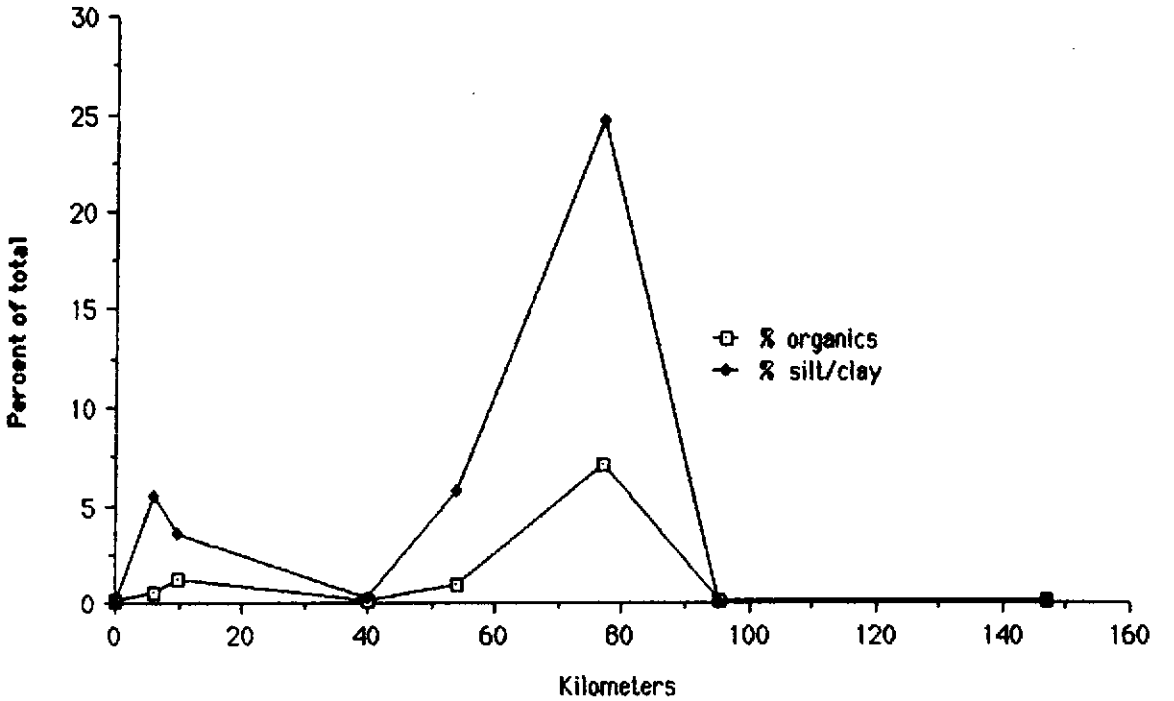


Figure 5. Sediment organic and silt/clay content during high flow.

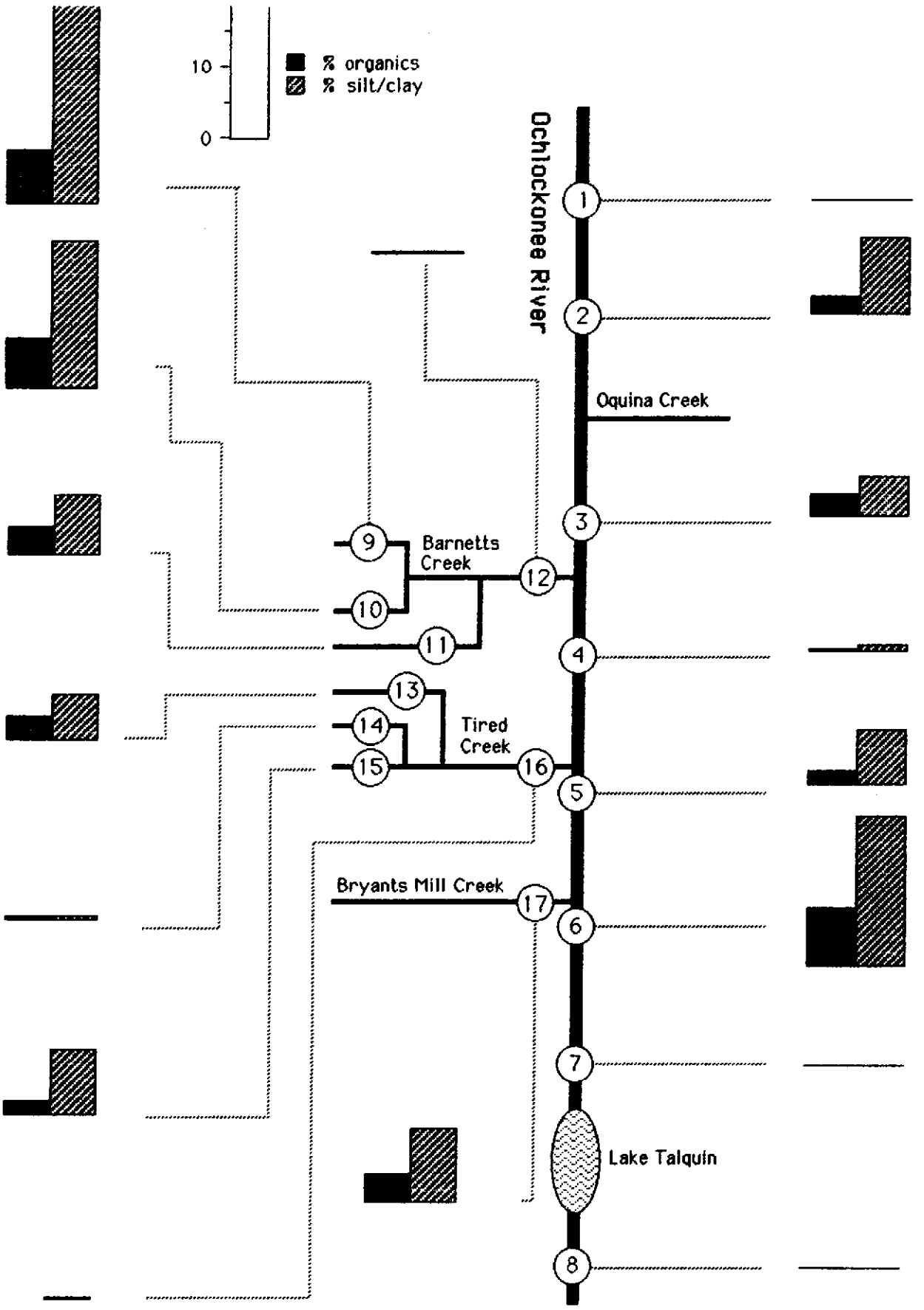


Figure 6.. Sediment silt/clay and organic fractions during low-water conditions.

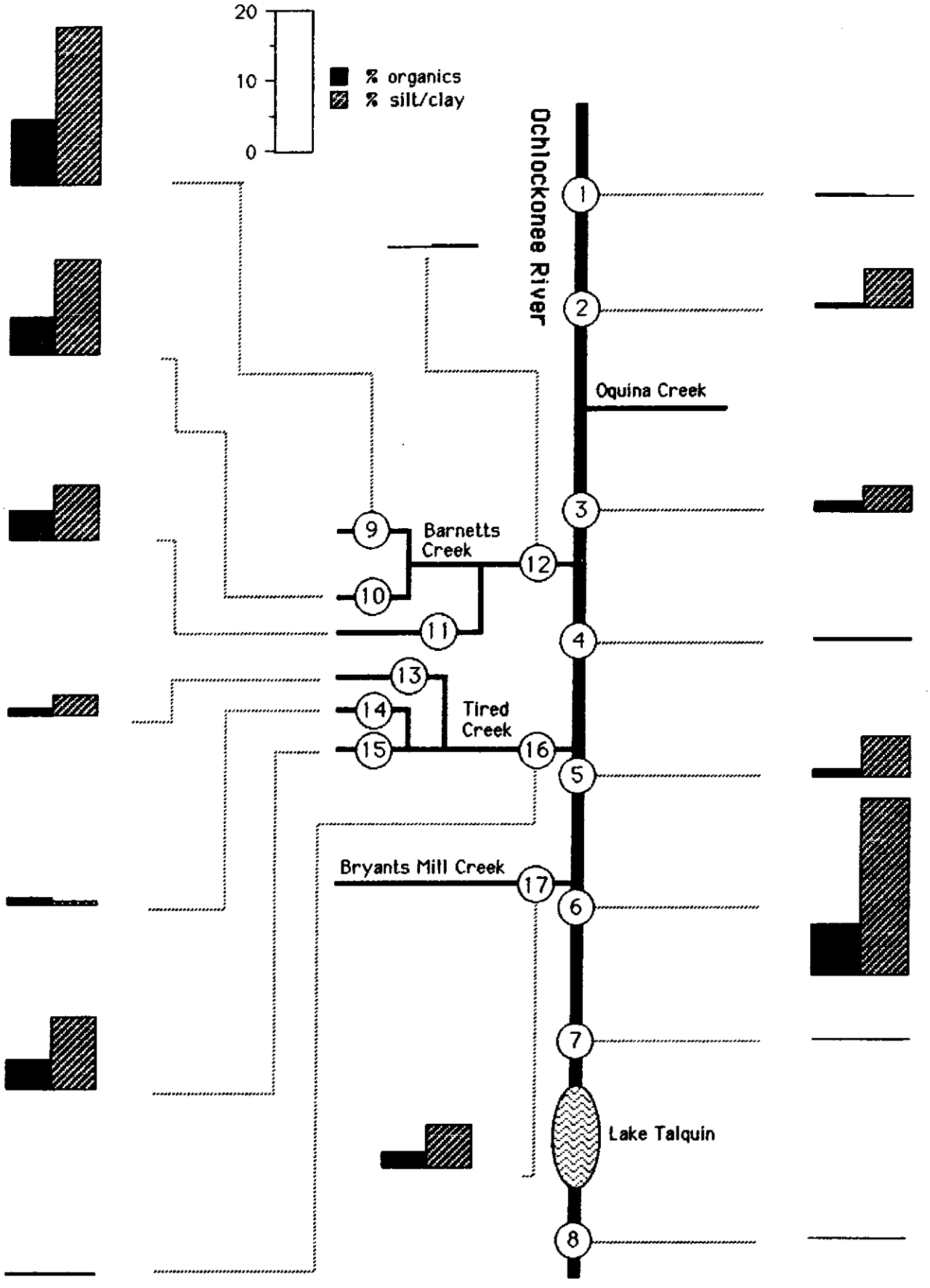


Figure 7.. Sediment silt/clay and organic fractions during high-water conditions.

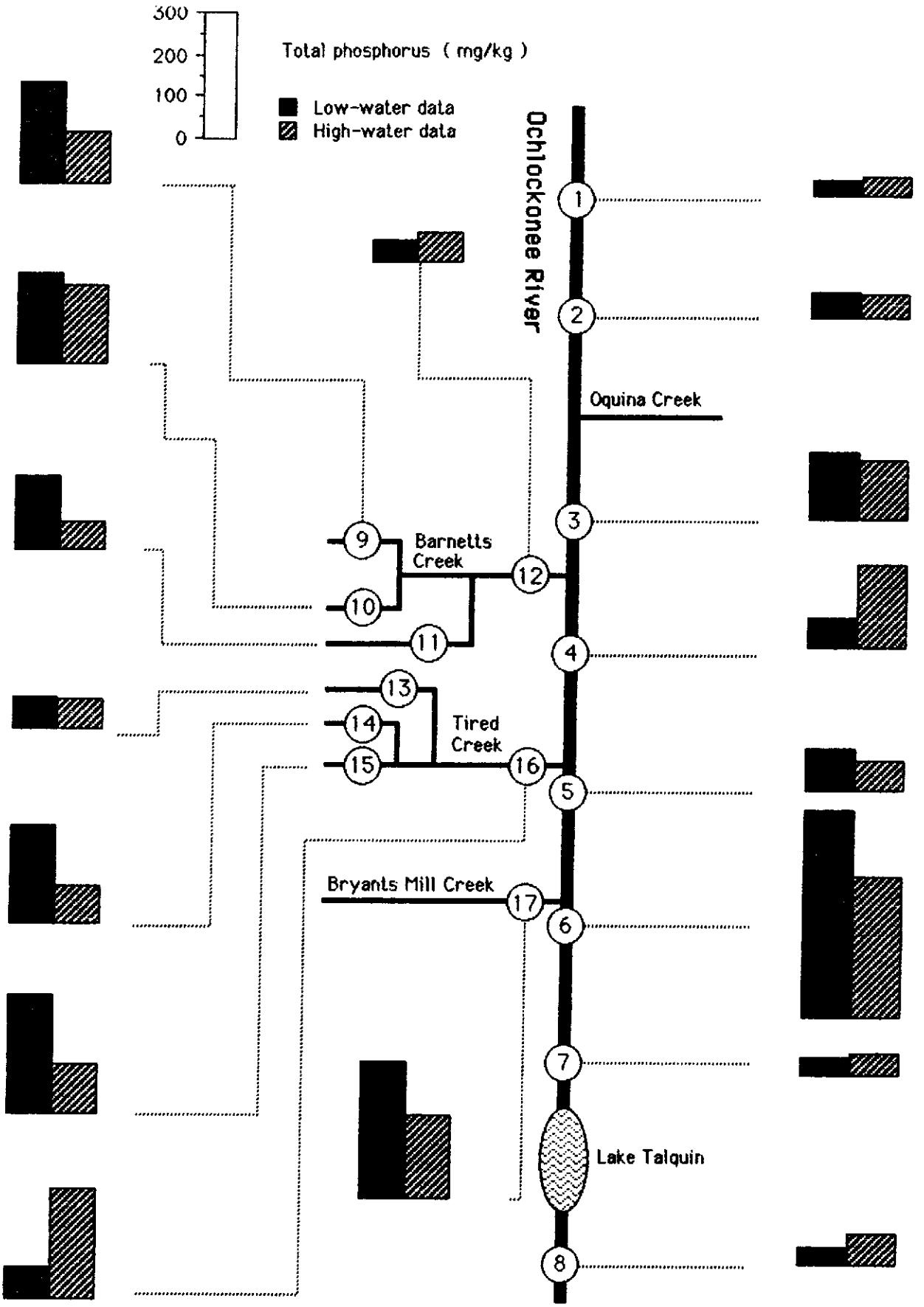


Figure 8.. Mean total sediment phosphorus for all stations.

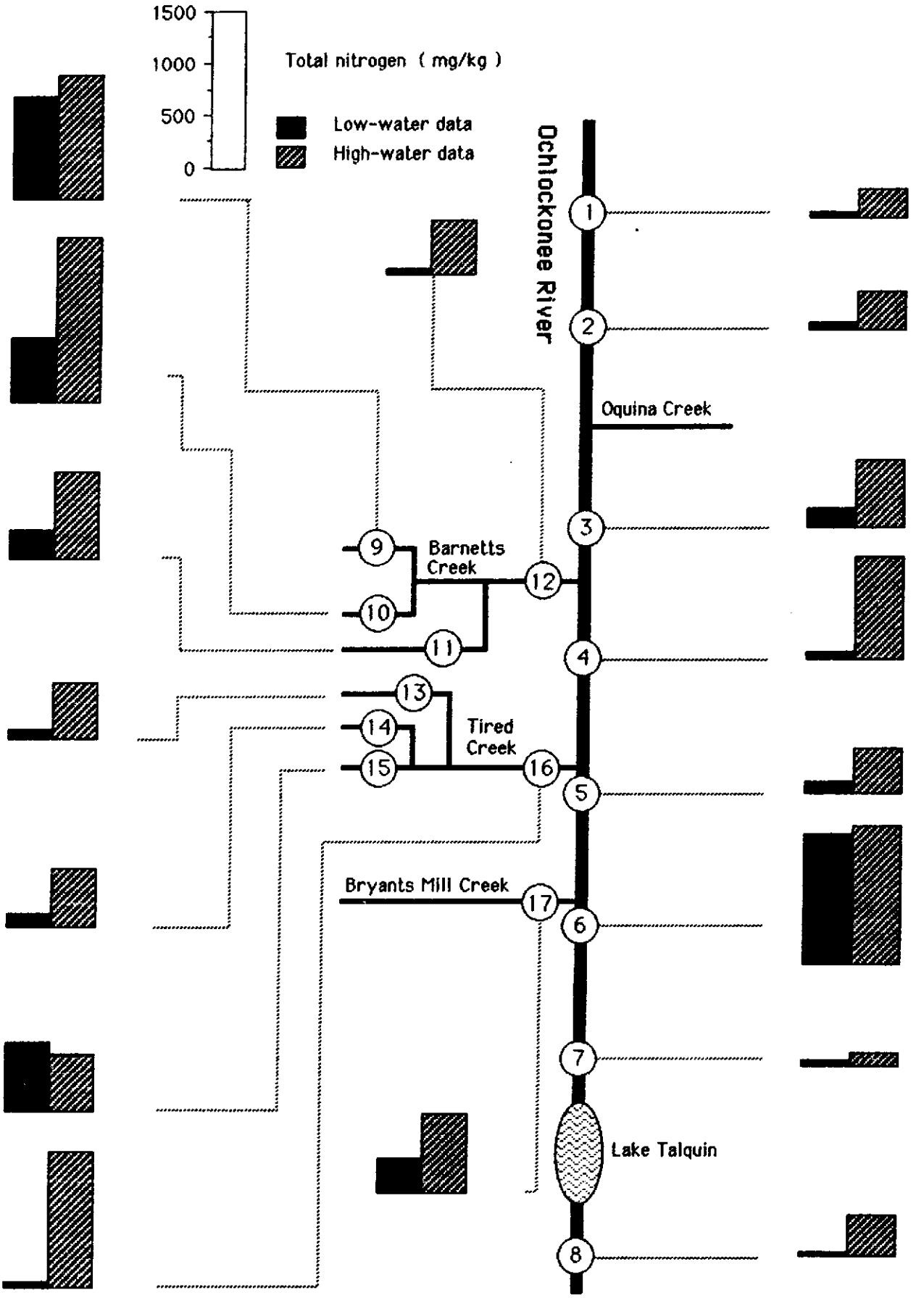


Figure 9.. Mean total sediment nitrogen for all stations.

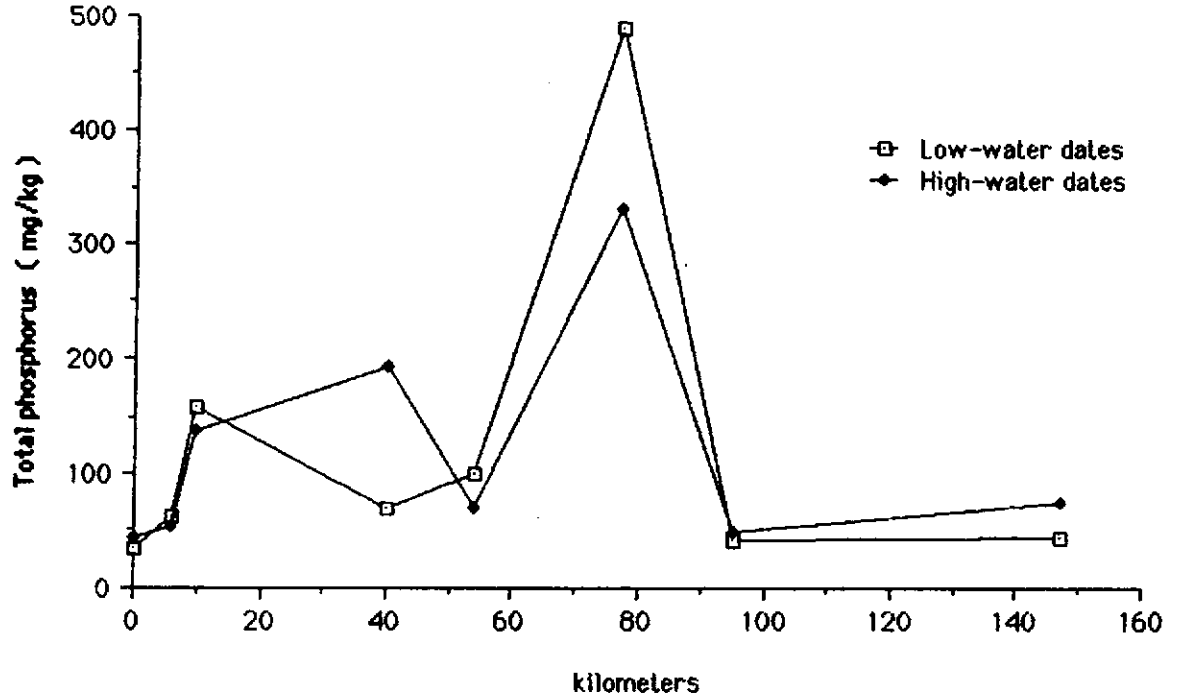


Figure 10. Mean sediment phosphorus content during low and high flow conditions by river kilometer.

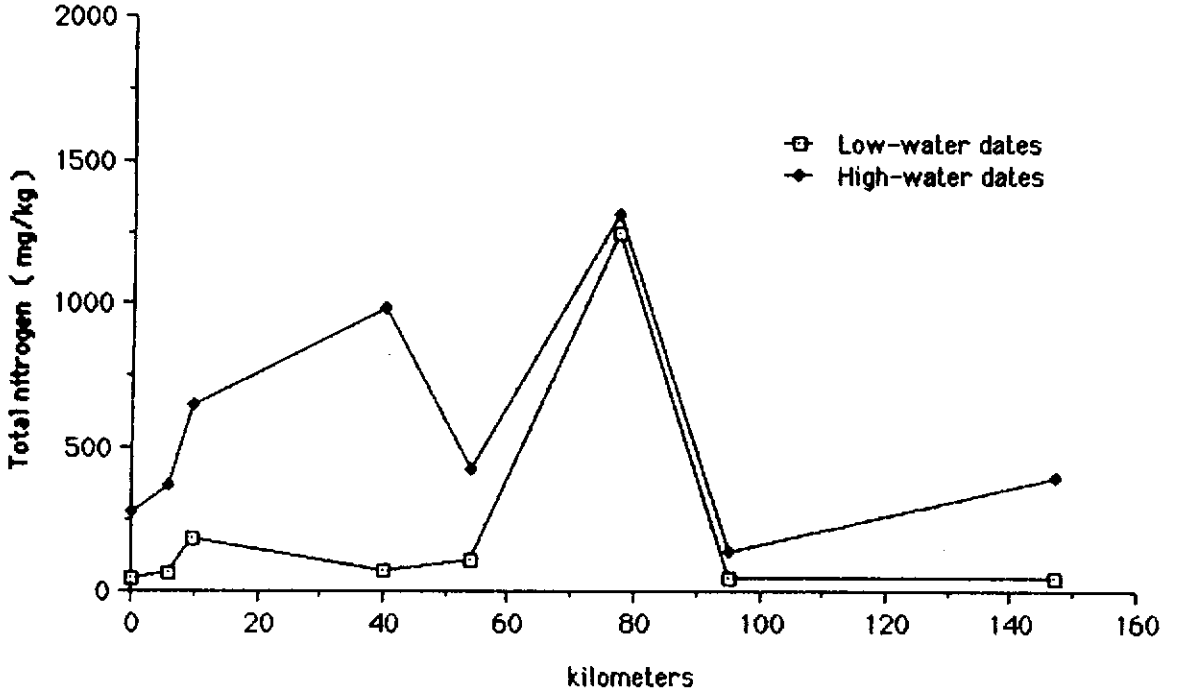


Figure 11. Mean sediment total nitrogen during low and high flow conditions by river kilometer.

phosphorus in the tributaries were found at Stations 16 and 17 during high flow conditions and at Stations 9, 10, 14, 15, and 17 during low flow conditions. Sediment nitrogen levels in the tributary streams were highest during the high flow period, with Stations 9, 10, and 16 exhibiting particularly high levels of sediment nitrogen. During the low flow period, nitrogen levels were highest at Stations 9, 15, and 10. Tributary sediment nutrient concentrations were generally lowest at Stations 11, 12, and 13.

Discussion

Tributary sediment analysis generally reflected land use patterns in proximity to the streams which were sampled. Stations 9 and 10, located in the midst of a mining operation and surrounded by agricultural lands, had elevated sediment nutrient content and a large proportion of silt and clay in the overall grain size distribution. These results reflected the impact of the combination of agriculture and mining, which is most likely responsible for large amounts of fine particulates and a portion of the phosphorus additions.

High sediment nutrient concentrations during high flow at Station 16 were indicative of a wash-out of nutrient-laden sediments from Stations 15, 13, and 14, which receive discharge from the Cairo Water Pollution Control Plant. An abandoned mining area and agricultural run-off contributed to sediment levels found at Station 17. Although no major industry currently operates in the area, erosion has contributed sediment loads similar to those found at Stations 6, 9, and 10. The amount of fine sediments and nutrients was not generally as high at Station 17, but the same trend was present.

River sediment analysis indicated that three of the stations may be suffering from sediment related problems. Station 3, which receives discharge water from the Thomasville Water Pollution Control Plant, reflected high sediment nutrient concentrations and a slight increase in fine particulate material. Slightly elevated sediment nutrient levels were measured at Station 4 during high flow conditions, most likely due to a combination of a wash-out of mining residue and other allocthonous inputs.

The most significant trend observed in the sediment data was that Station 6 consistently had the highest loads of organics, silts, and nutrients. It is noteworthy that turbidity values tended to decrease just beyond this vicinity. This suggests that allochthonous materials (eroded soils) originating farther upstream were transferred from the water column to the sediments in this area, resulting in the deposition of silts/clays, nutrients and organic matter. It is beyond the scope of this report to fully discuss specific mechanisms for this depositional phenomenon. Previous studies have often attributed such siltation effects to human activities (e.g. urbanization, agriculture) (Lenat et al. 1979, Dance and Hynes 1980). This accumulation of fine particulates observed at Station 6 is likely a result of agricultural run-off, and to a lesser extent, mining operations and natural run-off from areas within the flood plain.

in fish (i.e., lack of spawning habitat) and macroinvertebrate populations This accumulation of fine particulates observed at Station 6 is likely a result of agricultural run-off, and to a lesser extent, mining operations and natural run-off from areas within the flood plain.

Eroded soils account for approximately 80% of the national total of phosphorus loading, 73% of nitrogen loading, and 99% of the suspended solids load (Gianessi et al. 1986). Eroded croplands are responsible for approximately one-third of these loading totals. In Southwest Georgia, about 81,000 hectares of wetlands have been converted to other uses since 1953; much of this converted land is used for agricultural purposes and future land use estimates predict an increase in cropland (U.S.D.A 1982). Thus, sediment loading in the Ochlockonee River Basin is likely to increase although it may be difficult to predict where and when the impacts may occur, since the movement of such sediment loads through a watershed is extremely variable in time (Gianessi et al. 1986). Efforts to curb erosion may result in no observed effect until a considerable length of time has passed.

Conclusions

Data pertaining to the analysis of sediment in the Ochlockonee River and its tributaries indicated that sediment organic and nutrient content was elevated at several stations, but most prominently at Station 6. Increased nutrient and organic content was accompanied by a tendency toward the accumulation of fine particulate matter in most cases.

The area in proximity to Station 6 appeared to serve as a depositional zone for nutrient-laden sediments. This siltation is most likely the result of long-term land usage patterns involving the conversion of forest to cropland with a consequent increase of eroded soil entering the river.

PHYSICAL AND CHEMICAL WATER QUALITY

Methods

Sample recovery began 21 October, 1985, and continued every 28 days thereafter. Samples for chemical analysis were collected at both river and tributary stations in polyethylene bottles and transported on ice to the City of Tallahassee Water Quality Laboratory. The analyses performed, as well as the methodology used are listed in Tables 5 and 6. Portions of each sample were filtered to analyze "dissolved" constituents while unfiltered sample water was used to determine "total" constituents. Since this terminology, when associated with Total Kjeldahl Nitrogen results may be confusing, the words "filtered" and "unfiltered" are then used to describe "dissolved" and "total", respectively.

Dissolved oxygen and temperature were measured in situ utilizing a YSI Model 51B oxygen meter. Conductivity, alkalinity, hardness, and pH were determined at the FDER biology laboratory in Tallahassee immediately after returning from the field. A YSI S-C-T meter (Model 33) was used to measure conductivity. Alkalinity and hardness were calculated by Hach titrimetric methods. A Corning® pH meter (Model 10) was utilized for pH determinations.

In addition to the collection of samples for monthly turbidity analysis, daily samples for turbidity analysis were collected at Station 6 by Col. Nick Lester. Turbidity analyses were performed using a Hach Ratio Turbidimeter that provides turbidity readings in Nephalometric Turbidity Units (N.T.U.'s). Additionally, provisional daily discharge records of the Ochlockonee River at the U.S. Highway 27 bridge were made available to us by the U.S. Geological Survey. The U.S.G.S. gauging station is located approximately 13 km downstream from our Station 6. Therefore, daily measurements at these two places can be considered reasonably simultaneous for the purposes of this study. Other historic hydrologic data were also provided by U.S.G.S.

Rainfall data were supplied by Mr. Mike Rucker of WCTV Television. These data were collected at the WCTV station located on Florida Highway 12 near the Georgia-Florida border, approximately 8 km from the U.S.G.S. gauging station. Since no rainfall data were available for the Georgia portion of the Ochlockonee Basin, the data from WCTV were considered representative of significant rainfall events (i.e. > 0.5 in.) within the basin.

Results

The hydrologic conditions which occurred since 1980, including the study period, are presented in Figure 11A.

TABLE 5. Water chemistry parameters and methods (FDER Biology Laboratory).

PARAMETER	METHOD	UNITS	REFERENCE
pH	Electrometric	SU	U.S EPA 1979
Hardness	Titrimetric	mg/l	HACH Methods Man. 7th Ed.
Alkalinity	Titrimetric	mg/l $CaCo_3$	HACH Methods Man. 7th Ed.
Conductivity	YSI SCT Probe	umhos/cm^2	APHA 1985
Temperature	YSI Thermistor	°C	APHA 1985
Dissolved oxygen	YSI membrane electrode	mg/l	APHA 1985
Turbidity	HACH Model 1890 Ratio Turbidimeter	NTU	APHA 1985

TABLE 6. Water chemistry parameters and methods (Tallahassee Water Quality Laboratory).

PARAMETER	METHOD	UNITS	REFERENCE
Total & dissolved phosphate	Colorimetric Automated block digesteor	mg/l	U.S. EPA 1979
Ammonia	Colorimetric Automated Phenate	mg/l	U.S. EPA 1979
Nitrite-nitrate nitrogen	Colorimetric Cadmium reduction	mg/l	U.S. EPA 1979
Total Kjeldahl nitrogen	Colorimetric Semi-automate block digestor	mg/l	U.S. EPA 1979
Non-Filterable Residue	Total suspended matter, dried	mg/l	APHA et al. 1985
Total Residue	Total suspended matter, dried	mg/l	APHA et al. 1985

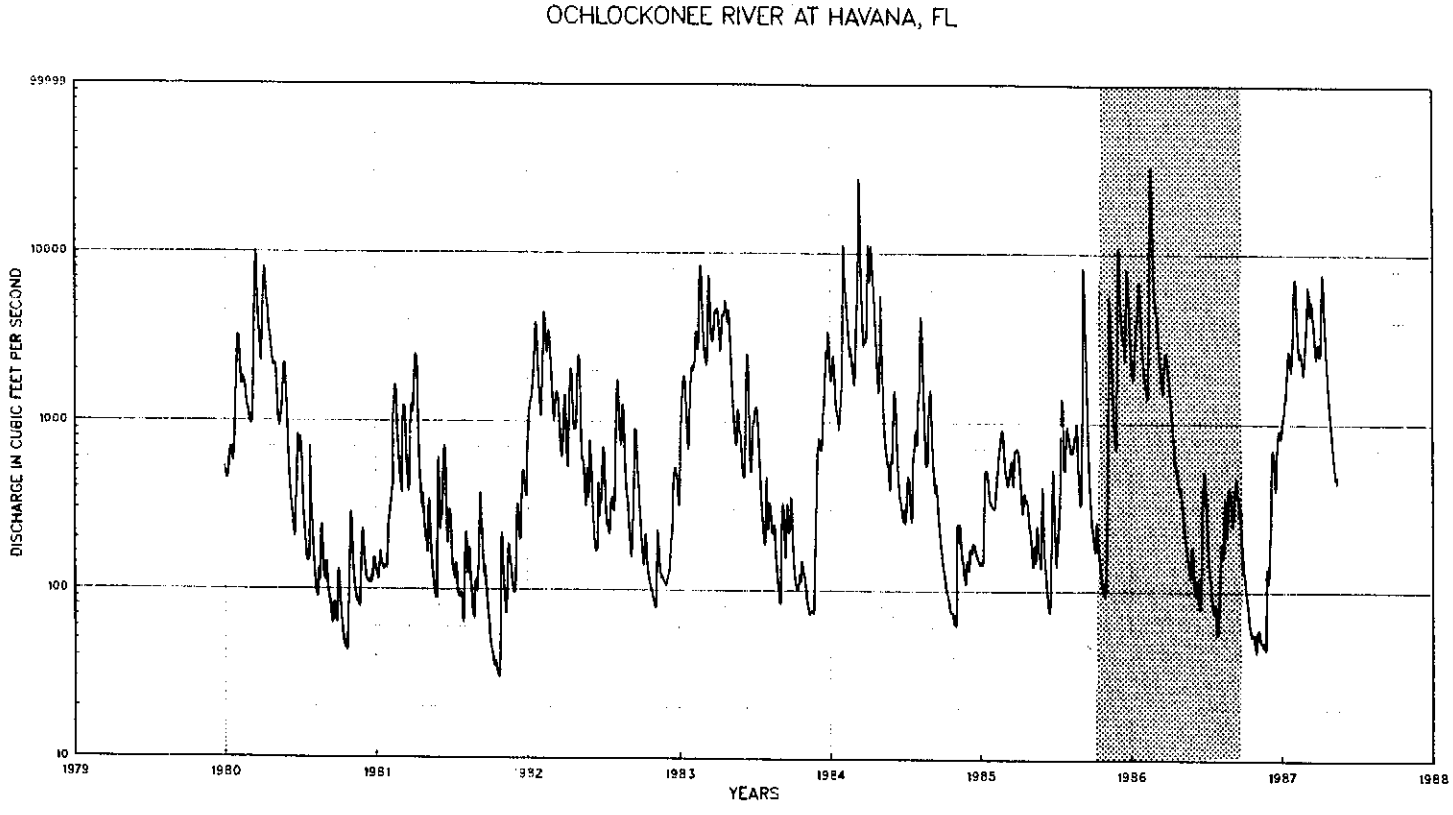


Figure 11A. Hydrograph for the Ochlockonee River at U.S. Highway 27 showing discharge since 1980. Shaded area represents study period. Graph provided by U.S.G.S.

pH

River pH values ranged from 4.8 to 7.0 during the 13 month study. Mean pH values for the eight river stations (Figure 12) showed a slight tendency to increase downstream between Station 1 (5.9) and Station 6 (6.3), while samples from Stations 7 and 8 reflected mean pH values slightly lower than those recorded at Station 6, (6.1 and 6.2, respectively).

Tributary pH values ranged from 4.6 to 7.1, with the highest mean pH value (6.4) recorded at Station 14 and the lowest (5.8) at Station 12 (Table 7).

Alkalinity

Alkalinity values in the river ranged from 0 to 60 mg/l $CaCO_3$, while tributary alkalinity ranged from 0 to 111 mg/l $CaCO_3$. Mean river alkalinity values ranged from 12.0 to 22.3 mg/l $CaCO_3$ (Figure 13). The highest mean value was recorded at Station 6 and the lowest at Station 8.

Mean tributary alkalinity ranged from 12.2 to 64.6 mg/l $CaCO_3$. The highest mean alkalinities measured were noted at Station 17 (34.1 mg/l), and Station 14 (64.6 mg/l) (Table 7).

Conductivity

Conductivity in both the river and the tributary streams was lowest during the winter months. This was probably due to the high amount of rainfall and the subsequent periods of flooding which occurred in the winter. Relatively dry conditions in spring and summer resulted in an increase in conductivity.

River conductivity ranged from 11 to 550 umhos/cm^2, with the highest mean values observed at Stations 5 (125 umhos/cm^2) and 6 (132 umhos/cm^2) and the lowest mean conductivities observed at Stations 2 (65.8 umhos/cm^2) and 8 (67.0 umhos/cm^2) (Figure 14). Although the highest mean conductivity occurred at Station 6, an anomalously high value of 550 umhos/cm was observed at Station 1, where relatively low conductivity levels were previously noted.

Conductivity values for all tributary stations ranged from 20 to 3900 umhos/cm^2. Several streams exhibited elevated mean conductivities, including Station 13 (1252 umhos/cm^2), Station 14 (290 umhos/cm^2), and Station 16 (184 umhos/cm^2), which are all located near Cairo, Georgia (Figure 15, Table 7). The lowest mean conductivity values were noted at Stations 11 and 12.

Hardness

River hardness values ranged from 3 to 70 mg/l. Mean river hardness ranged from 18 to 31.9 mg/l (Figure 16). Water samples from Stations 5, 6, and 7 exhibited slightly higher mean hardness than the upstream

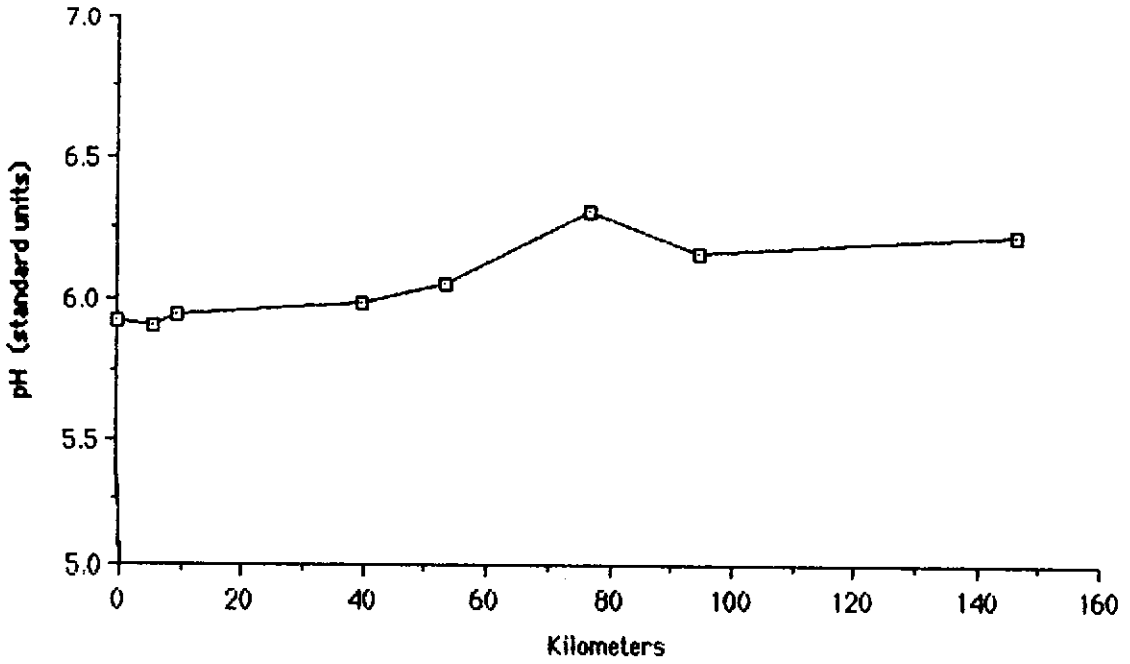


Figure 12. Mean pH by river kilometer.

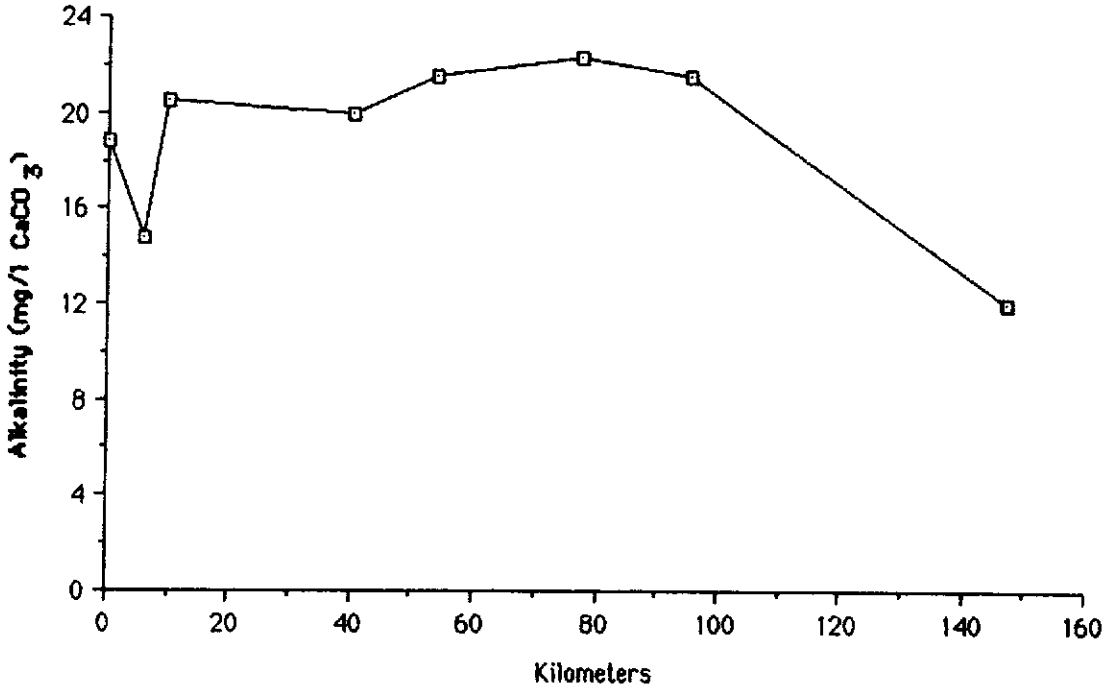


Figure 13. Mean alkalinity by river kilometer.

TABLE 7. Mean values for selected tributary station water chemistry parameters. Standard deviations are in parentheses.

Station	Conductivity (umhos/cm^2)	Alkalinity (mg/l $CaCO_3$)	Hardness (mg/l $CaCO_3$)	pH (s.u.)
9	71.1 (49.4)	14.2 (8.9)	20.7 (9.8)	6.0 (.58)
10	46.8 (12.2)	16.6 (8.1)	17.9 (7.4)	6.0 (.50)
11	37.6 (8.9)	13.7 (6.4)	10.6 (6.2)	5.9 (.55)
12	37.6 (9.7)	12.2 (6.7)	15.3 (6.6)	5.8 (.45)
13	1252.9 (1061)	28.5 (20.0)	48.6 (30)	6.1 (.37)
14	290 (128)	64.6 (36.6)	109.0 (50.2)	6.4 (.32)
15	88.3 (75.2)	19.6 (10.7)	26.8 (12.1)	6.3 (.49)
16	183.7 (89.3)	23.8 (14.7)	41.0 (21.9)	6.2 (.45)
17	104.9 (95.2)	34.1 (18.2)	38.5 (16.9)	6.3 (.42)

Station	Turbidity (NTU)	Total Suspended Solids (mg/l)	Dissolved Oxygen (mg/l)	Temperature (°C)
9	39.8 (26.9)	14.6 (11.5)	6.0 (2.7)	17.2 (6.4)
10	27.0 (28.5)	10.3 (6.6)	5.9 (2.5)	17.1 (6.1)
11	24.2 (18.2)	8.7 (6.0)	6.8 (2.0)	16.9 (5.9)
12	19.8 (11.6)	7.7 (5.1)	7.3 (1.9)	17.4 (5.9)
13	16.1 (17.7)	7.6 (2.9)	5.7 (2.3)	17.3 (5.9)
14	18.3 (25.8)	12.4 (6.6)	6.6 (2.1)	17.3 (5.6)
15	28.6 (15.6)	13.3 (8.6)	7.7 (1.5)	16.9 (6.1)
16	28.9 (36.7)	7.6 (3.7)	7.6 (1.6)	17.4 (5.8)
17	32.0 (44.4)	24.9 (53.9)	8.3 (1.4)	16.7 (5.5)

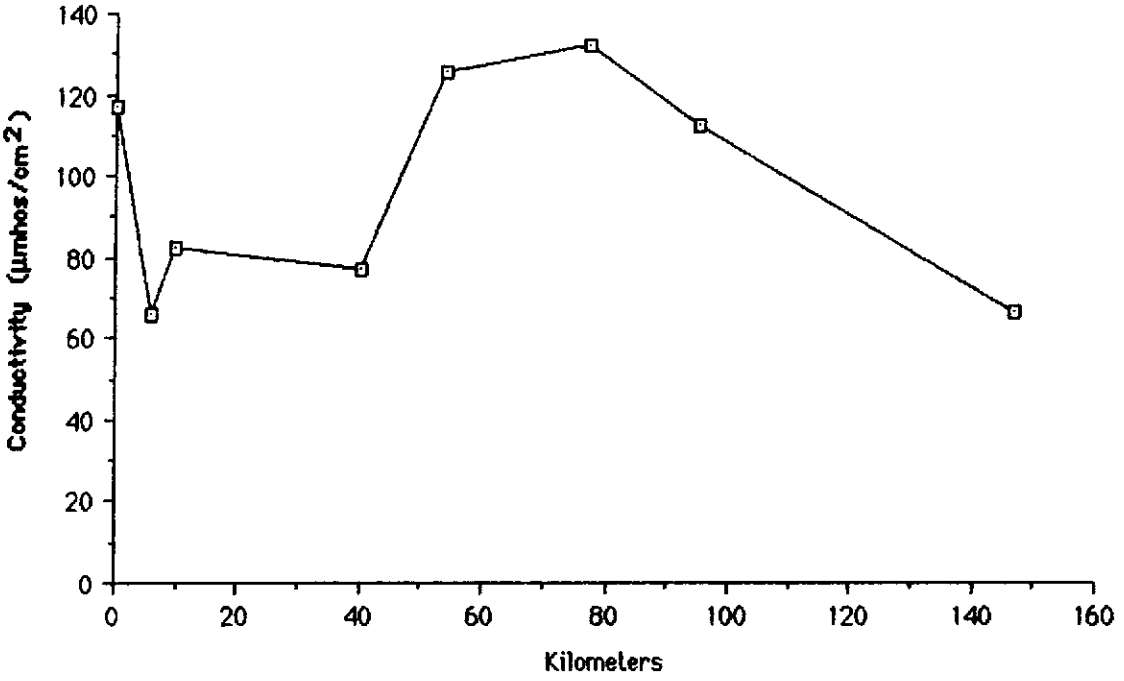


Figure 14. Mean conductivity by river kilometer.

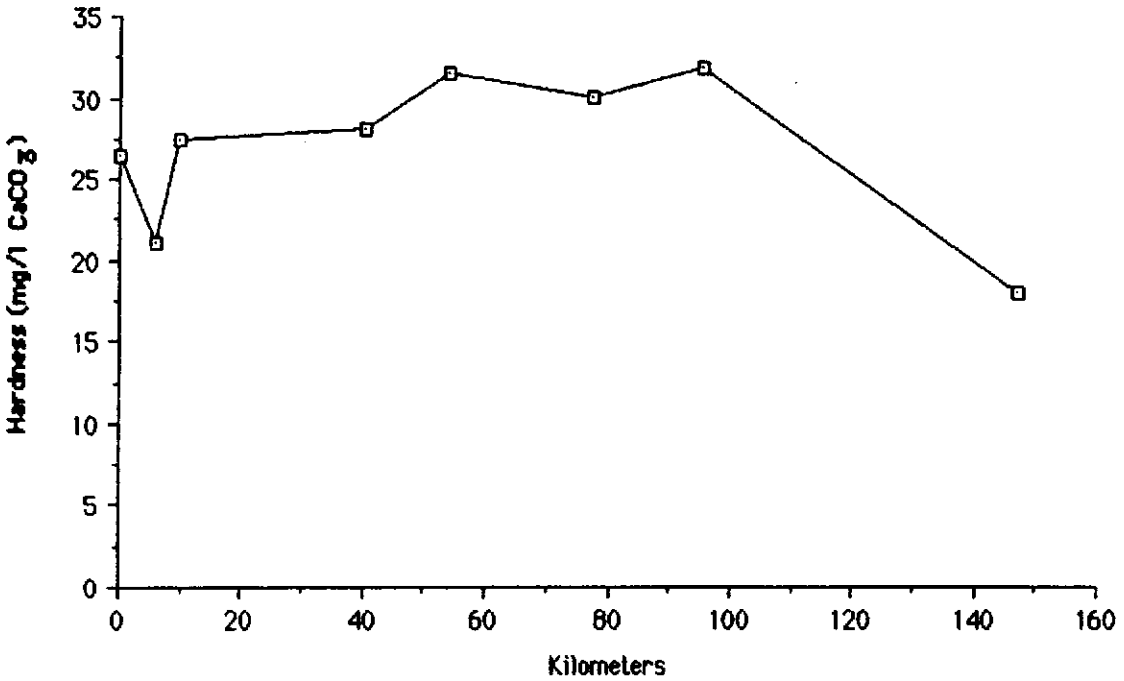


Figure 16. Mean hardness by river kilometer.

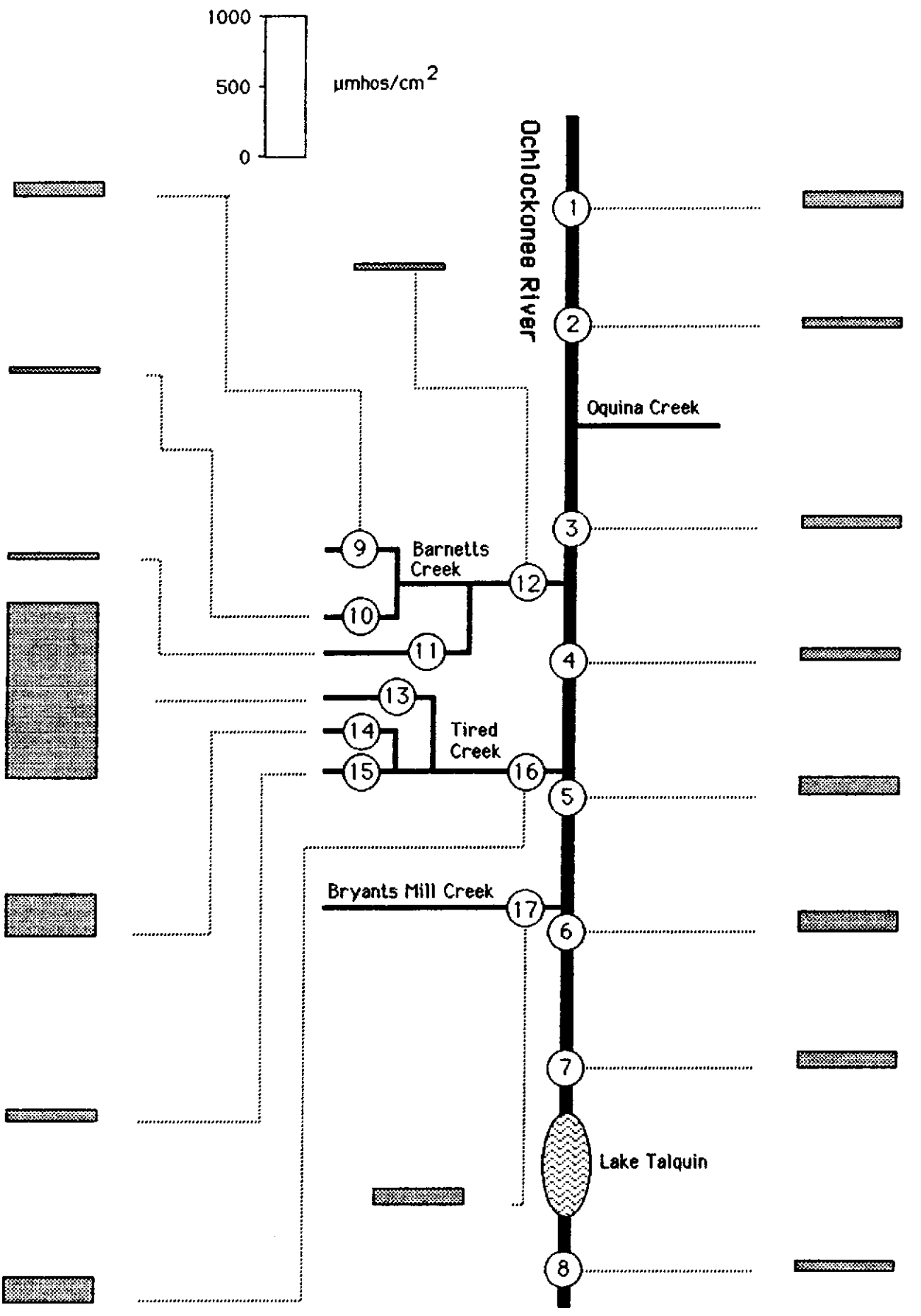


Figure 15. Mean conductivity.

stations (1, 2, 3, and 4), while mean hardness at Station 8, downstream of Lake Talquin, was considerably reduced when compared to other river stations.

Tributary hardness values ranged from 4 to 200 mg/l with the majority of variation observed at Stations 13 and 14. Mean hardness at Stations 13 and 14 was 48.6 mg/l and 109 mg/l, respectively. Mean hardness at the other tributary stations varied from 15.3 mg/l at Station 12 to 41 mg/l at Station 16 (Table 7).

Turbidity

Turbidity in the river (as measured during our monthly field trips) ranged from 2.5 to 61 NTU, while tributary turbidities varied from 4.4 to 185 NTU. Mean turbidity in the river increased from 11 NTU at Station 1 to 21.3 NTU at Station 4 and then declined slightly at Stations 5, 6, and 7 followed by a sharp reduction, to 8.1 NTU, at Station 8 (Figure 17).

Tributary stream turbidities varied greatly over the study period (Figure 18) and mean values were highest at Stations 9 (39.8 NTU) and 17 (32.0 NTU). Mean turbidities at Stations 13 and 14 were the lowest of all the tributary stations (Table 7).

During our study there were five major rainfall events, all of which occurred during the Fall and Winter of 1985-86, and nearly all of which resulted in flooding conditions as well as peak turbidities. From Spring to Fall 1986, however, moderate to low flow conditions prevailed in the Ochlockonee River. These conditions coincided with the minimum flow and turbidity measurements recorded during the study. Occasional peaks in turbidity that did not appear to be associated with rainfall were also noted throughout the study period (e.g. Figure 19 A, B, F, G, and H).

Total Suspended Solids

Total Suspended Solids (TSS) were generally higher during low flow conditions than during periods of flooding. Mean TSS during the high flow period peaked at Stations 6 and 7, while the highest TSS values were observed at Station 3 during low flow conditions.

Total suspended solids during the study (Figure 20) were highest at Station 6 ($\bar{x}$ = 8.4 mg/l) and lowest at Station 1 ($\bar{x}$ = 4.1 mg/l).

Mean tributary TSS was highest at Station 17 ($\bar{x}$ = 24.9 mg/l) followed by Station 9 ($\bar{x}$ = 14.6 mg/l), while the lowest mean TSS value was noted at Station 16 (Table 7, Figure 21).

Temperature

Mean temperature in the river steadily increased from 17.4°C at Station 1 to 20.2°C at Station 8 (Figure 22). Mean temperatures in the tributary streams varied very little from stream to stream, ranging from

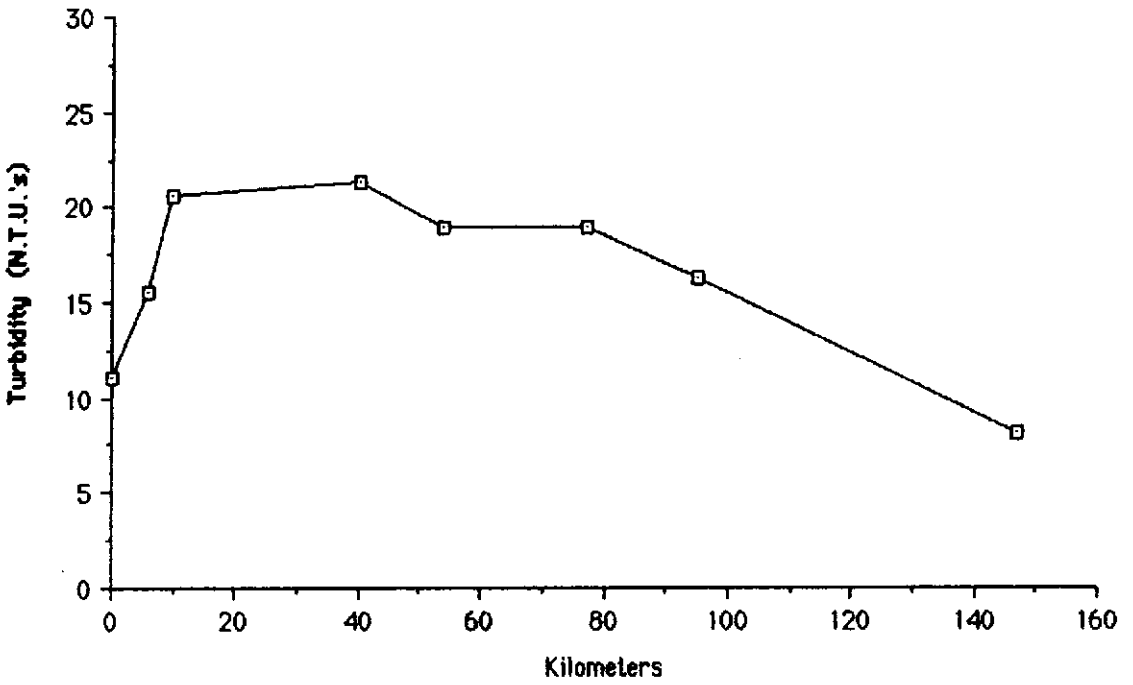


Figure 17. Mean turbidity by river kilometer.

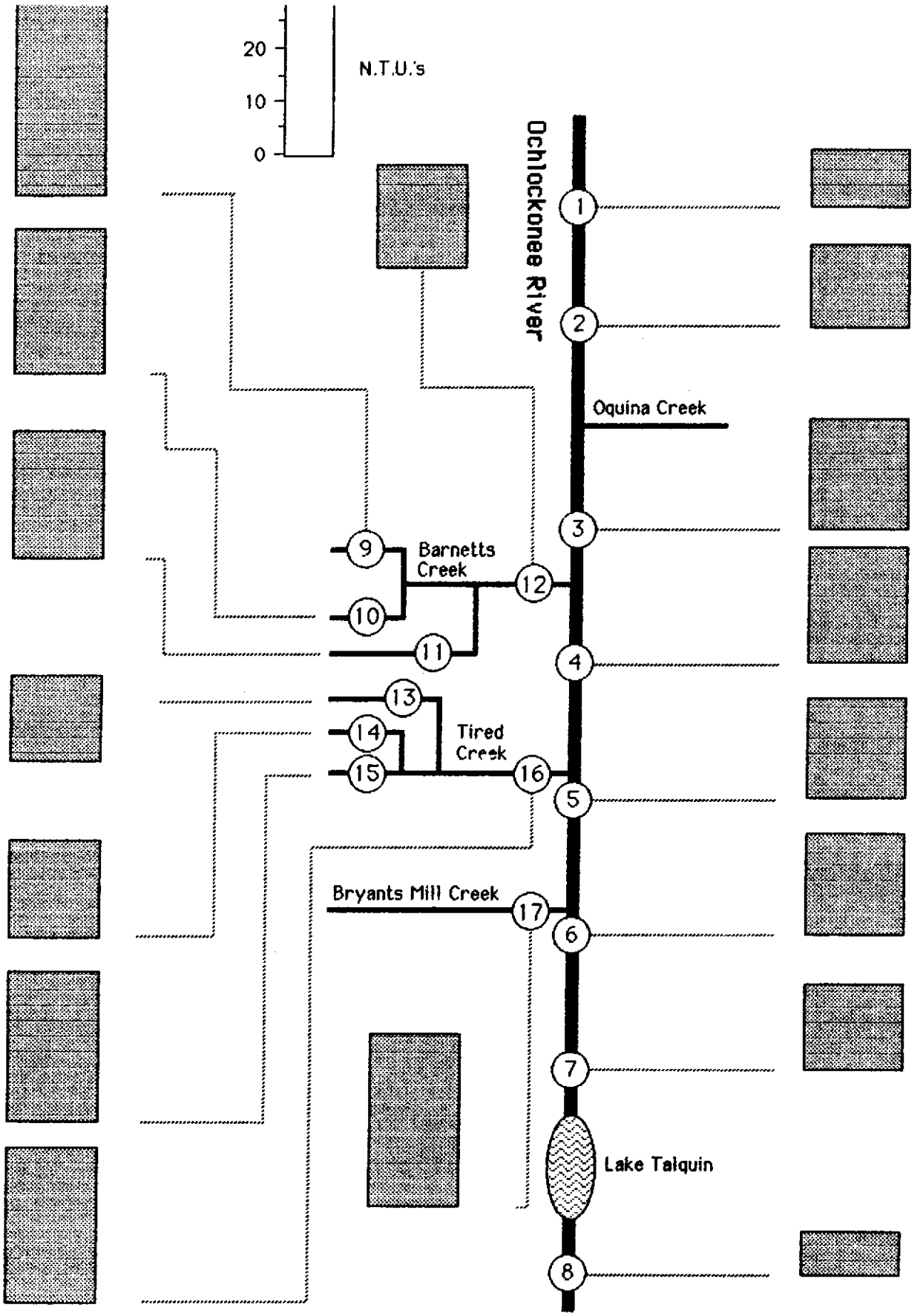


Figure 18. Mean turbidity.

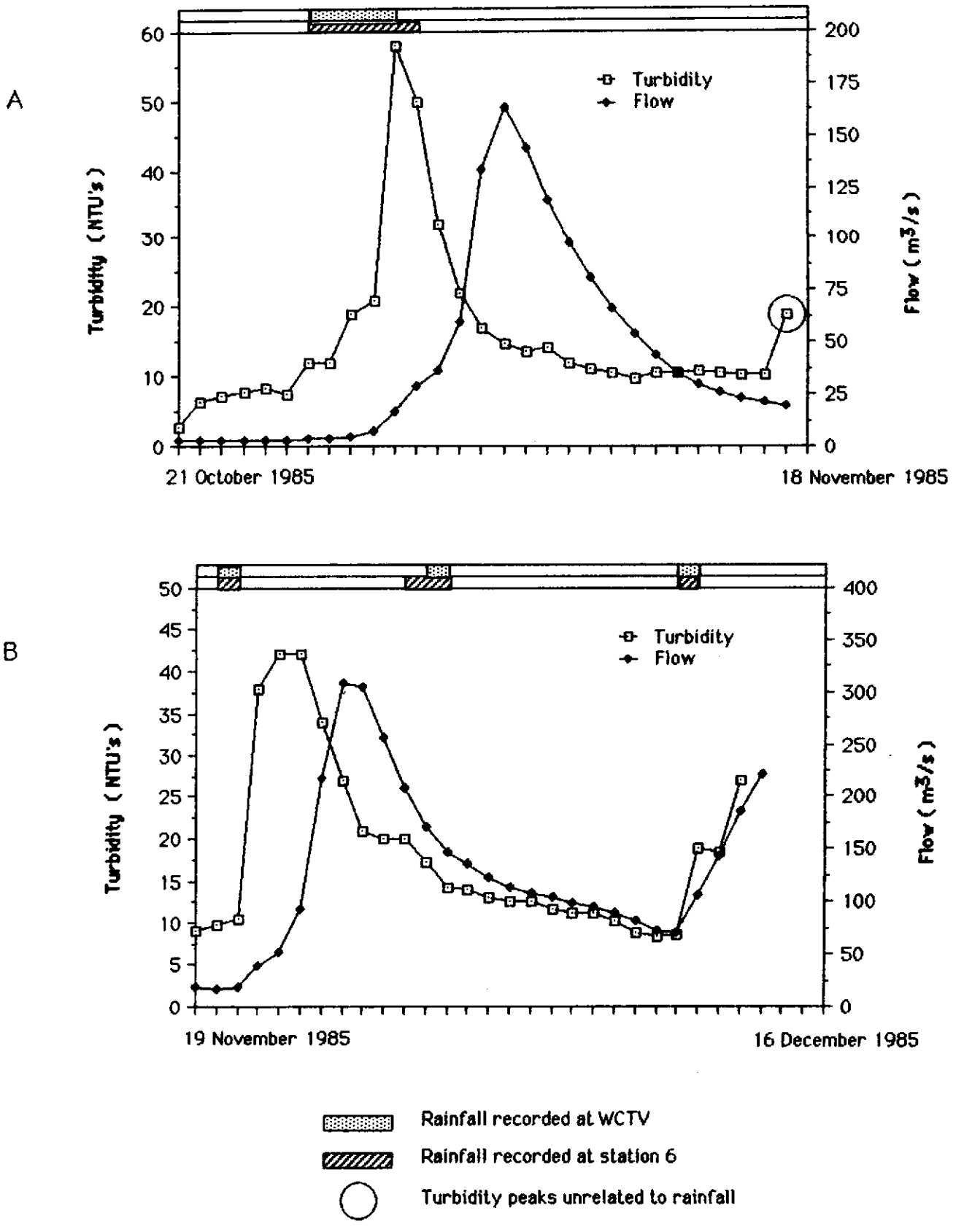
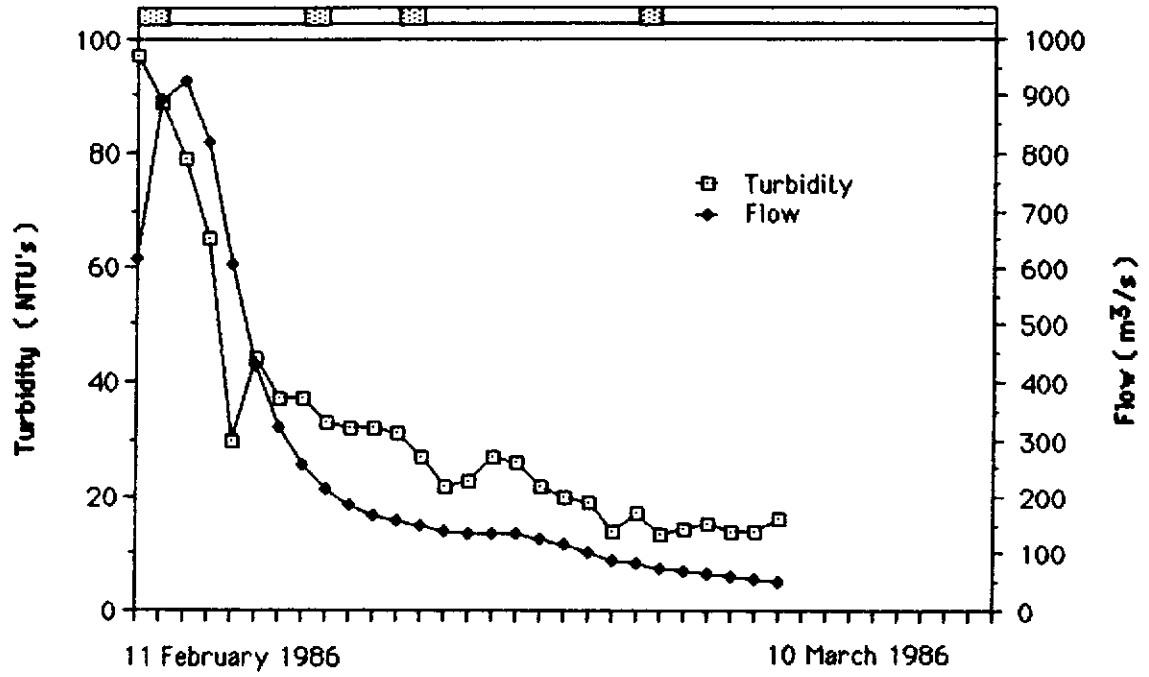
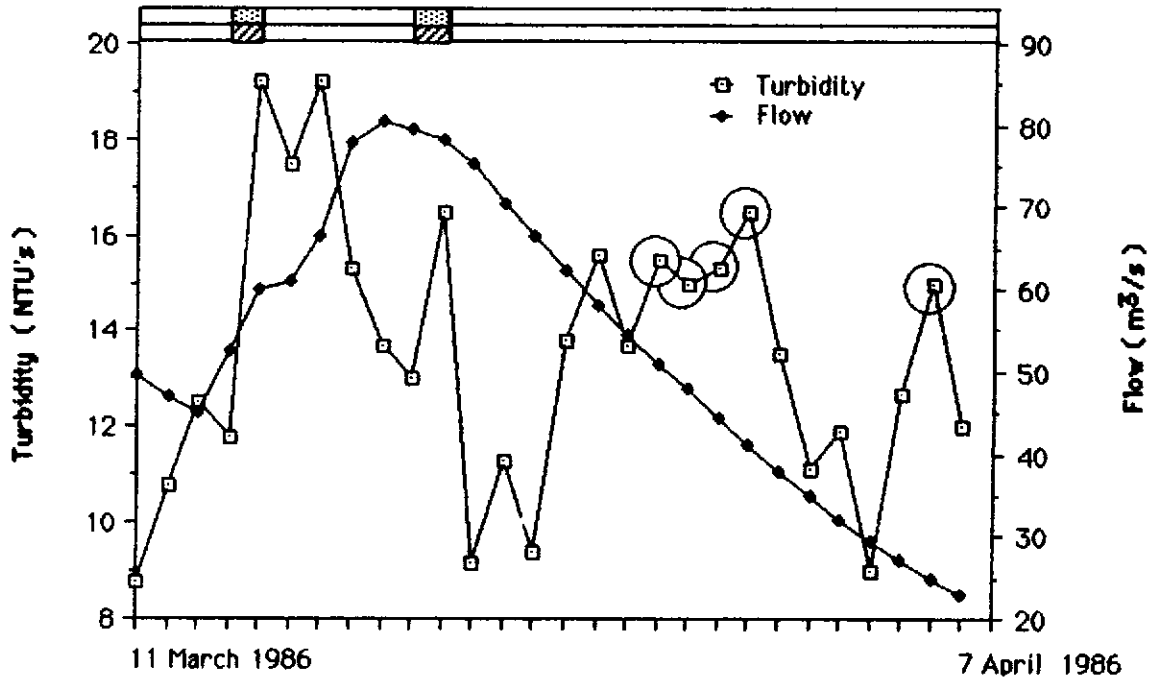


Figure 19. Daily flow and turbidity at station 6 .

E



F



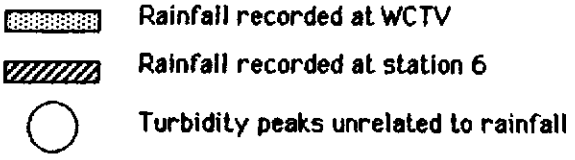
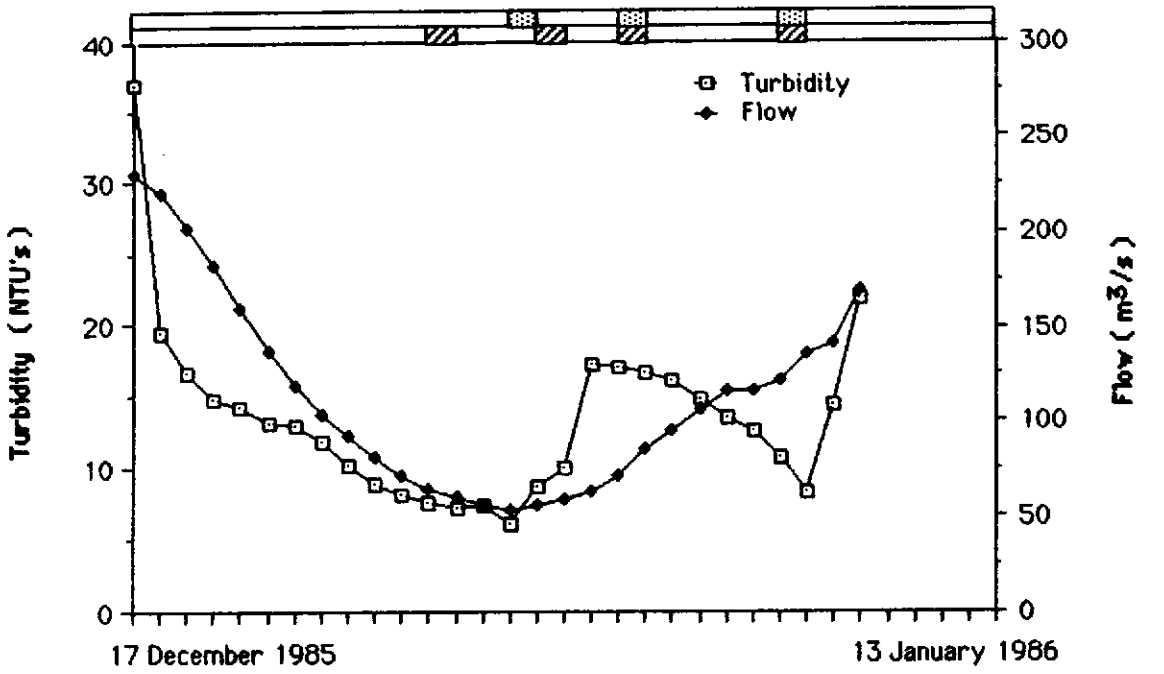
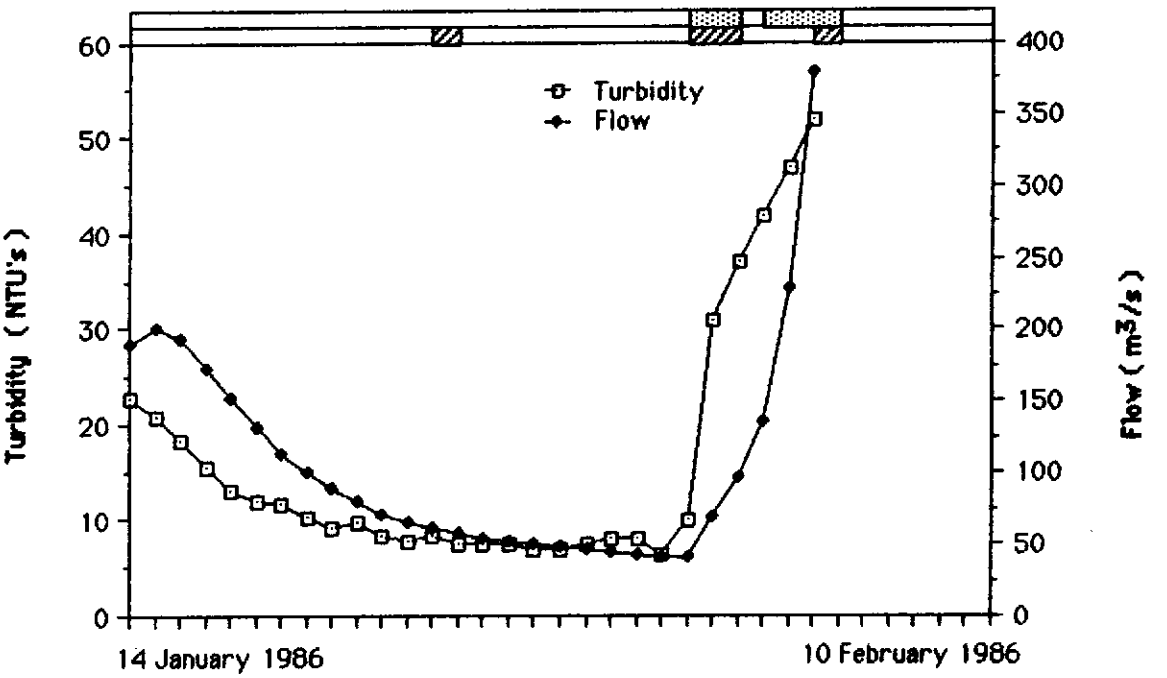


Figure 19. Continued.

C



D



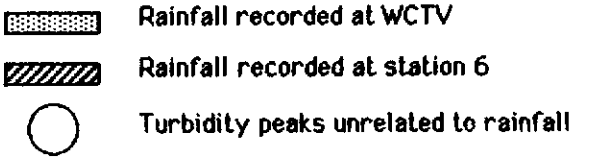


Figure 19. Continued.

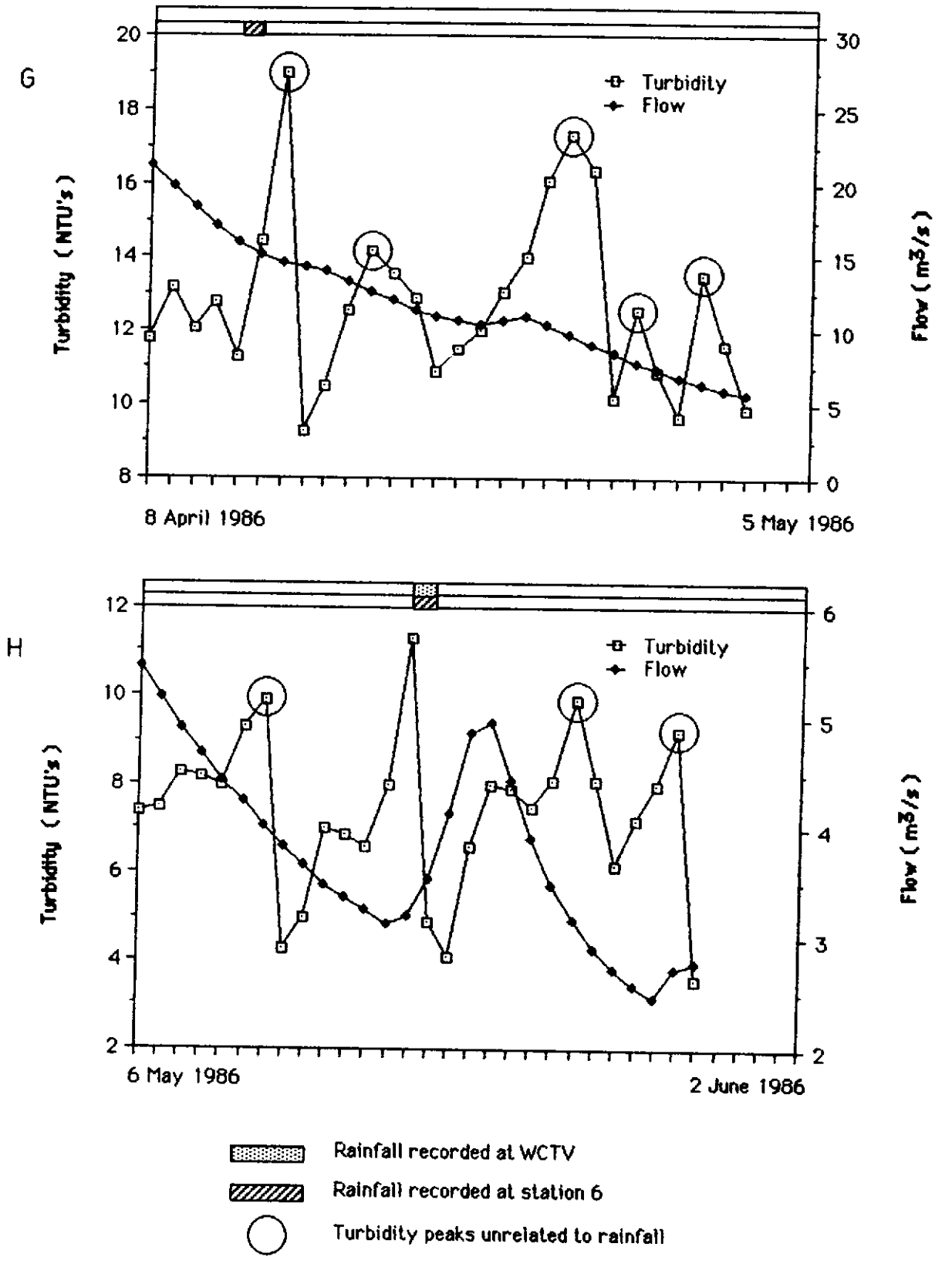


Figure 19. Continued.

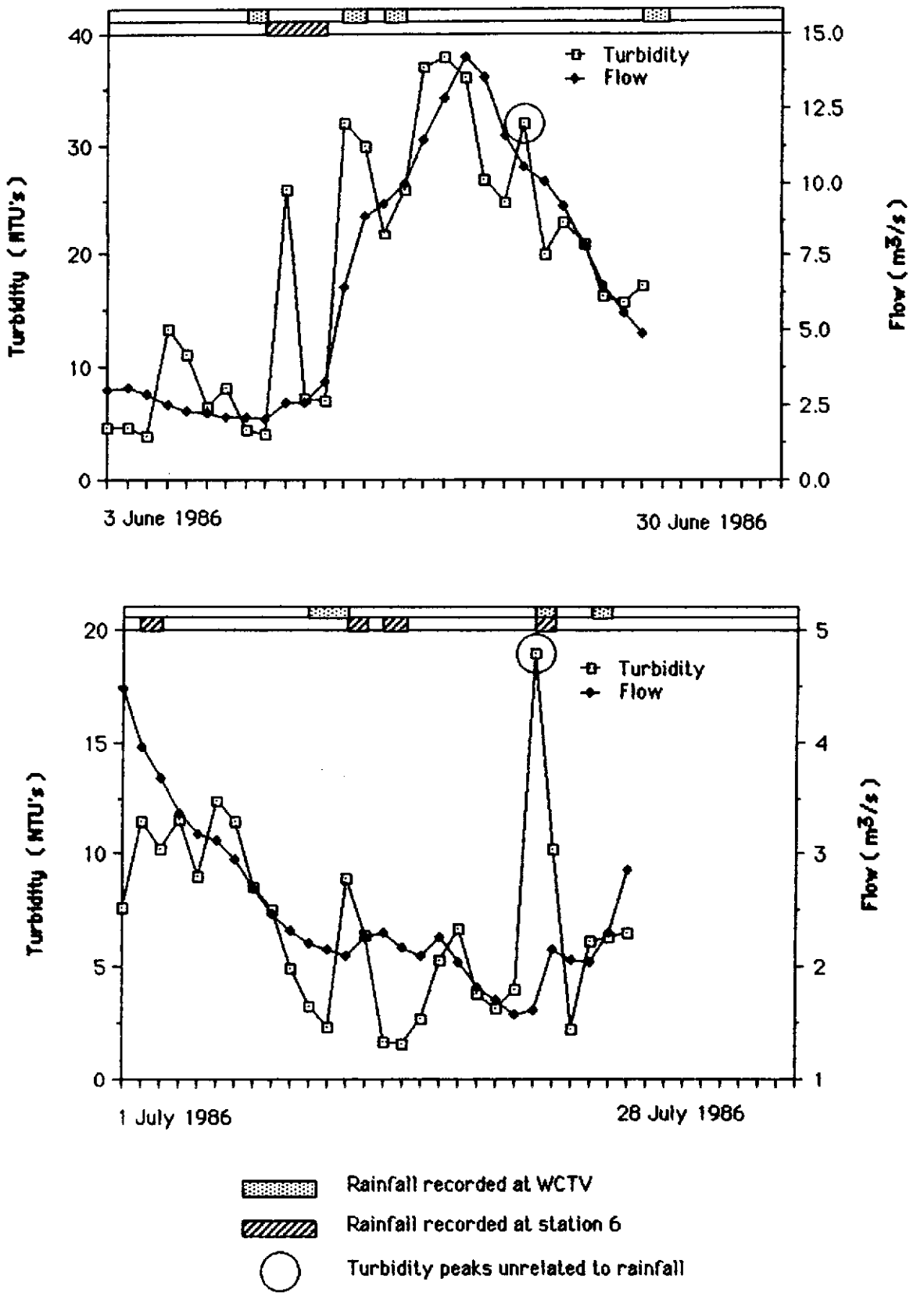
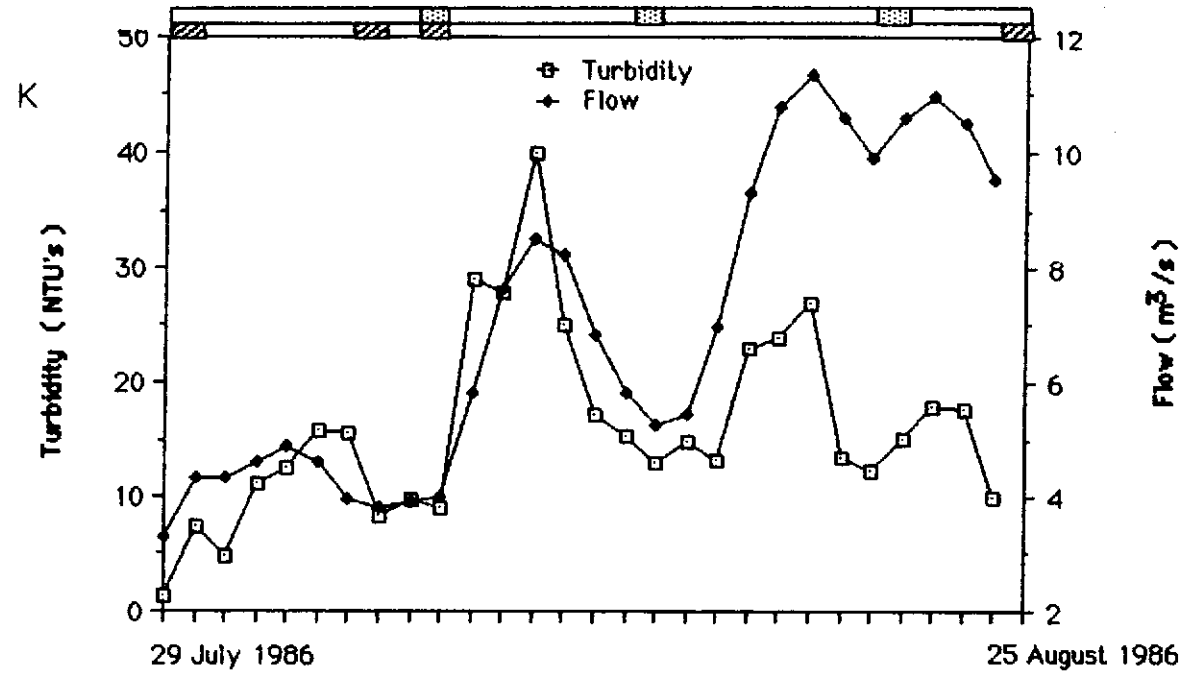
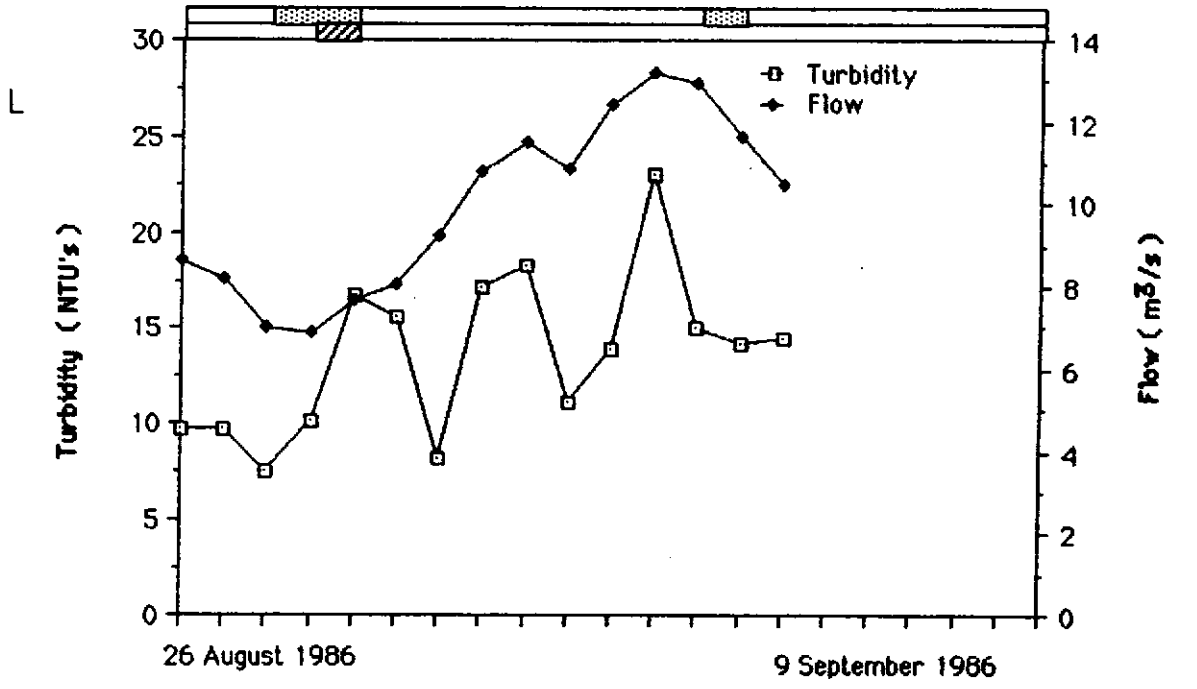


Figure 19. Continued.





Rainfall recorded at WCTV

Rainfall recorded at station 6

Turbidity peaks unrelated to rainfall

Figure 19. Continued.

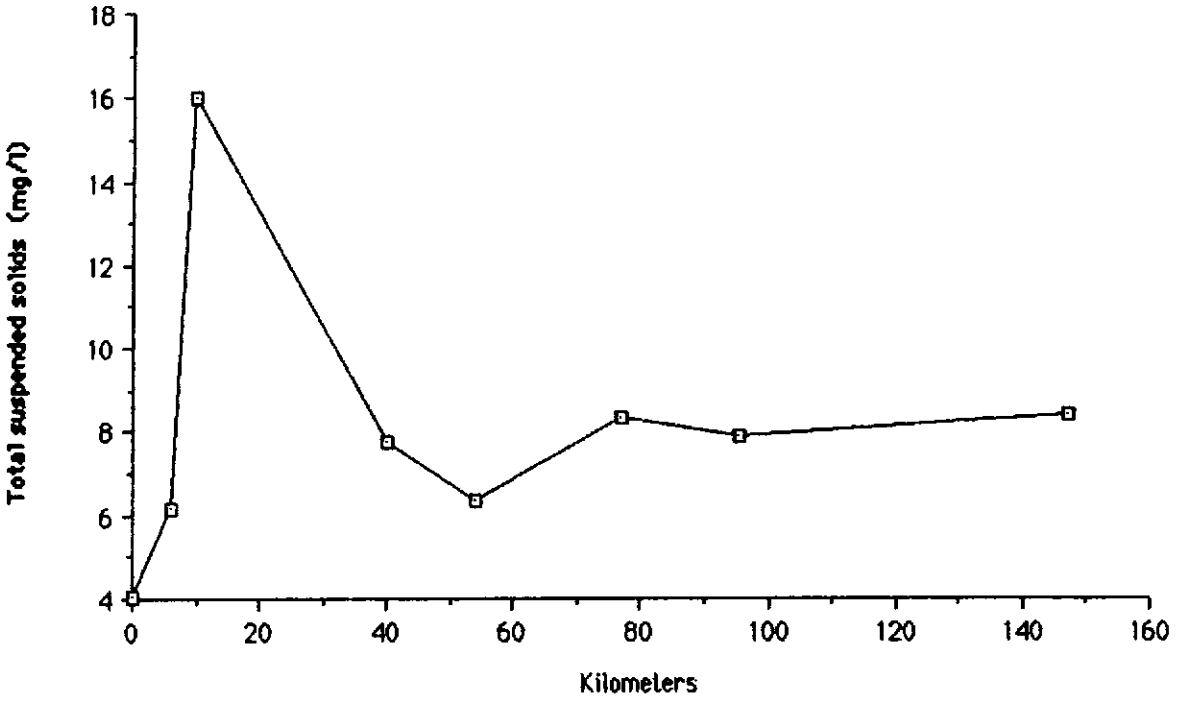


Figure 20. Mean total suspended solids by river kilometer.

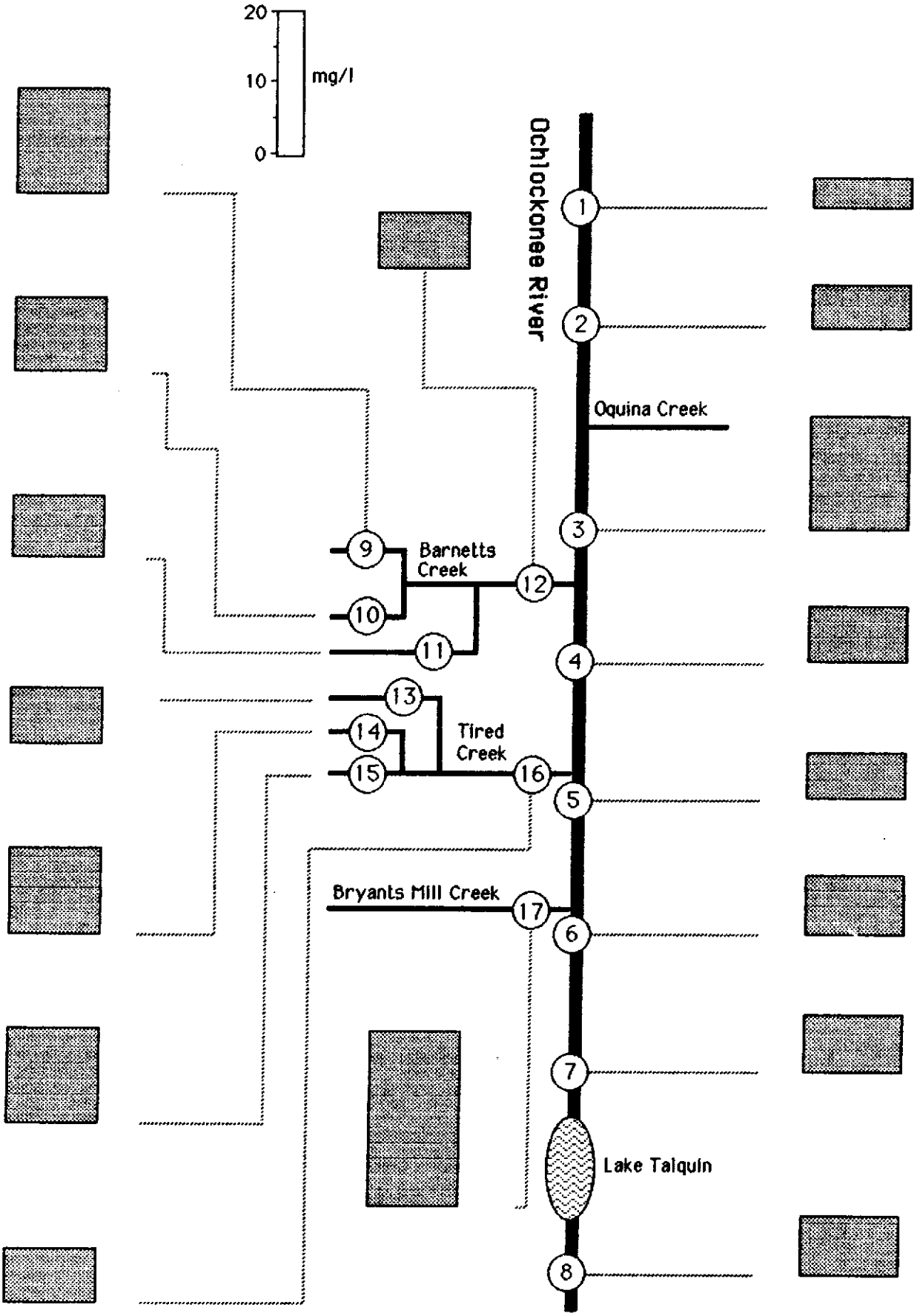


Figure 21. Mean total suspended solids.

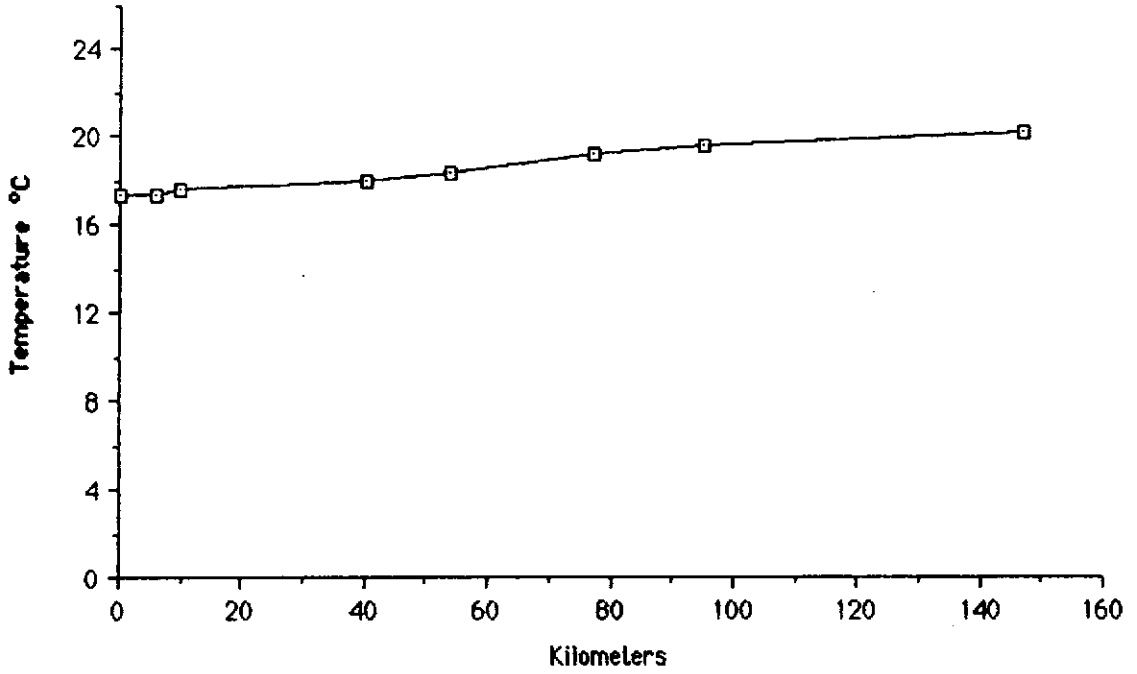


Figure 22. Mean temperature by river kilometer.

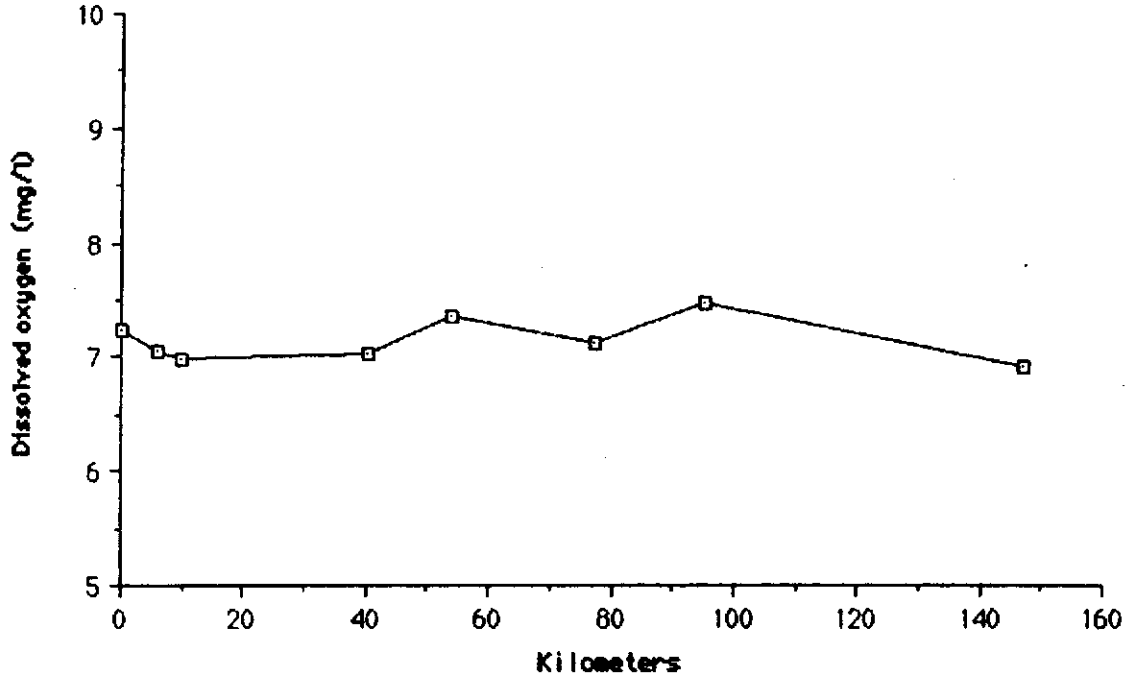


Figure 23. Mean dissolved oxygen by river kilometer.

16.7°C to 17.4°C (Table 7). River and tributary temperatures generally followed seasonal weather conditions.

Dissolved Oxygen

Dissolved oxygen (D.O.) in the river ranged from a minimum of 4.5 mg/l at Stations 2 and 3 in July and June, respectively, to a maximum of 11.0 mg/l at Station 1 in December. Mean dissolved oxygen in the river varied slightly from 6.9 mg/l to 7.5 mg/l, with the highest mean D.O. values observed at Station 7 and the lowest mean D.O. at Station 8 (Figure 23). During high flow conditions, mean dissolved oxygen reached a maximum at Station 3 and a minimum at Station 6. During low flow conditions dissolved oxygen reached a maximum at Station 7 and a minimum at Station 3 (Table 8).

Dissolved oxygen in the tributaries ranged from a minimum of 2.4 mg/l at Station 13 in June to a maximum of 11.1 mg/l at Station 9 in December. Mean dissolved oxygen at these stations varied from 5.7 to 8.3 mg/l (Table 7). The highest mean D.O. was observed at Station 17 and the lowest mean D.O. was noted at Station 13.

Phosphorus

Mean total phosphorus concentrations in the river were most varied during the summer months, ranging from .06 to .84 mg/l, and varied least during the winter months, ranging from .10 to .13 mg/l. Similarly, mean total phosphorus was highest while low flow conditions prevailed and lower during high flow conditions, ranging from .05 to .70 mg/l and from .10 to .26 mg/l, respectively.

Mean total phosphorus concentrations increased between Stations 1 and 3, where it peaked at .42 mg/l, and then declined slowly between Stations 4 and 8, where mean total phosphorus concentrations were the lowest (.10 mg/l) (Figure 24). Mean dissolved phosphorus followed the same trend, peaking at .34 mg/l at Station 3 (Figure 25).

Phosphorus concentrations in the tributary streams were generally low, with the exception of four locations: Stations 14, 13, 17, and 16. Mean total phosphorus concentrations at Stations 14, 13, and 17 were 1.45 mg/l, .50 mg/l, and .48 mg/l respectively, while that of Station 16, which is located downstream of Stations 13 and 14, was slightly lower at .39 mg/l (Figure 26). Mean total phosphorus levels at other tributary stations ranged from .09 to .27 mg/l (Table 9).

Mean dissolved phosphorus varied to a greater extent, but continued to follow the same trend observed with the mean total P concentrations. Mean dissolved phosphorus was highest at Stations 14 (.37 mg/l) and 16 (.33 mg/l). Mean dissolved phosphorus at the remaining stations ranged from .03 to .20 mg/l (Table 9).

TABLE 8. Monthly dissolved oxygen (mg/l) for all stations.

	RIVER STATION							
	1	2	3	4	5	6	7	8
Oct 85	8.6	8.6	8.0	8.6	9.2	6.1	9.2	8.4
Nov 85	7.0	6.6	6.6	7.0	7.2	8.6	7.5	5.5
Dec 85	11.0	10.0	11.0	9.0	9.2	7.3	8.6	10.2
Jan 86	8.8	10.6	10.2	9.2	8.2	9.2	8.4	9.0
Feb 86	7.2	7.6	7.8	7.6	7.6	8.1	7.7	8.2
Mar 86	9.2	9.2	9.2	8.8	8.8	8.2	8.8	8.6
Apr 86	7.2	7.8	7.4	6.2	6.4	5.8	6.8	6.6
May 86	6.4	6.0	5.6	6.2	7.1	6.5	6.7	5.8
Jun 86	5.0	5.0	4.5	5.1	5.7	6.5	5.6	5.8
Jun 86	5.2	4.8	4.7	5.4	5.8	5.2	6.1	4.5
Jul 86	4.8	4.5	4.6	5.8	5.8	6.2	6.2	5.8
Aug 86	6.7	6.0	6.2	6.4	6.8	6.1	7.0	5.4
Sep 86	6.3	5.9	5.5	5.7	6.4	5.9	6.8	5.2
Oct 86	7.9	6.2	6.6	7.6	9.0	10.0	9.2	7.8

TABLE 8. Continued.

	TRIBUTARY STATION								
	9	10	11	12	13	14	15	16	17
Oct 85	4.0	5.0	5.0	5.8	3.8	5.2	6.8	6.3	7.4
Nov 85	6.7	8.0	8.1	8.6	8.1	6.4	8.1	8.2	8.4
Dec 85	11.1	9.6	9.6	9.0	7.2	10.6	9.4	9.4	9.2
Jan 86	10.4	9.7	10.4	10.0	9.8	10.0	10.5	10.0	10.6
Feb 86	9.0	8.9	9.0	8.5	8.6	9.0	9.0	8.5	8.6
Mar 86	7.6	8.2	8.4	8.4	8.0	6.8	8.4	9.2	9.7
Apr 86	4.4	5.6	5.4	6.6	5.9	5.1	5.9	5.6	9.0
May 86	5.6	4.5	5.1	6.4	4.4	7.1	7.3	6.9	8.9
Jun 86	3.6	4.1	3.6	4.8	3.3	4.1	6.5	6.5	7.6
Jun 86	3.3	2.8	6.4	4.4	2.4	4.2	6.7	6.4	6.5
Jul 86	2.7	2.8	5.5	5.0	3.0	5.1	6.1	6.1	6.4
Aug 86	6.0	3.7	5.9	10.0	5.0	5.1	6.4	6.4	6.5
Sep 86	4.1	3.8	5.4	6.0	5.3	5.5	6.7	6.8	7.4
Oct 86	4.6	6.2	7.4	8.2	5.7	8.3	10.2	10.2	10.4

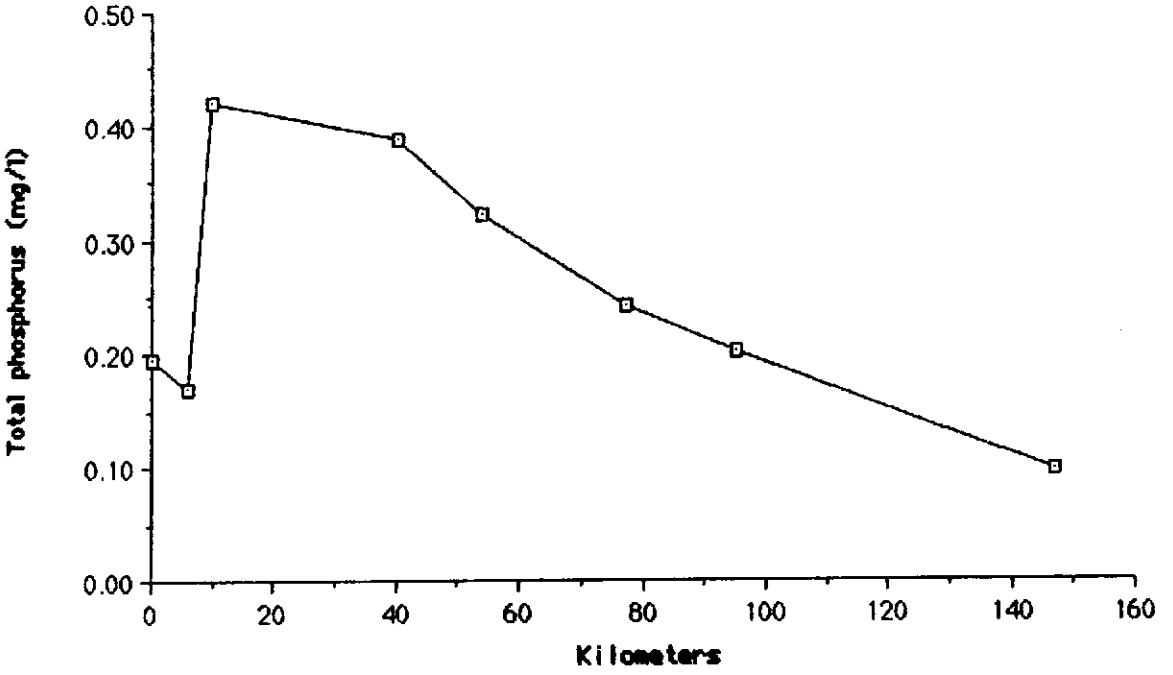


Figure 24. Mean total phosphorus by river kilometer.

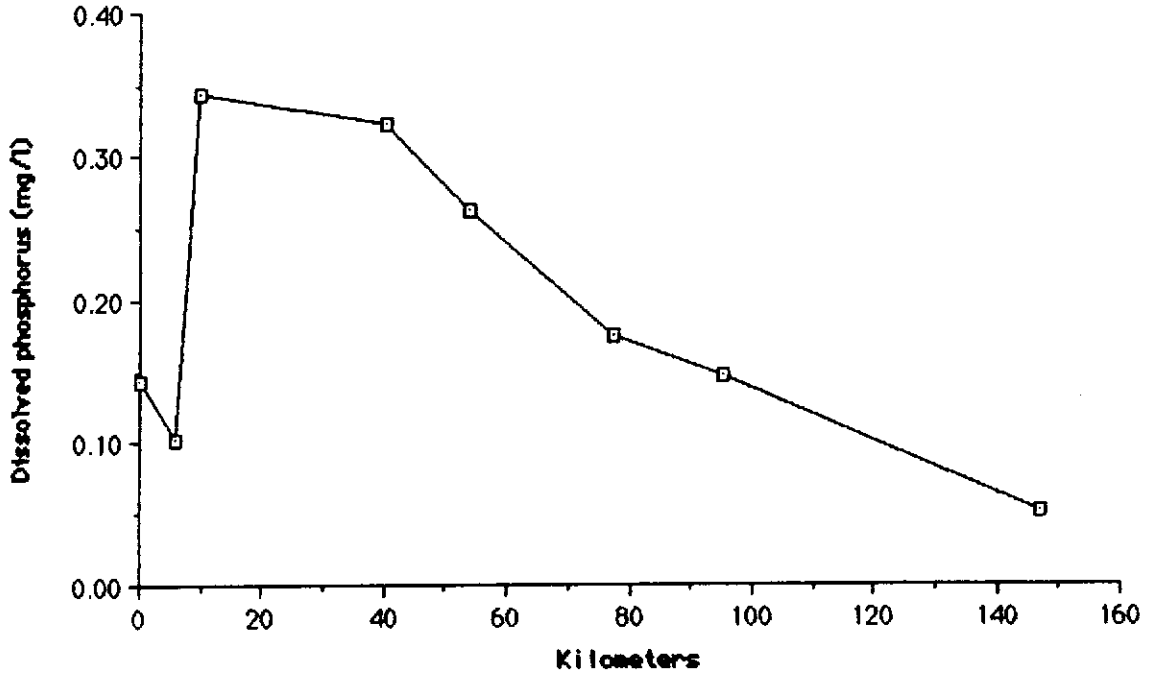


Figure 25. Mean dissolved phosphorus by river kilometer.

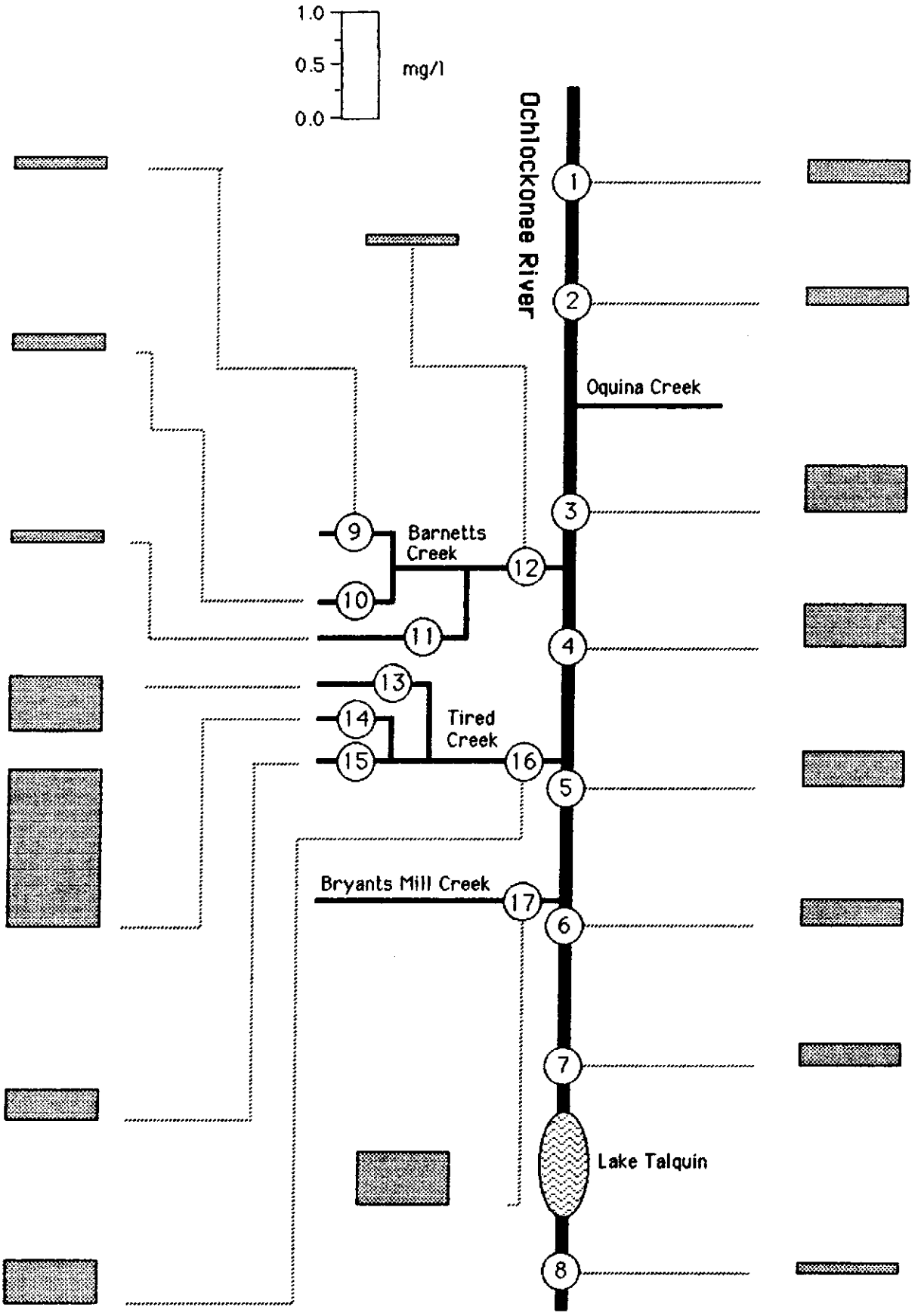


Figure 26. Mean total phosphorus.

TABLE 9. Means and standard deviation for tributary station total and dissolved phosphorus.

Station	Total Phosphorus (mg/l)	Dissolved phosphorus (mg/l)
9	.10 (.05)	.03 (.20)
10	.15 (.09)	.07 (.07)
11	.11 (.08)	.05 (.03)
12	.09 (.04)	.04 (.02)
13	.50 (.30)	.39 (.30)
14	1.45 (.99)	1.32 (1.20)
15	.27 (.13)	.20 (.15)
16	.39 (.21)	.33 (.25)
17	.48 (.31)	.37 (.33)

Nitrogen

Unfiltered and filtered total Kjeldahl nitrogen (TKN), total and dissolved ammonia, and dissolved nitrate/nitrite were determined for both river and tributary stations. There was slight to moderate variation in the various nitrogen species associated the fluctuations in water flow.

Mean unfiltered total Kjeldahl nitrogen in the river ranged from .53 to .70 mg/l while mean filtered TKN varied from .38 to .48 mg/l. The highest mean unfiltered TKN values were observed at Stations 4 (.70 mg/l), 5 (.66 mg/l), and 6 (.70 mg/l) (Figures 27 and 28).

Mean total ammonia concentrations ranged from .07 to .14 mg/l and exhibited a tendency to increase at Station 3 followed by a gradual decline in concentration as water traveled downstream (Figure 29). Mean dissolved ammonia ranged from .06 to .13 mg/l, peaking at Station 3 and following the same trend as observed in mean total ammonia.

Mean dissolved nitrate/nitrite concentrations in the river ranged from .17 at Station 8 to 1.07 mg/l at Station 5 (Figure 30). Mean nitrate/nitrite concentrations increased perceptibly at Stations 3 and 4, and then dramatically at Station 5, at one time reaching a concentration of 2.45 mg/l. Mean nitrate/nitrite levels declined downstream of Station 5 to .76 mg/l at Station 6 and .67 mg/l at Station 7. The lowest mean nitrate/ nitrite concentrations were observed downstream of Lake Talquin at Station 8 (.17 mg/l).

Tributary stream TKN values were generally higher than river values with mean unfiltered TKN ranging from .75 to 2.10 mg/l (Table 10). Mean total TKN concentrations were highest at Stations 9 (2.10 mg/l), 13 (1.93 mg/l), and 14 (1.88 mg/l), and lowest at Station 11 (.75 mg/l) (Figure 31). Mean filtered TKN values followed the same trends observed in mean unfiltered TKN data, however, concentrations in the filtered fraction were somewhat lower.

Ammonia levels varied to a much greater extent in the tributaries than in the river (Figure 32). Mean total ammonia ranged from .08 to 1.51 mg/l while mean dissolved ammonia varied from .07 to 1.45 mg/l (Table 10). The highest mean total ammonia concentrations were observed at Stations 9 (1.51 mg/l), 14 (1.28 mg/l), and 13 (.92 mg/l), and the lowest at Station 15 (.08 mg/l). Similar results were reflected in the mean dissolved ammonia data.

Mean dissolved nitrate/nitrite concentrations were generally low for the group of tributary streams near Ochlocknee, Georgia (Stations 9, 10, 11, 12) relative to the stations located to the south of Cairo, Georgia (Stations 13, 14, 15, 16, 17) (Figure 33). Mean nitrate concentrations for Stations 9-12 ranged from .17 to .36 mg/l, while those of Stations 13-17 ranged from 1.7 to 5.1 mg/l (Table 10). The highest nitrate levels were observed at Station 14, followed by Stations 16 and 15, while the lowest concentration was noted at Station 9.

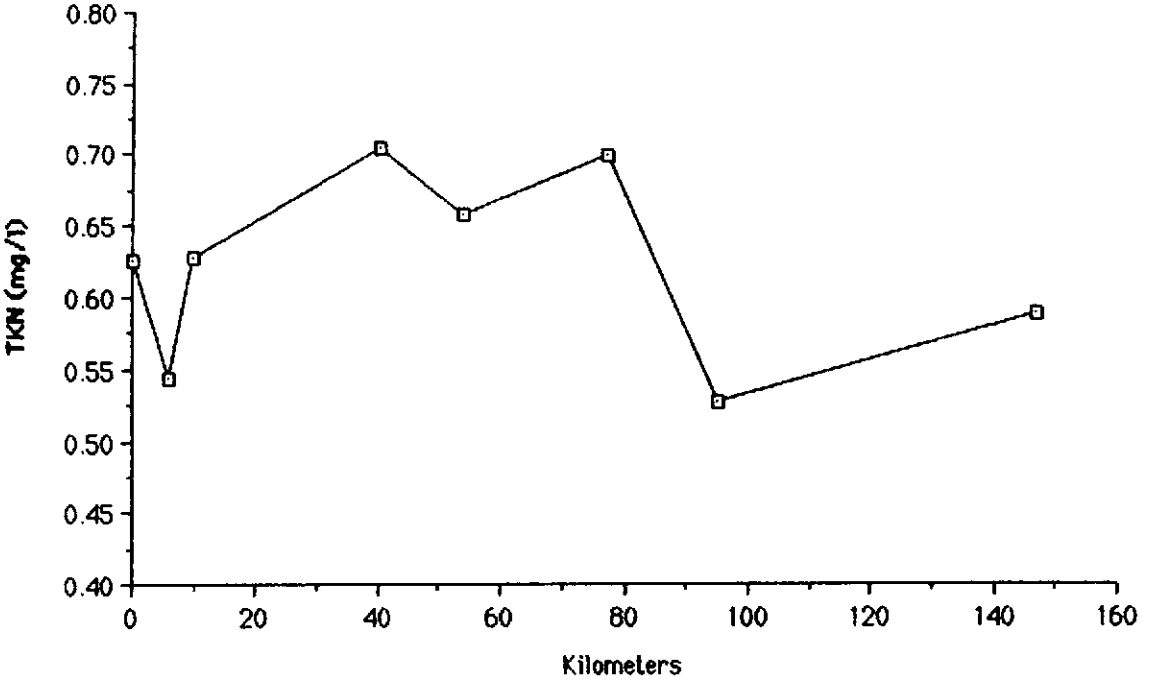


Figure 27. Mean total Kjeldahl nitrogen by river kilometer.

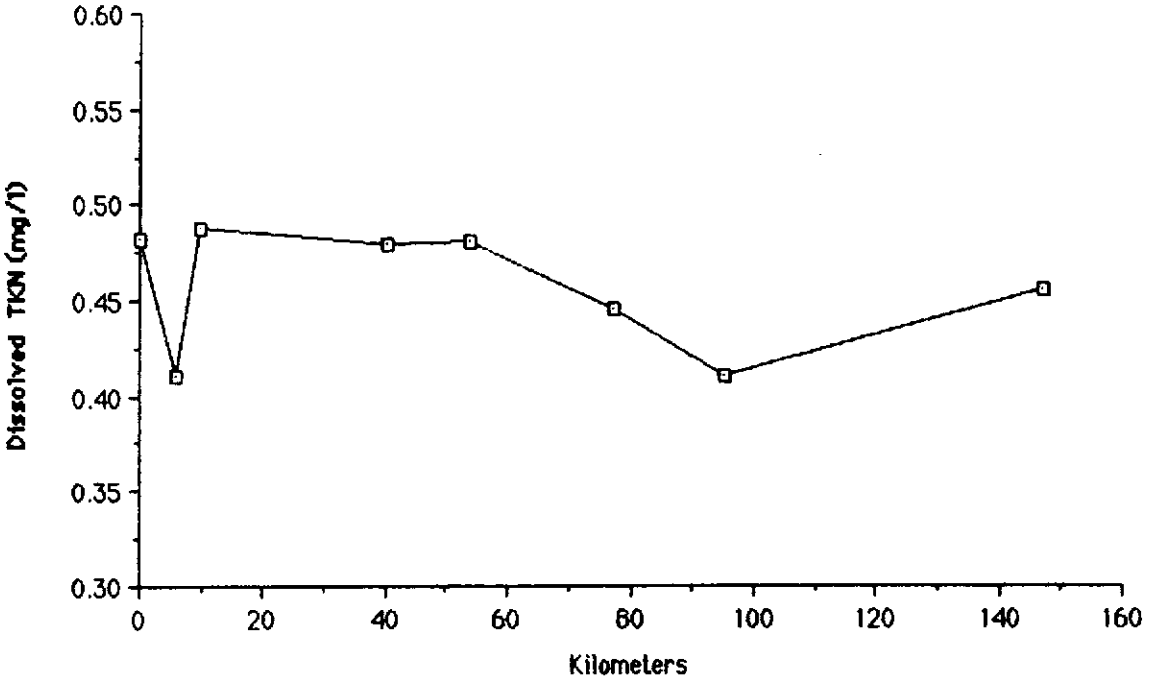


Figure 28. Mean dissolved total Kjeldahl nitrogen by river kilometer.

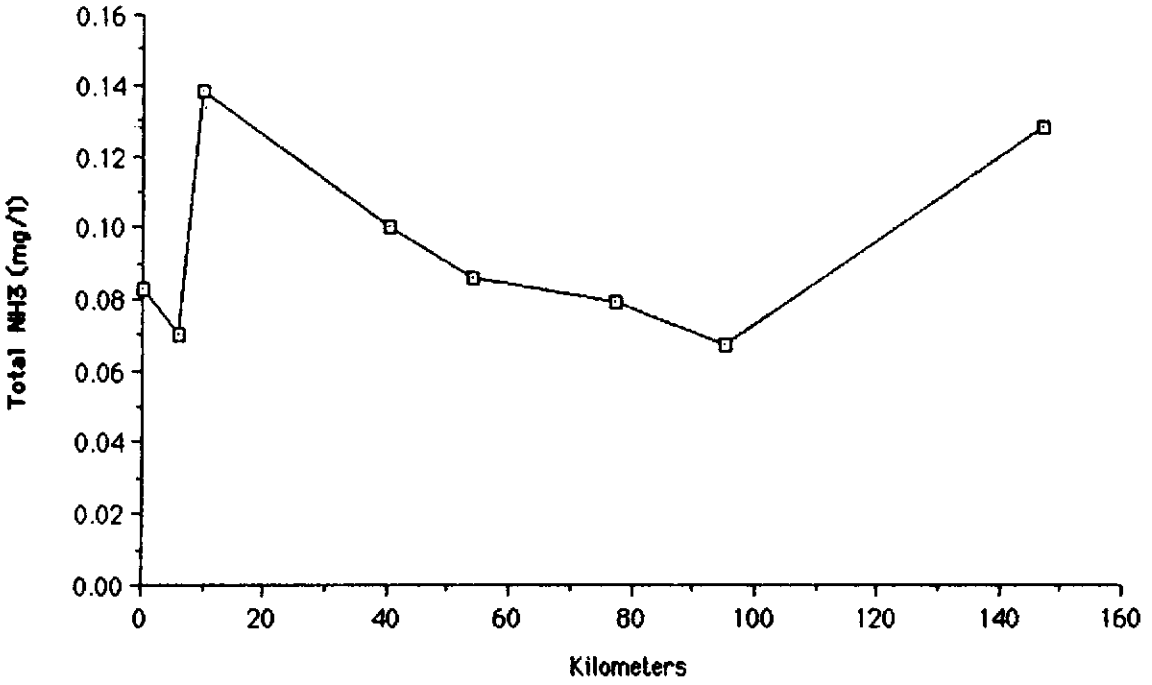


Figure 29. Mean total ammonia by river kilometer.

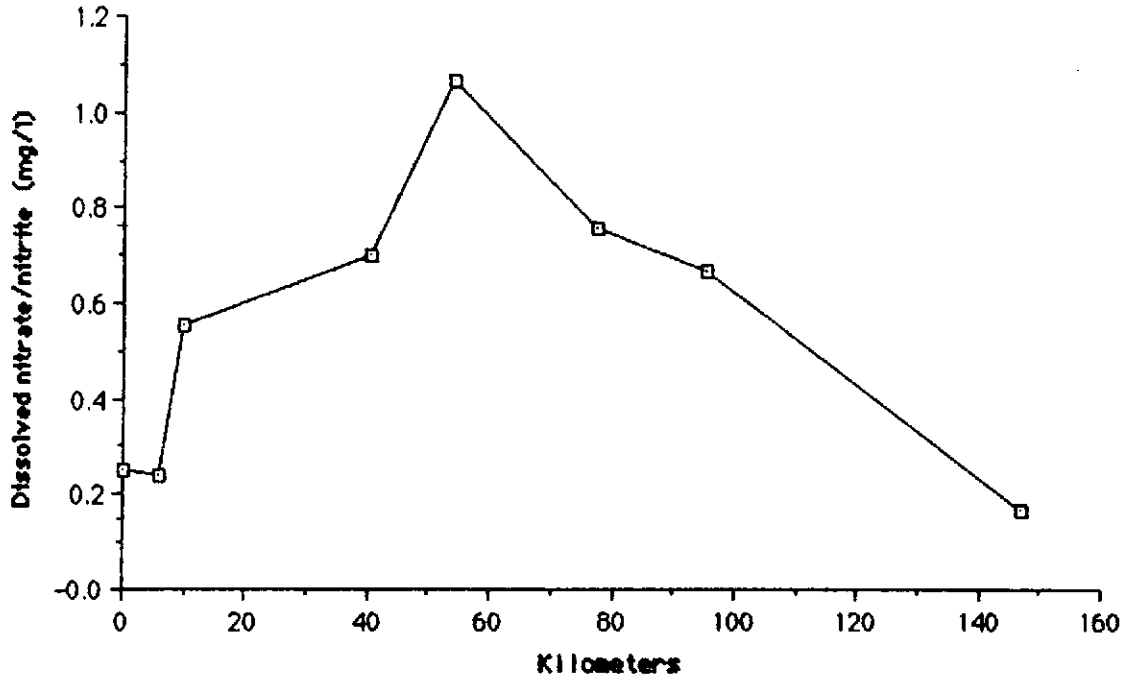


Figure 30. Mean dissolved nitrate/nitrite by river kilometer.

TABLE 10. Means and standard deviation for tributary station nitrogen species.

Station	Total Ammonia (mg/l)	Dissolved nitrate/nitrite (mg/l)	Unfiltered Total Kjeldahl nitrogen (mg/l)
9	1.51 (2.64)	.17 (.12)	2.10 (2.59)
10	.16 (.09)	.36 (.27)	.92 (.37)
11	.10 (.06)	.21 (.09)	.75 (.24)
12	.13 (.14)	.22 (.12)	.79 (.32)
13	.92 (1.16)	1.90 (1.25)	1.93 (1.11)
14	1.28 (1.32)	5.10 (3.39)	1.88 (.97)
15	.08 (.04)	2.31 (1.8)	.76 (.15)
16	.09 (.05)	2.50 (1.6)	.93 (.30)
17	.36 (.52)	1.70 (1.32)	.97 (.59)

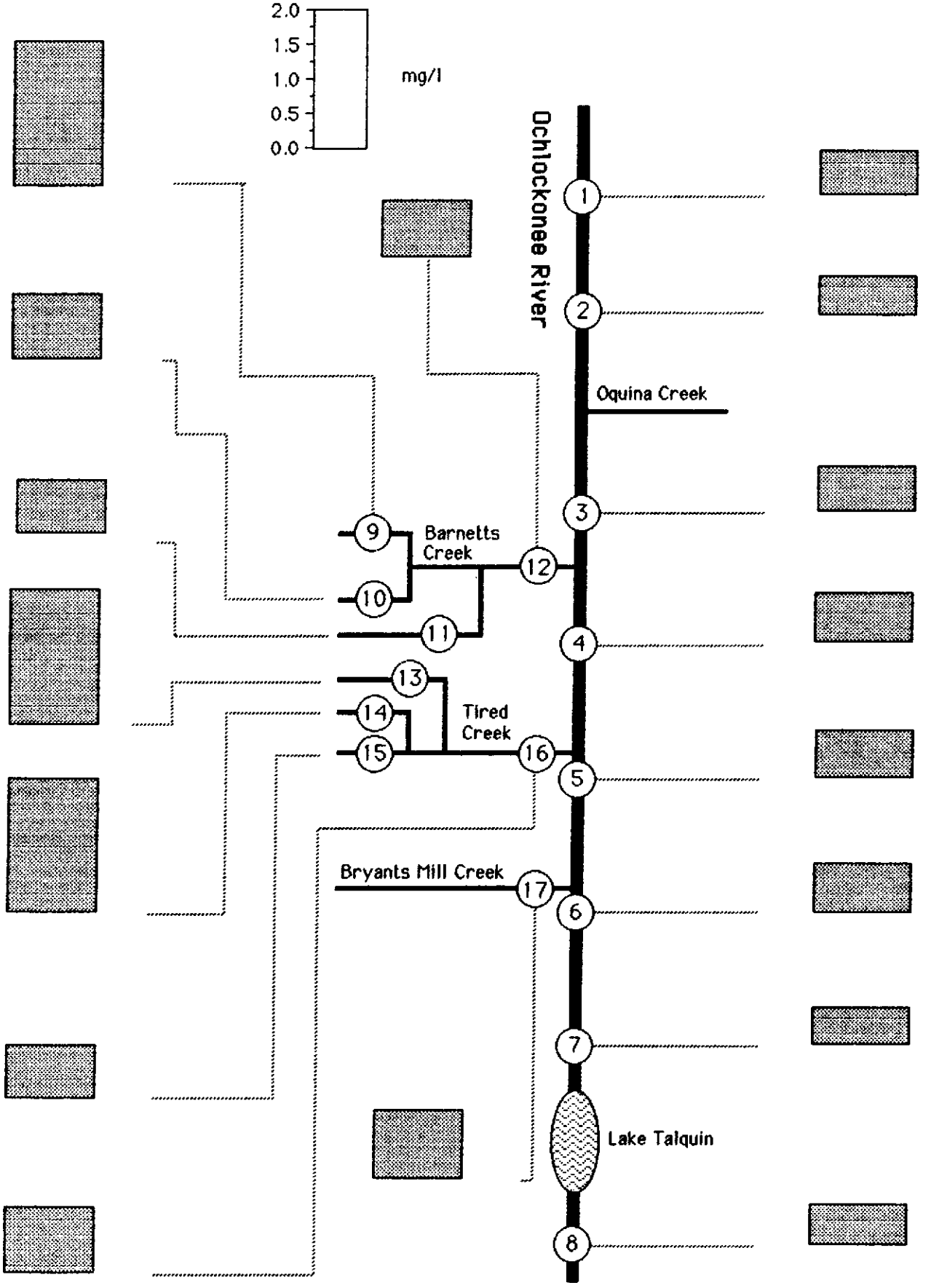


Figure 31. Mean total kjeldahl nitrogen.

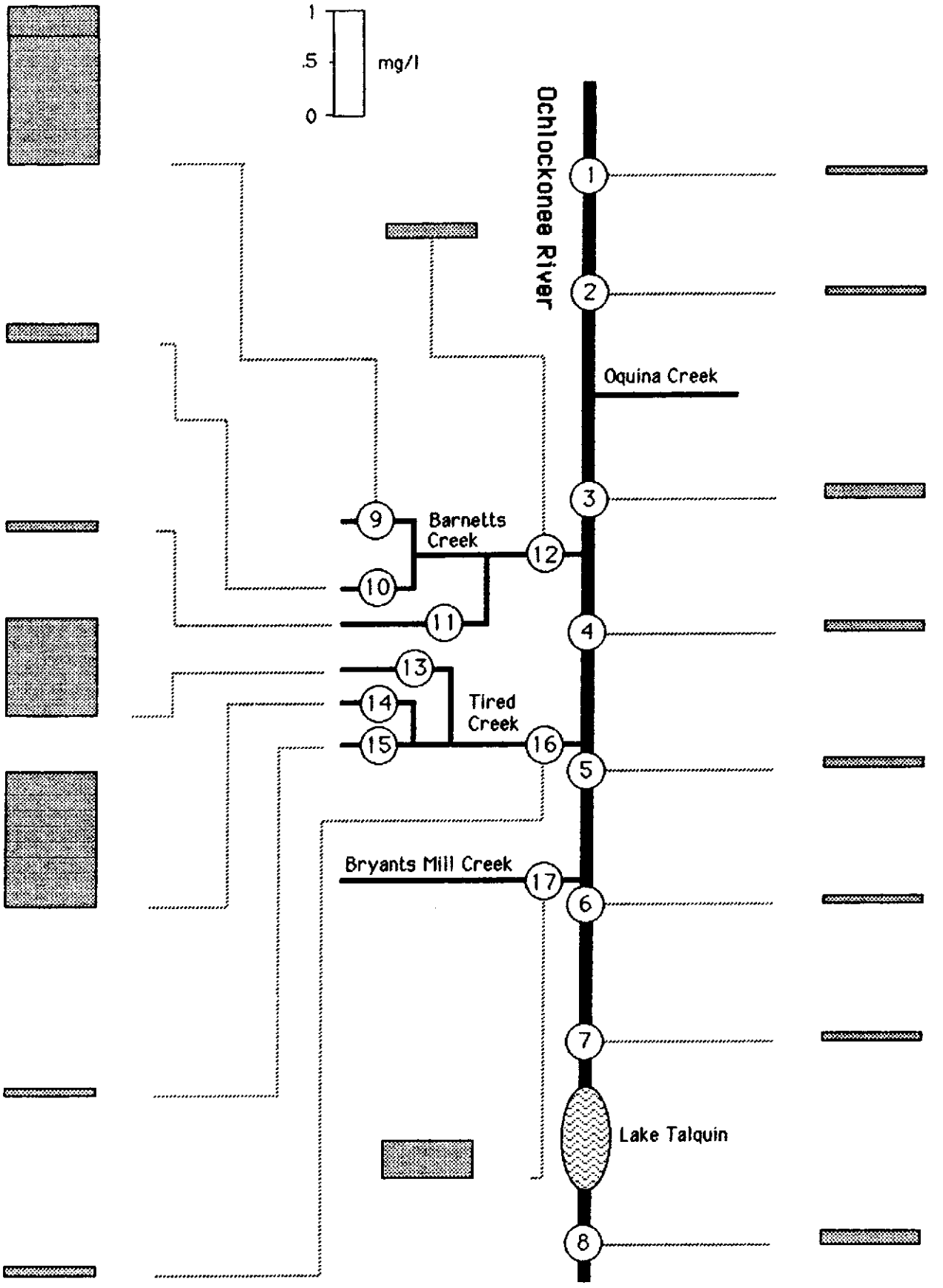


Figure 32. Mean ammonia.

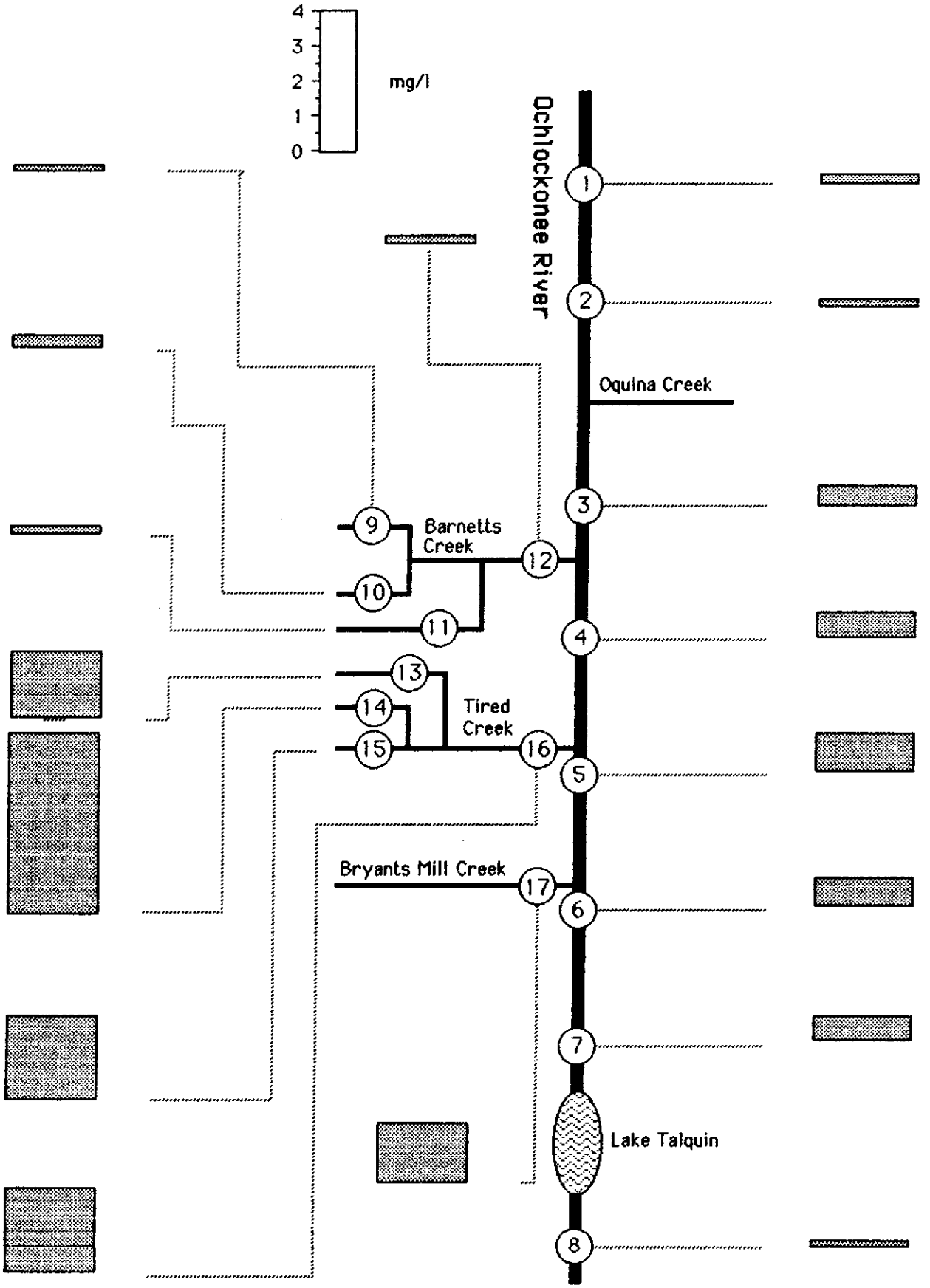


Figure 33. Mean nitrate/nitrite.

Levels of the different nitrogen species varied slightly due to flow conditions over the period of the study, exhibiting a tendency toward higher concentrations during low flow conditions.

Discussion

Although much of north Georgia experienced drought conditions during the time of this study, the Ochlockonee River exhibited flows well within normal historical ranges (Figure 11A). This suggests that variations observed in physical-chemical parameters, as well as in the biota, are not the result of unusual (i.e., very dry) hydrologic conditions.

pH

The pH of a given body of water is an expression of hydrogen ion activity, based on the negative logarithm of hydrogen ion concentration. The mobility, solubility, degree of dissociation, and potential toxicity of many elements are dependent on pH (Mason 1952, Lee & Hoadley 1967, Fritz 1980). River and tributary pH values were lowest during Winter and Spring and highest during Summer and Fall. This result may have been related to changes in flow and/or periphytic algal productivity, since increased algal growth during warm weather, low flow conditions tends to facilitate increases in pH.

Mean pH in the river did not vary significantly over the period of the study and reflected a normal range of pH values generally expected in rivers such as the Ochlockonee.

Mean pH values in the tributaries reflected some variation between groups, but all recorded measurements were consistent with results generally expected of such streams.

Alkalinity

Alkalinity is the ability of water to neutralize acids. It is implicitly related to pH (Bouwer 1978). Alkalinity values in the river and in the tributary streams were lowest during flooding episodes and highest during the dry summer months.

Mean alkalinity in the river increased slightly between Stations 1 and 6 followed by a slight drop at Station 7 and a dramatic decline in mean alkalinity at Station 8. These results generally paralleled pH measurements, which is expected since alkalinity and pH are closely related. The low alkalinities noted at Station 8 were likely the result of the passage of water through a large reservoir (Lake Talquin), which acts as a sink system for many constituents in the water column.

Mean alkalinity in the tributaries generally reflected expected conditions except at Stations 14 and 17. Alkalinities were high at Station 14 (64.6 mg/l) due to the discharge from the Cairo WPCP, however, the slightly elevated alkalinities at Station 17 point to the possibility

of some natural source of alkalinity, such as a spring, since a thorough exploration of the area did not uncover any point source contributor to the stream, except for an abandoned clay mining site.

Conductivity

Specific conductance is a measure of the capacity of water to conduct an electric current and serves as an indicator for the presence of inorganic ions. Industrial and municipal waste discharges have been shown to increase inorganic ion concentration and thus conductivity (Dye et al. 1980). Conductivity is affected by drought, precipitation, and the concentration of biologically active organisms, and can be utilized as an early indicator of changes in water quality (Slack and Kaufman 1975, Flora and Rosendahl 1982).

Although measurements in the river varied over a wide range, a trend toward increased conductivity was observed between Stations 2 and 6. This was most likely the result of tributary inputs from Oquina Creek above Station 3 and inputs from a series of tributary streams near Cairo, Georgia, which transport water from industrial and municipal treatment plants to the Ochlockonee River via Tired Creek. Conductivity values recorded downstream of Lake Talquin were low, as would be expected.

An anomolously high conductivity value of 550 umhos/cm^2 recorded at Station 1 in September 1986 may have been a consequence of an unusual discharge from an upstream water pollution control plant.

Tributary stream conductivity values generally reflected conditions in accordance with their usage. Samples from Station 13, which receives discharges from Roddenberry Company, exhibited extremely high conductivity values throughout the study. Mean conductivity at this station was 1252 umhos/cm^2, with a high value of 3900 umhos/cm^2 recorded in August, 1986.

Comparatively high conductivity values were also observed at Station 14, a recipient of treated water from the Cairo, Georgia, sewage treatment facility, although values here were considerably less then those observed at Station 13. Elevated conductivity values were noted at Station 16, a result of the influence of high conductivities from Stations 13 and 14. Consequently, the mean conductivity at Station 5 was 50 umhos/cm^2 higher than at Station 4.

Stations 9 and 10 are located below mining discharges, and conductivities in these streams reflected a slight increase, 71.1 and 46.8 umhos/cm^2, respectively, when compared to an adjacent stream (Station 11) which exhibited a mean conductivity of 37.6 umhos/cm^2. By the time water from Stations 9, 10, and 11 reached Station 12, conductivity values were similar to background levels.

Whereas mining operations appeared to have little or no effect on conductivities in the river, point source contributors in the area of Cairo, Georgia, have evidently influenced conductivity values not only in proximity to the outfall, but also further downstream in the river.

Hardness

The presence of large concentrations of alkaline earth elements (i.e., calcium and magnesium dissolved in water and combined with carbonates, sulfates, or chlorides) is measured as hardness. The U.S.G.S. defines softwater as water with a hardness of < 60 ppm, while Miller et al. (1974) regard softwater as water with a hardness of ≤ 75 ppm. Florida waters are generally soft in nature and exhibit carbonate hardness for the most part (Shannon and Brezonik 1972, Shampine 1975).

River hardness values varied most during low flow periods and reflected the soft water conditions generally found in this area. A subtle trend toward increased hardness in the lower reaches of the river was most likely a reflection of local geology rather than an important indicator of point/non-point source contributions. Hardness values from tributary stations reflected the same results for the most part, except for Stations 13 and 14, which again were observed to differ greatly from other tributary streams due to the influence of industrial and municipal discharges. Discharge from the Cairo Water Pollution Control Plant and Roddenberry Company probably contained chlorides or other constituents which affect hardness.

Turbidity

Turbidity is a measurement of light dispersion caused by particulate matter present in the water column. Turbidity values in the Ochlockonee were much higher than those measured in the adjacent Suwannee River system (FDER 1985).

As Hynes (1970) and numerous other authors have noted, most streams and rivers are reasonably clear during periods of low water, although never as clear as standing water. During flood conditions, turbidity increases with the increase in suspended material carried into the river. Dorris and Copeland (1963, in Hynes 1970), after a long study of the middle Mississippi River, found that turbidity and discharge were almost directly related. Hynes (1970) concluded that this phenomenon was fairly general for most streams and rivers.

Although mean turbidity for the whole study peaked at Station 4 (Figure 17) the pattern of turbidity peaks varied during the distinct periods of high and low flow in the river. During the period of high flow (and consequently, high turbidities), mean turbidity peaked at Station 6. Mean turbidity was highest at Station 3 during low flow conditions. It is noteworthy that turbidities at Station 7 were consistently lower than those at Stations 4, 5, and 6 during both high and low flow conditions. These results, along with data from sediment analysis, suggest that the area in proximity to Station 6 may serve as a depositional zone for suspended particulates.

Mean turbidity in the tributary streams was highest at Station 9, where the effect of a mining operation was evident. Turbidity associated with this mining operation dissipated quickly with measurements at Station 12 reflecting significant decreases in turbidity. Increased turbidities were also noted at Station 17, due most likely to run-off from an old quarry and agricultural sources combined. Turbidity at the other tributary stations appeared to be related to local topography and agricultural run-off (Table 7).

A comparison of the daily turbidity and discharge data for the period 22 October, 1985, to 9 September, 1986, (Figures 19A-L) shows how increases in turbidity were closely associated with rainfall, and thus with flooding or high water conditions on the river. In fact, a highly significant positive correlation was determined for daily flow and turbidity ($r = 0.683$, $p << .01$, $n = 323$). While turbidity increased during periods of increasing discharge, peak turbidities were generally observed a day or two before peak discharge was reached. This was particularly true for a late October flood (Figure 19). This phenomenon is likely the result of the "first flush" of detritus and sediments that are initially washed into the river during a storm event. As rainfall and consequent runoff continues, lesser amounts of this material wash into the river and thus, through the process of dilution, the turbidity is reduced at peak flows and afterward.

During the period of heaviest rainfall (February 1986) which was twice that of the most significant rainfall of the previous four months (Table 11), the peak turbidity (almost 100 NTU) of the entire study was observed. This implies that large quantities of eroding soils from upland areas enter the river system during heavy rainfall events, probably a consequence of the enormous land area utilized for agriculture in the basin. In contrast, during a similar flood event in February 1983 in the Suwannee River (a predominantly non-agricultural basin), turbidity peaked at around 9 NTU (FDER 1985).

A number of turbidity peaks that did not appear to be associated with any particular widespread rainfall events (and thus increases in discharge) were noted throughout the study. This was particularly true for the Spring and early Summer (Figures 19 F, G, and H), although such a peak was also observed in November, 1985. Several explanations appear possible: (1) an extremely localized rainfall event that increased turbidity for a short time or (2) possible discharges or "slugs" of turbid water from point sources, such as attapulgite mines, located upstream of Station 6. However, there is no direct evidence for either one of these scenarios.

Total Suspended Solids

Total suspended solids is a dry weight measurement of particulates in the water column.

TABLE 11. Major Rainfall Events and Associated Maximum Flow and Turbidity, Ochlockonee River Basin 1985-1986.

DATE	[a]Total Rainfall (cm)	[b]Maximum Daily Flow (m^3/s)	[c]Maximum Turbidity (NTU)
27-31 Oct 1985 (Hurricane Juan)	15.27	164	58
20-21 Nov 1985 (Hurricane Kate)	11.35	309	42
12-13 Dec 1985	12.85	229	37
10 Jan 1986	7.49	200	23
5-11 Feb 1986	33.32	926	97

[a] Measured at WCTV

[b] Measured at U.S. Highway 27 bridge. This value was the peak value associated with a rainfall event and does not necessarily coincide with dates of rainfall.

[c] Measured at Station 6. This value was the peak value associated with a rainfall event and does not necessarily coincide with dates of rainfall.

Total suspended solids (TSS) in the river generally reflected expected conditions with the exception of Station 3, located immediately downstream from Oquina Creek, into which recovered water from the Thomasville Water Pollution Control Plant and the Sunnyland meat packing plant is discharged. The total suspended solid load from Station 17 may be responsible for the slightly elevated TSS at Station 6, but the trend is slight.

TSS values in the tributaries were high in proximity to ongoing mining operations, but rapidly returned to background levels downstream. Total suspended solid loads at Station 17 were extremely high as compared to other stations. This increased TSS seems to be linked with natural erosion problems and possible run-off from an old quarry. The remaining stations reflected normally expected TSS values.

Temperature

Water temperature is an important physical characteristic which influences many aspects of an aquatic system. Temperature may often affect the population dynamics of aquatic organisms since many species exhibit susceptibility to large temperature fluctuations (Odum 1959). Temperature is a controlling factor in chemical reactivity and plays a significant role in the overall quality of water (Hutchinson 1957, Wetzel 1975).

Mean water temperatures in the river increased sequentially from station to station. This trend was observed during both high and low flow conditions. The increased trend in temperatures may represent an artifact of sampling time since sampling proceeded sequentially from upstream to downstream. However the warming of water which intially enters rivers through subterranean seeps and shaded tributaries is not an unusual occurrence (Hynes 1970).

Mean temperatures in the tributaries were generally uniform, with no indication of influence from upstream activity. Temperatures in both the river and the tributaries appeared unaffected by industrial or municipal activities.

Dissolved Oxygen

Dissolved oxygen (D.O.) levels in natural waters are the result of a complex series of physical, chemical, and biological interactions. D.O. is essential to the metabolic functions of most aquatic organisms and thus can serve as a very useful indicator of overall water quality.

Dissolved oxygen levels in the river were lower in the summer, especially at Stations 1, 2, 3, and 8 (approaching 4.0 mg/l). Low D.O. observed at Station 8 may have been the result of bottom discharge water released from a reservoir (Lake Talquin). D.O. in the upper river may have been slightly affected by point source inputs or natural conditions. D.O. levels in the tributaries were lower than, and varied more noticably than did oxygen levels in the river. Streams which

received discharge from municipal, industrial, or mining activities appeared to show signs of D.O. depletion, especially during low flow conditions. Particularly low D.O. levels (as low as 2.4 mg/l) were observed during the summer months at Stations 13 and 9 (Table 8), which are the receiving waters for discharges from Roddenberry Company and from mining operations, respectively. Low dissolved oxygen at Station 10 is attributed to stream morphology rather than a point source discharge. The water at this station, unlike other stations we studied, exhibited a tendency to pool and become stagnant.

D.O. concentrations in the river and tributaries appeared to be heavily influenced by flow and temperature conditions. Tributary streams exhibited little or no impact on the river stations downstream.

Phosphorus

Phosphorus is a primary nutrient that regulates aquatic plant growth in freshwater systems. Studies by numerous investigators (e.g., Ruttner 1953, Schindler et al. 1973, Devey and Harknes 1973, Wetzel 1975) suggest that the nutrient limiting plant (algal or macrophyte growth) in freshwater is predominantly phosphorus. The inorganic phosphates are the most important in biological terms, since algae can only assimilate phosphorus in this form (Stumm and Morgan 1970, Wetzel 1975, FDER 1985).

Phosphorus in surface water occurs almost exclusively in the fully oxidized form of phosphate (Hutchinson 1957, Stumm and Morgan 1970, Wetzel 1975). Natural processes of groundwater percolation, precipitation of atmospheric particulates, and terrestrial run-off are the primary modes of transportation of phosphate to natural waters (Keup 1968, Chapin and Uttormark 1973, Wetzel 1975). Industrial, agricultural, and domestic activities can also cause changes in ambient phosphate levels through direct discharge and natural transport mechanisms.

The cycling of phosphate within an aquatic system is directed by a set of complex interactions. Bacterial activity, pH, sediment composition, benthic fauna, D.O., algal growth, and industrial and agricultural loading all have an appreciable effect on the exchange equilibria of phosphate (Stumm and Morgan 1970, Wetzel 1975, Lean and Nalewajko 1976, Bates and Neafus 1980, Elwood et al. 1981, Matisoff et al. 1985).

Mean total phosphate and dissolved phosphate values in the river varied from .10 to .42 mg/l. Along the course of the river, these values showed a marked increase at Station 3, followed by a gradual decline in concentration at the remaining stations (Figure 24). The increased amount of phosphate present at Station 3 suggests that input from Oquina Creek may be responsible, since this creek receives nutrient-laden discharge from the Thomasville Water Pollution Control Plant, Sunnyland processing plant, and general run-off from the City of Thomasville. Algal growth potential studies corroborated these results (See Algal Assay Section). Mean total and dissolved phosphorus gradually declined downstream of

Station 3 due to uptake by algal populations and the interaction of clay particulates. The adsorption phenomena characteristic of phosphate and clays was further enhanced by slightly acidic water present in the Ochlockonee River (Wetzel 1975). Mean total and dissolved phosphorus concentrations in the water dropped abruptly between Station 5 (.32 mg/l) and Station 6 (.24 mg/l). This change seems to indicate that either substantial algal growth has occurred or that sedimentation of phosphorus-laden clay particulates was particularly enhanced in the vicinity of Station 6. Results from the analysis of sediment characteristics in the river indicated that the latter may be true (see Sediment Section).

Mean total and dissolved phosphorus values in the tributary streams generally reflected expected values except for the streams receiving recovered water from municipal and industrial sources near Cairo. Parkers Mill Creek (Station 14), which receives discharge from the Cairo Water Pollution Control Plant, exhibited total phosphorus concentrations as high as 3.5 mg/l, and displayed a mean total phosphorus concentration of 1.45 mg/l, followed by a mean of .50 mg/l at Station 13. Water from Station 16, which was located downstream from Stations 13 and 14, reflected slightly elevated total phosphorus concentrations. It was apparent, however, that phosphorus was being removed from the system through algal utilization and sedimentation so that effects from these sources were not immediately apparent in the Ochlockonee River. Elevated phosphorus concentrations at Station 17 were unexpected since mining operations at that particular site have been suspended. However, the possibility remains that run-off from the mined area could be contributing phosphate to the stream or that another source altogether is responsible.

Samples from stations in proximity to the Thor mining operation (Stations 9 and 10) exhibited low mean total and dissolved phosphorus concentrations. This was surprising, since such operations generally release phosphate-rich discharge water to effluent streams. Further exploration of the streams revealed areas where stream water pooled and in some cases became stagnant. This might explain the lack of phosphorus in these streams since the pooling of water would most likely allow sedimentation and algal uptake to occur.

In general, total and dissolved phosphorus concentrations were inversely related to river flow conditions. Minimum concentrations of phosphate were observed during high flow, probably due to dilution effects, while increased levels of phosphorus were noted when low flow conditions prevailed.

Nitrogen

Like the phosphorus species, the various compounds of nitrogen are integral to the biological and chemical activities in natural water. While some studies implicate phosphorus as the primary limiting nutrient in freshwater (Jordan and Bender 1973a, 1983b, Golterman 1975, Welch et al. 1978), other investigations point to nitrogen as the primary limiting

nutrient or at least as a secondarily important nutrient (Talling 1966, Moss 1969, Robarts and Southall 1977, Henry et al. 1984). In freshwater, nitrogen exists in several forms: dissolved molecular nitrogen, a large array of organic compounds (i.e., amino acids, amines, proteins, humic compounds), ammonia (NH_3/NH_4), nitrite (NO_2), and nitrate (NO_3).

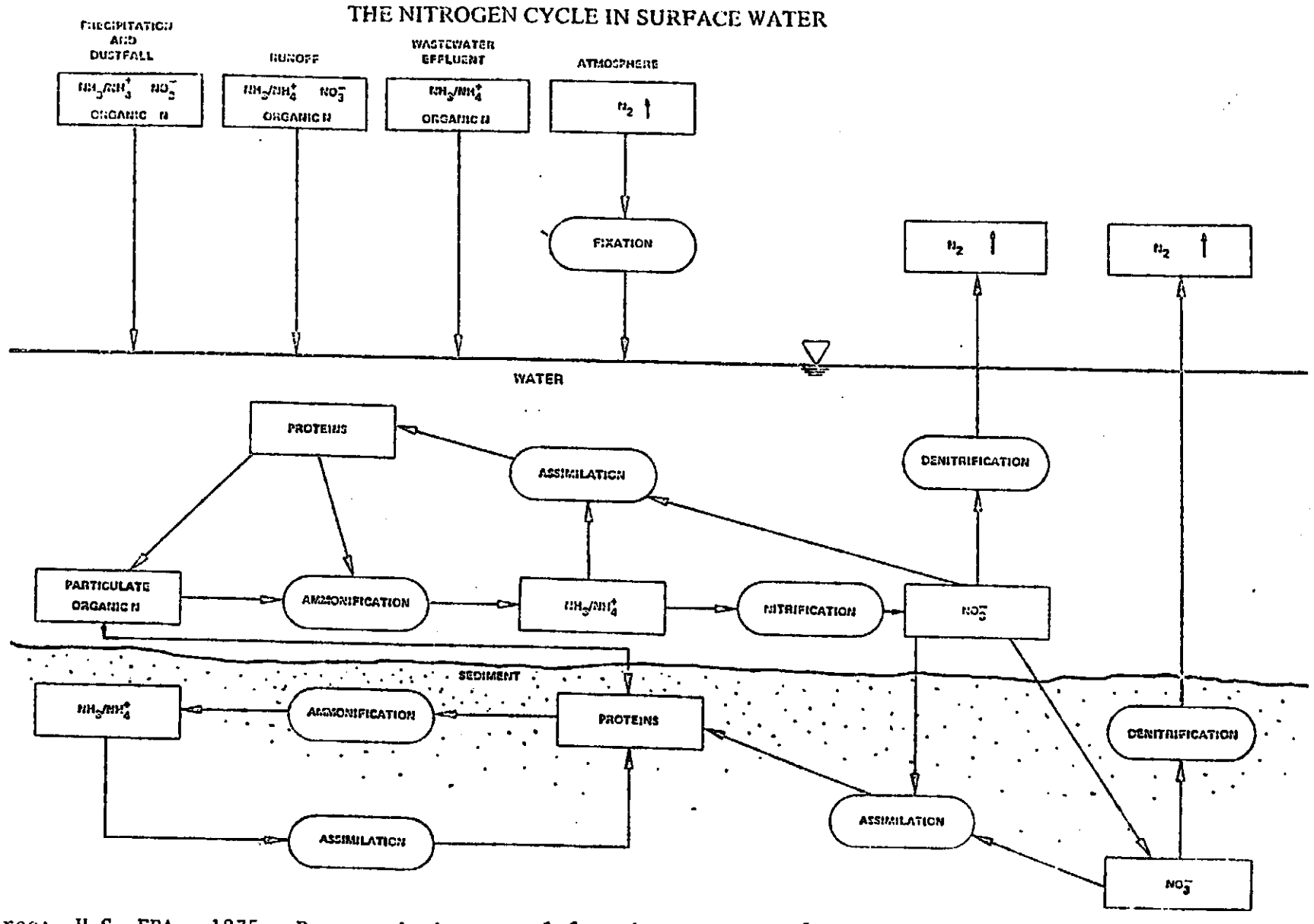
Nitrogen can reach surface waters in several ways. Precipitation and atmospheric particle fallout, characterized widely as minor sources of nitrogen, vary greatly from region to region in relation to meterological conditions and proximity to industrial areas (Wetzel 1975). However, in some cases, airborne nitrogenous compounds can account for a major portion of nutrient input. Likens et al. (1972) gathered data pointing to significant additions of nitrogen from precipitation and particle fallout. Surface run-off and subsurface groundwater movement are major contributors to the overall nitrogen budget of surface waters. These contributions are accentuated if soil and bedrock characteristics are biochemically conducive (Wetzel 1975, U.S. EPA 1975). Direct discharge of recovered water is also a concern in industrial areas.

Atmospheric nitrogen (N_2) becomes soluble in water according to the physico-chemical constraints, i.e., surface water temperature, of the body of water in which it is introduced. Additionally, atmospheric nitrogen can be fixed by certain heterocyst-producing blue-green algae and a few genera of bacteria (Azotobacter, Clostridium). The amount of fixed nitrogen produced by blue-green algal populations appears to be dependent on the amount of bioavailable nitrogen, i.e., ammonia and nitrate. More readily available nitrogen in the environment corresponds to reduced production of biologically fixed nitrogen (Fogg 1971, Wolk 1973). Fixation of atmospheric nitrogen can also occur electrically or photochemically (Hutchinson 1957).

As nitrogen can enter the ecosystem it may also exit through the mechanisms of outflow, volatilization, and bacterial denitrification or it may become bound and inert in bottom sediments. Nitrogen bound in bottom sediments may undergo remobilization due to benthic macroinvertebrate activity as demonstrated by Gardner et al. (1983). Keeney et al. (1970) and Konrad et al. (1970), however, found little correlation between amounts of total nitrogen in the sediments and lake productivity. A flow chart describing the nitrogen cycle in surface water is presented in Figure 34.

The most readily bioavailable forms of nitrogen utilized by phytoplankton are ammonia and nitrate (Harvey 1940, MacIsaac and Dugdale 1972, Morris 1974, Dye and Jones 1978). Nitrite is rarely taken up as a nutrient due to the toxic effects it has at high concentrations (Wood 1965, Morris 1974). Nitrites are highly labile compounds and thus concentrations in nature are usually very low. Nitrates, on the other hand, can be found more readily in the environment and thus are utilized preferentially by algae.

FIGURE 34.



Source: U.S. EPA. 1975. Process design manual for nitrogen control.

Although studies on tropical and subtropical aquatic habitats can be found, a great number of the definitive works on nutrient limitation and interaction were carried out in northern temperate lakes. This situation leaves some ambiguity in comparing data from subtropical regions such as Florida, to the values reported for temperate regions. Data exist which suggest that Florida aquatic habitats respond differently to nutrient enrichment when compared to northern aquatic habitats (Dye and Jones 1978).

Mean unfiltered and filtered total Kjeldahl nitrogen values were found to vary only slightly in relation to different flow conditions, and ranged from .53 to .70 mg/l for unfiltered TKN values and from .38 to .48 mg/l for the filtered TKN fraction. The highest mean unfiltered TKN values were observed at Stations 4, 5, and 6, however, these results were not indicative of any apparent trend in the river.

Ammonia concentrations in the river were slightly higher during low flow conditions and were consistently higher at Station 3. The increase in total and dissolved ammonia at Station 3 is probably due to inputs from Oquina Creek, which transports recovered water from the Thomasville Water Pollution Control Plant and discharges from Sunnyland Foods to the Ochlockonee River. Although the increased levels of ammonia at Station 3 were minimal, rising from a mean of .07 mg/l at Station 2 to .14 mg/l at Station 3, ammonia reached background levels only after traveling some 30 miles downstream to Station 6, and may have contributed significantly to algal productivity (See Algal Assay Section).

One of the most significant findings associated with nitrogen and water quality in the Ochlockonee was the observed variation in nitrate/nitrite concentrations in the river. Upstream Stations 1 and 2 were noted as having the lowest mean nitrate/nitrite concentrations in the river, .25 mg/l and .24 mg/l respectively. However, mean nitrate/nitrite levels consistently increased at Station 3 (.55 mg/l), peaked at Station 5 (1.07 mg/l), and sometimes reached concentrations as high as 2.45 mg/l. Nitrate/nitrite levels declined only slightly at Stations 6 and 7, but finally returned to background levels downstream of Lake Talquin, indicating the uptake or deposition of this nutrient in Lake Talquin.

Results of nutrient analyses from tributary water samples indicated that tributaries in proximity to the Cairo area, particularly Tired Creek (Station 14), were associated with high levels of nitrate/nitrite in the Ochlockonee River. Nitrate/nitrite concentrations in Tired Creek, a recipient of recovered water from the Cairo Water Pollution Control Plant, and possibly of run-off from a nursery, were consistently above 2 mg/l and on two occasions, reached levels considered toxic (9.27 mg/l and 14.7 mg/l).

Mean nitrate/nitrite concentrations in other streams near Cairo (Stations 13, 15, 16, 17) were also elevated, ranging from 1.7 to 2.5 mg/l, probably a result of industrial discharges (Station 13; $\bar{x}$ = 1.9 mg/l) and agricultural activities (Stations 15 and 17, x = 1.7 and 2.5 mg/l, respectively). Nitrate/nitrite concentrations for the group of tributaries northeast of Cairo (Stations 9-12) ranged from .17 to .36 mg/l and generally reflected expected conditions.

Total and dissolved ammonia concentrations in the tributaries were highest at Stations 9, 14, and 13, however, these levels quickly declined to acceptable concentrations in short distances, thus having no apparent effect downstream.

Unfiltered TKN exhibited characteristics similar to ammonia in that high concentrations observed at Stations 9, 14, and 13 were quickly dissipated so as to reflect concentrations similar to control streams.

Multivariate Techniques

Discriminant analysis aids in isolating the parameters which vary the most among sampling stations. Discriminant analysis techniques were applied to water chemistry data compiled over the entire course of the study, as well as from the distinct periods of high and low flow conditions in both the river and the tributaries. Results of these analyses indicated that station groups from the low flow period and the combined data were identical, while station clusters from the high flow period were grouped in an altogether different manner. This was true for both the river and tributary streams.

Cluster analysis of combined river data delineated three distinct groups, composed of Stations 1, 2, and 8; Stations 3 and 4; and Stations 5, 6, and 7 (Figure 35). The first Discriminant Function (DF1) was based on nitrate/nitrite concentrations and turbidity, which accounted for 59.5% of the variance among the groups. The second Discriminant Function (DF2) increased the explained variance to 79.7%, due to the influence of phosphate in the river.

Similarly, discriminant analysis of data collected during low flow conditions separated groups into clusters identical to those found in the combined data. The percent of variance assigned to DF1 and DF2 were, however, slightly different. Discriminant Function 1, based on nitrate/nitrate concentrations and turbidity, accounted for 57.8% of the among-group variance while DF2, based primarily on phosphate, was responsible for an additional 25.9% of the variation between stations (Figure 36).

Results of discriminant analysis of data collected during high flow conditions were completely different from those involving combined and low flow data. The parameters designated as responsible for the majority of variation were total ammonia and turbidity (DF1), accounting for 46.5% of variation, and pH (DF2), which accounted for an additional 28.1% of

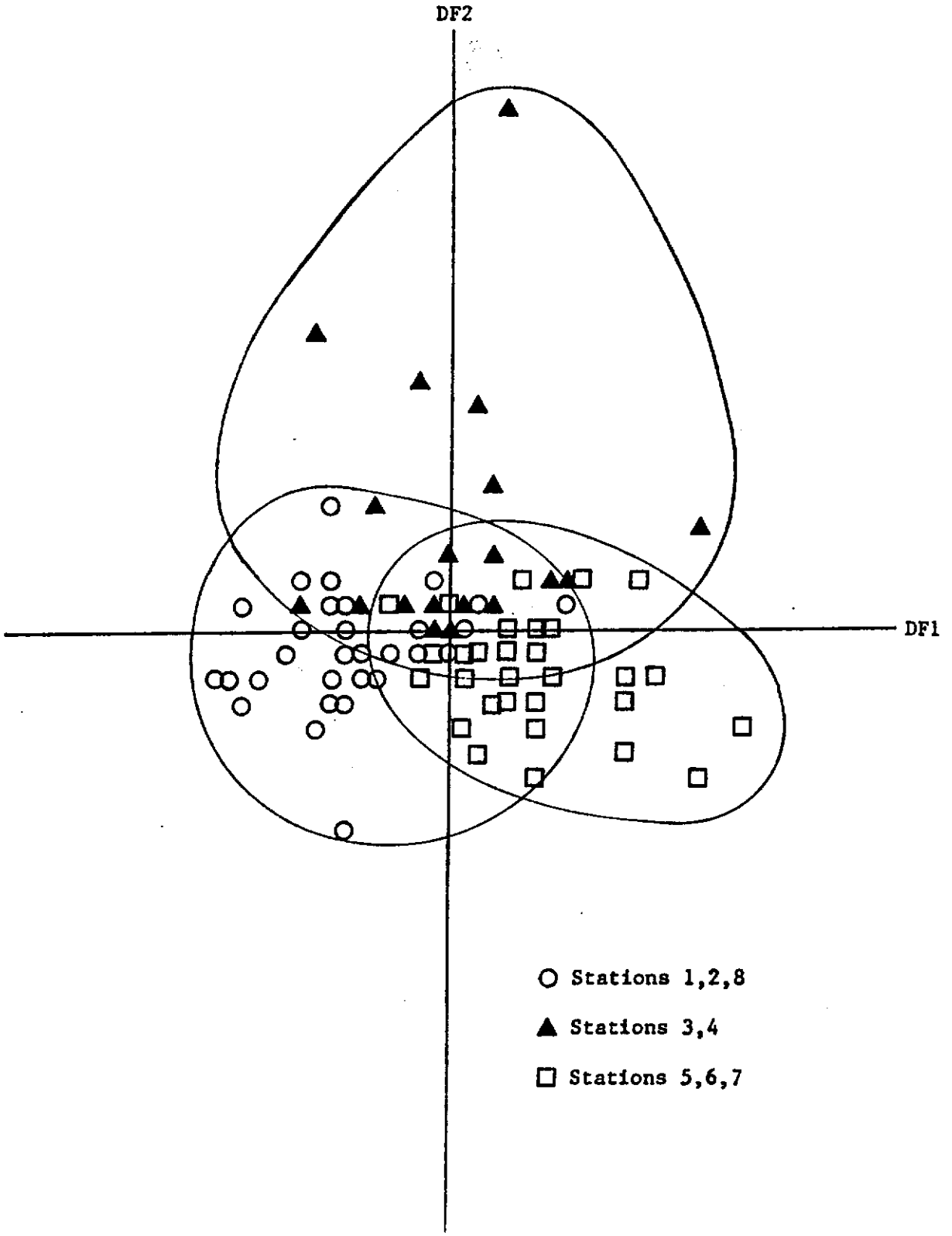


FIGURE 35. Orientation of river station groups in discriminant space for the entire sampling period.

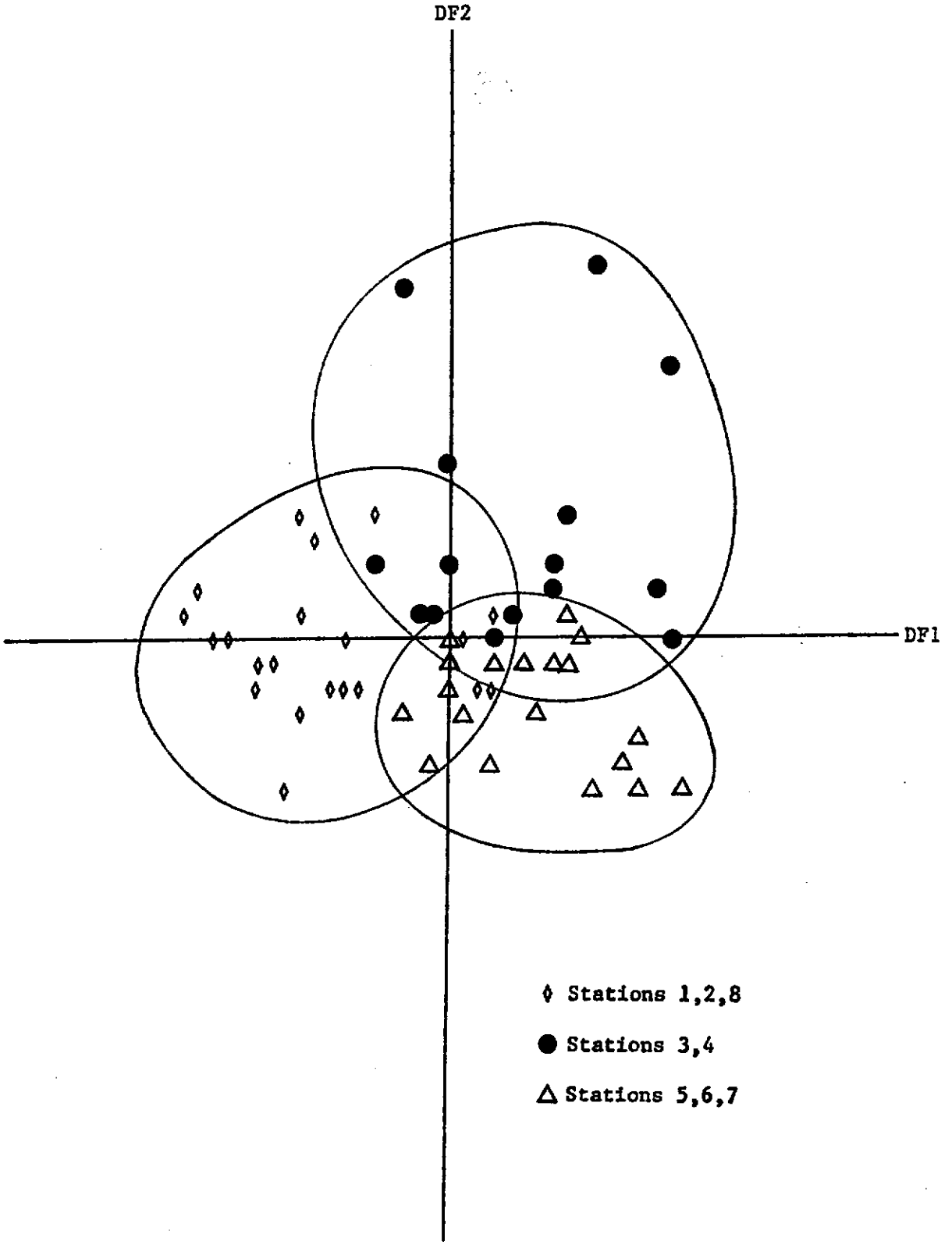


FIGURE 36. Orientation of river station groups in discriminant space for the period of low flow.

among-group variation. The resulting scatterplot (Figure 37) clustered stations into 3 groups, which were made up of Stations 1 and 2; Station 8; and Stations 3, 4, 5, 6, and 7.

Discriminant analysis of water chemistry data from the tributaries was similar to the results describing the river, in that combined and low flow data were closely related while high flow data exhibited distinctly different characteristics. Discriminant analysis of combined data from the tributary stations resulted in a scatterplot depicting four groups which consisted of Stations 9, 10, 11, and 12; Station 13; Station 14; and Stations 15, 16, and 17 (Figure 38). Discriminant Function 1, which was responsible for 51.7% of the variation, was associated with phosphate and nitrate/nitrite concentrations while conductivity (DF2) accounted for an additional 27.7% of variation among the stations. Clearly, Stations 13 and 14 stand out as dramatically different from surrounding stations. This is further evidence that point-source discharges are affecting these creeks.

Discriminant analysis applied to low flow data from tributary stations resulted in identical groupings, however, phosphate (DF1) was responsible for 48.4% of the among-group variation followed by conductivity (DF2) which explained and additional 29.4% of the variation (Figure 39).

Conditions during high flow episodes caused the results of discriminant analysis of tributary stations to yield a different characterization than was observed in the combined and low flow results. Although the clustering of groups remained the same, the parameters responsible for the majority of variation were different. Discriminant Function 1 was based on a combination of total ammonia, dissolved oxygen, and nitrate/nitrite, and accounted for 61.9% of the among-group variation. Discriminant Function 2 was based on conductivity and total Kjeldahl nitrogen, and was responsible for an additional 26.7% of group variation (Figure 40).

Discriminant analysis applied to low flow data from tributary stations resulted in identical groupings, however, phosphate (DF1) was responsible for 48.4% of the among-group variation followed by conductivity (DF2) which explained and additional 29.4% of the variation (Figure 39).

Conditions during high flow episodes caused the results of discriminant analysis of tributary stations to yield a different characterization than was observed in the combined and low flow results. Although the clustering of groups remained the same, the parameters responsible for the majority of variation were different. Discriminant Function 1 was based on a combination of total ammonia, dissolved oxygen, and nitrate/nitrite, and accounted for 61.9% of the among-group variation. Discriminant Function 2 was based on conductivity and total Kjeldahl nitrogen, and was responsible for an additional 26.7% of group variation (Figure 40).

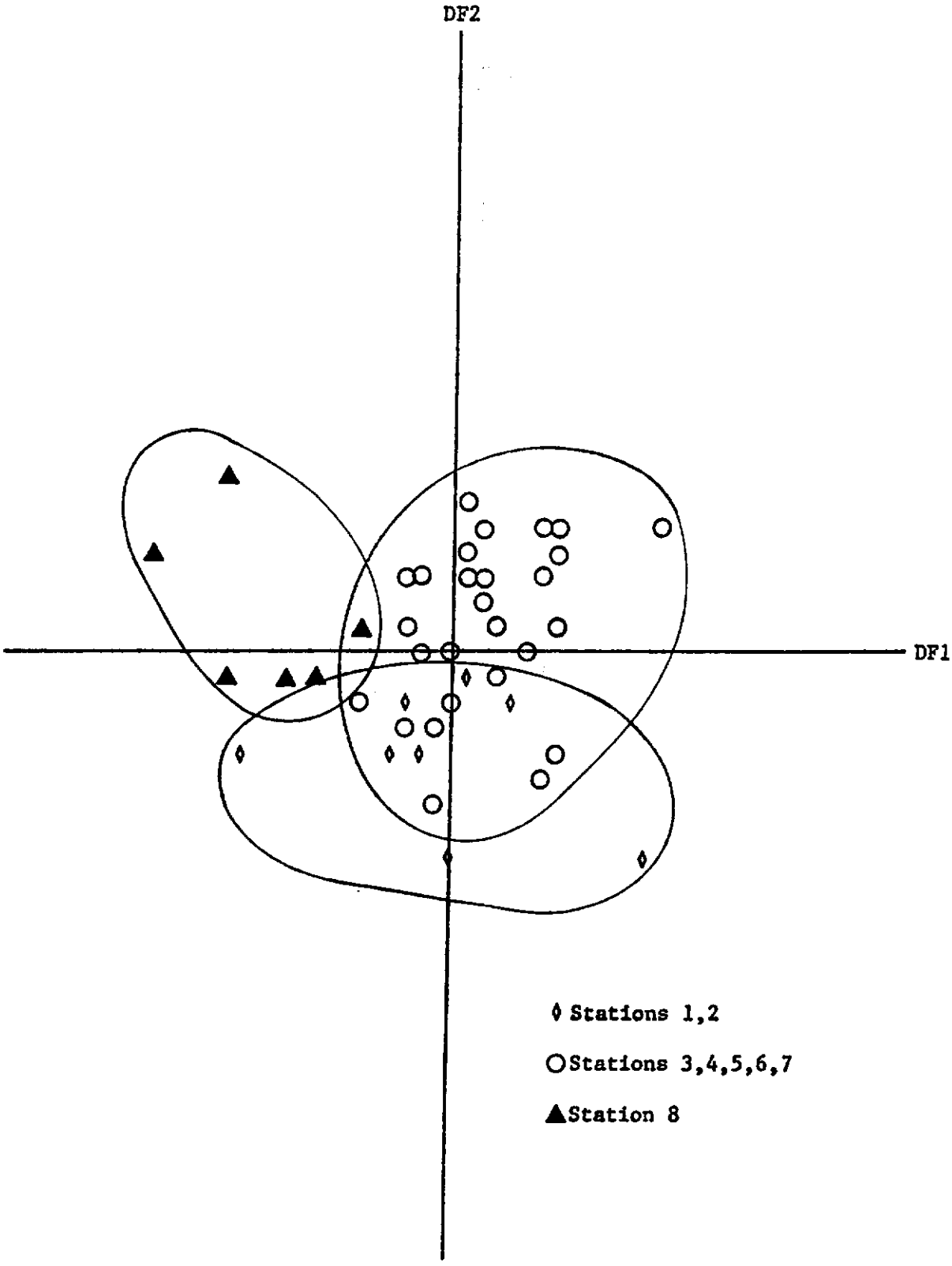


FIGURE 37. Orientation of river station groups in discriminant space for the period of high flow.

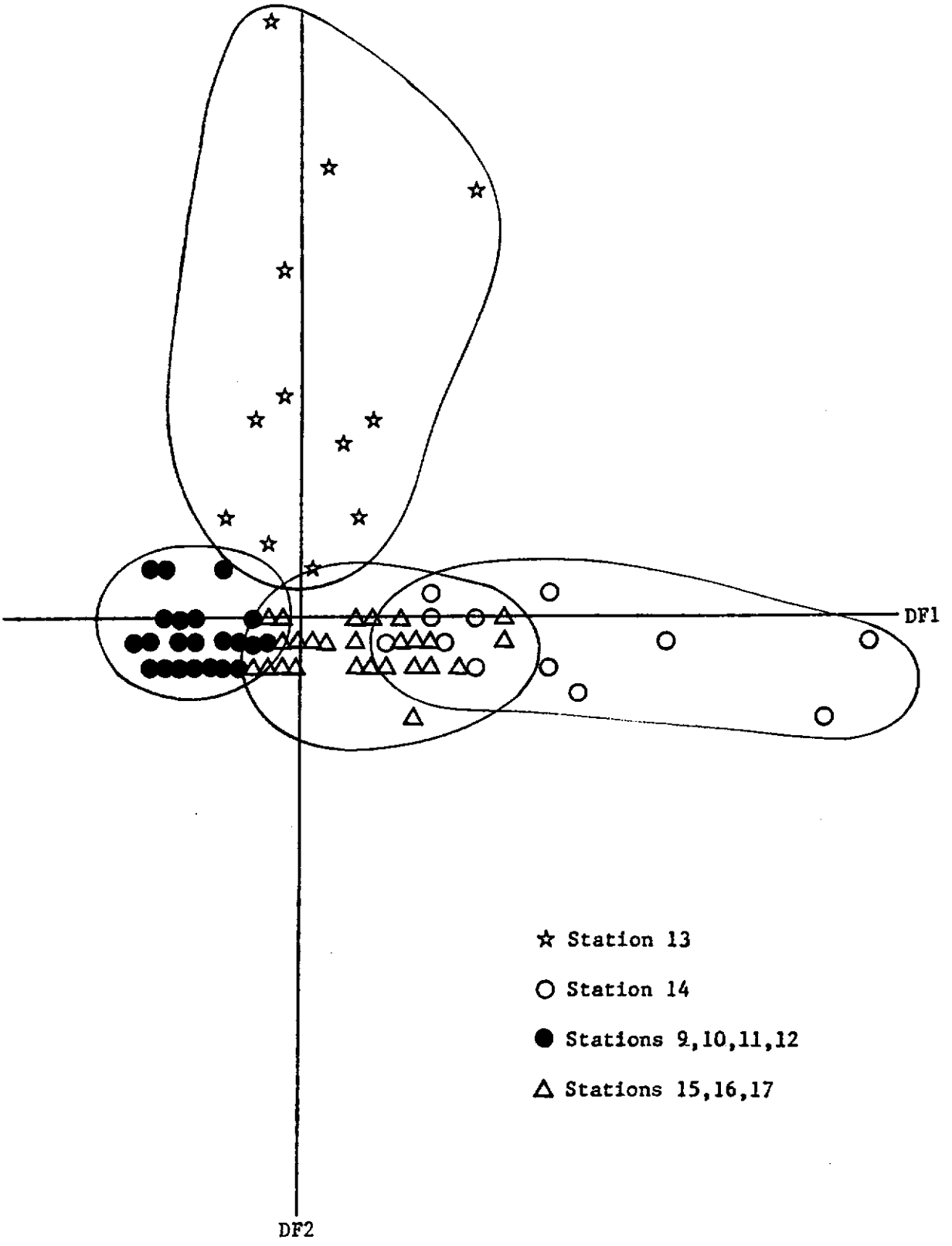


FIGURE 38. Orientation of tributary station groups in discriminant space for the entire sampling period.

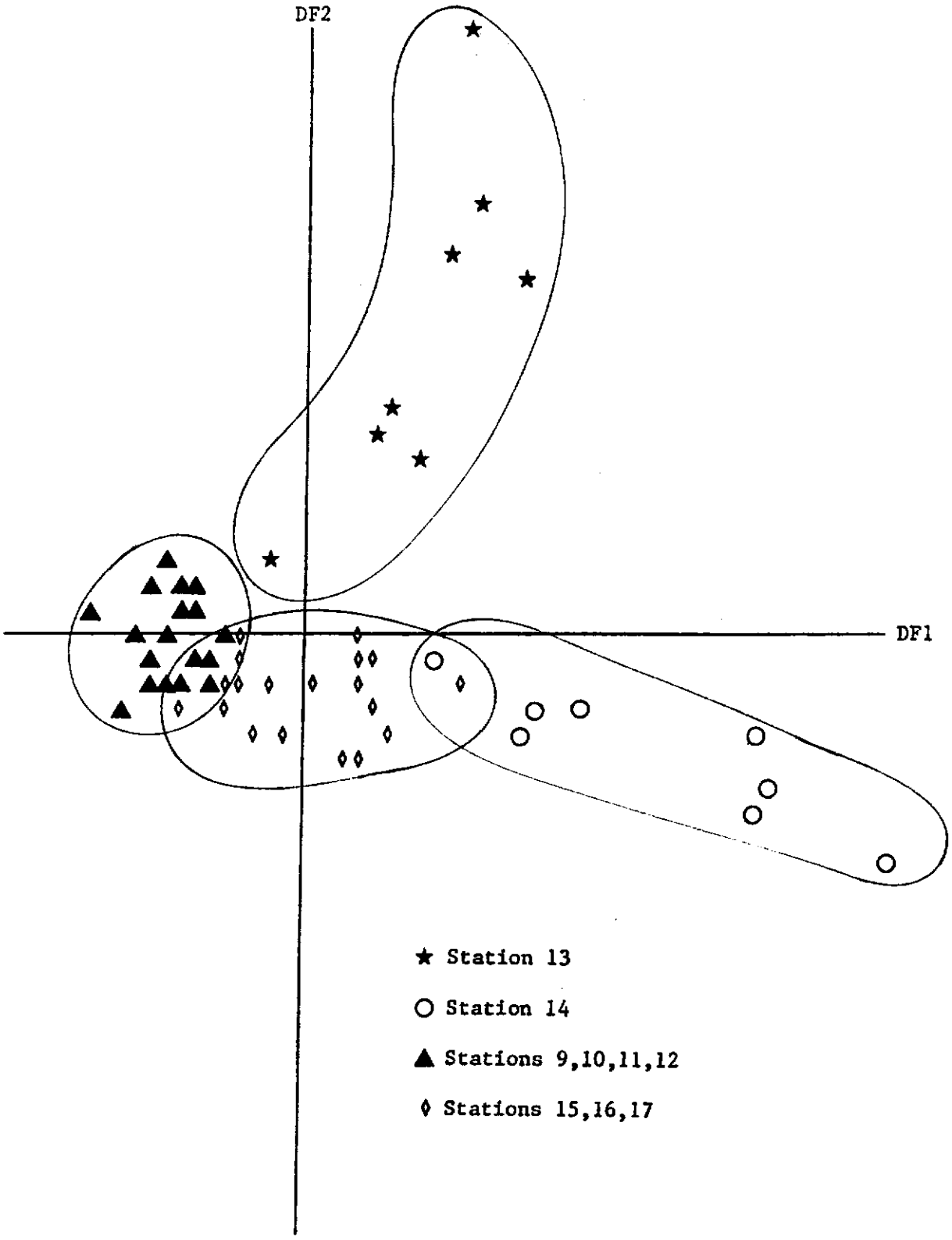


FIGURE 39. Orientation of tributary station groups in discriminant space for the period of low flow.

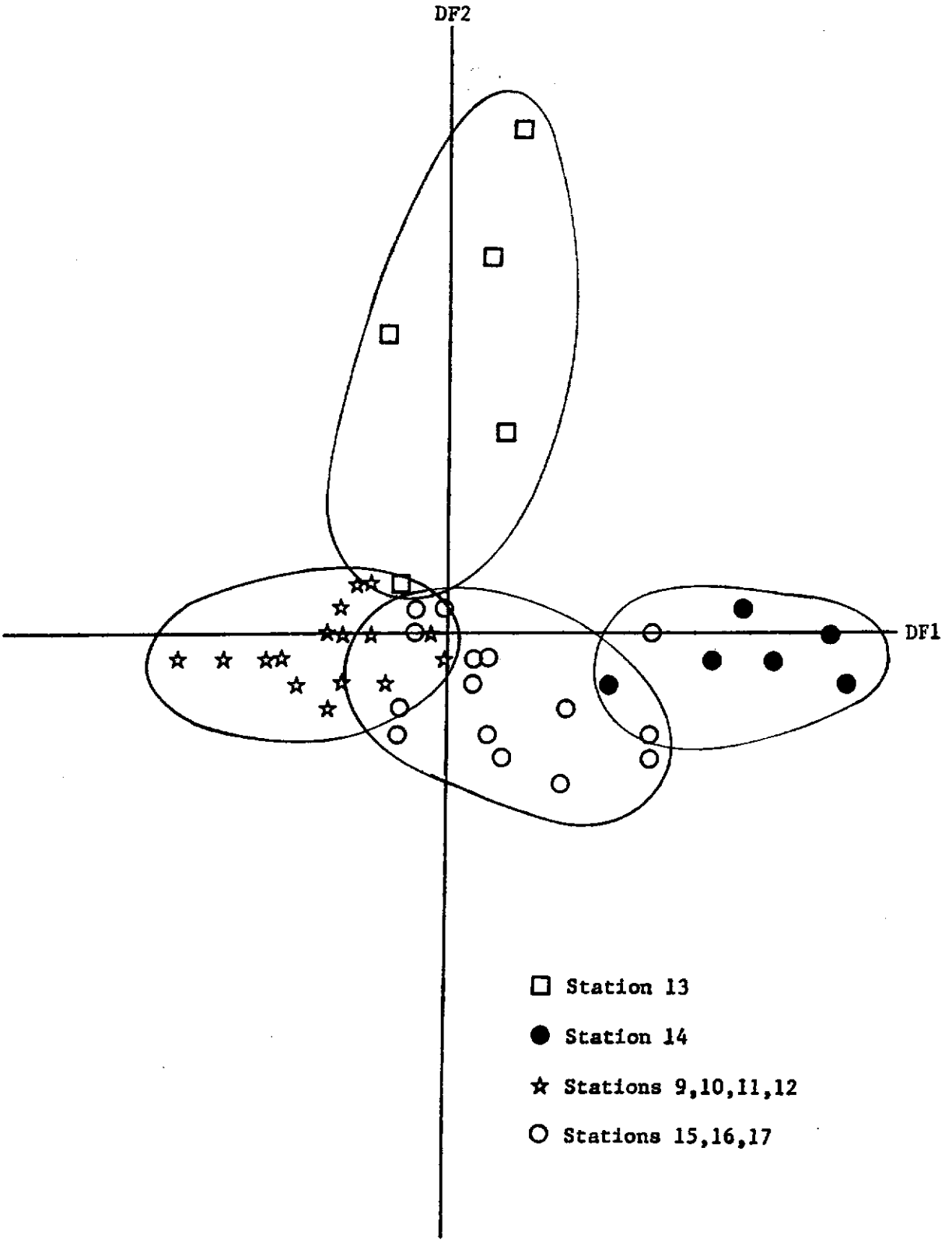


FIGURE 40. Orientation of tributary station groups in discriminant space for the period of high flow.

Historical Data

Data from previous studies retrieved from STORET (the E.P.A. water quality data computer storage system), and ongoing studies by U.S.G.S., have been compiled for comparison with DER results. Data retrieved from the U.S.G.S. Station near Havana, Florida, were quite useful, covering the periods between 1957 and 1962 and from 1965 through 1986. Data from other stations in the river (including the U.S.G.S./Ga. EPD cooperative station 3.2 miles north of the state line) were also compiled, but many measurements were too sporadic, and the period of record too short to be very useful in comparing historical trends. Means and standard deviations for compiled historical data measured at the U.S.G.S. Havana station are listed in Tables 12 and 13. No significant trends appeared in connection with the analysis of total phosphate, turbidity, conductivity, or alkalinity and hardness, however, data for several of these parameters were somewhat incomplete.

Total nitrogen concentrations appeared to be on the increase in the Ochlockonee River, which may reflect the increased usage of land for agricultural purposes. The mean total nitrogen concentration in 1957-1958 (U.S.G.S. gauging Station 7) was .33 mg/l, and by 1980 mean concentrations of total nitrogen reached levels as high as 7.43 mg/l (Figure 41). Mean total nitrogen concentrations for 1981 and 1982 (the only times such data were available) at the U.S.G.S./Ga EPD station (3.2 miles north of the State line) were 8.56 mg/l and 6.45 mg/l, respectively.

Since data from sediment analysis suggested a possible increase in sediment loads in the river, time series analysis (using the method of Buell and Grams 1985) was performed on data compiled since 1957. This involved linear regression of dissolved solids data on water discharge to remove streamflow-related variance in the solids data. Time series of flow-residual solids data were then tested for temporal trend using Spearman's rank correlation analysis ($r = .384$, $p = .01$). The results indicated a significant trend toward an increased solids load (Figures 42 and 43). This coincides with changes in land use patterns in the Ochlockonee Basin during the same time interval (see Land Use and Erosion Section). Time series analysis performed on solids data measured at the U.S.G.S./EPD station 3.2 miles above the State line also indicated a trend of increasing solids content, but the results were not significant at the 95% level. This lack of significance was probably due to the limited amount of data available at this station.

Increased sediment loading can have a variety of effects on stream habitats, as was pointed out in the Georgia DNR Ochlockonee River Basin Water Quality Investigation (June 1973), most importantly on organisms vital to the foodweb, such as macroinvertebrates. Continued increases in sediment loading in the Ochlockonee River can only exacerbate existing problems.

TABLE 12. Yearly means of historical data from U.S.G.S. gauging station near Havana, Florida. Standard deviations are in parentheses.

Year Oct - Sep	Solids Tons/Day	Total Nitrogen (mg/l as NO_3)[a]	Total Phosphorus (mg/l)	Turbidity (JTU)
1957-1958	327.3 (224)	.33 (.27)	No Data	No Data
1958-1959	207.7 (159)	.74 (.54)	"	"
1959-1960	179 (142)	.43 (.30)	"	"
1960-1961	348.7 (634)	.50 (.33)	"	"
1961-1962	40.9 (24)	.53 (.57)	"	"
1966-1967	33.2 (10.6)	.80 (.49)	"	"
1967-1968	36.0 (25.3)	1.31 (1.27)	"	"
1968-1969	87.0 (40.4)	1.04 (.92)	.60 (.41)	"
1969-1970	169.2 (122.2)	1.54 (1.14)	.58 (.26)	"
1970-1971	127.5 (136.5)	2.01 (1.13)	.56 (.19)	23.6 (15.5)
1971-1972	251.8 (324)	1.50 (1.84)	.79 (.73)	13.3 (4.1)
1972-1973	265 *	5.48 (2.99)	.13 (.06)	19 (9.62)
1973-1974	54.5 (2.12)	4.7 (1.3)	.20 (.1)	27 (15.1)

* Denotes the presence of only one data point for the sampling period indicated.
[a] U.S.G.S. parameter number 71887, which is a combination of several other nitrogen parameters.

TABLE 12. Continued.

Year Oct - Sep	Solids Tons/Day	Total Nitrogen (mg/l as NO_3)	Total Phosphorus (mg/l)	Turbidity (JTU)
1975-1976	142.7 (84)	3.99 (.92)	.14 (.05)	23.2 (11.4)
1976-1977	198.5 (189.4)	4.28 (1.41)	.17 (.09)	15.7 (9.2)
1977-1978	224.5 (262.3)	4.32 (1.14)	.31 *	17.5 (9.5)
1978-1979	328.6 (386.5)	5.12 (1.17)	.61 (.12)	19.6 (9.7)
1979-1980	158.6 (139.7)	6.04 (1.5)	.64 (.22)	8.7 (8.5)
1980-1981	72.0 (55)	7.43 (1.85)	1.11 (.26)	10.6 (6.6)
1981-1982	615.5 *	No Data	.85 (.39)	20.7 (7.6)
1982-1983	228.0 (181.8)	"	.48 (.21)	9.8 (3.9)
1983-1984	287.2 (110.9)	"	.43 (.08)	20.5 *
1984-1985	94.2 (47.2)	"	.55 *	9.4 (5.9)
1985-1986	448.5 (231)	"	.59 (.43)	8.9 (2.9)

* Denotes the presence of only one data point for the sampling period indicated.

TABLE 13. U.S.G.S. data gathered from 1957-1986 at U.S. 27, Havana, FL.

	MEAN (RANGE)			
	pH (Standard units)	Conductivity (umhos/cm^2)	Alkalinity (mg/l $CaCO_3$)	Hardness mg/l $CaCO_3$
Aug 1957 - Jul 1965	6.5 (5.8-7.9)	77.6 (24-201)	14.8 (5-42)	18.2 (5-48)
May 1966 - Nov 1970	6.7 (5.2-7.7)	138 (45-270)	21.3 (4-75)	27.2 (12-93)
Dec 1970 - Apr 1976	6.7 (6.1-7.5)	111.6 (44-320)	15.2 (5-30)	22.7 (10-44)
May 1976 - Sep 1986	6.6 (5.9-7.1)	152.8 (38-600)	17.6 (4-38)	24 (5-54)

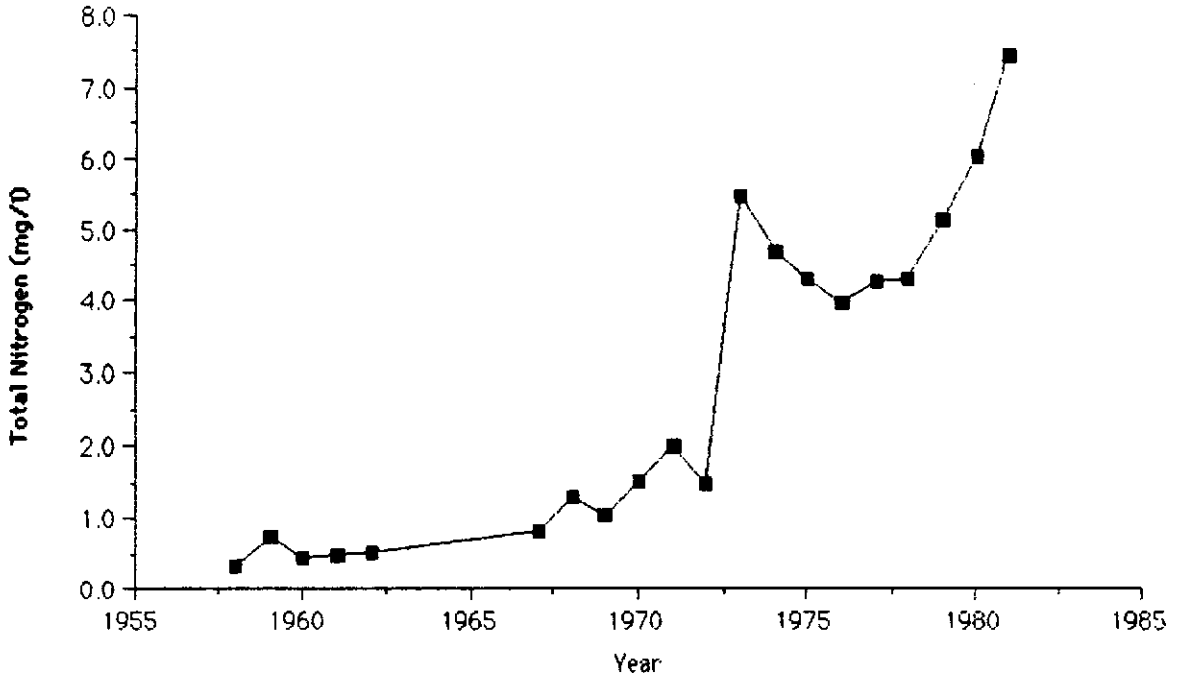


Figure 41. Mean total nitrogen concentrations (as NO_3) for USGS station 7 near Havana Fl. by year.

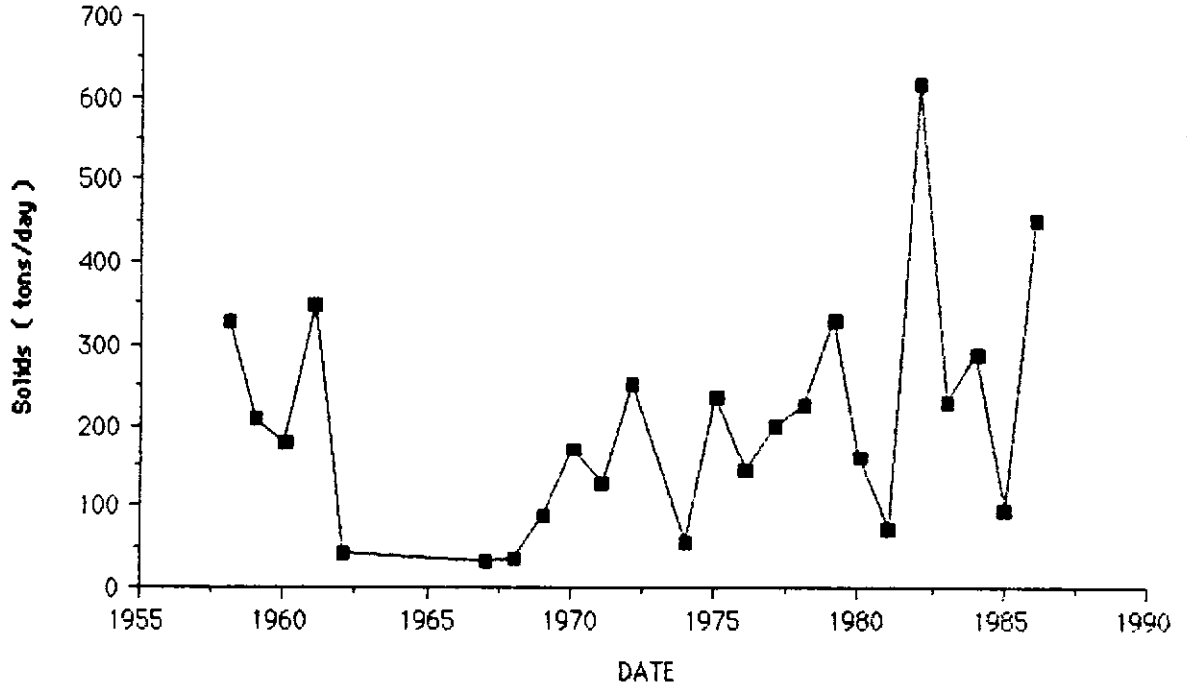


Figure 43. Mean solid loads for USGS station 7 near Havana Fl. by year.

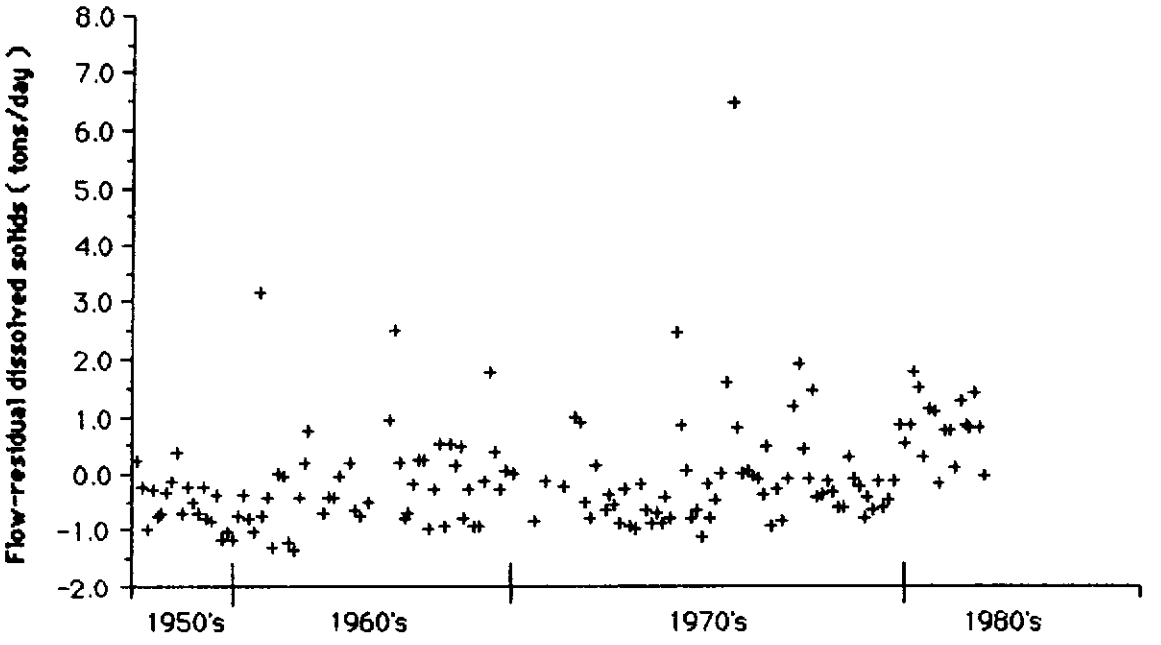


Figure 42. Time series analysis of regression data on solids and flow at USGS station 7 near Havana Fl.

Conclusions

Selected physico-chemical parameters seemed to reflect point and non-point source inputs which may have influenced the distribution of the biota of the river. Dissolved oxygen (D.O.) concentrations were occasionally depressed (below 4.0 mg/l) in the tributaries downstream of certain point sources. Although D.O. values never fell below 4.0 mg/l in the river, they sometimes approached this level at Stations 1, 2, 3, and 8 during the summer. Phosphorus concentrations peaked at Station 3, probably as a result of point source inputs from Oquina Creek. Tributary phosphorus and conductivity values were highest in the Tired Creek system. No phosphorus enrichment and only slightly elevated conductivities were observed at Station 5, downstream of that system. Nitrate enrichment was, however, observed at both Stations 3 and 5, probably as a result of inputs from Oquina Creek and Tired Creek, respectively.

Multivariate techniques isolated turbidity as the physical element accounting for the majority of variation among stations. In the Florida portion of the Ochlockonee River, extremely high turbidity values, particularly during high flow conditions, appeared to be the major water chemistry problem. Time series analysis of flow-corrected historical solids data indicated a significant increase in the solids content of the river since the 1960's. A trend of increasing total nitrogen was also observed. This corresponded with noteworthy increases in agricultural activities and, consequently, erosion in the basin during the same time period.

CHRONIC TOXICITY BIOASSAYS

Introduction

Bioassays of fish and other aquatic organisms are the most direct and cost-effective approaches to the measurement of potentially toxic substances in complex effluents (Peltier and Weber 1978). They are useful for a variety of purposes, including the determination of: 1) the suitability of environmental conditions for aquatic life, 2) the toxicity of an effluent, 3) the amount of wastewater treatment needed and the effectiveness of treatment methods, and 4) compliance with water quality standards, effluent requirements, and discharge permits (A.P.H.A. et al. 1985).

Chronic bioassays evaluate the effects of long term exposure of aquatic organisms to chemicals, effluents, or polluted water bodies. The most widely recognized sublethal chronic effects are those which produce various growth and reproductive impairments.

Since the Ochlockonee River supports viable fish, benthic invertebrate, and algal populations, the purpose of the chronic bioassays was to determine whether a sublethal toxicity problem exists in the river. By testing water samples collected from numerous locations in the study area, a wide range of data can be obtained which may help locate sources of discharges, or non-point source run-off. Additionally, since chronic tests can also be used to demonstrate acute toxicity, sources of acute toxicity can also be identified.

Methods

The aquatic organism chosen for use in these chronic tests was a freshwater macroinvertebrate, the cladoceran Ceriodaphnia dubia. The functional role of cladocerans is important to the biological community as these organisms convert phytoplankton and, perhaps more importantly, bacteria, into animal protein that is of nutritional value to vertebrates such as fish (Mount and Norberg 1983). This makes cladocerans a logical choice for use in aquatic toxicity testing since they are also readily available and are easily adaptable to laboratory conditions. They require little space and are among the more sensitive of aquatic organisms to toxic chemicals (Horning and Weber 1985).

Ceriodaphnia dubia has a world-wide distribution, is abundant and is important in the food web of freshwater streams, reservoirs, and lakes. Compared with other cladocerans, C. dubia has been determined to be more sensitive in toxicity tests and easier to culture (Horning and Weber 1985). Additionally, data obtained from C. dubia tests have been comparable to previous long-term chronic bioassays using Daphnia sp.

A continuous culture of Ceriodaphnia dubia was obtained from the U.S. EPA laboratory in Athens, Georgia, in June, 1985. This culture was kept under a 16:8 light-dark cycle in four 2.5 gallon aquaria, filled with unchlorinated DER well water. The Ceriodaphnia were fed a liquified blend of Fleishmann's® yeast, digested Purina Trout Chow® and Cerophyl® in suspension (3 mls) twice daily and once daily (6 mls) on weekends. The culture aquaria were kept at a constant temperature of 25° ± 2° C. The aquaria were cleaned weekly by siphoning off half the water along with detritus, algae, and excess organisms, then refilled with fresh well water.

Seven-day static renewal tests were conducted using methods similar to those of Horning and Weber (1985). C. dubia were exposed to control water and increasing concentrations of effluent or test water using ten replicates for each concentration. Results of the bioassays were based upon test organism survival and reproduction. Control organisms should produce three broods of neonates within a seven day time period.

For each series of bioassays (3-6 tests) and the culturing of test neonates, conditioned control water was used, consisting of 10 liters of DER well water to which 15 mls of digested Trout Chow® mixture was added then aerated for one week or more.

It was felt the DER well water was suitable for the continuous culture if proper food was supplied, and, therefore, that it was suitable for use as control water for the bioassays. Generally, toxicity tests should be conducted under conditions similar to those in which the animals were cultured (Adema 1978). Weekly measurements of the well water for the previous year provided confidence that each batch of conditioned control water would be adequate (Table 14). Procedures for culturing test organisms from gravid adults began no later than seven days prior to the start of a test. Approximately 300 gravid adults from the stock culture were obtained and placed into 700 mls of conditioned water (conditioned the prior week), left to acclimate in an incubator (25° ± 2°C, 16:8 light/dark cycle), and fed 0.5 mls of blended C. dubia food. One or two adults at a time (20 total for each test to be run) were transferred using a disposable borosilicate glass transfer pipet to individual one-ounce disposable salad dressing cups (manufactured by Anchor Hocking Plastics Division, obtained from Plastics, Inc., St. Paul, Minnesota). These cups (chambers) were soaked overnight in deionized water and filled with 15 mls of conditioned water. Plexiglass® (1/4") racks were built to hold the chambers, five rows by ten replicates, large enough to contain one entire bioassay. The chambers were filled with a device constructed in the laboratory similar to that shown in Figure 44.

One drop (.04 mls) of C. dubia food and two drops (.08 mls) of an algal culture (Ankistrodesmus sp; obtained in July, 1986 from Carolina Biological Supply) were placed into each cup daily. Cowgill et al. (1985) found that increased productivity resulted when Ankistrodesmus convolutus was fed to C. dubia. The feeding regime was enhanced in June by the addition of Ulothrix sp. (an alga growing in lab tank cultures) until

TABLE 14. Monthly means for DER well water characteristics, October, 1985 - November, 1986.

Month	Temperature °C	DO mg/l	pH	Conductivity mg/l	Alkalinity as $CaCO_3$	Hardness as $CaCO_3$
Oct 85	22.6	7.6	7.6	218	104	115
Nov 85	21.7	8.1	8.0	227	107	117
Dec 85	22.2	7.9	7.8	238	101	118
Jan 86	21.2	7.8	8.2	222	102	117
Feb 86	21.4	7.6	7.9	208	112	113
Mar 86	21.7	7.9	7.6	215	108	113
Apr 86	21.4	8.3	7.7	211	104	117
May 86	22.2	7.9	7.9	214	106	118
Jun 86	22.4	8.0	7.7	215	112	116
Jul 86	21.5	8.2	7.8	213	116	123
Aug 86	22.3	7.6	7.7	216	115	118
Sep 86	21.8	8.1	7.8	218	116	115
Oct 86	22.5	8.1	7.8	226	115	118
Nov 86	21.9	8.3	7.7	238	114	116

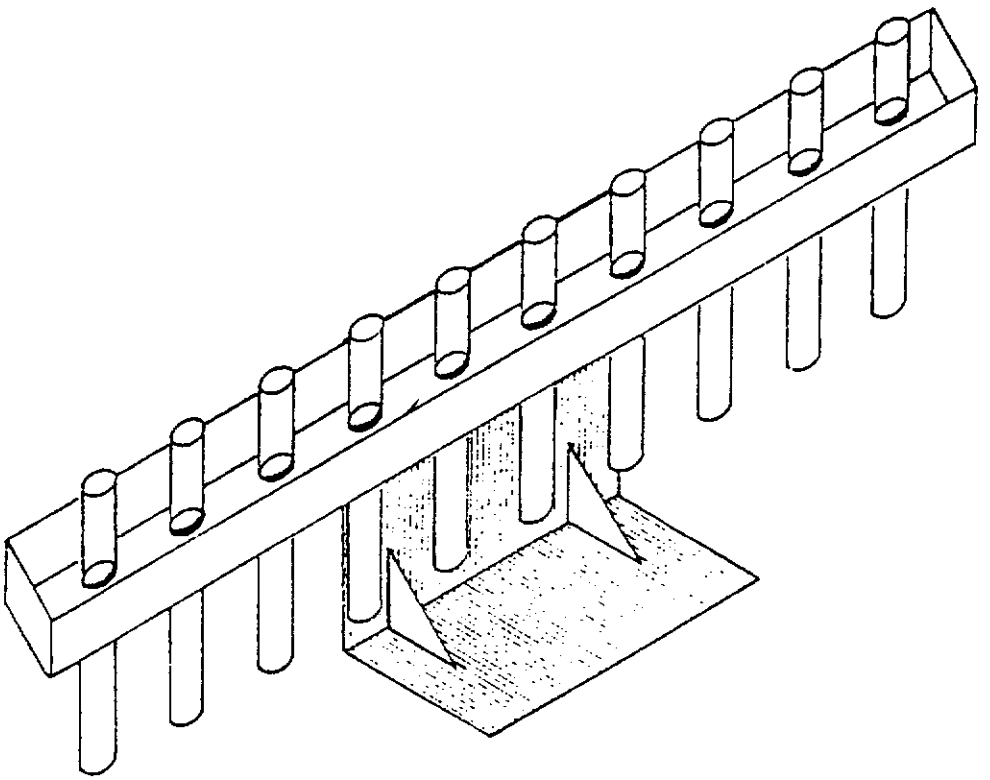


Figure 44. A device for dispensing 15 mls of test solution into beakers for the life cycle test.

Ankistrodesmus sp. was obtained and cultured. The size of broods increased in the control concentrations with the introduction of algae and provided greater similarity between tank cultures and test chambers. Ankistrodesmus sp. also proved easier to culture than Ulothrix.

Culture water was changed every two days prior to commencement of the bioassay series. The neonates were counted and discarded when culture water was changed. To obtain neonates released within four hours for the bioassay, it was necessary 24 hours prior to the start of the test, to change the culture water and feed the organisms. To assure a random selection of organisms, after four hours all neonates were removed and placed into 50 ml borosilicate jars filled with the conditioned control water prepared for the forthcoming static renewal test. These organisms were fed two drops of C. dubia food and four drops of Ankistrodesmus sp. The jars were then sealed loosely with Parafilm® and placed into the incubator overnight.

On the same day, grab samples of effluent, mixing zone waters, river, or tributary waters were collected in collapsable plastic containers and transported on ice to the DER biology laboratory, where they were stored in a refrigerator (4°C) until used. All tests were initiated within 24 hours of sample collection. On the day of, and prior to the test, each water sample container was placed in a warm water bath and the temperature allowed to rise to 23° $\pm$ 2°C. This was done to avoid any temperature stress to the test organisms when they were introduced into the test solutions. The same grab sample was used throughout one test.

Enough test solution (300 mls) was prepared for each test concentration, using the same batch of control water as the neonates and sample water. In most of the bioassays the ratio of control water to test water solution mixed were: control 100%/0%, 75%/25%, 50%/50%, 25%/75%, and 0%/100% using ten replicates, 15 mls per chamber. These solutions were mixed in concentrations prescribed by Horning and Weber (1985) with the exception of the 75% test solution. This concentration was added to obtain greater accuracy, especially for the river and tributary samples. The remaining test sample water was stored at 4°C for later use. These solutions were prepared in autoclaved flint glass 1 liter jars. Normally a series of bioassays was performed using one control for 3-6 tests. Water quality characteristics monitored included temperature, dissolved oxygen, pH, conductivity, alkalinity, and hardness. The latter two were only performed on control water and 100% test water. If their presence was suspected, values for total residual chlorine using HACH® Kit Model CN-70 and ammonia as N (Orion Research Microprocessor Ionalyzer/901®) were also measured.

After measurements were recorded, the test water treatments were poured into the rinsed test chambers using the solution pouring rack which had also been rinsed with deionized water (Figure 44). To avoid contaminating each prepared solution, care was taken to pour from lowest to highest concentration and rinse the rack with deionized water between each treatment water poured. Individual C. dubia neonates ($\leq$ 24 hours)

were loaded, one per test chamber. The organisms were fed one drop of C. dubia food and two drops of Ankistrodesmus sp. daily. Chambers were examined daily. Neonates were then counted and discarded, after which the adults were fed. Test waters were prepared, water quality characteristics recorded, and treatments renewed twice during the bioassay using the same procedures as before. Dissolved oxygen measurements were performed on solutions after 48 hours of exposure to ensure that mortality was not due to lack of oxygen. The test lasted 7 days $\pm$ 2 hours.

The test organisms should produce three or more broods of young during a seven-day period (Horning and Weber 1985). The number of young produced per adult female was determined by taking the total number of young produced until either the death of the adult or the end of the experiment, whichever came first. If an animal died before producing young, it was included in the analysis and zero was recorded as the number of young produced. The calculation of the mean number of young produced per adult for each toxicant concentration provided a combined measure of the toxicant's effect on mortality and reproduction (Horning and Weber 1985).

Quality control was monitored by using 48 hour acute toxicity tests performed on Ceriodaphnia dubia to determine sensitivity of the organism to the reference toxicant, sodium lauryl sulfate. Control water was used as dilution water. Results of the standard reference toxicant tests are presented in Table 15.

Results

Dunnett's Procedure (Dunnett 1955) and Fisher's Exact Test (Finney 1948, Pearson and Hartley 1962) were used for statistical analysis of the production of neonates and survival of adults, respectively (Horning and Weber 1985). Dunnett's Procedure includes an analysis of variance (ANOVA) used in the comparison of each toxicant treatment to the control mean. The total number of neonates produced per individual organism was entered and normalized with a $\log_{10}$ transformation. The resulting NOEC (no observed effect concentration) and LOEC (lowest observed effect concentration or the minimum difference in total number of neonates produced in the control and each treatment which was statistically significant) were determined from the Dunnett's Procedure. The chronic value (ChV) was calculated as follows:

$$ChV = \text{Antilog}\ (\text{Log}_{10}\ (NOEC) + \text{Log}_{10}\ (LOEC))/2$$ (Horning and Weber 1985)

Fisher's Exact Test was used to determine significant difference (SD) between the survival of the adults in the control and each toxicant treatment. Data are presented in Table 16, as simply the minimum treatment showing a statistically significant difference from the control (Horning and Weber 1985).

TABLE 15. Results of standard reference toxicant bioassays using sodium lauryl sulfate (ppm).

Month	LC_{50}
Aug 85	1.6
Nov 85	1.6
Feb 86	2.2
Apr 86	8.2
May 86	5.2
Jun 86	5.4
Jul 86	5.1
Aug 86	[a]
Sep 86	3.5
Oct 86	5.8

[a] Irregular distribution of mortality. LC_{50} could not be calculated.

TABLE 16. Results of Ceriodaphnia dubia bioassays.

STATION #	BIOASSAY #	DATE	PARAMETERS TEMP °C	DO mg/l	pH	CONDUCTIVITY umhos/cm²	ALKALINITY $CaCO_3$	HARDNESS $CaCO_3$	RESULTS CONTROL	25	50	75	100%	ChV	SD	COMMENTS
1	39	18 Jul 86	22.2-26.2	8.5-9.6	6.9-8.2	115-188	31	31	179	126	243	169	252	a	b	
1	51	8 Aug 86	21.7-25.1	7.3-11.4	6.9-8.1	95-192	20	20	156	205	231	229	199	a	b	
1	64	12 Sep 86	23.3-24.1	8.9-9.1	6.9-7.9	90-211	21	23	0	0	0	0	0		c	Cause of mortality unknown
2	40	18 Jul 86	22.0-25.4	8.4-10.2	6.9-8.2	98-235	28	27	179	146	135	158	218	a	b	
2	65	12 Sep 86	23.3-25.9	8.6-9.1	6.9-7.9	80-211	29	27	0	0	0	0	0		c	Cause of mortality unknown
3	41	18 Jul 86	22.0-25.2	8.5-9.5	7.2-8.2	205-348	68	75	179	115	34	0	0	35.36	75	Toxicity due to input of point-sources and nonpoint sources into Oquina Creek
3	52	8 Aug 86	22.0-25.0	7.3-9.4	7.8-8.1	135-232	15	20	156[d]	189	235	201	189	a	b	
3	66	12 Sep 86	17.9-23.3	8.8-9.1	7.3-7.9	105-211	20	31	0	0	1	0	1		c	Cause of mortality unknown
4	42	18 Jul 86	22.0-24.5	8.6-10.6	7.4-8.2	220-275	60	65	179	125	244	251	190	a	b	
4	68	12 Sep 86	23.1-23.3	8.4-9.1	7.2-7.9	100-211	62	68	0	0	0	0	1		c	Cause of mortality unknown
5	38	11 Jul 86	23.7-26.7	7.6-10.1	7.2-8.0	228-295	61	57	89	91	111	104	181	a	b	
5	43	18 Jul 86	22.0-25.6	8.5-10.4	7.2-8.0	205-278	61	65	179	233	148	194	169	a	b	
6	45	1 Aug 86	21.0-24.0	8.4-11.4	7.1-7.6	145-200	32	40	217	283	341	325	166	a	b	
6	53	8 Aug 86	22.3-24.7	7.2-10.8	7.3-8.1	146-200	44	35	156	215	192	237	262	a	b	
6	46	1 Aug 86	22.1-23.6	8.5-11.2	7.2-8.0	148-202	31	38	217	320	286	308	165	a	b	

[a] No chronic value.
[b] No significant difference.
[c] Control mortlaity > 20%.
[d] Concentrations for this assay: Control, 5, 10, 25, 100%.

TABLE 16. Continued.

STATION #	BIOASSAY #	DATE	PARAMETERS TEMP °C	DO mg/l	pH	CONDUCTIVITY umhos/cm^2	ALKALINITY $CaCO_3$	HARDNESS $CaCO_3$	RESULTS CONTROL	25	50	75	100%		ChV	SD	COMMENTS
7	47	1 Aug 86	21.7-23.5	8.5-11.0	7.3-7.8	182-206	44	45	217	264	267	281	236		a	b	
8	48	1 Aug 86	23.2-24.6	8.1-11.0	7.0-7.9	72-188	21	18	217	250	204	244	148		a	b	
9	14	13 May 86	24.5-27.8	8.1-9.7	6.6-8.0	86-230	5	17	47[e]	60	99	68	68	140	a	b	
9	55	28 Aug 86	21.9-25.9	8.1-8.9	5.0-7.8	170-220	10	43	0	9	2	6	5			c	Cause of mortality unknown.
9	60	5 Sep 86	21.4-26.4	7.9-10.8	5.1-8.0	140-240	11	30	160	168	146	141	68		86.60	b	
10	13	8 May 86	22.7-25.9	7.2-3.8	6.5-7.9	68-252	10	30	89[e]	116	164	158	162	61	a	b	
10	56	28 Aug 86	21.9-24.0	6.3-8.1	6.5-7.8	74-220	23	25	0	2	8	11	21			c	Cause of mortality unknown.
11	61	5 Sep 86	21.4-25.9	8.4-10.9	6.5-8.2	68-240	18	21	169	179	189	176	180		a	b	
12	20	6 Jun 86	23.6-29.3	7.9-8.0	6.4-8.0	52-248	10	23	249	208	344	320	201		a	b	
13	1	9 Dec 85	20.9-24.6	7.3-9.1	6.5-8.0	225-1780	16	49	0[f]	0	0	0	0			c	High conductivity attributed to Roddenberry point source upstream.
13	3	29 Jan 86	22.1-26.2	7.6-8.1	7.5-8.4	222-1395	10	22	28	0	10	-	29			c	" "
13	4	19 Feb 86	24.4-25.7	7.4-9.14	6.4-8.0	249-400	18	20	0[h]	0	11	-	0			c	Lower conductivity due to rainfall event prior to sampling
13	5	4 Mar 86	24.1-25.7	8.0-9.2	6.8-7.1	200-1220	39	43	21	56	28	-	0			c	High conductivity attributed to Roddenberry point-source upstream.

[a] No chronic value.
[b] No significant difference.
[c] Control mortality > 20%.
[e] Concentrations for this assay: Control, 5, 10, 25, 50, 100%.
[f] Concentrations for this assay: Control, 10, 25, 50, 100%.
[g] Concentrations for this assay: Control, 5, 50, 100%.
[h] Concentrations for this assay: Control, 30, 50, 100%.

TABLE 16. Continued.

PARAMETERS									RESULTS								
STATION #	BIOASSAY #	DATE	TEMP °C	DO mg/l	pH	CONDUCTIVITY umhos/cm²	ALKALINITY $CaCO_3$	HARDNESS $CaCO_3$	CONTROL	25	50	75	100%		ChV	SD	COMMENTS
13	15	13 May 86	24.5-27.1	8.1-8.8	6.9-8.1	209-800	15	32	47[e]	73	79	138	124	156	a	b	Lower conductivity due to rainfall event.
13	36	11 Jul 86	21.0-31.5	6.6-10.6	6.9-7.9	250-1800	73	89	89	125	104	65	117			c	High conductivity attributed to low flow conditions.
13	57	28 Aug 86	21.9-23.9	8.4-9.1	7.1-7.8	220-2300	35	58	0	0	19	3	1			c	" "
13	62	5 Sep 86	21.4-25.8	8.5-11.2	7.2-8.2	210-1610	23	36	169	200	231	237	115		86.60	b	" "
14	2	29 Jan 86	22.1-27.5	7.3-8.1	7.2-8.4	222-274	67	47	28[g]	0	0	5	-	8		c	Methodology not perfected.
14	6	4 Mar 86	23.0-25.6	7.6-8.3	6.8-7.9	55-245	45	63	34	62	29	25	20			c	" "
14	16	13 May 86	24.5-26.6	7.9-9.4	7.5-8.1	209-610	98	164	47[e]	114	79	35	64	0	a	100	NH_3N measured 4.0 ppm
14	37	11 Jul 86	24.0-25.0	7.6-10.3	7.0-8.0	290-600	100	152	89	108	87	127	21			c	Cause of mortality unknown
14	58	28 Aug 86	21.9-23.2	7.7-8.9	7.3-7.8	180-320	95	119	0	9	12	11	11			c	" "
14	63	5 Sep 86	21.4-26.2	8.7-10.6	7.4-8.1	210-370	75	113	169	126	95	40	8		61.24	75	Total Cl_2 measured 0.0 ppm
15	21	6 Jun 86	20.4-29.9	8.0-9.9	6.6-8.0	95-218	13	34	249	343	318	257	260		a	b	
16	22	6 Jun 86	22.3-27.5	7.8-9.1	7.0-8.1	188-239	23	47	249	258	84	24	0		35.36	50	Total Cl_2 measured 0.0 ppm-Toxicity attributed to effects of upstream point source discharges.
17	17	13 May 86	25.2-27.9	7.9-9.8	7.3-7.8	145-232	52	62	87[e]	109	116	145	137	96	a	b	

[a] No chronic value.
[b] No significant difference.
[c] Control mortality > 20%.
[e] Concentrations for this assay: Control, 5, 10, 25, 50, 100%.
[g] Concentrations for this assay: Control, 5, 50, 100%.

TABLE 16. Continued.

PARAMETERS									RESULTS								
STATION #	BIOASSAY #	DATE	TEMP °C	DO mg/l	pH	CONDUCTIVITY umhos/cm^2	ALKALINITY $CaCO_3$	HARDNESS $CaCO_3$	CONTROL	25	50	75	100%		ChV	SD	COMMENTS
17	23	6 Jun 86	23.2-28.5	8.1-9.4	7.0-8.1	148-235	48	61	249	349	333	352	283		a	b	High reproduction rate probably due to unknown nutrient or bacterial source.
17	44	1 Aug 86	22.0-23.9	8.2-10.4	6.9-8.0	139-218	53	43	217	264	331	333	300		a	b	" "
T'Ville WPCP	10	18 Apr 86	22.5-26.8	7.8-9.2	7.0-8.2	250-800	58	130	110[i]	99	81	98	118	27	54.77	b	Total Cl_2 measured prior to de-chlorination 9.3 ppm sample taken at point of of discharge (p.o.d.).
T'Ville WPCP	11	18 Apr 86	22.8-25.4	7.8-8.8	8.0-8.4	235-322	63	135	164[j]	79	36	24	11	0	0.17	1.0	Total Cl_2 measured prior to 9.3 ppm. Sample taken at p.o.d.
T'Ville WPCP	19	13 May 86	25.2-27.9	8.0-8.7	7.4-8.3	212-810	106	165	87[k]	129	105	103	101	0-0	35.36	50	Total Cl_2 measured 1.5 ppm. NH_3N measured 10.0 ppm.
T'Ville WPCP	27	13 Jun 86	24.8-27.6	5.2-8.1	7.5-8.1	220-560	145	161	210	82	0	0	0		35.36	25	Total Cl_2 measured 0.8 before de-chlorination. NH_3N measured 10.0 ppm.
Above T'Ville WPCP	18	13 May 86	25.2-26.3	7.9-9.9	7.7-8.2	220-1320	120	170	87[e]	147	101	68	68	69	2.76	50	Total Cl_2 measured 0.0 ppm, NH_3N measured 0.4 ppm.
Above T'Ville WPCP	26	13 Jun 86	24.0-26.9	7.6-9.9	7.3-8.1	220-405	46	87	210	312	295	207	161		a	100	High flow conditions, sample taken 100 ft above discharge.
Above T'Ville WPCP	67	13 Sep 86	23.1-23.5	8.7-9.1	7.4-7.9	211-580	52	89	0	1	0	0	0	0		c	Sample taken 100 ft above discharge

[a] No chronic value.
[b] No significant difference.
[c] Control mortlaity > 20%.
[e] Concentrations for this assay: Control, 5, 10, 25, 50, 100%.
[i] Concentrations for this assay: Control, 0, 3, 10, 30, 100%.
[j] Concentrations for this assay: Control, 0.1, 0.3, 1.0, 3.0, 10.0%.
[k] Concentrations for this assay: Control, 1, 5, 10, 25, 50, 100%.

TABLE 16. Continued.

STATION #	BIOASSAY #	DATE	PARAMETERS TEMP °C	DO mg/l	pH	CONDUCTIVITY umhos/cm²	ALKALINITY $CaCO_3$	HARDNESS $CaCO_3$	RESULTS CONTROL	25	50	75	100%		ChV	SD	COMMENTS
Pine Tree Blvd	25	13 Jun 86	24.8-27.6	7.9-10.4	7.2-8.1	220-400	52	83	210	263	246	208	200		a	100	Sample taken from tributary to Oquina Creek. Receives stormwater runoff from city recreational park.
Sunny-land	31	20 Jun 86	24.9-25.6	0.3-8.2	6.4-8.1	210-3100	200	195	124	118	7	0	0		35.36	75	Low DO due to high BOD. Samples taken from overflow discharge. High conductivity due to industrial discharge. Concentrations were aerated.
Sunny-land	50	8 Aug 86	21.9-25.1	7.3-10.8	7.5-8.1	215-2020	130	190	156	165	141	142	26		86.60	100	Sample taken at NPDES permitted discharge. Note high conductivity.
Above Sunny-land	30	20 Jun 86	24.8-25.6	7.6-8.7	7.1-8.1	210-225	68	106	124	203	125	40	8		86.60	50	Sample taken 100 ft above discharge.
Chatham Road	24	13 Jun 86	24.5-27.6	7.6-10.2	7.0-8.1	135-235	27	53	210	224	185	24	4		61.24	50	Above Sunnyland. Creek receives stormwater runoff from the City of Thomasville. Origin of creek within the city.
Below T'Ville WPCP	49	8 Aug 86	20.6-25.2	7.3-9.5	7.5-8.1	198-650	110	115	156	148	89	4	0		61.24	59	Sample taken 300 ft below discharge. Cl_2 measured at 0.3 ppm. Sample de-chlorinated. NH_3N measured at 1.37 ppm.
Cairo WPCP	8	25 Mar 86	24.5-25.0	9.3-9.8	7.6-8.3	275-340	31	69	0	0	0	-	0			c	Methodology not perfected.
Cairo WPCP	29	20 Jun 86	24.4-25.6	7.8-9.0	7.3-8.1	210-438	114	128	Laboratory accident at 5 days.								

[a] No chronic value.
[c] Control mortality > 20%.

TABLE 16. Continued.

STATION #	BIOASSAY #	DATE	PARAMETERS TEMP °C	DO mg/l	pH	CONDUCTIVITY umhos/cm²	ALKALINITY $CaCO_3$	HARDNESS $CaCO_3$	RESULTS CONTROL	25	50	75	100%		ChV	SD	COMMENTS
Cario WPCP	35	11 Jul 86	23.5-32.9	7.3-8.3	7.3-8.0	295-700	125	143	89[k]	96	9	0	0		15.81	25	Sample taken at p.o.d. Total Cl_2 measured at 0.0 ppm.
Above Cairo WPCP	28	20 Jun 86	24.4-26.5	7.8-8.9	7.0-8.1	131-220	25	46	124	189	253	124	122		[a]	b	Sample taken 100 ft above discharge.
Rodden-berry	7	25 Mar 86	24.6-25.8	6.8-9.5	7.5-8.4	362-625	32	39	0	0	1	-	0			c	Lower conductivity attributed to flow conditions.
Rodden-berry	34	11 Jul 86	23.7-27.1	7.1-9.9	7.3-8.0	250-4000	47	125	89	77	22	121	19			c	Sample taken 1 mile below p.o.d.
Rodden-berry	54	28 Aug 86	21.9-23.8	8.7-8.9	7.4-7.8	220-2300	46	79	0	0	0	0	0			c	" "
Rodden-berry	59	5 Sep 86	21.4-25.1	8.6-10.6	7.4-8.2	210-4550	34	58	169	132	128	81	0		70.71	100	" "

[a] No chronic value.
[b] No significant difference.
[c] Control mortality > 20%.
[k] Concentrations for this assay: Control, 1, 5, 10, 25, 50, 100%.

Results of the 64 Ceriodaphnia dubia chronic toxicity bioassays are presented in Table 16. Twenty-one of these tests were invalidated due to either excessive control mortality (> 20%) or to the failure of the controls to produce at least three broods of neonates during the test. Of the valid results obtained from the river station bioassays, only one (Station 3), downstream from Oquina Creek, proved to be both chronically and acutely toxic. Water from four tributary stations (9, 13, 14, and 16) proved to be chronically toxic, with two of these (14 and 16) also exhibiting acute toxicity. All point source discharges and mixing zone waters sampled were found to be either chronically toxic or acutely toxic or both. The remaining bioassays indicated no toxicity.

In 21 bioassays, organisms exposed to 50% or 75% test water treatments exhibited an increase in reproduction, while in 15 bioassays organisms exposed to 100% test water showed a decrease in reproduction when compared to the 50 and 75% treatments. Record high reproduction rates were noted for two tests conducted on water sampled from Station 17 (Tests 23 and 44, June 6, 1986, and August 1, 1986, respectively). The production of neonates in the 50 or 75% concentrations averaged 332 and 343, respectively. As with many of the bioassays the number of neonates in the 100% treatment fell. An average of 292 organisms was noted for the two bioassays. This production of young was significantly greater than the number of young produced by the controls (249 and 213 neonates, respectively). The bioassay conducted on Station 12 (June 6, 1986) also produced a high number of neonates, with 344 counted in the 50% concentration and 320 in the 75%. The 100% treatment again showed a decrease (201).

On June 13, 1986, samples from Oquina Creek were collected to determine whether this was the source of the toxicity exhibited at Station 3. Samples were collected at sites along Oquina Creek including: (1) Chatham Road, above the Sunnyland packing plant, (2) Pine Tree Boulevard, a bridge over a small tributary to Oquina Creek not influenced by the Sunnyland effluent, (3) a point 100 meters above the discharge pipe of the Thomasville Water Pollution Control Plant, and (4) the point of discharge of the treatment plant itself. The Chatham Road test resulted in a chronic value of 61.24% and a significant difference at 50% compared with survival of control organisms. Both the chronic tests performed on Pine Tree Boulevard and the sample collected 100 meters above the Thomasville Water Pollution Control Plant resulted in no chronic value but a significant difference in survival of adults in the 100% concentration compared to the control was noted. The final bioassay on sample waters taken directly from the NPDES permitted pipe of the Thomasville plant resulted in a chronic value of 35.36% and a significant difference in the 50% concentration after the sample was de-chlorinated (Table 16).

The Sunnyland NPDES permitted discharge pipe was also located and the effluent tested June 20, 1986, and August 8, 1986. The results of these bioassays indicated that the wastewater produced calculated chronic values of 35.36% and 86.60%, respectively. Also, a significant difference was noted in the number of surviving adults exposed to the 75% and 100%

treatments respectively, compared to the number of surviving adults in the control. Physical-chemical characteristics of the effluent (sampled on June 20, 1986) indicated a low dissolved oxygen concentration (0.3 mg/l) and an unusally high conductivity (3100 umhos/cm^2). This test was aerated. For the August 8th test, a conductivity of 2020 umhos/cm^2 was measured.

Additional chronic bioassays of the discharge from the Thomasville Water Pollution Control Plant (Tests 10, 11, and 19) all resulted in chronic or acute toxicity, with the exception of Test #10 (no significant difference in adult survival). Chronic values calculated for those tests were 54.77%, 0.17%, and 35.36%, respectively. Significant differences in reproduction between exposed organisms and the controls for Tests 11 and 19 occurred in the 1.0% and 50% treatments, respectively. It was noted that the total residual chlorine measured for these samples was 9.3 mg/l. The sample used in Test 10 was de-chlorinated prior to use. For Test 19, total residual chlorine measured 1.5 mg/l, but was de-chlorinated prior to use. Of the samples collected 100 meters above the Thomasville WPCP discharge, the May 13th bioassay (Test 18) resulted in a calculated chronic value of 2.76, and a significant difference in adult survival in the 50% concentration. The results of the June 13th test indicated acute toxicity in the 100% treatment.

Of the seven tests performed on Stations 9, 10, 11, and 12 of the Barnett Creek watershed, two were invalidated due to control mortality greater than 20%. The September 5, 1986 bioassay on samples from Station 9 (Test 60) produced a chronic value of 86.60%. However, there was no acute effect. The balance of the tests indicated no chronic or acute toxicity. Of the two bioassays conducted on Station 4, below Barnett's Creek, the July 18th test (Test 42) resulted in no toxicity and the September 12th test (Test 68) was invalidated due to excessive control mortality.

A total of 25 tests were performed on water from the Tired Creek region, including Station 5. Eight tests were conducted on samples from Station 13. Of these, five were discarded due to excessive control mortality and one was discarded because fewer than three broods were produced. Successful bioassays were conducted May 13, 1986, (Test 15) and September 5, 1986 (Test 62). The former indicated no toxicity while the latter produced a chronic value of 86.60%. No significant difference in adult survival was observed. The principal discharge affecting Station 13 was effluent produced by the Roddenberry Company, a food processing plant. Four bioassays were conducted from a sample collected approximately one mile downstream from the point of discharge. One bioassay, (Test 59) performed September 5, 1986, resulted in a chronic value of 70.71% and a significant difference in the 100% concentration. Due to excessive control mortality, the remaining bioassays were invalidated. Conductivity measured in the samples varied from 625 to 4550 umhos/cm^2 for all tests. All other water quality characteristics were normal.

Six bioassays were performed on samples from Station 14. Of these, a chronic value of 61.24% was measured in the September 5, 1986 test (Test 63) and a significant difference in adult survival was observed in the 75% treatment. For the May 13, 1986 test (Test 16) a significant difference was only measured in the 100% concentration. The remainder of the bioassays were invalidated due to excessive control mortality and, in one case, because fewer than three broods were produced.

The principal discharge influencing Station 14 is the Cairo Water Pollution Control Plant. Three tests were conducted on samples obtained at the point of discharge and one test from a sample of water 100 meters above the discharge. One of the three bioassays of the Cairo plant was invalidated due to excessive control mortality and another test was terminated because of a laboratory accident. The July 11, 1986 test (Test 35) resulted in a chronic value of 15.81% and a significant difference in the survival of adults compared to the control in the 25% treatment. For the sample taken above the discharge, no chronic value or significant difference resulted.

Stations 15 and 16 were sampled on June 6, 1986. A chronic value of 35.36% was measured in water from Station 16 (Test 22) and a significant difference noted in the 50% concentration. Station 5 was sampled on July 11 and July 18, but neither test indicated toxicity.

A total of ten bioassays were conducted for Stations 1, 2, 6, 7, and 8. None of these bioassays detected chronic or acute effects, although two were discarded for excessive mortality.

Discussion

Oquina Creek

Static renewal bioassays revealed chronic toxicity and/or acute toxicity at all points sampled along Oquina Creek. It is apparent from the results of these tests that there are three primary sources of pollution entering this creek. Two point-source discharges, effluent from the Sunnyland hog processing plant, and the Thomasville Water Pollution Control Plant (WPCP) (6.5 MGD) affect the water quality of Oquina Creek and river Station 3. The third source of toxicity is non-point source run-off from the City of Thomasville.

Toxicity in the point-source samples may be related to high ammonia levels, high conductivities, and/or unknown toxic constituents. Unfortunately, the Sunnyland point-source was not located for the June 13, 1986, series of bioassays. However, noting the range of conductivities in the sample obtained above the Thomasville WPCP, Sunnyland was most likely not discharging at the time of that sampling.

Both chlorinated and de-chlorinated samples from the Thomasville WPCP tested chronically and acutely toxic. High levels of total residual chlorine were at least partially responsible for the mortality in both chlorinated samples. Toxicity in the de-chlorinated samples of the water pollution control plant may have been due to elevated ammonia levels (10.0 mg/l) or unknown toxic components or both.

Bioassays performed on Oquina Creek samples obtained above Sunnyland (Test 30), at the Chatham Road overpass (Test 24), and at the Pine Tree Boulevard crossover (Test 25) detected chronic toxicity. The cause of toxicity within these samples is unknown. Note that none of these samples was affected by any of the known industrial discharges into the creek. This does not preclude the possibility of unreported or non-permitted discharges.

Toxicity of samples taken 500 meters below the Thomasville WPCP (Test 49) and at Station 3 (Test 41) may be attributed to the water pollution control plant, the Sunnyland plant, and to nonpoint-sources.

Tired Creek

Ammonia was probably the primary cause of mortality attributed to discharges from the Cairo Water Pollution Control Plant (Test 35). Other possible constituents of the discharge may have contributed to mortality (FDER 1983, 1984, 1986a). Acute mortality at Station 14 (Tests 16 and 63) was probably caused by the effects of toxic constituents of the discharge from the Cairo WPCP. There are no other point-source discharges between the Cairo plant and Station 14 (two miles downstream). The bioassays performed on water samples collected above the Cairo WPCP (Test 28) showed no toxicity. Nonpoint-source run-off from the surrounding agricultural area could possibly contribute to the toxicity.

Toxicity in samples from the Roddenberry Company (Test 59) and Station 13 (Test 62), 1.8 miles downstream of the industrial discharge, may have been due to high conductivities and possibly to other components of the discharge. The effects of these two discharges, Cairo WPCP and Roddenberry, contributed to the toxicity observed at Station 16. However, at Station 5 (Test 38 and 43), approximately 10 miles downstream, no toxicity was measured. Reasons for this are likely to be instream self-purification and dilution.

Station 15, considered a control for this creek system, was not downstream of either the water pollution control plant or the Roddenberry plant. The only discharge into this creek was surface run-off from the surrounding area, and no toxicity was observed here at the time of the bioassay in June, 1986 (Test 21).

Barnetts Creek

Static renewal tests performed on stations within the Barnetts Creek watershed, Stations 9, 10, 11, and 12, resulted only in chronic toxicity for one sample taken at Station 9 in September, 1986 (Test 60). The only

known source of possible contaminants is the Floridin Company, Thor Mine at the headwaters of the tributary and agricultural operations in the watershed. The cause of mortality was possibly high levels of dissolved ammonia (McCormick et al. 1984) recorded for the month of September (5.68 mg/l compared to .20 mg/l in May, when the previous bioassay on Station 9 was conducted).

This toxicity was not found in water tested from Stations 12 (Test 20) and 15, probably due to the dilution of the water from the Branch of Barnetts Creek (Station 10), and Barnetts Creek (Station 11). Station 4, downstream of the watershed, showed no toxicity due to dilution effects of the previously named creeks and the Ochlockonee River itself.

Other Stations

Bioassays performed on Station 1 (Tests 39 and 51) resulted in no toxicity. This indicates that discharges from the City of Moultrie WPCP (4.0 MGD) and the City of Doerun WPCP (.15 MGD) were not toxic at the time of sampling. One test performed on waters of Station 2 (Test 40) receiving the discharges from the City of Meigs (.75 MGD) and the City of Pelham, (.15 MGD), exhibited no toxicity. Nonpoint-source run-off in the area seemed to have no effect in the summer and early fall months when these stations were tested.

Bioassays conducted on samples obtained from Stations 6, (Tests 45, 53, and 46), 7 (Test 47), and 8 (Test 48) indicated no toxicity as a result of discharges into the upper reaches of the Ochlockonee River. Results from these bioassays show adequate numbers of neonates in all test treatments. Bioassays on Station 17 (Tests 17, 23, and 44), upstream from Station 6, show similar results.

Conclusions

The results of sixty-four chronic bioassays using the cladoceran Ceriodaphnia dubia pinpointed toxicity from municipal and industrial discharges into tributaries of the Ochlockonee River. Oquina Creek, originating in Thomasville, receives discharge from Sunnyland Foods, Inc. and the Thomasville Water Pollution Control Plant. Additionally, this creek also receives stormwater run-off from the city. All three of these influences show an effect on the water quality at river Station 3, with one bioassay measuring toxicity there.

Sources of toxicity in the Tired Creek watershed are discharges from the Cairo Water Pollution Control Plant, discharging into Parkers Mill Creek, and the W. B. Roddenberry Company, discharging into Little Tired Creek. Bioassays conducted on samples from Stations 13, 14, and 16 show toxicity from these sources, however no effect was seen at Station 5 downstream of these discharges.

Chronic bioassays performed on river Stations 1, 2, 4, 6, 7, and 8 all resulted in no toxicity. Municipal discharges upstream of Stations 1 and 2 had little or no effect on the reproduction and survival of C. dubia. Discharges upstream from Stations 4, 6, 7, and 8 did not have any toxic effects at these stations during the study.

ALGAL GROWTH POTENTIAL AND LIMITING NUTRIENT ASSAYS

Introduction

Algal growth potential and limiting nutrient algal assays have been utilized to assess the effects of nutrient additions from municipal, industrial, and agricultural wastewaters to river and lake systems (Green et al. 1975; Cain et al. 1979; Ram and Plotkin 1983; Miller and Maloney 1971). Generally, nutrient additions stimulate algal growth, particularly, additions of nitrogen and phosphorus (Miller et al. 1974; Miller et al. 1978; Gerloff and Skoog 1957) since they are usually the primary nutrients limiting algal growth in natural waters (Gerhart and Likens 1975; Miller et al. 1974; Shiroyama et al. 1975).
The objectives of the algal assay portion of this study were to:

1) assess the current nutrient condition of the Ochlockonee River by measuring the algal growth potential,

2) determine the nutrient(s) that might be limiting algal growth in the river, and

3) determine the effect(s) of major nutrient discharges into the Ochlockonee on #1 and #2 above.

Methods and Materials

Algal growth potential and limiting nutrient assays, following the methods of Miller et al. (1978), were performed on water samples from eight stations in the Ochlockonee River. Algal growth potential assays were performed on water samples from nine stations located on tributaries of the Ochlockonee River. Monthly water samples for the algal assays were collected in opaque two liter polyethylene jugs, placed on ice, and transported to the laboratory. In the laboratory, the samples were autoclaved to destroy any indigenous algae or bacteria. After cooling, the samples were filtered through prewashed Whatman® glass fiber filters (GF/C) and 0.45 um membrane filters (Gelman® GA/6). Prewashing the filters with distilled water was necessary to remove phosphate detergents used in manufacturing the filters (Cahn 1967). Aliquots (60 ml) of the filtered samples were placed in 250 ml Erlenmeyer flasks and "spiked" with predetermined levels of nitrogen, phsophorus, and disodium (ethylenedinitrilo) tetraacetate (EDTA). EDTA is a synthetic organic ligand which is added to media or test waters to assure that necessary trace elements are available to support algal growth (Miller et al. 1978). Three nutrient spikes were used: Nitrogen (1.0 mg/1); phosphorus (0.1 mg/1); and EDTA (1.0 mg/1), alone and in combination. Unspiked water from each station was used as a control and for determination of algal growth potential. The spiked samples were placed on shaker racks under constant lighting (400 ± 10% ft-C) and temperature (22° ± 2°C) to acclimate for 24 hours. Following acclimation, the samples were inoculated with approximately 1000 cells/ml of 7-10 day old test algae. The alga selected

was Selenastrum capricornutum, a unicellular green alga, originally obtained from the E.P.A. Environmental Research Laboratory in Corvallis, Oregon, and cultured in the FDER laboratory (Roll 1981). A growth reference sample series was used to check the viability of the test algae and the nutrient spikes. The growth reference consisted of artificial growth media (PAAP) (Miller et al. 1978) as a control and PAAP media which had various nutrients omitted and then added. The growth reference series consisted of:

PAAP
PAAP w/o P
PAAP w/o P, + P Spike
PAAP w/o N
PAAP w/o N, + N Spike
PAAP w/o EDTA
PAAP w/o EDTA, + EDTA Spike

The treatment series for limiting nutrient assays consisted of:

Control
Control + N Spike
Control + N + P Spike
Control + EDTA Spike
Control + P Spike
Control + N + P + EDTA Spike

The growth response of the algae was monitored for 14 days by cell counts performed on days 1, 7, and 14 with an electronic particle counter (Coulter® Model ZBI) equipped with a mean cell volume attachment. The cell counts and mean cell volume data were entered into a computer program, ALGASSY (Miller et al. 1978), which produced a summary of calculated dry weight yields. Algal growth curves (mean dry weights vs. time) were plotted and a graph produced for each spike and control over the 14 day period by the computer program ASSYPLOT (Miller et al. 1978).

At the beginning of the data analysis, a decision based on hydrologic data was made in which monthly mean flow which exceeded 28.32 m^3/s was to be considered "high flow" and monthly mean flow which was less than 28.32 m^3/s was to be considered "low flow". This distinction was based on flow data measured at the U.S.G.S station located at the U.S. Hwy. 27 bridge over the Ochlockonee River. The monthly mean flow was considered appropriate for periphyton and benthic samples which were incubated and collected on a 28 day cycle but not appropriate for algal assay samples which were grab samples taken on the sampling date. Therefore, the flow on the day the algal assay samples were taken was used instead of the monthly mean. The use of 28.32 m^3/s as the boundary between low flow and high flow remained the same.

Limiting nutrients were determined in the laboratory by the addition of nitrogen and phosphorus, both singularly and in combination, to aliquots of sample water. Limiting nutrients were predicted based upon

the ratios of total soluble inorganic nitrogen to dissolved orthophosphate in the water samples. A ratio of < 10:1 suggests nitrogen as the limiting nutrient, a ratio of > 11:1 suggests phosphorus limitation and a ratio of 10 - 11:1 suggests co-limitation (N and P) (Miller et al. 1974; Shiroyama et al. 1975; Miller et al. 1978). These ratios are approximations, and nutrient limitation based on the chemical ratios does not always parallel the results of the algal assays.

The following definitions should be helpful in interpreting the results of the algal assays:

Co-limitation: When the maximum standing crops (MSC's) of both N and P spiked samples were significantly greater than the control, but were not significantly different from each other; or when the only spike(s) significantly different from the control was the N + P spike and/or the N + P + E spikes.

P-limitation: Significant maximum standing crop responses were obtained only by addition of phosphorus, singly and/or in combination with nitrogen and EDTA.

N-limitation: Significant maximum standing crop responses were obtained only by addition of nitrogen, singly and/or in combination with phosphorus and EDTA.

Algal Growth Potential (AGP): The assay results of an unspiked sample, based on nutrient availability.

Results

River Stations

Mean algal growth potential (AGP) (Table 17, Figure 45) decreased from Station 1 to Station 2, increased through Station 5, and then decreased through Station 8. The lowest mean AGP was observed at Station 8, the highest at Station 5. The maximum AGP and nutrient concentrations occurred at Station 3. The minimum AGP and TSIN occurred at Station 1 and the minimum OPO_4 occurred at Stations 2 and 3. Generally, minimum AGP values were observed during high flow and maximum during low flow, except for Station 8, where both extremes were measured in high waters.

Limiting nutrients (Table 18) were determined at all river stations. Nitrogen was determined to be the limiting nutrient in 77 samples, while phosphorus was found to be limiting in 26 samples. Nitrogen and phosphorus co-limitation was determined in nine samples.

The bioavailable TSIN was determined from the algal growth obtained in the phosphorus spiked samples. As shown in Table 19, the mean bioavailable TSIN ranged from 93.2% at Station 1 to 116.8% at Station 3. The mean AGP at the eight river stations followed the same pattern as the mean total soluble inorganic nitrogen (TSIN) concentration (Figure 46). The bioavailable phosphorus was determined on the basis of the algal

TABLE 17. Mean, minimum, and maximum algal growth potential in milligrams per liter at the river stations and the flow when the minimum, maximum occurred.

Station	Mean	Minimum	Flow when Minimum occurred	Maximum	Flow when Maximum occurred
1	13.640	0.206	high	38.622	low
2	10.692	0.231	high	27.069	low
3	33.677	0.345	high	137.074	low
4	40.205	0.504	high	125.187	low
5	56.769	5.721	high	119.664	low
6	46.994	7.549	high	103.367	low
7	39.108	0.962	high	93.604	low
8	10.183	0.622	high	20.719	high

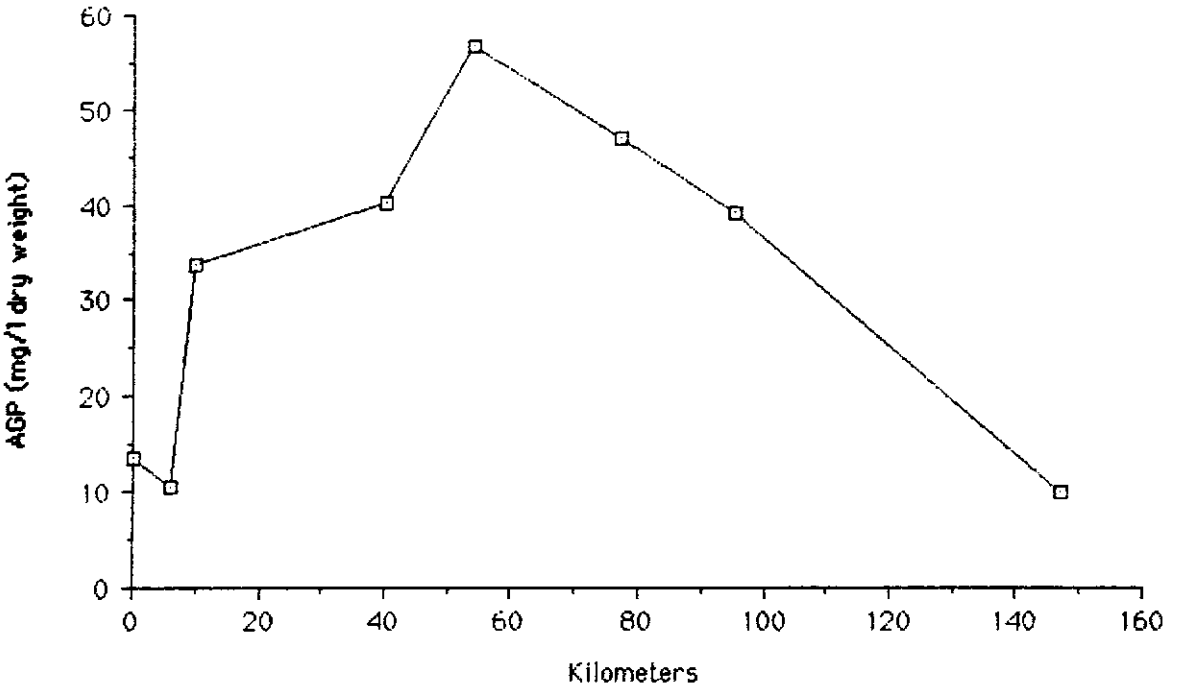


Figure 45. Mean algal growth potential by river kilometer.

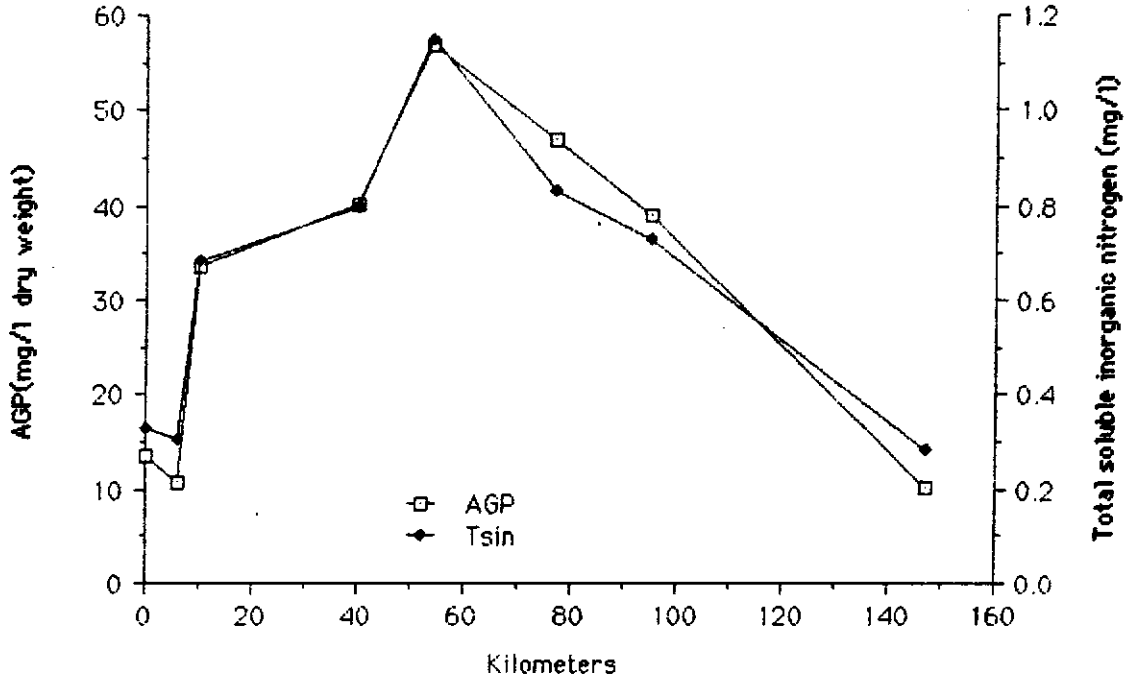


Figure 46. Mean algal growth potential and total soluble inorganic nitrogen by river kilometer.

TABLE 18. Ratios of total soluble inorganic nitrogen to orthophosphate and the limiting nutrient determined by algal assay and predicted by the chemical ratios.

STATION	1			2			3			4			5			6			7			8		
DATE	D	PD	N:P	D	PD	N:P	D	PD	N:P	D	PD	N:P	D	PD	N:P	D	PD	N:P	D	PD	N:P	D	PD	N:P
OCT	N	N	1	N	N	1.3	N	N	2.1	N	N	1.4	N	N	3.7	N	N	7.7	N	N	5.6	C	N	7.3
NOV	N	N	4.75	N	N	3.8	N	N	4.7	N	N	5.1	N	P	12.8	C	N	5.3	N	N	6.0	N	N	8.0
DEC	P	C	10.6	P	N	7.3	P	N	7	P	N	4.4	P	N	3.7	C	N	3.4	N	N	3.8	N	N	3.1
JAN	P	P	12.0	P	P	14.5	P	P	15.0	P	N	9.0	P	N	7.7	C	N	7.8	C	N	8.3	C	N	7.4
FEB	P	N	5	P	N	5.2	P	N	4.6	P	N	4.0	C	N	3.4	P	N	4.7	P	N	3.8	P	N	5.5
MAR	P	N	8.2	P	N	7.0	C	N	9.6	N	N	5.7	N	N	7.1	P	N	9.3	P	N	6.8	P	N	6.6
APR	N	N	6.0	N	C	10.0	N	N	4.6	N	N	4.0	N	N	5.0	N	N	5.5	N	N	5.9	N	N	6.2
MAY	N	N	4.8	N	N	5.9	N	N	3.2	N	N	4.3	N	N	7.9	N	P	12.0	N	N	9.8	N	N	7.2
JUN 2	N	N	1.0	N	N	2.2	N	N	1.4	N	N	3.4	N	N	7.5	N	N	5.3	N	N	4.3	N	N	3.3
JUN 30	N	N	1.0	N	N	1.5	N	N	1.5	N	N	1.4	N	N	2.2	N	N	2.1	N	N	2.0	P	N	6.8
JUL	N	N	3.0	N	N	1.4	N	N	1.1	N	N	1.6	N	N	2.2	N	N	3.9	N	N	9.3	C	N	8.3
AUG	N	N	1.1	N	N	1.6	N	N	1.6	N	N	2.0	N	N	2.5	N	N	2.6	N	N	2.7	P	N	3.4
SEP	N	N	0.4	N	N	0.7	N	N	1.2	N	N	2.3	N	N	3.7	N	N	3.7	N	N	2.9	P	N	3.1
OCT	N	N	0.1	N	N	0.4	N	N	1.3	N	N	2.2	N	N	4.2	N	N	5.0	N	N	5.9	P	N	3.2

D = Determined
PD = Predicted

TABLE 19. Means of the percentage of bioavailable TSIN and orthophosphate at the river stations.

Station	Mean Percent Bioavailable TSIN	Mean Percent Bioavailable OPO_4
1	93.2% ±20%	47.4% ±20%
2	99.4% ±20%	45.8% ±20%
3	116.8% ±20%	39.0% ±20%
4	103.5% ±20%	36.5% ±20%
5	101.5% ±20%	48.8% ±20%
6	106.6% ±20%	70.1% ±20%
7	95.4% ±20%	60.4% ±20%
8	100.9% ±20%	46.1% ±20%

growth obtained in the nitrogen spiked samples. The mean bioavailable orthophosphate ranged from 36.5% at Station 4 to 70.1% at Station 6. The mean orthophosphate (OPO_4) concentrations (Figure 25, Chemistry Section) decreased from Station 1 to Station 2, increased at Station 3 and then decreased through Station 8.

Tributary Stations

The tributary stations are located on three tributary systems. The Barnetts Creek system includes Stations 9, 10, 11, and 12; Stations 13, 14, 15, and 16 are in the Tired Creek system, and Station 17 is in Bryants Mill Creek. Stations 12 and 16, located between the confluence of their respective grouping and the river, and Station 17, are considered the primary tributary stations. The maximum and minimum AGP values (Table 20) of these three stations were found to occur during low flow and high flow, respectively. The mean AGP of Station 16 was approximately 30 times greater than the mean AGP at Station 12, and the mean AGP of Station 17 was approximately 25 times greater than that at Station 12.

Discussion

Algal Growth Potential

The decrease in nutrient concentrations and the resultant decrease in AGP from Station 1 to Station 2, although not considered to be very significant, could possibly be the result of dilution, as the volume of the river increased from Station 1 to Station 2. The Little Ochlockonee River converges with the Ochlockonee upstream of Station 2 and accounts for most of the volume increase.

The increase in mean AGP (31.5%) at Station 3 compared to Station 2 was the result of the corresponding increase in mean nutrient concentrations at Station 3 over the nutrient concentrations at Station 2. Station 3 is downstream of the confluence of Oquina Creek with the river. Oquina Creek receives discharges from a food processing plant and a sewage treatment plant as well as surface runoff. As shown in Table 21, the AGP of samples taken upstream of discharges from food processing plants and sewage treatment plants generally had lower AGP than samples taken below these discharges. It is suggested that the increase in nutrient concentrations and the resulting increase in AGP at Station 3 was related to the discharges and to runoff into Oquina Creek.

Station 4 is located downstream of the confluence of the Barnetts Creek tributary group. This group of tributaries receives runoff from mining and agriculture. Station 12 is located between the confluence of the tributaries and the Ochlockonee River. The mean AGP of Station 4 was 19.3% greater than that at Station 3. This increase is directly attributable to the 17% increase in TSIN at Station 4 as compared to Station 3. The mean AGP and nutrient concentrations at Station 12 were found to be considerably less than the values at either Stations 3 or 4, therefore, it is suggested that this tributary group had only a slight impact upon the AGP results obtained from Station 4.

TABLE 20. Mean, minimum, and maximum algal growth potential in milligrams per liter of the tributary stations and the flow when the minimum and maximum occurred.

Station	Mean	Minimum	Flow when Minimum occurred	Maximum	Flow when Maximum occurred
9	0.736	0.909	low	3.559	low
10	17.592	0.209	high	71.004	low
11	5.047	0.121	high	21.637	low
12	3.429	0.092	high	18.058	low
13	107.030	20.698	high	199.100	low
14	93.157	25.496	low	166.391	high
15	79.093	0.691	high	193.280	low
16	101.780	2.341	high	174.430	low
17	85.289	20.841	high	151.830	low

TABLE 21. AGP of stations located upstream and downstream of point source discharges into various tributaries.

DATE	Above Cairo WPCP	Station 14	Above Roddenberry	Station 13	Above Sunnyland	Below Sunnyland	Below Thomasville WPCP
8-86	44.656	113.759	2.113	115.322	2.631	No Sample	No Sample
9-86	0.964	76.253	6.479	151.889	0.214	90.577	198.095
10-86	0.198	59.464	3.177	160.391	3.304	96.375	64.862

The Tired Creek tributary system enters the river between Stations 4 and 5. This tributary group receives discharges from food processing, a sewage treatment plant, and agricultural runoff. The mean AGP at Station 5 was 41.2% greater than that recorded at Station 4. This increase in AGP is directly attributable to the 43.6% increase in the mean TSIN concentration at Station 5 as compared to Station 4. The mean AGP and nutrient concentrations from Station 16, which represents the integration of Stations 13, 14, and 15, were significantly greater than the values recorded from Station 5. The significant increase in the mean concentration of TSIN, and the corresponding increase in mean AGP and TSIN at Station 5 over Station 4, appear to be partially attributable to the nutrient loading of this tributary group.

The mean AGP at Station 6 was 17% less than that recorded at Station 5. The tributary upon which Station 17 was located enters the river between Stations 5 and 6. Although having significantly higher mean values for AGP and nutrients than Stations 5 or 6, this tributary would not appear to have an impact on the AGP measured at Station 6. An interesting observation, (more fully discussed in the sediment section), is that during low flow, the sediment sample from Station 6 contained approximately 12 times more nitrogen and five times more phosphorus than did the Station 5 sediment sample. During high flow both nitrogen and phosphorus concentrations were approximately three times greater at Station 6 than at Station 5. This suggests that utilization and/or adsorption and subsequent sedimentation of phosphorus and nitrogen play a role in the apparent lack of impact of the tributary upon the AGP from Station 6.

Mean AGP at Station 7 decreased by 16.8%, from the mean AGP recorded at Station 6. There are no known continuously flowing tributaries located between Stations 6 and 7; these values, therefore, are seemingly a continuation of the decreasing concentrations of nutrients in the river.

Mean AGP at Station 8 was 74% less than that recorded at Station 7. The decrease in nutrients and therefore AGP from Station 7 to Station 8 is probably a result of the nutrients being utilized or deposited in Lake Talquin, which is located between Stations 7 and 8.

Limiting Nutrients

As noted in the results, the majority of the samples from the river stations were nitrogen limited. During 10 of the 14 sampling dates when the flow, as measured at the U.S. Highway 27 bridge, was less than 28.32 m^3/s, the determined limiting nutrient was accurately predicted by chemical ratios in 91% of the samples. When the flow exceeded 28.32 m^3/s (4 sampling dates), the accuracy of the prediction of the laboratory-determined limiting nutrients was reduced to 28%. The majority of the samples which were found to be phosphorus limited at Stations 1 through 7 were taken during the period of high flow when the OPO_4 concentrations were lowest. Although most of these samples had TSIN to OPO_4 ratios of less than 10:1 (which suggests nitrogen limitation) it would appear that the orthophosphate concentrations in these samples were not bioavailable to the test algae.

Station 8 was phosphorus limited (6 occurrences) more than any other station, although the chemical ratios were well within the nitrogen limiting range. The maximum orthophosphate concentration at Station 8 was 0.07 mg/l, again suggesting that when the orthophosphate concentrations were low, the phosphorus was not readily bioavailable to the test algae.

Further evidence for nitrogen generally being the primary limiting nutrient is demonstrated by the mean bioavailability of TSIN approaching 100% at the river stations (Table 19). Individual samples varied, and some exceeded 100% bioavailable TSIN, which indicates that other sources of nitrogen were being utilized by the test algae (Claesson 1980). Figure 46 more clearly shows the relationship of TSIN to AGP results in the river. In the majority of the samples which were phosphorus limited, orthophosphate was less than 10% bioavailable.

Flow

As seen in Figures 47, 48, 49, and 50, the AGP of the river and tributary stations was generally less during periods of high flow and greater during periods of low flow. Note that flow data was obtained from the U.S.G.S. Havana station, and is used here strictly to demonstrate the reciprocal relationship between AGP and flow. TSIN and OPO_4 concentrations were also generally inversely related to flow (Chemistry Section). The AGP of all stations, except for river Station 8 and tributary Station 14, were negatively correlated with the flow (Table 22).

Correlations of the AGP of the river stations (Table 23) and the tributary stations (Table 24) with various physical and chemical parameters show that, as expected, the nitrate/nitrite, TSIN, total and dissolved phosphate, and pH had the most significant correlations with AGP. The nitrate/nitrite fraction of the TSIN had the highest correlation with AGP. As the majority of samples were nitrogen limited and nitrate/nitrite comprised the greatest proportion of the TSIN, this was not unexpected.

Conclusions

Substantial increases in algal growth potential (AGP) noted at Stations 3 and 5 were due to nutrient additions from tributary inputs. These tributaries receive domestic and industrial discharges from both Thomasville and Cairo, Georgia. Other tributaries receiving mining or nonpoint source discharges had little or no effect on AGP.

A significant correlation between AGP and total soluble inorganic nitrogen was observed, and nitrogen was also determined to be the primary limiting nutrient. During flood conditions, AGP was reduced at Stations 1-7, and phosphorus limitation became predominant.

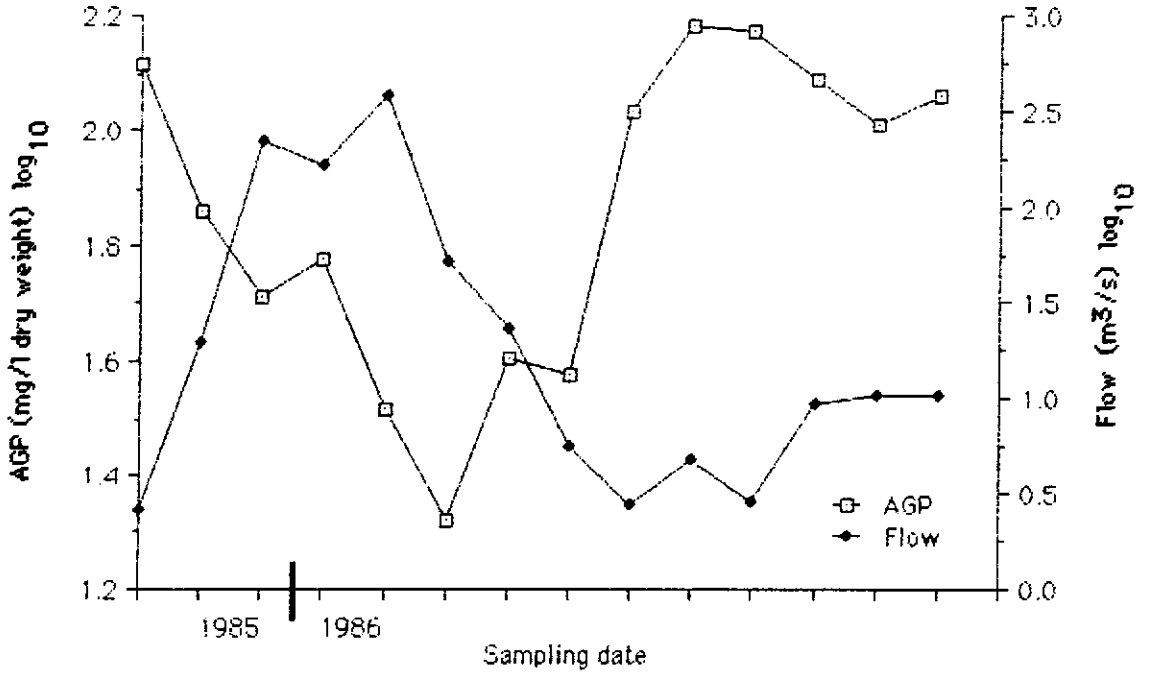


Figure 47. Mean algal growth potential and flow for tributary station 17 by sampling date.

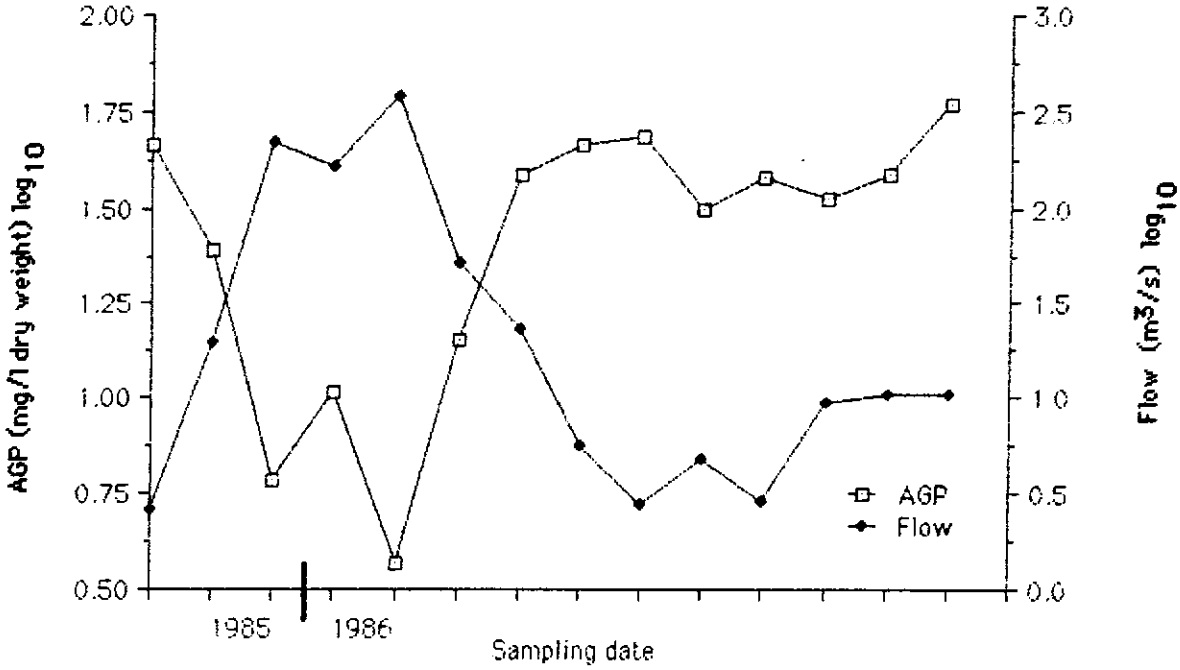


Figure 48. Mean algal growth potential and flow for river stations by sampling date.

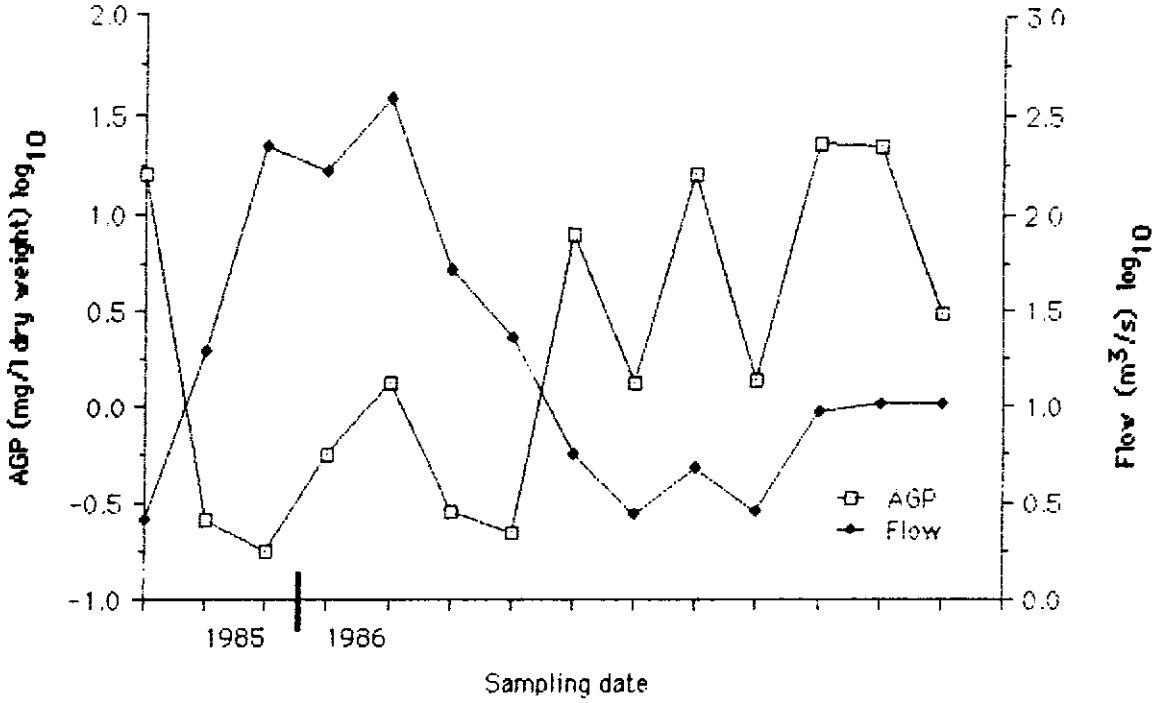


Figure 49. Mean algal growth potential and flow for tributary stations 9-12 by sampling date.

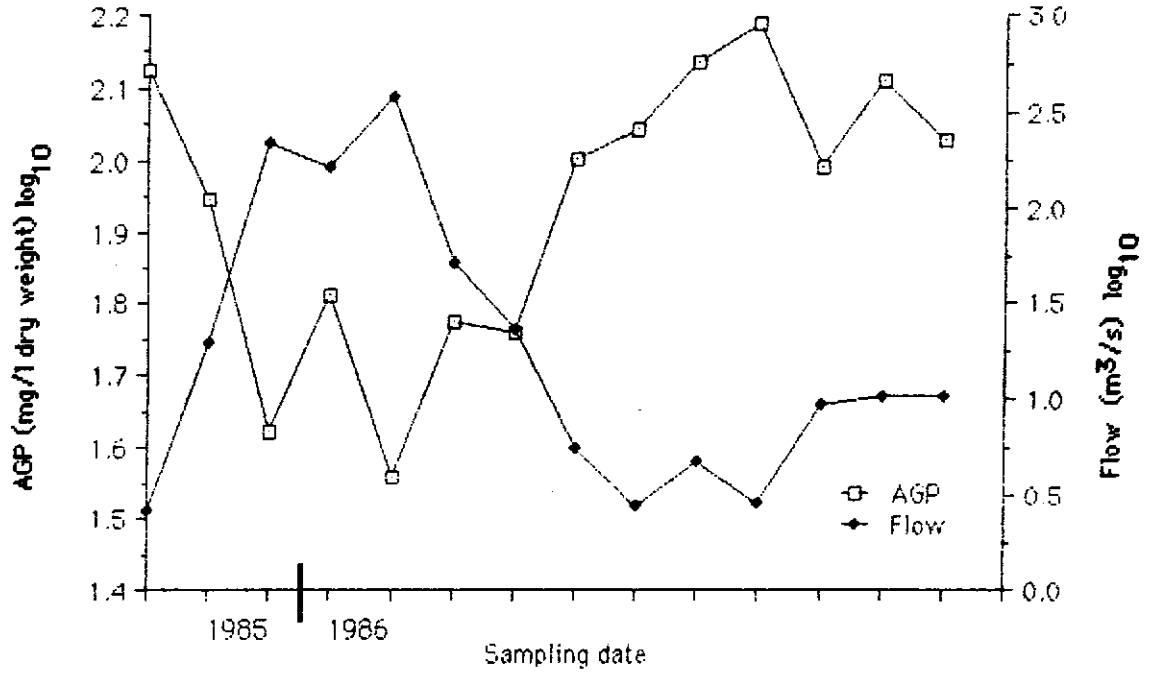


Figure 50. Mean algal growth potential and flow for tributary stations 13-16 by sampling date.

TABLE 22. Correlations of the algal growth potential of all stations with flow.

STATION	r	Significance	STATION	r	Significance
1	- .374	NS	9	- .313	NS
2	- .449	NS	10	- .479	.10 > P > .05
3	- .571	.05 > P > .02	11	- .372	NS
4	- .686	.01	12	- .352	NS
5	- .813	.01	13	- .838	.01
6	- .751	.01	14	.479	.1 > P > .05
7	- .777	.01	15	- .774	.01
8	.312	NS	16	- .876	.01
			17	- .657	.02 > P > .01

Table 23. Correlations of river algal growth potential and various physical and chemical parameters.

ALGAL GROWTH POTENTIAL VS.	r	SIGNIFICANCE
Free Water Chlorophyll-a	.441	.01 > P
Periphyton Chlorophyll-a	.294	.01 > P
Total Ammonia	.164	.10 > P > .05
Dissolved Ammonia	.187	.10 > P > .05
Total Kjeldahl Nitrogen	-.028	NS
Total Kjeldahl Nitrogen (Dissolved)	-.180	.10 > P > .05
Total Phosphate	.718	.01 > P
Ortho Phosphate (Dissolved)	.726	.01 > P
Dissolved Nitrite/Nitrate	.929	.01 > P
Total Soluble Inorganic Nitrogen	.924	.01 > P
pH	.431	.01 > P

TABLE 24. Correlations of tributary algal growth potential and various physical and chemical parameters.

ALGAL GROWTH POTENTIAL VS.	r	SIGNIFICANCE
Free Water Chlorophyll-a	-.011	NS
Total Ammonia	.106	NS
Dissolved Ammonia	.114	NS
Total Kjeldahl Nitrogen	.180	.01 > P > .05
Total Kjeldahl Nitrogen (Dissolved)	.157	.01 > P > .05
Total Phosphate	.394	.01 > P
Ortho Phosphate (Dissolved)	.391	.01 > P
Dissolved Nitrite/Nitrate	.633	.01 > P
Total Soluble Inorganic Nitrogen	.552	.01 > P
pH	.436	.01 > P

BACTERIA

Introduction

Total coliform and fecal coliform bacteria have traditionally been used to determine water quality. Two additional groups, fecal streptococci and total aerobic bacteria, are used to further differentiate the type of pollution.

The purpose of this portion of the project was to investigate potential sources of pollution associated with the Ochlockonee River Basin using selected bacteria: total coliform, fecal coliform, fecal streptococci, and total aerobic bateria.

Methods and Materials

Water samples were taken in 6 oz. screw cap, sterile glass bottles and kept on ice until processing. Samples were taken from a small boat using the full arm sweep method. Ideally, samples were taken from a depth of two feet, but in some streams and shallows only the top few inches could be sampled. All samples were collected in duplicate.

Samples were processed within 24 hours of collection following A.P.H.A. et al. (1985) and U.S. EPA (1978). Membrane filter analysis was the method chosen for total coliform, fecal coliform, and fecal streptococci determinations. The pour plate method was used for the total aerobic (standard) plate count determinations.

Millipore® filter apparatus and either Millipore® HC type or Gelman® GN6 membrane filters were used throughout this study. Filters, after evacuation of the sample aliquots, were incubated on three types of media: M-Endo (Difco®) to enumerate total coliforms, M-FC Broth (Difco®) with 1% Rosalic acid to enumerate fecal coliforms, and KF-Streptococcus Agar (Difco®) to enumerate fecal streptococci. All media were made according to the manufacturer's directions. Filters were incubated at either 35.0 $\pm$ 0.5°C for total coliform (24 hours) and fecal streptococci (48 hours) determinations or 44.5 $\pm$ 0.2°C for fecal coliform determinations (24 hours). Colonies were counted manually and recorded.

The pour plate method was used for the determination of the total aerobic bacteria. Aliquots of sample (1.0 and 0.1 ml) were introduced into 15X100 mm petri dishes. Molten standard plate count agar (Difco®) was added, mixed with sample, and allowed to solidify. Plates were incubated at 34.0 $\pm$ 0.5°C for 24 hours. Colonies were counted using a Fisher electric colony counter.

Results

During this study, duplicate water samples were collected at each of the seventeen sites during the fourteen sampling trips. Each sample was analyzed for total aerobic bacteria (SPC), total coliform (TC) bacteria, fecal coliform (FC) bacteria, and fecal streptococci (FS) bacteria. Bacterial densities presented in this section are geometric means of twenty-eight data points per station (Table 25).

Total Aerobic Bacteria

Total aerobic bacterial counts are commonly referred to as standard plate counts (SPC). These bacteria, grown at 35°C and reported as number of organisms per milliliter of sample (#org/ml), reflect the portion of the heterotrophic bacterial population which has sanitary significance (U.S. EPA 1977). Results are shown in Figure 51 and Table 26.

The mean SPC bacteria ranged from 343 org/ml (Station 8) to 2118.9 org/ml (Station 14). The mean bacterial density for the river stations (Station 1-8, 567.9 org/ml) was lower than that for the tributary stations (Stations 9-17, 971.6 org/ml).

Station 1 was the northernmost station of the study area. Since the river extends north of this station, a number of upstream sources potentially impact Station 1, i.e., Moultrie Water Pollution Control Plant. Mean SPC densities at Station 1 were low (484.2 org/ml), remained low at Station 2 (471.6 org/ml), then increased at Station 3 (709.6 org/ml). Station 3 receives tributary waters carrying discharges from the Thomasville Water Pollution Control Plant and the Sunnyland Plant. The impact cannot be fully determined since no sampling point was located on this tributary. A modest increase was noted at Station 4 (725.6 org/ml). This station is downstream of Barnetts Creek (Station 12, 707.8 org/ml) and serves to integrate Horse Creek (Station 9, 508.5 org/ml) and the two upper branches of Barnetts Creek (Station 10, 589.0 org/ml, and Station 11, 603.1 org/ml). It appears that additional run-off entering between Stations 9-11 and Station 12 may increase the SPC densities at Station 12.

A slight decline (602.8 org/ml) was observed at Station 5. Since Station 5 receives the discharge of Tired Creek (Station 16, 795.8 org/ml) this was somewhat unexpected. The upper branches of Tired Creek and Parkers Mill Creek receive Roddenberry Company discharge (Station 13, 1529.7 org/ml), agricultural runoff (Station 15, 816.8 org/ml), and the Cairo Water Pollution Control Plant discharge (Station 14, 2118.9 org/ml), respectively.

Station 6 (643.7 org/ml) is the northernmost station located in Florida. It is in the Ochlockonee River, below confluences with Bryants Mill Creek (Station 17, 1074.5 org/ml) and Iamonia Slough (no station). A moderate decline in mean SPC densities (563.0 org/ml) was shown at Station 7, with further decline at Station 8 (343.0 org/ml) the southernmost station of this study, located below Lake Talquin.

TABLE 25. Geometric means for fecal coliform (FC), total coliform (TC), fecal streptococci (FS), total aerobic bacteria (SPC), and the fecal coliform to fecal streptococci ratio (FC:FS) by station.

Station	FC	TC	FS	SPC	FC:FS
1	299.0	7767.8	263.7	484.2	1.13
2	139.0	9390.7	138.4	471.6	1.00
3	242.2	12900.3	177.0	709.6	1.37
4	137.5	6910.4	124.2	725.6	1.11
5	111.2	9198.1	123.8	602.8	0.90
6	134.7	11061.1	122.9	643.7	1.10
7	78.9	9287.5	94.1	563.0	0.84
8	50.5	8693.6	86.2	343.0	0.59
9	452.8	20568.4	398.0	508.5	1.14
10	289.9	15055.4	314.7	589.0	0.92
11	302.3	11937.1	344.3	603.1	0.88
12	225.3	13486.5	375.5	707.8	0.60
13	1489.0	33946.9	2741.6	1529.7	0.54
14	4609.9	82110.8	1346.2	2118.9	3.42
15	405.9	17350.0	406.7	816.8	1.00
16	509.0	15223.0	479.0	795.8	1.06
17	478.0	24740.0	813.0	1074.5	0.59

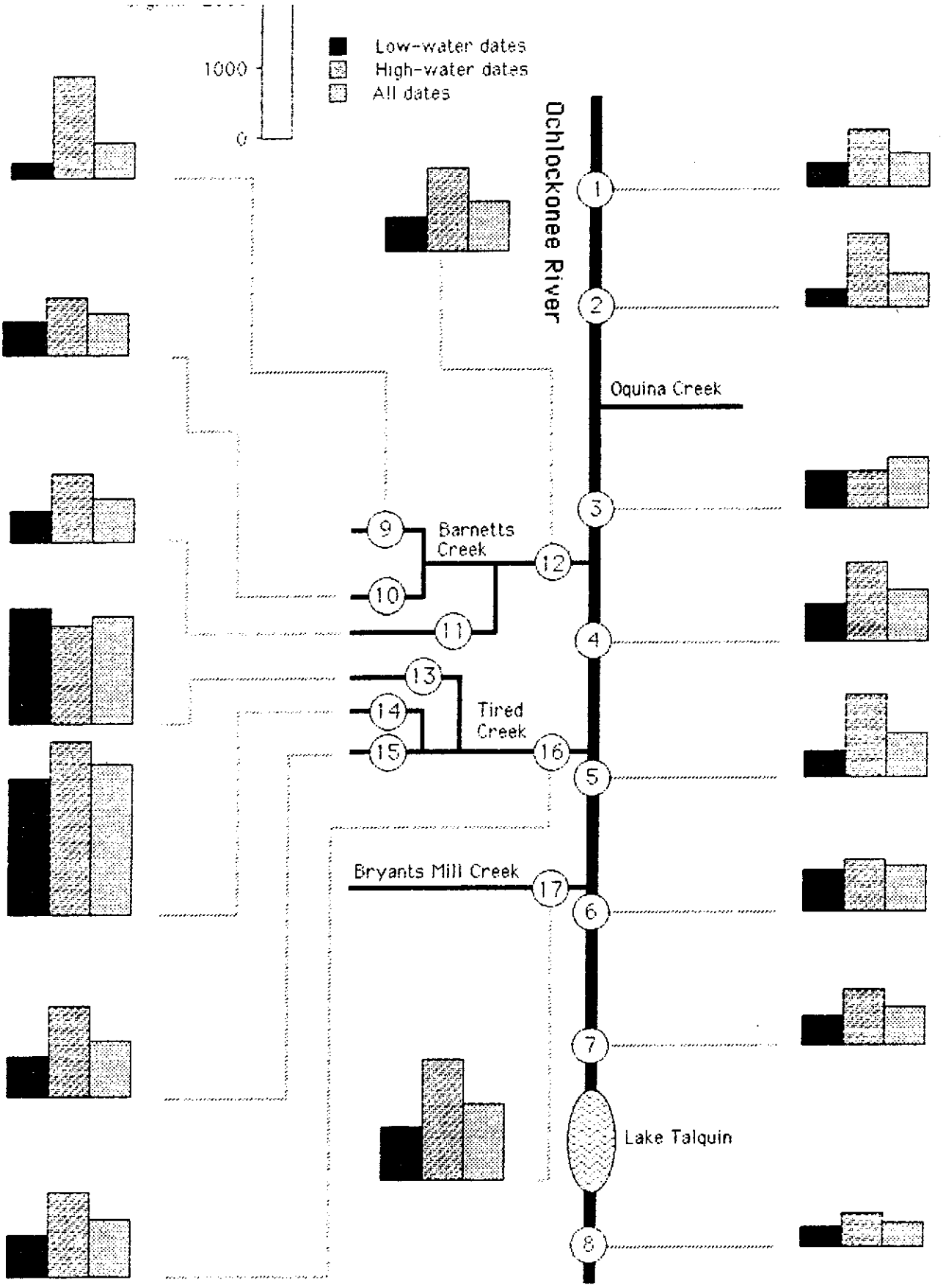


Figure 51. Standard plate count bacterial densities, geometric means of all sampling dates.

TABLE 26. Standard plate count bacterial densities, geometric means.

RIVER STATION	LOG	#
1	2.5150	327.3[a]
	2.9117	816.0[b]
	2.6850	484.2[c]
2	2.4191	262.5
	3.0130	1030.4
	2.6736	471.6
3	2.7313	583.6
	3.0107	1024.9
	2.8510	709.6
4	2.7201	524.9
	3.0481	1117.1
	2.8607	725.6
5	2.5633	365.9
	3.0694	1173.3
	2.7802	602.8
6	2.7694	588.0
	2.8611	726.3
	2.8087	645.7
7	2.6283	424.9
	2.9135	819.4
	2.7505	563.0
8	2.4273	267.5
	2.6793	477.9
	2.5353	343.0

TRIBUTARY STATION	LOG	#
9	2.3616	229.9
	3.1659	1465.2
	2.7063	508.5
10	2.6697	467.4
	2.9045	802.6
	2.7703	589.3
11	2.6361	432.6
	2.9818	959.0
	2.7804	603.1
12	2.6852	484.4
	3.0694	1173.3
	3.1846	1529.7
13	3.2134	1636.1
	3.1456	1398.3
	3.1846	1529.7
14	3.2811	1910.3
	3.3861	2432.6
	3.3261	2118.9
15	2.7568	571.2
	3.1191	1315.5
	2.9121	816.8
16	2.7713	590.6
	3.0734	1184.1
	2.9008	795.8
17	2.8787	756.3
	3.2344	1715.5
	3.0312	1074.5

[a] low water dates
[b] high water dates
[c] all dates

River flow over the term of this study was variable, thus prompting an investigation of the bacterial association with river flow. Two periods were identified as follows: Low flow was less than 28.32 m^3/s and occurred between April, 1986 and October, 1986; high flow was greater than 28.32 m^3/s and occurred between October 1985 and March 1986. Results are shown in Figure 51 and Table 26, the low, high, and combined flows, measured as the geometric means of data for each category. It is interesting to note that high flow SPC bacterial densities were approximately two fold greater than the low flow period. It appears that these bacteria were strongly associated with stream flow.

Total Coliform Bacteria

Mean total coliform bacteria densities were high throughout the river and tributaries (Figure 52), ranging from a low at Station 4 (6910.4 org/100 ml) to a high at Station 14 (82110.8 org/100 ml). The second lowest density during this study was determined at Station 1 (7767.8 org/100 ml). Densities at Station 2, which receives waters from the Little Ochlockonee, were higher (9390.7 org/100 ml) than those at Station 1. Increased mean densities at Station 3 (12900.3 org/100 ml) appeared to be due to the influence of the Thomasville Water Pollution Control Plant and Sunnyland discharges. The lowest total coliform density of the study (6910.4 org/100 ml) was found at Station 4. The closest tributary influence to this station is Barnetts Creek; however, the distance of approximately a mile appears sufficient to reduce entrained bacteria by dilution, dispersion, or the settling out of particle associated coliform bacteria.

Station 5 (9198.1 org/100 ml) is influenced by Tired Creek (Stations 13-16). The high concentration of total coliform bacteria from Station 16 (15223.0 org/100 ml) appears to be responsible for the elevated densities at Station 5. Mean densities at Station 16 reflect upstream inputs from the Roddenberry Company (Station 13; 33946.9 org/100 ml), the Cairo WPCP (Station 14, 82110.8 org/100 ml), and agricultural run-off (Station 15, 17350.0 org/100 ml).

Station 6 (11061.1 org/100 ml) is influenced by Bryants Mill Creek (Station 17, 24740.0 org/100 ml). Agriculture and the non-operational Floridin Mining Co. were the only potential sources affecting Station 17. Southward from Station 6, mean total coliform densities consistently declined at Station 7 (9287.5 org/100 ml) and Station 8 (8693.6 org/100 ml).

Figure 53 shows the relative magnitudes of total coliform densities as compared to selected numerical densities. It appears that total coliform densities were very high throughout the entire Ochlockonee River project area.

A review of the total coliform data separated into high and low flow (Figure 53 and Table 27) shows that densities at river stations during low flow were approximately two fold greater than those at the high flow.

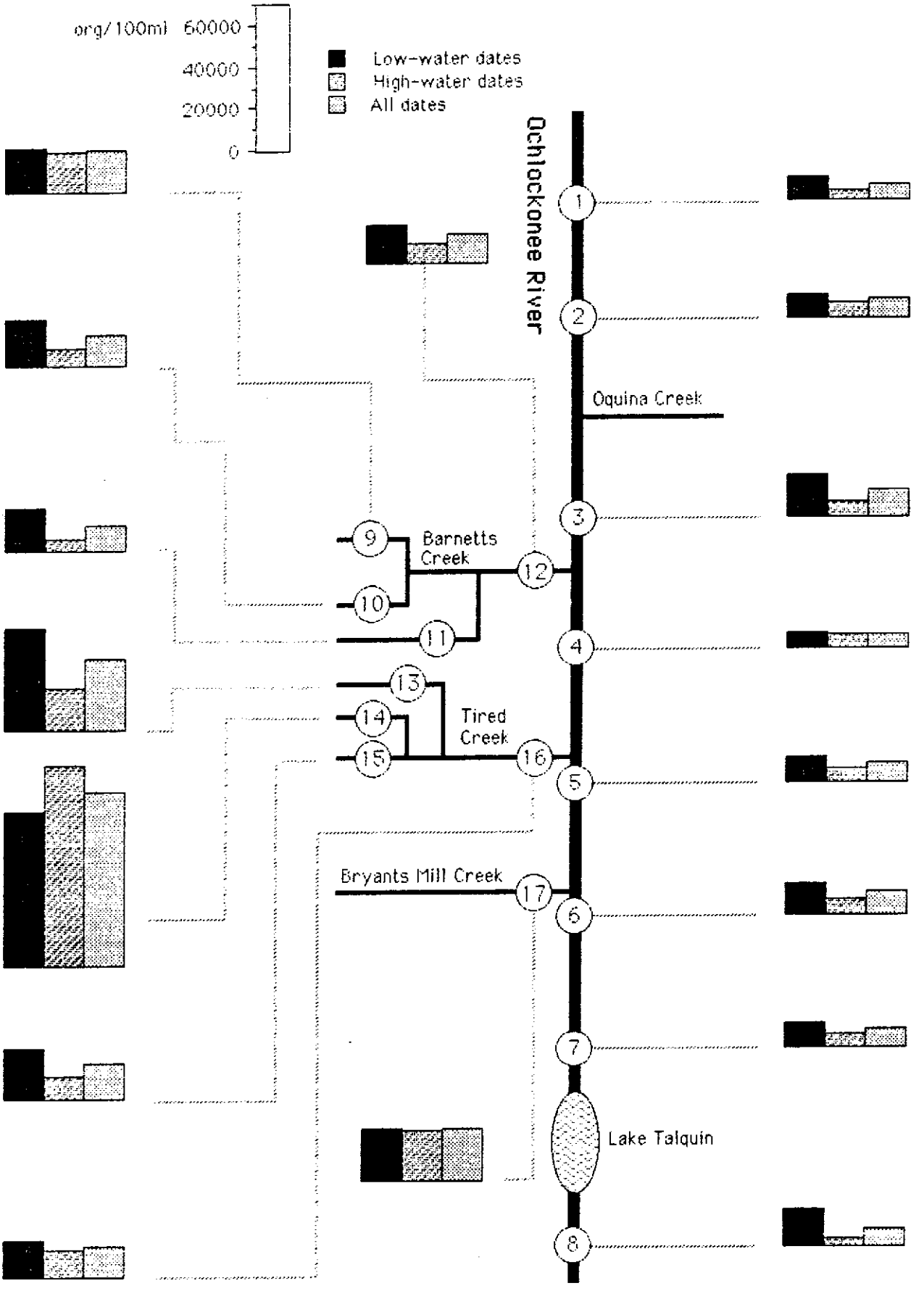


Figure 52. Total coliform bacterial densities, geometric means of all sampling dates.

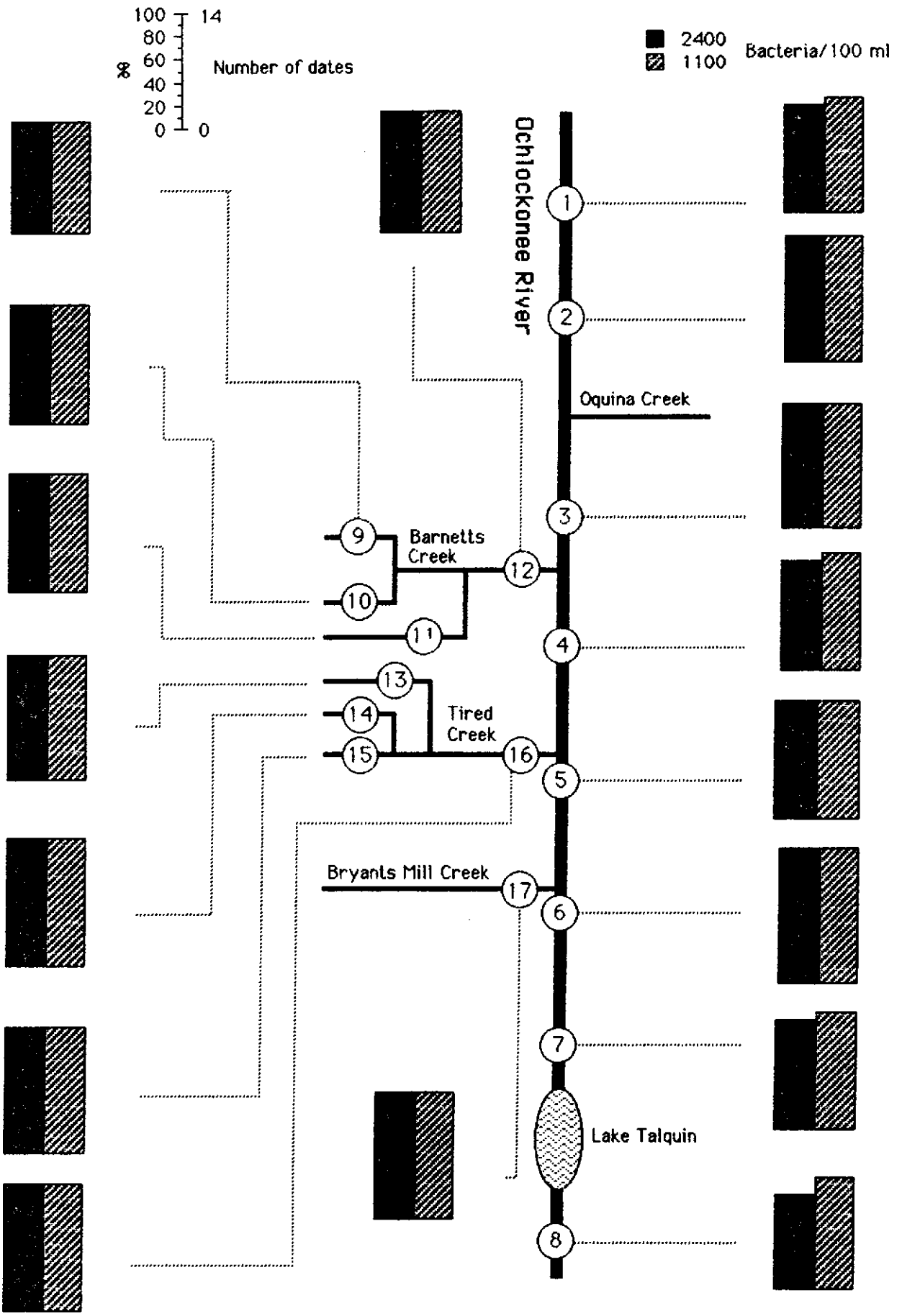


Figure 53 Percentage of total coliform bacteria samples in excess of selected numerical densities for all 14 sampling dates.

TABLE 27. Total coliform bacterial densities, geometric means of all sampling dates.

RIVER STATION	LOG	#	TRIBUTARY STATION	LOG	#
1	4.0386	10929.3	9	4.3298	21369.8
	3.6926	4927.2		4.2910	19543.4
	3.8903	7757.8		4.3132	20568.4
2	4.0394	10949.6	10	4.3528	22532.0
	3.8837	7650.7		3.9441	8792.3
	3.9727	9390.7		4.1777	15055.4
3	4.3088	20361.0	11	4.3078	20314.2
	3.8463	7019.4		3.7678	5858.7
	4.1106	12900.3		4.0769	11937.1
4	3.8591	7229.4	12	4.2624	18297.9
	3.8133	6505.8		3.9533	8980.5
	3.8395	6910.4		4.1299	13486.5
5	4.0871	12220.8	13	4.6940	49431.1
	3.8992	6298.0		4.3132	20568.4
	3.9637	9198.1		4.5308	33946.9
6	4.1767	15021.0	14	4.8652	73316.2
	3.7992	7357.0		4.9800	95499.3
	4.0438	1106.1		4.9144	82110.8
7	4.0802	12028.2	15	4.3933	24734.3
	3.8182	6579.6		4.0340	10814.3
	3.9679	9287.5		4.2393	17350.0
8	4.2369	17254.4	16	4.2392	17346.0
	3.5423	3485.8		4.1069	12790.9
	3.9392	8693.6		4.1825	15223.0
			17	4.4030	25293.0
				4.3806	24021.5
				4.3934	24740.0

Tributary stations, with the exception of Station 13, reflected a similar trend. Densities at Station 13 were greater during high flow periods than the low flow periods.

Fecal Coliform Bacteria

Mean fecal coliform bacteria densities for all stations (Figure 54 and Table 28) ranged from a low of 50.5 org/100 ml (Station 8) to a high of 4609.9 org/100 ml (Station 14). Tributary densities were consistently greater than river densities. The profile of the river was similar to the previously reported total coliform densities. Densities at Station 1 (299.0 org/100 ml) were the highest of the river stations. Densities at Station 2 were lower (139.0 org/100 ml). Densities at Station 3 increased to 242.2 org/100 ml, apparently the result of the Oquina Creek discharge. Densities at Station 4 decreased to 137.5 org/100 ml. Although the closest tributary discharge was Barnetts Creek (Station 12, 225.3 org/100 ml), no apparent influence was noted at Station 4. Station 5 (112 org/100 ml) is immediately downstream from Station 16, Tired Creek, and although mean densities at Station 16 were moderately high (509.5 org/100 ml), it appears that Station 5 was little influenced by them.

Densities at Station 6 (134.7 org/100 ml) were elevated above those noted at Station 5. The closest associated tributary station is Station 17 (Bryants Mill Creek, 478.0 org/100 ml). Below Station 6, densities consistently decreased (Station 7, 79.9 org/100 ml; Station 8, 50.5 org/100 ml).

Fecal coliform densities, reported as percentage greater than selected numerical values, are shown in Figure 55 for all data and in Figure 56 for data related to high flow months. A further investigation of the high-low flow trend (Figure 54 and Table 28) shows that fecal coliform densities were consistently 2-6 times greater in high flow periods than low flow periods.

Fecal Streptococci Bacteria

Mean fecal streptcocci bacterial densities (Figure 57) ranged from a low of 86.2 org/100 ml (Station 8) to a high of 2741.6 org/100 ml (Station 14). River densities were consistently lower than those at tributary stations. The profile of the stations was similar to all previously reported bacterial densities. Densities at Station 1 (263.7 org/100 ml) were the highest reported for the river stations. Densities at Station 2 decreased (138.4 org/100 ml), then increased at Station 3 (177.0 org/100 ml) just downstream from Oquina Creek. Densities at Station 4 (124.2 org/100 ml) appeared to be minimally affected by Barnetts Creek (Station 12, 375.5 org/100 ml). Densities at Station 5 (123.8 org/100 ml) appeared to be unaffected by the discharge from Tired Creek (Station 16, 479.0 org/100 ml). It is interesting to note that the highest mean densities of this study were reported for the Roddenberry Company discharge (Station 13, 2741.6 org/100 ml) and for the Cairo WPCP discharge (Station 14, 1346.2 org/100 ml). However, these elevated densities did not appear to

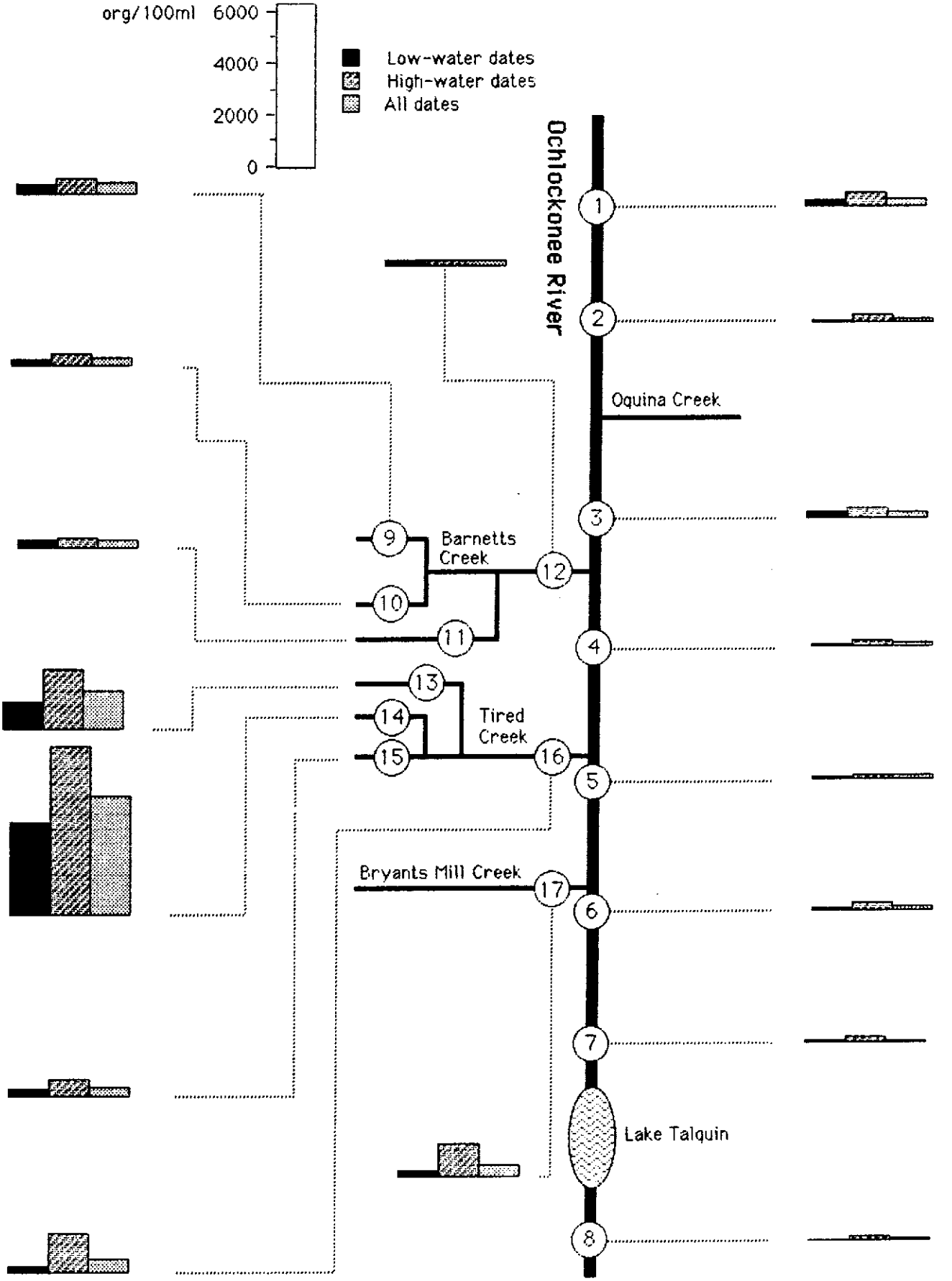


Figure 54. Fecal coliform bacterial densities, geometric means of all sampling dates.

TABLE 28. Fecal coliform bacterial densities, geometric means of all sampling dates.

RIVER STATION	LOG	#
1	2.2760	188.8
	2.7420	552.1
	2.5757	299.0
2	2.2762	85.3
	2.4259	266.6
	2.1429	139.0
3	2.2762	188.9
	2.5282	337.4
	2.3842	242.2
4	2.0332	108.0
	2.2780	189.7
	2.1384	137.5
5	1.9004	79.5
	2.2405	174.0
	2.0462	111.2
6	1.9581	90.8
	2.3574	277.7
	2.1293	134.7
7	1.5696	37.1
	2.3337	215.6
	1.8971	78.9
8	1.3914	24.6
	2.1194	131.6
	1.7034	50.5

TRIBUTARY STATION	LOG	#
9	2.5833	383.1
	2.7529	566.1
	2.6559	452.8
10	2.3375	217.5
	2.6285	425.1
	2.4622	289.9
11	2.4162	260.7
	2.5662	368.3
	2.3528	225.3
12	2.3213	209.6
	2.3949	248.3
	2.3528	225.3
13	3.0283	3566.9
	3.3656	2320.6
	3.1729	1489.0
14	3.5523	3566.9
	2.8122	6489.3
	3.6637	4609.9
15	2.4452	278.7
	2.8261	670.0
	2.6084	405.9
16	2.3617	230.0
	3.1666	1467.6
	2.7067	509.0
17	2.3650	231.7
	3.0987	1255.2
	2.6794	478.0

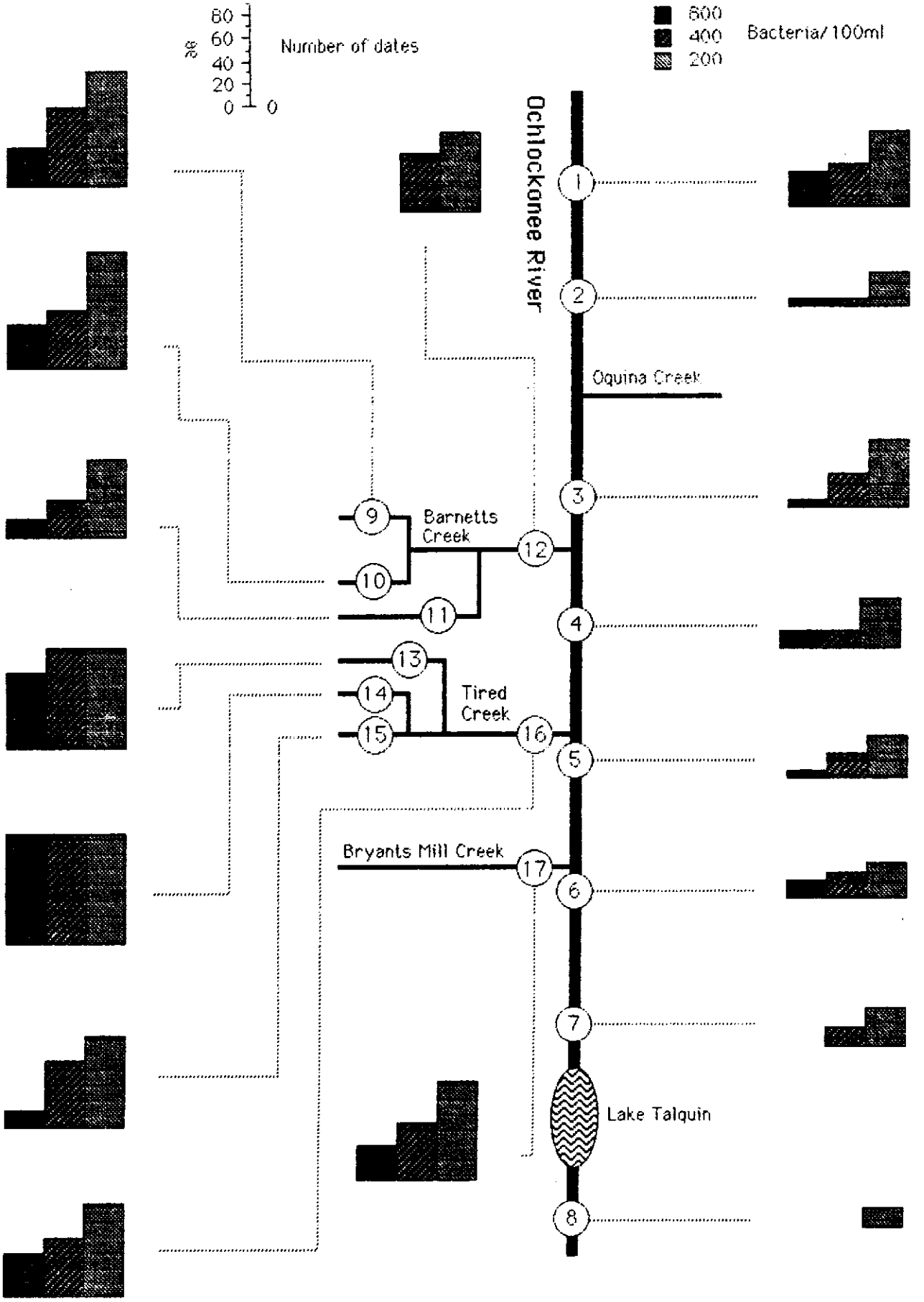


Figure 55. Percentage of fecal coliform bacteria samples in excess of selected numerical densities for all 14 sampling dates.

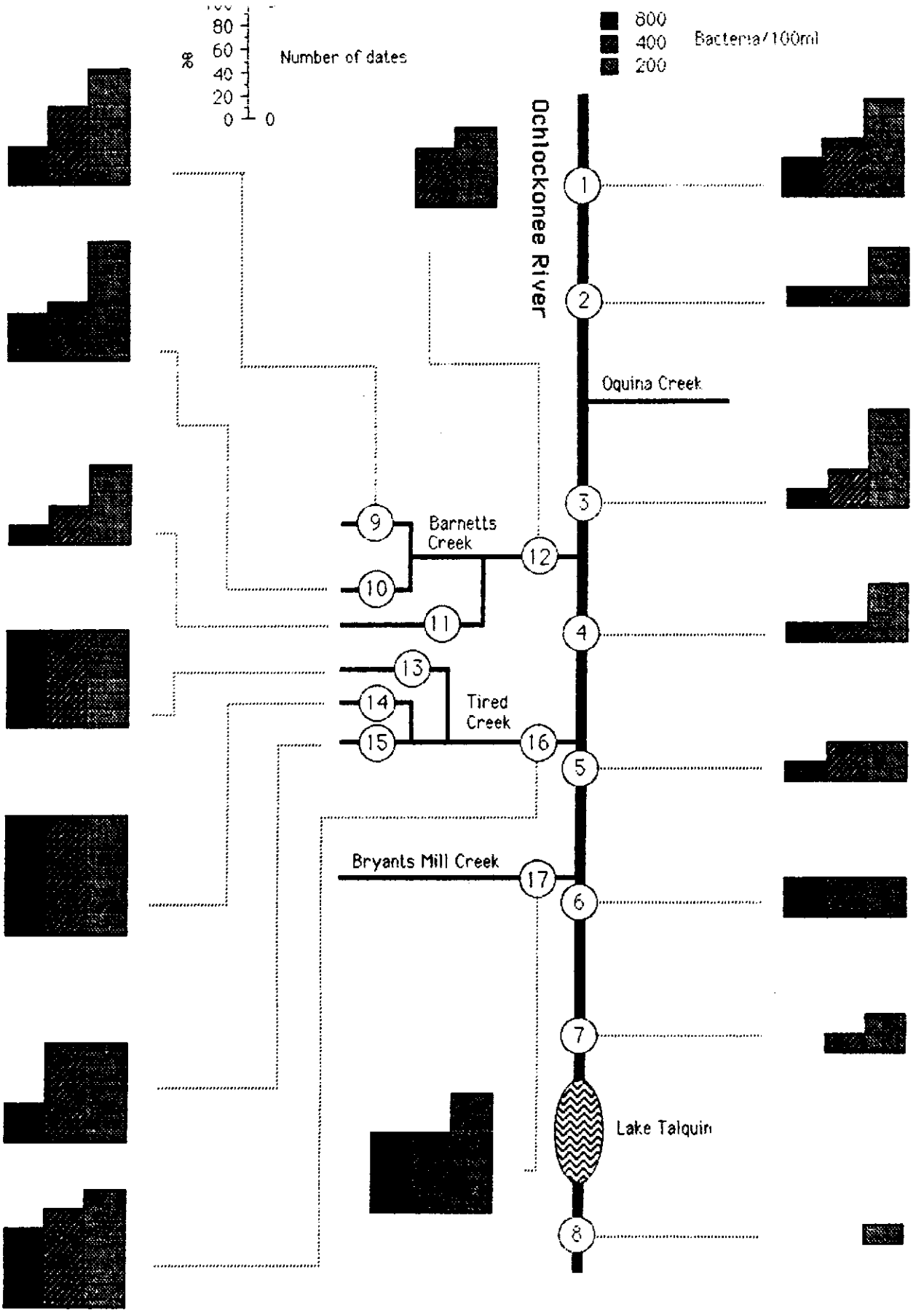


Figure 56. Percentage of fecal coliform bacteria samples in excess of selected numerical densities for six high-water sampling dates.

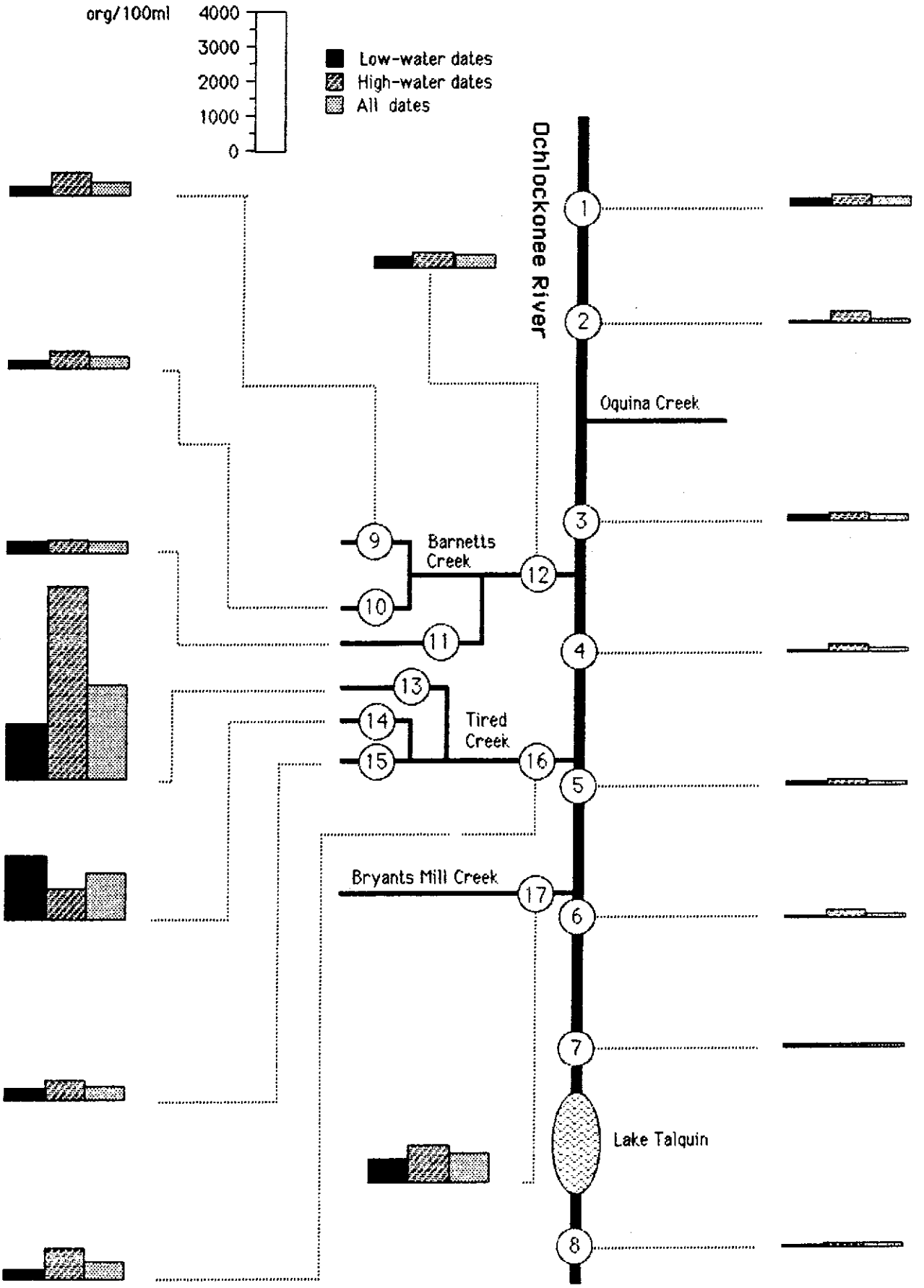


Figure 57. Fecal streptococci bacterial densities, geometric means of all sampling dates.

impact Station 16 or Station 5, downstream. Densities at Station 6 (122.9 org/100 ml) were approximately the same as those at Station 5. The impact of Bryants Mill Creek (Station 17, 813.0 org/100 ml) appears to maintain rather than enhance the densities of fecal streptococci bacteria in the river. South of Station 6, mean densities decreased (Station 7, 94.1 org/100 ml; Station 8, 86.2 org/100 ml).

Investigation of the high-low flow comparisons, (Figure 57 and Table 29) shows that densities during high flow periods were approximately 1-3 times greater than those during low flow periods.

Discussion

Statistical analyses were performed to investigate the relationship between the four bacterial groups and selected environmental parameters (Table 30) using Pearson's Correlation Coefficient. The value of the Pearson's Coefficient, r, ranges from -1 to +1. Values close to 0 indicate little relationship between the two parameters in question: values near to -1 or +1 indicate that the points fall very close to a straight line with negative or positive slope, respectively (Brown and Hollander 1977).

All four bacterial groups were significantly associated with station location ($p = .001$). SPC was the only bacterial group associated with the date of sampling ($p = .001$); the negative correlation indicated that, as time progressed, SPC densities decreased. As noted earlier, high flow was associated with the earlier months and low flow with the later months of the study. Thus, indirectly, the SPC bacteria appear to be associated with high flow.

Total coliform bacteria, fecal coliform bacteria, and fecal streptococci bacteria levels were significantly correlated with total suspended solids (TSS; $p \leq .002$), temperature (TEMP; $p \leq .005$), and conductivity (COND; $p \leq .005$). Fecal coliform and fecal streptococci bacteria were significantly ($p = .001$) correlated with turbidity (TURB); total coliform bacteria ($p = .309$) and SPC ($p = .073$) were not.

Results of this study indicate that the four bacterial groups investigated vary substantially within this portion of the Ochlockonee River Basin. Variations among stations, as well as at each station appear to be the result of environmental influences on a variety of bacterial sources. Within this area of the Ochlockonee River Basin, industrial discharges, recovered waters from sewage treatment facilities, agricultural run-off, and mining activities alter the natural bacterial populations. Once introduced into the surface waters, bacterial densities are suppressed or enhanced by environmental factors. Among the environmental factors investigated, total suspended solids, turbidity, pH, conductivity, and river flow (an indirect measure of local rainfall) were significantly related to the bacterial densities recorded during our study.

TABLE 29. Fecal streptococci bacterial densities, geometric means of all sampling dates.

RIVER STATION	LOG	#	TRIBUTARY STATION	LOG	#
1	2.3396	218.6	9	2.4338	271.5
	2.5297	338.6		2.8215	663.0
	2.4211	263.7		2.5999	398.0
2	1.8574	72.0	10	2.3428	220.2
	2.5196	330.8		2.7047	506.6
	2.1412	138.4		2.4979	314.7
3	2.1493	141.0	11	2.5036	318.9
	2.3797	239.7		2.5814	381.4
	2.2480	177.0		2.5369	344.3
4	1.9050	80.4	12	2.5224	333.0
	2.3461	221.9		2.6441	440.7
	2.0940	124.2		2.5746	375.5
5	2.0091	102.1	13	3.2063	1608.1
	2.2039	159.9		3.7468	5582.1
	2.0926	123.8		3.4380	2741.6
6	1.9105	82.2	14	3.2689	1857.4
	2.3278	212.7		2.9428	876.6
	2.0894	122.9		3.1291	1346.2
7	1.9847	96.5	15	2.4984	315.1
	1.9584	90.9		2.7572	571.7
	1.9734	94.1		2.6098	406.7
8	1.7978	62.8	16	2.4733	297.4
	2.1193	131.6		2.9536	898.7
	1.9356	86.2		2.6803	479.0
			17	2.8184	658.3
				3.0323	1077.2
				2.9101	813.0

TABLE 30. Pearson's correlation coefficients for selected parameters: (Each entry includes - r the correlation coefficient; the number of cases in parenthesis; and p the significance level.)

	STA	DATE	FC	TC	FS	SPC	TSS	TEMP	pH	COND	TURB
STA	1.0000 (238) p= .001	.0000 (238) p= .500	.3673 (238) p= .001	.3742 (238) p= .001	.4080 (238) p= .001	.2440 (238) p= .001	.1484 (238) p= .011	-.0645 (238) p= .161	.1786 (238) p= .003	.1869 (238) p= .002	.1801 (238) p= .003
DATE		1.0000 (238) p= .500	-.0122 (238) p= .426	.1212 (238) p= .031	.1006 (238) p= .061	-.2443 (238) p= .001	.1299 (238) p= .023	.2328 (238) p= .001	.1280 (238) p= .024	.0719 (238) p= .135	.1354 (238) p= .018
FC			1.0000 (238) p= .001	.3469 (238) p= .001	.6028 (238) p= .001	.4049 (238) p= .001)	.2021 (238) p= .001	-.3029 (238) p= .001	-.1766 (238) p= .003	.2110 (238) p= .001	.2626 (238) p= .001
TC				1.0000 (238) p= .001	.3204 (238) p= .001	.1778 (238) p= .003	.1845 (238) p= .002	.2834 (238) p= .001	.1657 (238) p= .005	.2924 (238) p= .001	.0325 (238) p= .309
FS					1.0000 (238) p= .001	.3515 (238) p= .001	.2040 (238) p= .001	-.1718 (238) p= .004	-.2339 (238) p= .001	.1651 (238) p= .005	.3477 (238) p= .001
SPC						1.0000 (238) p= .001	.1104 (238) p= .045	-.0860 (238) p= 093	-.0632 (238) p= .166	.1787 (238) p= .003	.0946 (238) p= .073
TSS							1.0000 (238) p= .001	.0239 (238) p= .357	-.0386 (238) p= .277	-.0638 (238) p= .164	.6164 (238) p= .001
TEMP								1.0000 (238) p= .001	.4096 (238) p= .001	.1339 (238) p= .019	-.1475 (238) p= .011
pH									1.0000 (238) p= .001	.1337 (238) p= .020	-.2068 (238) p= .001
COND										1.0000 (238) p= .001	-.1540 (238) p= .009
TURB											1.0000 (238) p= .001

Tributary stations were higher in recoverable densities than the river stations, probably because most of the domestic, industrial, and agricultrual sources discharge to tributary waters. Streams and rivers without man-induced pollution self-purify through a process of bacterial dilution, dispersion, and die-off as water travels from tributaries to its final destination. Thus, bacterial densities would be expected to decrease as one progresses downstream from the headwaters. However, when man-induced pollution sources enter the stream, the bacterial populations are substantially increased in the vicinity of the discharge with lesser effects downstream. In this study, sources which appeared to affect tributary waters were (in the order of greatest impact): 1) The Cairo Water Pollution Control Plant (Station 14); 2) The Roddenberry Company (Station 13); 3) suspected mining operations (Stations 9, 10, and 17); and 4) agricultural run-off (Stations 11, 15, and possibly 17). Sources which appeared to affect river water bacterial densities were Moultrie Water Pollution Control Plant (Station 1); Oquina Creek (Station 3); and Bryants Mill Creek at Station 6.. Why Station 5, downstream of Tired Creek (Station 16), was not more directly affected by the domestic and industrial bacterial densities at Stations 13 and 14 is not clear.

Of the environmental factors investigated, river flow appeared to have the greatest effect on the bacterial densities. It was noted that SPC, fecal coliform, and fecal streptococci bacteria were 2-6 times greater during the high flow period than the low flow period. Total coliform bacteria did not follow this pattern. The higher total coliform densities were noted during low flow conditions. The Pearson's Correlation Coefficient Analysis suggests that, in this system, total coliform bacteria were significantly associated with TSS but independent of turbidity whereas all other bacteria were significantly associated with both TSS and turbidity. Thus, it is reasonable to speculate that the turbidity associated bacteria were correlated with high flow and that the total coliform bacteria associated with the total suspended solids appeared to settle out rapidly and result in low water column densities. Further, the apparent increase of total coliform bacteria during low flow periods may be the result of growth of the sediment-associated bacteria entering the water column. Geldreich, et al. (1968) has noted previously the potential for in situ coliform growth in freshwaters.

The measured densities of the coliform bacteria have regulatory implications. In Florida (Table 31) both total coliform and fecal coliform bacteria are specified in the state's water quality criteria; Georgia (Table 32) cites only fecal coliform bacteria. Of the stations surveyed, river Stations 6-8 are located in Florida; all other tributary and river stations are located in Georgia. Application of Georgia's standards to the data from Georgia stations indicated fecal coliform violations at Stations 13 and 14, the Roddenberry Company and the Cairo Water Pollution Control Plant, respectively. Application of Florida's standards to the data collected from Florida stations indicated that Stations 6, 7, and 8 were consistently in violation of the most lenient total coliform standards (2400 org/100 ml). Data for Station 6 also indicated that fecal coliform violations (> 800 org/100 ml) occurred 33%

TABLE 31. Florida water quality standards applicable to the Ochlockonee River Study area.

FAC 17-3.121 Criteria: Class III Waters
Recreation-Propagation and Management of Fish and Wildlife - Surface Waters

(5) Bacteriological Quality - fecal coliform bacteria shall not exceed a monthly average of 200 per 100 ml of sample, nor exceed 400 per 100 ml of sample, nor in 10 percent of the samples, nor exceed 800 per 100 ml on any one day, nor exceed a total coliform bacteria count of 1,000 per 100 ml as a monthly average, nor exceed 1,000 per 100 ml in more than 20 percent of the samples examined during any month, nor exceed 2,400 per 100 ml at any time. Monthly averages shall be expressed as geometric means based on a minimum of 10 samples taken over a 30 day period. Either MPN or MF counts may be utilized.

TABLE 32. Georgia water quality standards applicable to the Ochlockonee River Study area (Title 391, Chapter 3, Rule 6).

391-3-6.03(6) - (c) Fishing, Propagation of Fish, Shellfish, Game and Other Aquatic Life; or for any other use requiring water of a lower quality:

1. Dissolved Oxygen: A daily average of 6.0 mg/l and no less than 5.0 mg/l at all times for waters designated as trout streams by the State Game and Fish Division. A daily average of 5.0 mg/l and no less than 4.0 mg/l at all times for waters supporting warm water species of fish.

2. pH: Within the range of 6.0-8.5.

3. Bacteria: Fecal coliform not to exceed a geometric mean of 1,000 per 100 ml based on at least four samples taken over a 30-day period and not to exceed maximum of 4,000 per 100 ml.

4. Bacteria: (Applicable only to waters designated as approved shellfish harvesting waters by the appropriate State agencies). The requirements will be consistent with those established by the State and Federal agencies responsible for the National Shellfish Sanitation Program.

5. Temperature: Not to exceed 90 degrees F. At no time is the temperature of the receiving waters to be increased more than 5 degrees F above intake temperature except that in estuarine waters the increase will not be more than 1.5 degrees F. In streams designated as primary trout or smallmouth bass waters by the State Game and Fish Division, there shall be no elevation or depression of natural stream temperatures. In streams designated as secondary trout waters there shall be no elevation or depression exceeding 2°F of natural stream temperatures.

6. Toxic Wastes, Other Deleterious Materials: None in concentrations that would harm man, fish and game or other beneficial aquatic life.

of the time during high river flows. This appears to be a result of the influence of Station 17, and to a lesser extent, Station 5. It is difficult to separate waters at the state line, especially under high flow conditions, since Georgia's tributary waters and river water directly affect Florida waters. The data demonstrate that violations of the Florida fecal coliform standard did occur during high flow conditions.

Historical data for the study area are limited; however, fecal coliform data were collected by the State of Georgia (GEPD 1973) at a number of locations close to our sampling stations. Locations consistent with current river Stations 1, 2, and 4 were reviewed by GEPD and reported at 210 org/100 ml, 150 org/100 ml, and 36 org/100 ml, resepctively. Oquina Creek discharge, which influences Station 3, was reported to have 430,000 org/100 ml. Although no bacterial analyses were done in the vicinity of Stations 13-16, GEPD recognized the potential impacts of the existing facilities. In the vicinity of Station 14 GEPD reports "water quality at this station was classified as polluted due to residual wastewater pollutants from the Cairo wastewater treatment facility and urban run-off from the Cairo area." And, in the vicinity of Station 13, GEPD reported "using definitions applicable to this report, this stream was assessed polluted in the 1967 investigation. Presently, the stream is categorized as moderately polluted...It is emphasized that water quality had been greatly enhanced in this portion of Little Tired Creek since 1967. The Roddenberry Company's wastewater treatment facility had been operated in a continuously efficient manner." It appears that current data are consistent with those previously reported and appear to reflect characteristic, historical fecal coliform trends in the Ochlockonee River Basin.

Conclusions

The highest densities of all categories of bacteria were associated with tributary stations, especially stations with domestic and industrial discharges such as in the Thomasville and Cairo areas. Downstream impacts in Florida waters from upstream Georgia waters only occurred during flood conditions. Excessively high levels of fecal coliform bacteria originating in Georgia (predominately from Bryants Mill Creek, Station 17) resulted in Florida water quality violations at Station 6 during periods of high river flow. Mean total coliform bacteria were consistently greater than 2400 org/100 ml throughout the river system. Florida Stations 6, 7, and 8 were therefore in violation of State water quality standards for this parameter.

PERIPHYTON AND CHLOROPHYLL

Introduction

Periphyton refers to the community of microorganisms inhabiting surfaces of underwater vegetation, rocks, and other substrates. This community is also commonly referred to as "Aufwuchs" or sometimes "epilithon" (Round 1964, U.S. EPA 1973, Swift 1981). Through photosynthesis, periphyton communities are responsible for the production of large quantities of both bioavailable organic matter and dissolved oxygen. Due to the sedentary nature of periphyton, its community composition, structure, and biomass are sensitive to changes in water quality and are often used as indicators of ambient conditions (Butcher 1947, Fjerdingstad 1964, Lowe 1974). Additionally, alterations in the structure and relative abundance of various elements of the algal community making up the periphyton are among the first symptoms of change in an aquatic habitat (Vollenweider 1974, Spodniewska 1978). Although periphyton communities are usually dominated by diatoms, they are generally quite diverse, often containing hundreds of taxa (Sládečková 1962, Hutchinson 1957).

The goals of this portion of the study were to assess differences in community composition and structure of periphyton along the river that may be associated with point and non-point source pollution loading from the upper reaches of the river. These changes could then be related to differences in water quality which ultimately affect the fishery resource of the Ochlockonee River.

Methods and Materials

Artificial substrates were utilized for sampling of periphyton in this study. Numerous studies have indicated that communities grown on artificial substrates, though not identical, are comparable to those grown on natural substrates (Flemer 1970, Hynes 1970, Tuchman 1979, Thompson et al. 1982). Glass slides were chosen due to the uniformity of their construction, the ease of procuring them in quantity, and because of their widespread use in similar studies (FDER 1985, Hufford and Collins 1976, Swift 1981, Thompson et al. 1982, Yount 1956). Also, the use of glass slides in a uniform sampling rack (periphytometer) reduces variability associated with substrate, water depth, and current (Patrick et al. 1954, Brown 1976, Pryfogle and Lowe 1979).

Nine standard, 75x25 mm microscope slides were placed in stainless steel racks that were floated approximately 15 cm below the water surface. Samples were collected from the eight primary stations, taking care to float the racks in areas of similar flow and light. Duplicate racks were placed at each station to compensate for the possible loss of samplers. Despite this precaution, samplers were not recovered 20 out of 104 times (Table 33).

TABLE 33. Missing periphyton data.

	STATION							
DATE	1	2	3	4	5	6	7	8
11-18-85					X			
12-16-85						X	X	
1-13-86								
2-10-86								
3-10-86			X	X				
4-7-86	X				X			
5-5-86	X		X	X	X		X	
6-2-86	X				X			
6-30-86		X				X		
7-28-86								
8-25-86							X	X
9-22-86								X
10-20-86					X			

After 28 days incubation, the slides were removed and placed in one of two tubes for analysis of phaeopigment-corrected chlorophyll *a*, and for taxonomic identification and enumeration. The slides for chlorophyll *a* analysis were placed in deionized water and stored on ice. The others were preserved in 5% formalin. Samples for determination of free-water chlorophyll *a* were taken at each of the 17 stations; water was collected in opaque Nalgene® bottles and stored on ice.

Pigment analysis was conducted within 24 hours of collection. For periphyton, four or five slides were scraped into deionized water and divided into two subsamples of equal volume. In the case of free water samples, two replicates were used. These subsamples/replicates were filtered through 0.45 um glass fiber filters (Whatman® GF/C) and rinsed with magnesium carbonate solution. The filters were then macerated with a fluted Teflon® tissue grinder, extracted in 90% aqueous acetone/magnesium carbonate mixture for 18 to 24 hours, and then centrifuged. Optical density of the supernatant was measured with a Beckman Model 35 double beam spectrophotometer at 664 nm for chlorophyll *a*. The samples were then acidified with 2 drops of 1.0N HCl to degrade the chlorophyll *a* molecules into phaeopigment compounds. Optical density was then measured at 665 nm. The monochromatic equation of Strickland and Parsons (1972) was used to calculate phaeopigment-corrected chlorophyll *a*.

For algal identification, periphyton was scraped from the preserved slides and diluted to a known volume. These samples were used both for identification of the total algal community and for analysis of the diatom fraction. The portion of the sample used to identify the algal community was diluted with deionized water until proper counting densities were achieved. Ütermohl counting chambers and a Wild® M-40 inverted microscope were used for identification and enumeration. The number of fields counted varied with algal density. Counting was continued until 200 to 250 cells/filaments/colonies were encountered. The taxonomic keys listed in the Literature Cited were used for algal identification. Densities, in number of cells/mm^2, were determined from raw counts using the known volumes and dilutions.

The portions of the samples for diatom analysis were mixed with approximately 20 ml of 50% hydrogen peroxide and heated for 20 minutes on a warm laboratory hot plate. Potassium dichromate (1-2 g) was added to the mixture to complete the oxidation of the sample. After cooling, the sample was diluted with approximately 500 ml of deionized water, allowed to settle for 24 hours, and decanted. After several dilutions and settlings of cells, a measured portion of the concentrate was air dried onto a 0.17 um coverslip and permanently mounted onto a glass slide with Hyrax® mounting medium.

For each sample, 200-250 frustules (except where diatom density was very low) were identified to the species level using the references in the Literature Cited. An oil immersion lens (Zeiss®) was used at 500x and 1250x, and raw counts were then used to determined the percent composition of each diatom taxon. These proportions were then applied to the number

of diatoms counted in the total periphyton identification portion, and densities in number of cells/mm^2 were calculated. In the following text, diatoms (Bacillariophyta) are considered as an independent division. Chrysophytes other than diatoms are referred to as chrysophytes. Statistical analyses performed on the periphyton data included normal and inverse numerical classification (cluster analysis) using the 50 most dominant taxa, which constituted 93.1% of the total. Multiple discriminant analysis was used to identify physical-chemical factors that were most directly associated with the station groupings derived from biological data. This technique was used to relate species abundance and distribution patterns to abiotic parameters.

Results

General Overview

A total of 244 taxa in five algal divisions were identified during the course of this study. Diatoms were the most abundant, representing 71.3% of the taxa collected followed by chlorophytes (14.8%) and cyanophytes (9.4%). A list of all taxa identified, along with the number of occurrences at each site, is given in Table 34.

Average percent composition measurements of the three most abundant algal divisions indicated that diatoms were clearly dominant, ranging from 74.8 to 86.1% (Table 35, Figure 58). A drop in percent diatoms was observed at both Stations 3 and 6, but was more dramatic at Station 3. These decreases in diatom proportion were compensated for by increases in the percent cyanophyte population at both stations. The proportion of chlorophytes remained relatively stable, and ranged from 4.0 to 7.9%. The combined proportions of chrysophytes, euglenophytes, and pyrrhophytes accounted for less than one percent of the algal community at all stations.

Because community diversity measurements are often utilized as a tool for evaluation of water quality (Patrick et al. 1954, Hohn 1961, Pryfogle and Lowe 1979), the Shannon-Weaver diversity index ($\bar{d}$) was calculated for each sample. This index is based on the number of taxa and the equitability of their distribution. Average diversity (Table 36) over the entire sampling period was very similar for all stations, ranging from 3.1 at Station 5 to 3.4 at Station 2. A pooled variation of this diversity index was also calculated. Pooled $\bar{d}$ followed nearly the same trend as the mean, though generally higher and ranged from 3.6 at Station 5 to 4.8 at Station 2. The pooled diversity measurement is highly dependent on the total number of taxa, and thus the relatively low number of taxa collected from Station 5, along with a high mean abundance of periphyton, contributed to the lower pooled diversity calculated for this station.

Species richness is also a useful diversity measure, and is expressed as total and mean number of taxa. Total species richness was lowest at Station 5 (91 taxa) while the highest species richness (120 taxa) was noted at Station 2 (Table 36). The total number of taxa is largely

TABLE 34. Periphyton taxa and number of occurrences at each station, Ochlockonee River, October 1985 to October 1986.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
CYANOPHYTA								
Anabaena sp.	3	4	1	3	3	3	6	2
Aphanocapsa sp.	2	3	5	-	2	-	-	1
Aphanothece sp.	-	1	4	2	2	1	2	-
Chamaesiphon sp.	-	-	-	-	-	-	1	-
Chroococcus sp.	3	2	3	2	1	3	1	3
Coelosphaerium sp.	-	-	-	1	-	1	-	-
Dactylococcopsis sp.	3	2	3	1	2	1	2	3
Gloeocapsa sp.	1	1	-	-	-	-	-	-
Gloeothece sp.	1	-	-	-	-	-	-	-
Gomphosphaerium sp.	-	3	-	1	-	-	-	-
Hapalosiphon sp.	1	-	-	-	1	-	-	-
Lyngbya sp.	2	4	1	1	-	6	2	2
Merismopedium sp.	-	-	1	-	-	1	-	1
Microcystis/Anacystis sp.	10	12	11	11	8	11	10	11
Oscillatoria sp.	4	4	5	5	2	3	3	4
Phormidium sp.	5	5	6	4	4	3	3	5
Plectonema sp.	1	-	-	-	-	-	-	-
Rhabdoderma sp.	1	1	-	-	-	-	-	-
Spirulina sp.	1	-	-	-	-	-	-	-
Stigonema sp.	1	-	-	2	-	-	-	1
Synechocystis sp.	1	-	-	-	-	-	-	-
Unknown Cyanophyte filament 1	1	-	-	-	-	-	-	-
Unknown Cyanophyte filament 2	2	1	-	-	-	-	1	1
CHLOROPHYTA								
Arthrodesmus sp.	-	-	-	-	-	-	1	-
Askenasyella sp.	-	-	-	1	-	-	-	-

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
Basicladia sp	1	-	-	-	-	-	-	-
Botryococcus sp.	9	8	10	6	5	6	6	6
Bulbochaete sp.	-	-	-	1	-	-	-	-
Characium sp.	-	4	1	3	2	-	-	2
Chlamydomonas sp.	2	6	1	1	2	2	2	2
Chlorella sp.	1	1	2	1	1	1	-	2
Chlorococcum sp.	1	2	1	-	-	2	1	1
Cladophora sp.	1	1	-	-	-	1	1	-
Closterium sp.	3	3	2	5	1	-	3	7
Coleochaete sp.	-	1	-	2	2	-	-	-
Cosmarium sp.	3	1	2	3	2	1	4	6
Crucigenia sp.	-	-	-	-	1	-	-	-
Dictyosphaerium sp.	-	-	-	-	-	-	-	1
Euastrum sp.	1	-	-	-	-	-	-	-
Gloeocystis sp.	-	3	1	1	1	-	-	1
Gonatozygon sp.	-	-	1	-	-	1	-	-
Kirchneriella sp.	-	-	1	-	-	-	-	2
Mougeotia sp.	3	3	2	3	1	-	1	2
Oedogonium sp.	3	6	-	4	1	4	2	2
Oocystis sp.	2	4	1	2	-	5	3	2
Palmella sp.	1	-	-	-	1	-	-	-
Palmodictyon sp.	1	-	-	-	-	-	-	1
Pleurotaenium sp.	1	-	-	1	-	-	-	-
Protococcus sp.	-	1	-	-	-	-	-	-
Protoderma sp.	1	3	1	3	2	2	2	2
Pseudulvella sp.	-	-	-	1	-	-	-	1
Scenedesmus sp.	2	2	-	1	1	1	2	4
Sphaerocystis sp.	3	-	1	-	-	-	1	1
Spirogyra sp.	-	1	-	2	2	1	1	1
Staurastrum sp.	3	5	1	2	-	2	3	2
Stigeocolonium sp.	-	1	1	2	1	-	-	-

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
Tetraedron sp.	-	-	1	-	-	-	-	-
Ulothrix sp.	-	1	-	1	1	2	2	2
Unknown Chlorophyte sp.	-	1	-	-	1	1	-	-
CHRYSOPHYTA								
Characiopsis sp.	-	1	-	-	-	-	-	-
Derepyxis sp.	-	-	1	-	-	-	-	-
Dinobryon sp.	-	-	1	-	-	1	-	-
Mallomonas sp.	-	-	-	1	-	-	-	2
Ophiocytium sp.	-	-	1	1	-	-	-	-
Stipitococcus sp.	3	-	1	1	-	1	1	-
Bacillariophyta								
Achnanthes sp.	-	-	1	-	-	-	-	-
A. affinis	-	1	-	-	-	-	-	1
A. exigua	7	9	7	8	6	5	7	7
A. hauckiana	5	2	1	4	2	1	4	3
A. hungarica	1	-	-	1	1	1	-	-
A. hustedtii	-	-	-	-	-	-	1	-
A. lanceolata	6	8	7	7	5	7	7	9
A. linearis	7	9	6	7	5	5	4	8
A. minutissima	-	3	-	-	-	-	-	-
A. pinnata	1	-	-	1	-	-	-	-
Amphora oralis	1	-	-	1	1	1	-	-
Anomoeonis serians	-	-	-	-	-	-	1	-
Bacillaria paradoxa	-	1	-	-	-	2	2	1
Biddulphia laevis	-	-	-	-	-	1	3	2
Caloneis ventricosa	-	1	-	-	-	-	-	1
Carpatogramma crucicula	3	4	-	4	1	3	4	5

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
Cocconeis sp.	-	1	-	-	-	-	-	-
C. fluviatilis	5	3	2	7	4	9	9	7
C. hustedtii	1	-	-	4	1	3	3	2
C. placentula	-	-	-	-	-	1	1	-
C. thumensis	-	-	-	1	1	-	1	1
Cyclotella sp.	2	-	1	1	-	2	-	2
C. atomis	-	-	-	-	-	-	-	3
C. comta	-	-	1	-	-	-	-	2
C. meneghiniana	1	1	3	-	-	1	-	2
C. stelligera	-	1	1	-	-	2	1	3
Cymbella sp.	-	-	-	1	-	-	-	-
C. aspera	1	4	-	1	1	1	1	1
C. lunata	-	-	-	-	-	-	-	1
C. minuta	3	10	7	3	3	5	4	9
C. naviculiformis	1	-	-	-	-	-	-	-
C. tumida	-	-	-	-	-	-	-	2
Diploneis sp.	1	-	1	-	-	-	-	-
D. pseudovalis	-	-	-	-	-	1	-	-
D. puella	2	1	1	3	-	4	4	1
Eunotia sp.	-	1	1	2	1	1	-	-
E. arcus	-	1	1	1	-	-	-	1
E. curvata	4	6	3	1	2	3	2	3
E. diodon	2	2	-	1	1	1	2	-
E. exigua	1	1	1	-	-	-	-	-
E. flexuosa	-	1	-	-	-	-	-	-
E. formica	-	-	-	-	-	-	-	-
E. incisa	2	1	1	-	1	-	-	1
E. maior	-	-	1	-	1	-	-	-
E. meisteri	-	1	-	-	1	1	-	1
E. naegelii	1	5	2	-	1	1	1	3
E. pectinalis	8	11	10	10	8	9	10	9

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
E. perpusilla	-	2	-	-	-	-	-	-
E. praerupta	-	-	1	-	-	-	-	-
E. sudetica	-	1	-	1	-	-	-	-
E. tautoniensis	-	-	-	1	-	-	-	1
E. tenella	-	1	2	-	1	-	-	-
E. vanheurckii	1	1	2	3	1	1	1	3
Fragilaria capucina	-	-	-	1	1	-	2	-
F. construens	-	-	-	-	-	1	1	-
F. crotonensis	-	2	1	1	-	1	-	3
F. harrissonii	1	-	-	-	-	-	-	-
F. leptostauron	-	-	-	-	-	-	3	3
F. pinnata	1	1	-	-	1	-	-	-
F. vaucheriae	-	-	-	1	2	-	2	3
F. virescens	-	-	-	-	-	1	1	2
Frustulia rhomboides	2	7	7	5	1	6	3	4
F. vulgaris	1	-	-	-	-	-	-	-
Gomphonema sp.	-	-	-	-	1	-	-	-
G. affine	4	5	4	-	-	1	1	2
G. apiculatum	-	-	1	-	-	-	-	-
G. gracile	-	3	3	3	4	4	2	2
G. grunowii	-	-	-	-	1	-	-	-
G. instabilis	-	-	-	-	1	-	-	-
G. parvulum	7	12	10	11	7	8	9	9
G. sphaerophorum	-	-	-	1	-	-	-	-
G. subclavatum	-	-	-	1	-	-	-	-
Gyrosigma acuminatum	-	-	-	-	-	-	1	-
G. nodiferum	-	-	-	-	-	1	1	-
G. obscurum	1	-	-	-	-	-	-	-
G. spencerii	1	1	-	3	1	3	4	2
Melosira granulata	-	1	-	-	-	-	-	8
M. islandica	1	-	1	-	1	-	-	2

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
M. italica	1	-	-	1	-	-	-	-
M. varians	6	7	4	4	3	5	3	5
Meridion circulare	5	2	3	2	1	1	1	-
Navicula sp.	-	-	1	2	-	-	3	1
N. anglica	-	1	1	1	-	1	-	-
N. arvensis	-	-	-	-	-	-	-	1
N. capitata	5	6	2	6	2	3	2	2
N. cocconeiformis	-	-	-	-	1	-	-	-
N. cryptocephala	-	-	1	-	-	-	1	1
N. cuspidata	-	-	-	-	-	1	1	-
N. elginensis	-	-	1	1	-	-	-	-
N. exigua	-	-	2	1	-	2	-	1
N. fragilarioides	-	-	-	1	-	-	-	-
N. gastrum	-	1	-	-	-	-	-	-
N. halophila	-	-	1	1	-	1	-	-
N. lateropunctata	-	4	2	4	2	4	2	3
N. minima	-	1	1	-	-	-	-	1
N. mutica	-	-	1	-	-	-	-	1
N. paucivisitata	1	-	-	-	-	-	-	-
N. protracta	3	2	2	1	1	1	1	1
N. pupula	3	5	4	2	1	5	3	6
N. radiosa	4	6	1	4	2	3	3	6
N. rhynchocephala	6	7	7	7	3	6	5	3
N. subtilissima	-	-	-	-	-	1	-	-
N. 'shadow'	1	-	-	1	-	-	-	-
N. viridula	-	1	-	1	3	4	2	3
Neidium affine	-	1	-	2	-	1	1	-
N. bisulcatum	-	-	-	-	-	1	-	-
Nitzschia sp.	-	-	-	-	-	-	1	-
N. acicularis	1	1	1	-	-	1	-	-
N. acuta	-	2	-	-	-	-	-	-

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
N. amphibia	1	1	2	2	-	1	-	-
N. apiculata	-	-	-	-	-	1	-	-
N. capitellata	1	-	-	-	-	-	1	-
N. commutata	-	-	-	-	-	-	1	-
N. dissipata	1	1	1	-	-	-	-	-
N. fasciculata	1	-	-	-	-	-	-	-
N. filiformis	-	1	2	2	2	4	4	1
N. fonticola	2	1	1	-	1	1	1	4
N. frustulum	-	-	1	-	-	-	-	1
N. gracilis	-	2	-	1	-	1	-	1
N. holsatica	-	1	1	1	-	-	-	-
N. ignorta	-	-	-	1	-	-	-	-
N. kutzingiana	1	-	-	1	-	1	-	-
N. lorenziana	-	1	-	-	-	-	-	-
N. microcephala	-	1	-	-	-	-	-	-
N. obtusa	-	2	2	-	1	-	-	1
N. palea	7	8	7	6	7	7	7	7
N. parvula	1	2	2	2	2	3	2	-
N. romana	-	1	-	-	-	-	-	-
N. sublinearis	1	-	-	-	1	2	1	-
N. subtilis	1	-	2	2	-	-	-	-
N. stagnorum	1	-	-	-	-	-	-	-
N. thermalis	-	-	1	1	-	-	1	-
N. tryblionella	1	2	-	4	1	3	3	-
Opephora martyi	-	-	-	-	-	-	1	-
Pinnularia sp.	3	1	-	3	1	4	1	1
P. abaujensis	1	1	2	1	-	-	-	1
P. accuminata	-	-	-	2	-	-	-	-
P. acrosphaeria	-	-	-	-	-	-	1	-
P. appendiculata	-	-	2	-	-	-	-	-
P. braunii	-	-	-	-	-	-	1	-

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
P. divergens	-	-	-	-	-	-	1	-
P. gibba	-	-	2	1	-	1	-	-
P. mesogonglya	-	1	-	-	-	-	-	-
P. mesolepta	-	1	-	-	-	-	-	1
P. subcapitata	1	-	1	-	-	-	1	2
P. termitina	-	-	-	-	-	-	-	1
Rhopalodia gibberula	-	1	-	-	-	-	-	-
Staroneis anceps	1	-	-	1	-	1	-	-
S. phoenicenteron	-	-	-	-	-	-	-	1
S. smithii	-	-	1	-	-	-	-	-
Stephanodiscus astraea	-	-	-	-	-	-	-	2
S. hautzschii	-	-	1	-	-	-	1	2
Surirella sp.	-	1	-	-	-	-	-	-
Surirella sp. 1	-	-	-	1	-	-	-	-
Surirella sp. 2	-	-	-	1	-	-	-	-
S. angustata	1	2	-	1	-	-	2	1
S. linearis	3	2	-	-	1	2	2	2
S. ovalis	-	-	-	1	-	-	-	-
S. robusta	1	1	-	-	-	-	1	1
S. tenera	-	1	1	4	1	2	2	-
Synedra sp.	-	-	-	-	1	-	-	-
S. acus	-	-	-	-	-	-	-	1
S. amphicephala	-	1	1	1	1	1	-	1
S. fasciculata	-	-	-	1	1	-	-	-
S. filiformis	2	-	1	1	1	1	-	-
S. incisa	-	-	-	1	1	-	-	-
S. miniscula	-	-	-	1	1	-	-	-
S. 'undefined'	-	1	-	-	-	-	-	1
S. radians	-	1	1	-	-	-	-	-
S. rumpens	-	1	2	2	1	-	2	4
S. ulna	10	11	5	8	7	6	5	7

TABLE 34. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
Tabellaria fennestrata	-	-	-	-	-	1	-	1
Thalassiosira fluviatilis	3	3	-	-	1	-	1	-
Unidentified diatom sp.	1	-	-	1	1	-	-	-
EUGLENOPHYTA								
Euglena sp.	-	-	-	-	-	-	-	-
Phacus sp.	-	3	2	1	-	1	-	1
Trachelomonas sp.	-	1	2	-	1	2	-	-
PYRRHOPHYTA								
Gymnodinium sp.	-	1	1	-	-	-	-	-
Peridinium sp.	-	-	-	-	-	-	1	-

TABLE 35. Numbers of periphyton taxa and percent composition of selected major algal divisions, Ochlockonee River, October 1985 to October 1986.

Number of Taxa	STATION 1	2	3	4	5	6	7	8
Cyanophyta	18	13	10	11	9	10	10	11
Chlorophyta	19	21	17	21	18	15	16	21
Chrysophyta	1	1	4	3	0	2	1	1
Bacillariophyta	67	82	70	80	63	71	71	79
Euglenophyta	0	2	2	1	1	3	1	1
Pyrrhophyta	0	1	1	0	0	0	1	0
% Composition (+ std. dev.)								
Cyanophyta	12.4 (± 7.3)	8.2 (± 5.1)	19.4 (± 10.9)	8.8 (± 4.7)	10.9 (± 5.8)	14.1 (±13.9)	13.0 (± 7.2)	9.7 (± 5.4)
Chlorophyta	6.2 (± 4.7)	5.7 (± 3.4)	5.0 (± 3.7)	5.5 (± 4.1)	7.9 (± 6.4)	7.4 (± 8.5)	4.3 (± 4.3)	4.0 (± 3.4)
Chrysophyta	0.6 (± 1.6)	0.03 (± 0.1)	0.4 (± 1.0)	0.3 (± 1.0)	0	0.08 (± 0.2)	0.04 (± 0.1)	0.07 (± 0.2)
Bacillariophyta	80.7 (± 10.5)	85.7 (± 6.8)	74.8 (± 14.0)	85.3 (± 8.3)	81.2 (± 10.6)	78.2 (± 16.3)	82.6 (± 7.4)	86.1 (± 7.7)
Euglenophyta	0	0.2 (± 0.6)	0.4 (± 0.7)	0.04 (± 0.1)	0.04 (± 0.1)	0.2 (± 0.4)	0.04 (± 0.1)	0.07 (± 0.2)
Pyrrhophyta	0	0.08 (± 0.3)	0.04 (± 0.1)	0	0	0	0.06 (± 0.2)	0

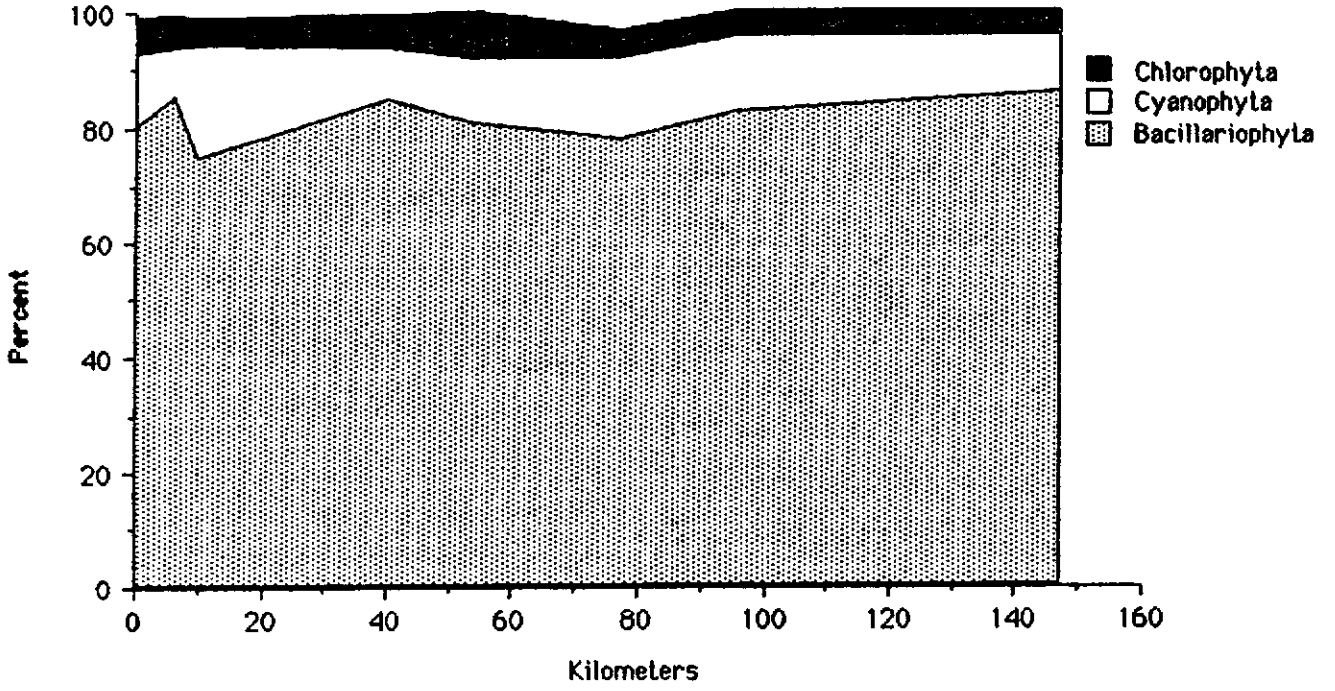


Figure 58. Mean percent composition of the three major algal divisions by river kilometer for all dates.

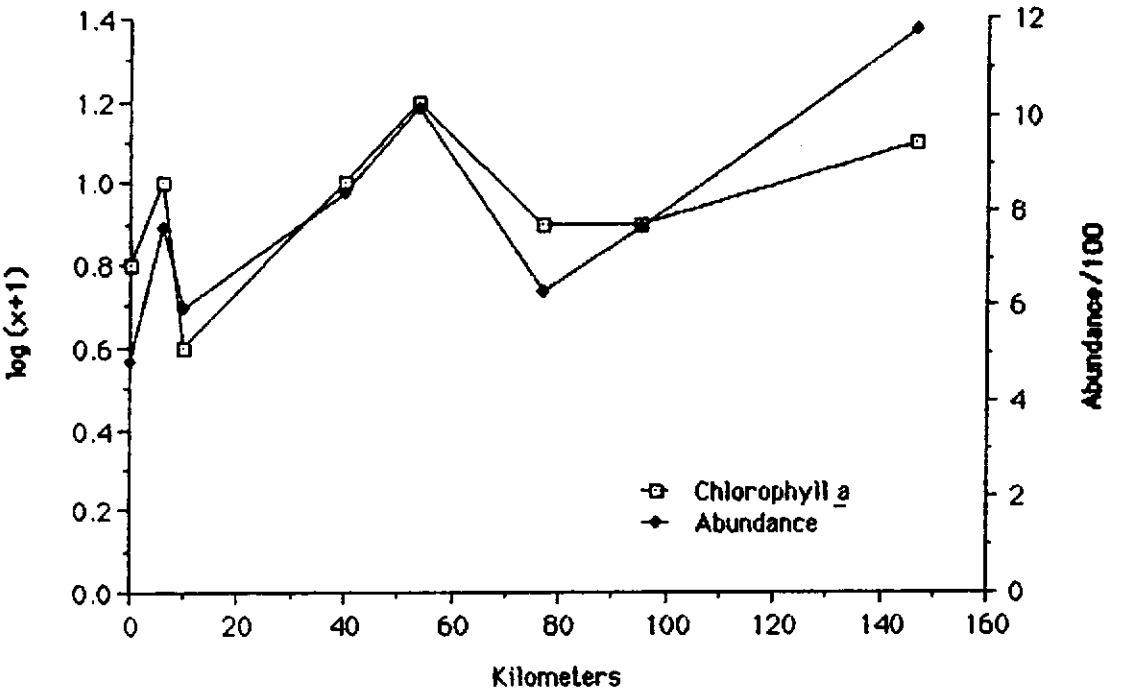


Figure 59. Mean periphyton abundance (#/ mm^2) and chlorophyll a (mg/mm2) by river kilometer.

TABLE 36. Abundance, chlorophyll a, species richness, and diversity, Ochlockonee River, October 1985 to October 1986.

STATION	1	2	3	4	5	6	7	8
$\bar{x}$ Abundance (#/mm^2) (± std. dev.)	486.1 (± 231.0)	762.5 (± 711.0)	595.2 (± 592.0)	839.0 (± 555.0)	1018.4 (± 963.0)	632.3 (± 633.0)	762.6 (± 576.0)	1179.5 (+ 920.0)
Number of samples	10	12	11	11	8	11	10	11
Total # taxa	105	120	104	116	91	101	100	113
$\bar{x}$ # taxa (± std. dev.)	25.8 (± 8.7)	27.8 (± 9.4)	22.4 (± 5.0)	25.5 (± 11.2)	22.1 (± 6.5)	23.1 (± 7.3)	24.4 (± 11.8)	27.5 (± 12.7)
$\bar{x}$ Shannon-Weaver diversity (± std. dev.)	3.3 (± 0.8)	3.4 (± 0.7)	3.3 (± 0.7)	3.3 (± 1.0)	3.1 (± 0.8)	3.3 (± 0.7)	3.2 (± 1.0)	3.3 (± 0.8)
Pooled Shannon-Weaver diversity	4.4	4.8	4.4	4.3	3.6	4.6	4.3	4.2
$\bar{x}$ # Individuals (#/mm^2)								
Cyanophyta	50.4	61.5	87.5	57.5	66.1	62.3	109.3	92.2
Chlorophyta	21.5	32.2	20.4	34.5	59.8	17.0	17.3	34.4
Chrysophyta	3.1	0.2	1.8	1.5	0	0.6	0.3	0.7
Bacillariophyta	410.5	665.7	483.5	745.4	892.0	551.8	635.2	1051.4
Euglenophyta	0	1.9	1.7	0.1	0.6	0.6	0.4	0.7
Pyrrhophyta	0	1.0	0.2	0	0	0	0.1	0
Chlorophyll a (mg/mm^2) (± std. dev.)	4.8 (± 4.9)	9.5 (± 11.1)	3.4 (±2.6)	9.2 (± 7.8)	13.7 (± 13.4)	6.9 (± 7.1)	6.9 (± 6.8)	10.3 (± 7.1)

affected by the number of samples, and only eight periphyton racks were recovered from Station 5 over the course of the study. Thus, the seemingly reduced species richness at Station 5 could merely be an artifact of missing data. Average species richness values, however, indicated that Station 5 was still the lowest with a mean of 22.1 taxa. This was very similar to the mean of 22.4 taxa found at Station 3. The highest average species richness values were recorded from Stations 2 and 8 (27.8 and 27.5 taxa, respectively).

The number of taxa identified in each algal division is given in Table 35. As would be expected, more taxa of the Bacillariophyta (diatoms) were collected from all sites. It is interesting to note, however, that although the chlorophytes constituted a smaller percentage of total algae than the cyanophytes, a greater number of chlorophyte taxa were collected from all stations. The numbers of taxa for the three major divisions compared to the total number of taxa were very similar except for Station 1, where a slightly higher percentage of blue-green taxa and lower percentage of diatom taxa was observed.

Mean abundance (#/mm^2) over the sampling period was calculated for all divisions separately and in combination (Table 36). Algal abundance ranged from 486.1/mm^2 at Station 1 to 1179.5/mm^2 at Station 8, though much variation in monthly measurements was observed at all stations. Average abundance dropped sharply at Stations 3 and 6.

Since algal cells vary in size, cell counts may not give a totally accurate indication of biomass (Swift 1981). Therefore, chlorophyll *a* has been widely used as an indirect measure of biomass (Yount 1956, Sládeček and Sládečkova 1964, Odum 1971, Hooper-Reid and Robinson 1978). Monthly chlorophyll *a* values were quite variable, and means ranged from 3.4 to 13.7 mg/mm^2 (Table 36). Biomass levels, as represented by chlorophyll *a*, peaked at Stations 2, 5, and 8, and were lowest at Stations 1 and 3. Trends in mean abundance and chlorophyll *a* were fairly parallel, as illustrated by Figure 59. Simple linear regression of chlorophyll *a* on abundance resulted in a highly significant correlation (r^2 = .405, p = .01). Similar regressions were performed on chlorophyll *a* data from each of the eight river stations. Results are given below, and monthly abundance and chlorophyll *a* values are depicted in Figure 60.

Station	1	2	3	4	5	6	7	8
r^2	.363	-.057	.277	.120	.963	.470	.498	.715
p	.05	NS	.05	NS	.01	.05	.05	.01

The significant correlations between algal density and chlorophyll *a* imply that the variation in chlorophyll *a* can be explained in terms of algal density. The reasons for the lack of correlation between these two parameters at Stations 2 and 4 is not readily apparent, but is probably related to algal community composition.

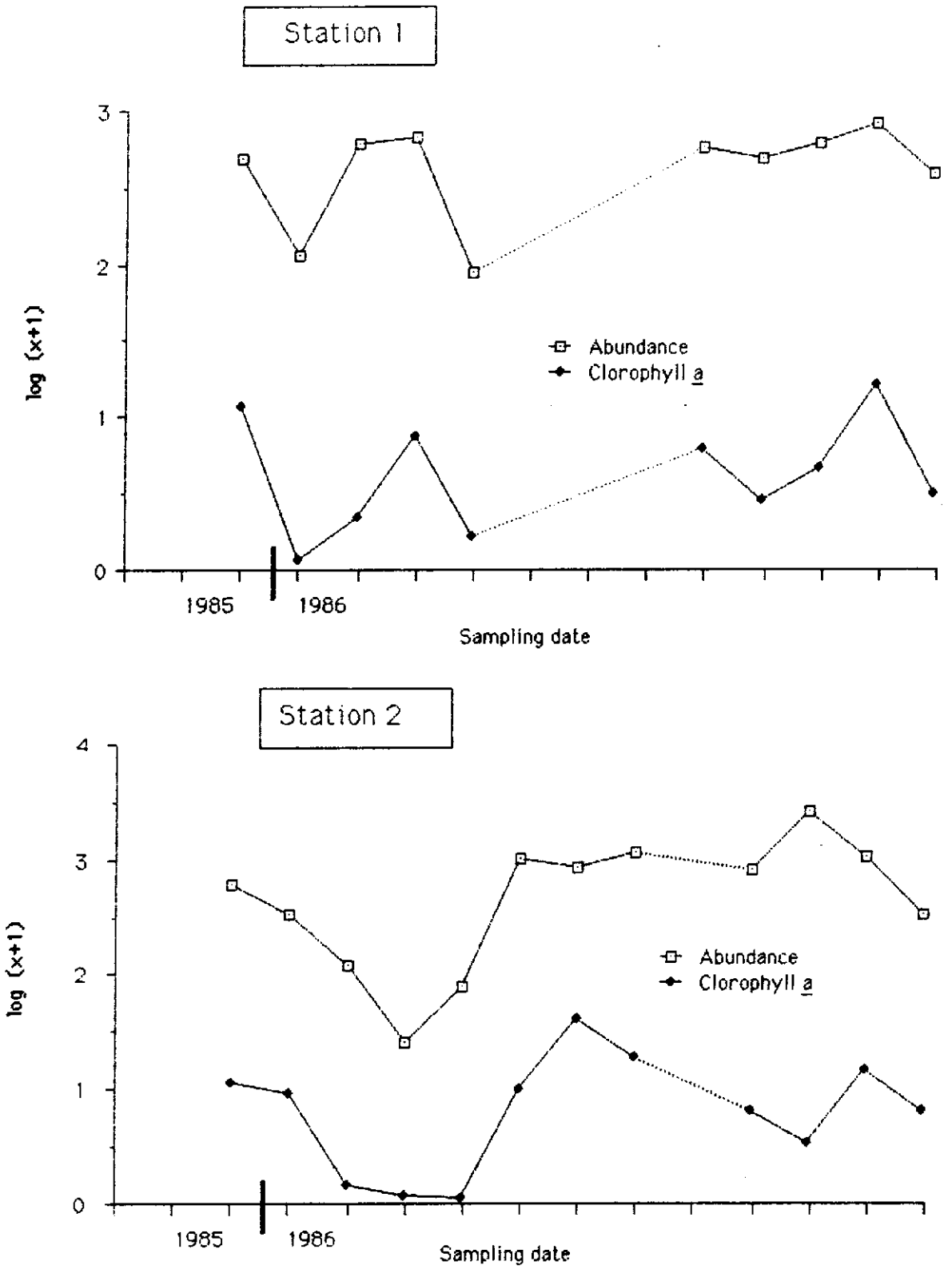
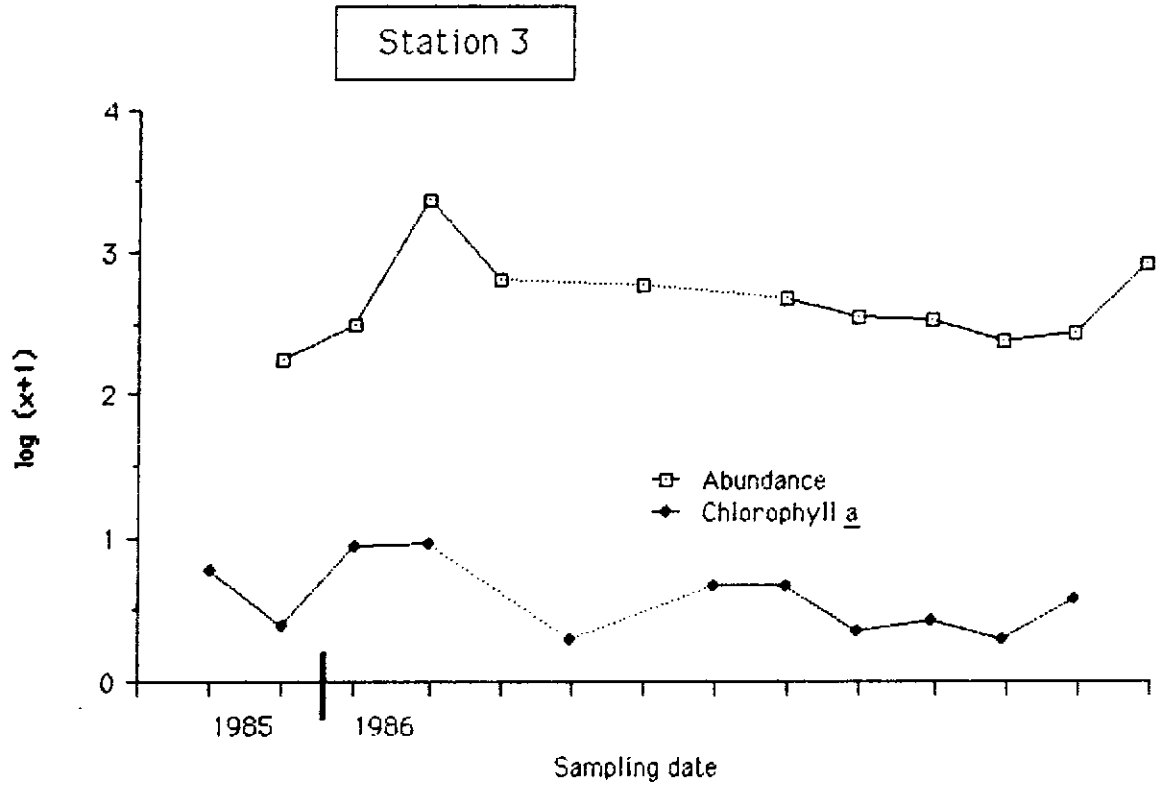


Figure 60. Periphyton abundance (#/mm^2) and chlorophyll a (mg/mm^2) by sample date. All values transformed by log (x+1).



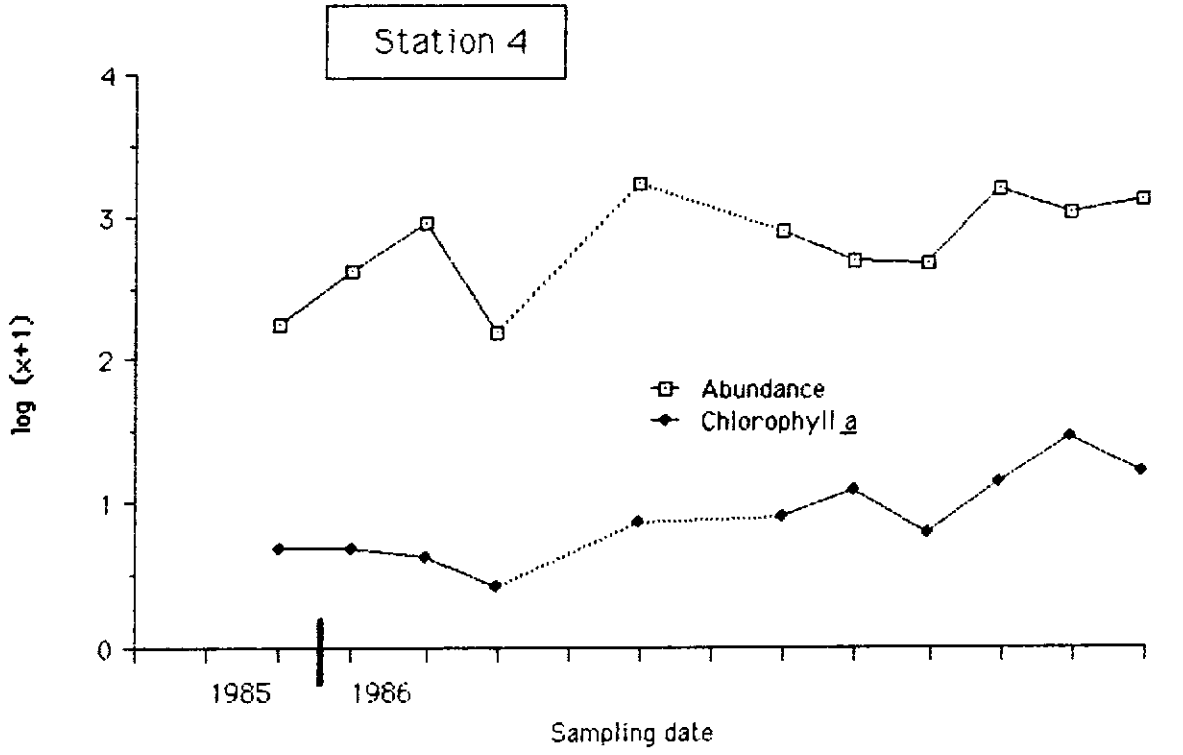


Figure 60. Cont. Periphyton abundance (#/mm^2) and chlorophyll a (mg/mm^2) by sample date. All values transformed by log (x+1)

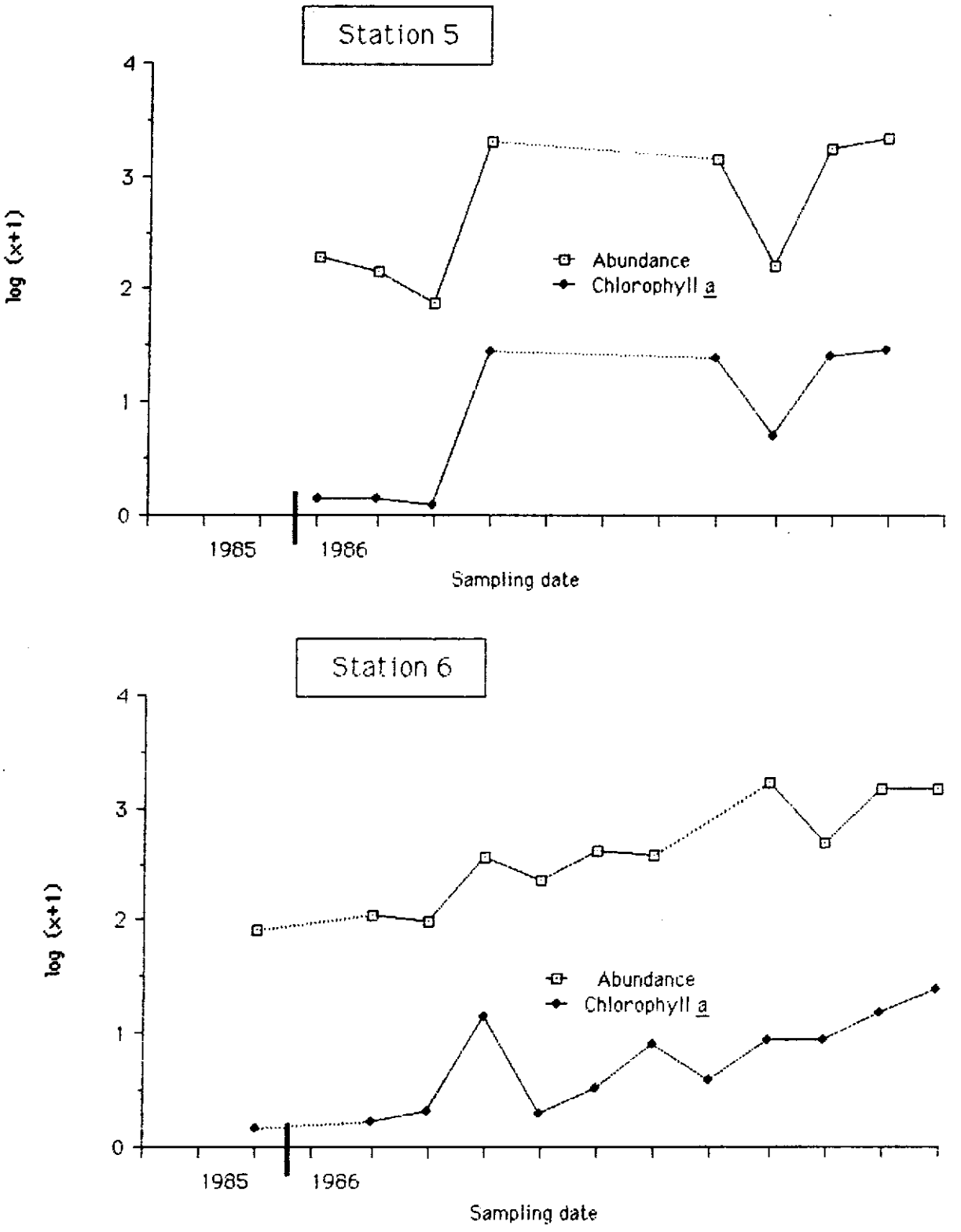


Figure 60. Cont. Periphyton abundance (#/mm^2) and chlorophyll a (mg/mm^2) by sample date. All values transformed by log (x+1).

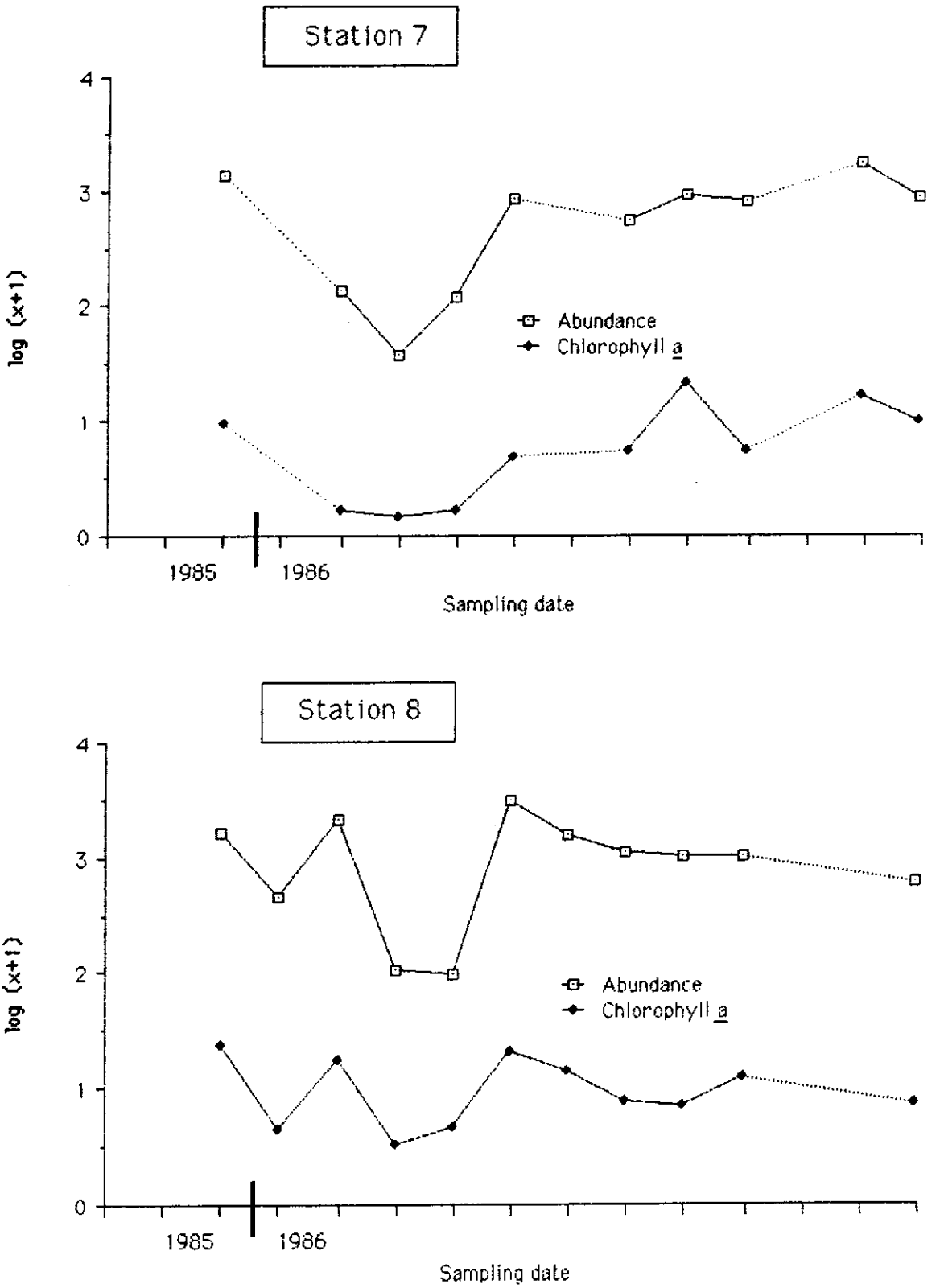


Figure 60. Cont. Periphyton abundance (#/mm^2) and chlorophyll a (mg/mm^2) by sample date. All values transformed by log (x+1).

Mean free-water chlorophyll a was measured at both river and tributary stations (Table 37). In the river, means ranged from 1.2 ug/l at Station 1 to 10.1 ug/l at Station 3. Chlorophyll a levels at Stations 5 and 6 were also relatively high, 5.3 ug/l and 5.2 ug/l, respectively. The variation from month to month at these three stations (3, 5, and 6) was quite high, resulting from one or a few sample dates where chlorophyll a levels were extremely elevated.

At the tributary stations, chlorophyll a was higher than that measured in the river, ranging from 2.1 ug/l at Station 12 to 16.2 ug/l at Station 10. It is not clear why the test waters at Station 10 produced such high chlorophyll a levels compared to nearby tributaries with similar inputs, but this may be related to sediment nutrients and flow regime. Chlorophyll a levels were relatively high at Station 14 as well (8.1 ug/l), but were more consistent, as were elevated nutrient levels in this tributary.

Correlation analyses were performed on abundance, chlorophyll a, algal growth potential (AGP), and several physico-chemical parameters for the river stations. Some notable correlations included:

Periphyton chl-a vs. abundance	.642 (p = .01)
Abundance vs. AGP	.276 (p = .02)
Abundance vs. NO_2NO_3	.255 (p = .05)
Abundance vs. turbidity	-.290 (p = .01)
Periphyton chl-a vs. AGP	.294 (p = .01)
Periphyton chl-a vs. turbidity	-.291 (p = .01)
Free-water chl-a vs. AGP	.411 (p = .01)
Free-water chl-a vs. TSIN (NO_2NO_3+NH_3)	.407 (p = .01)
Free-water chl-a vs. PO_4	.459 (p = .01)

The positive correlation in biomass estimates indicates that one could be used to estimate the other with a fair degree of certainty. Abundance, periphyton chlorophyll a, and free-water chlorophyll a were all positively correlated with algal growth potential. Both abundance and periphyton chlorophyll a were negatively correlated with turbidity, suggesting an inhibition of the algal population with increasing turbidity. Abundance and NO_2NO_3 were postively correlated, which is not surprising since the river waters were mostly N-limited (See Algal Assay Section). Free-water chlorophyll a was not significantly correlated with either biomass estimator, nor was a negative relationship with turbidity observed. A positive correlation was, however, noted between free-water chlorophyll a and total soluble inorganic nitrogen (TSIN) and dissolved phosphate.

Seasonal and Flow Regime Effects

Certain periphyton data were grouped according to season and flow level in an attempt to separate their respective effects and identify trends. The seasonal groups were as follows: Winter (December to February), Spring (March to May), Summer (June to August), and Fall

TABLE 37. Free-water chlorophyll *a* for river and tributary stations, Ochlockonee River, October 1985 to October 1986.

RIVER		TRIBUTARY	
STATION	Chl-*a*(ug/l)± std. dev.	STATION	Chl-*a*(ug/l)± std. dev.
1	1.2 ± 0.5	9	3.4 ± 2.2
2	1.8 ± 1.3	10	16.2 ± 19.4
3	10.1 ± 13.4	11	2.3 ± 2.1
4	1.9 ± 1.3	12	2.1 ± 1.1
5	5.3 ± 13.4	13	3.6 ± 2.9
6	5.2 ± 10.8	14	8.1 ± 4.8
7	2.9 ± 2.0	15	2.3 ± 1.6
8	3.6 ± 2.9	16	3.4 ± 3.9
		17	3.7 ± 4.1

(September to November). Chlorophyll a and abundance curves followed similar trends (Figure 61); values were low in winter and increased to a fall maximum. From spring to summer, chlorophyll a levels decreased slightly while abundance did not change appreciably. Seasonal trends in species richness and diversity were similar to each other throughout the sampling period, and were relatively low in winter and spring (Figures 62 and 63). In the summer, diversity and number of taxa peaked, and then declined in fall.

Two groups were formed according to flow. The high flow group was defined as greater than 28 m^3/s and included sampling dates from November, 1985, to March, 1986. The low flow group, or less than 28 m^3/s, was composed of dates from April to October, 1986. Mean abundance, species richness, diversity, percent composition, and chlorophyll a are given for high and low flow periods in Tables 38 and 39, respectively.

The most pronounced difference in percent composition of the three major algal divisions was in the relative proportions of cyanophytes and diatoms (Figures 64 and 65). During the high flow period, the percent of diatoms at Station 6 plunged to 62.4, accompanied by increases in both cyanophytes and chlorophytes. When the water level was low, diatoms constituted 71.2% of the population at Station 3 while the other stations ranged from 82.4 to 88.1%.

Diversity was notably lower during high flow conditions (Figure 66). Averages ranged from 2.7 to 3.2 when flow was high and from 3.2 to 3.8 during low flow. Within any flow regime the diversity values were not significantly different from each other.

As would be expected, species richness measurements were substantially higher during the low flow period (Figure 67). When the river was in flood stage, mean numbers of taxa were very similar along the river, ranging from 15.3 to 19.3. When the flow was low, the mean number of taxa per station was generally higher except at Stations 3 and 5, as was noted with yearly means.

Mean abundance was approximately two to five times greater during the low flow period (Figure 68). The low flow and yearly average varied together, though, during flood conditions, the trends were not the same. For example, from Stations 1 to 2 and particularly Stations 3 to 4 a substantial increase in algal density was observed during the low flow period; abundance sharply decreased at these sites when water level was high. Periphyton chlorophyll a measurements (Figure 69) peaked at Stations 2 and 5 during low flow conditions, and at Stations 3 and 5 during high flow. As was noted with the abundance data, trends were not consistent between the two flow regimes in the upper stations, but followed more closely below Station 4.

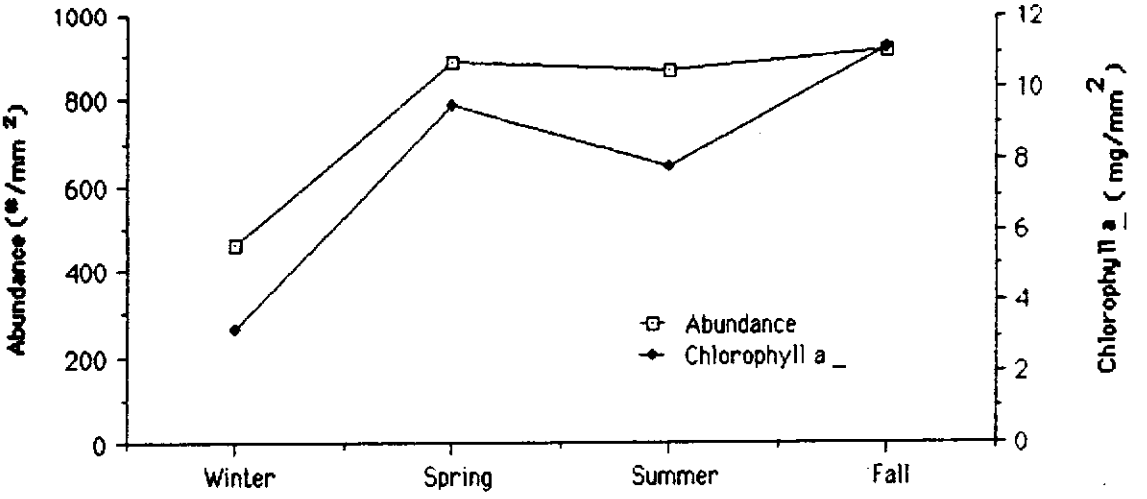


Figure 61. Mean periphyton abundance and chlorophyll a by season.

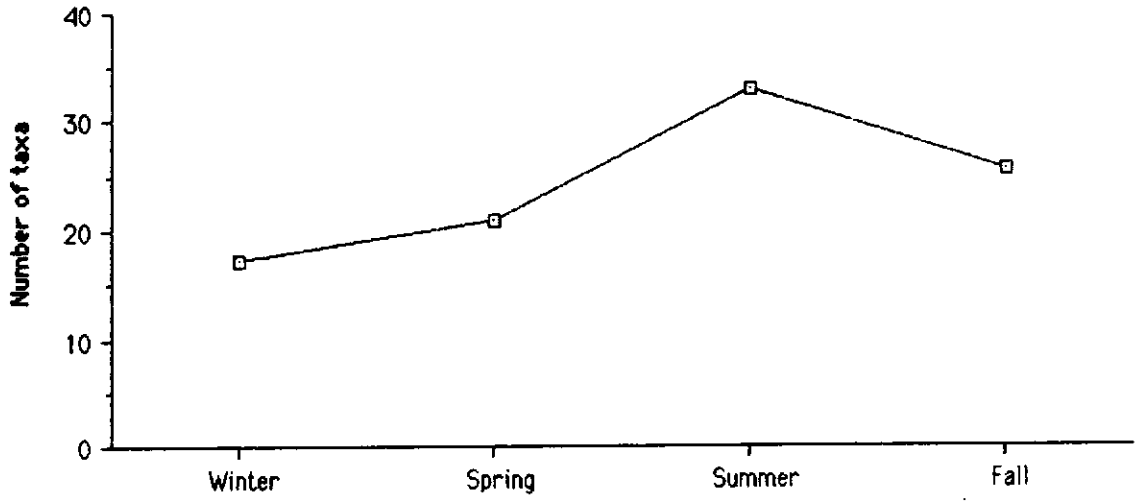


Figure 62. Mean number of periphyton taxa by season.

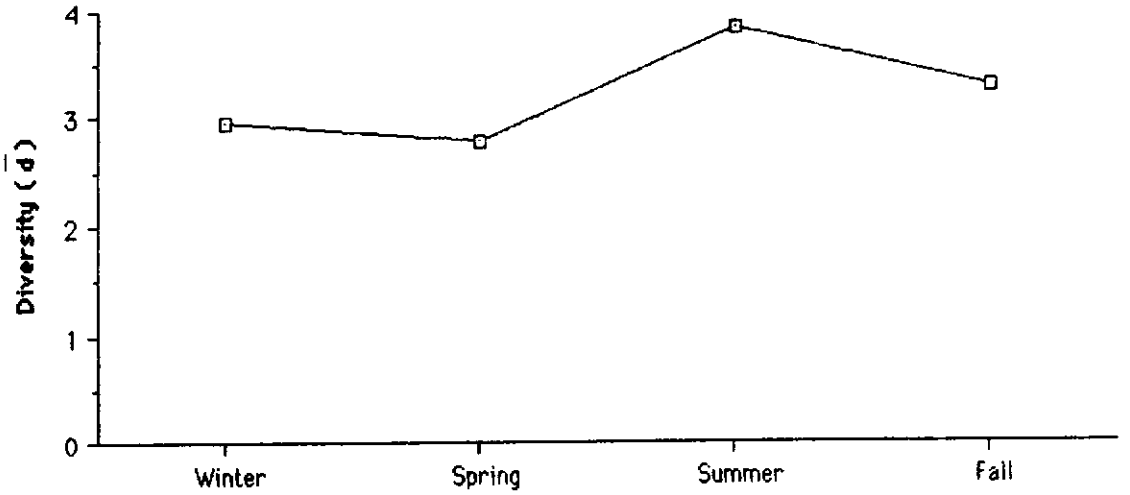


Figure 63. Mean periphyton Shannon-Weaver diversity by season.

TABLE 38. Periphyton abundance, chlorophyll a, species richness, diversity, and percent composition of major algal divisions for the sampling period of high flow (> 28 m^3/s), Ochlockonee River, October, 1985, to March, 1986.

STATION	1	2	3	4	5	6	7	8
Number of samples	5	5	4	4	4	4	4	5
$\bar{x}$ Abundance (#/mm^2) (± std. dev.)	397.3 (± 277.6)	236.3 (± 247.0)	860.3 (± 966.0)	414.9 (± 353.6)	619.6 (± 966.2)	161.6 (± 131.4)	427.0 (± 658.9)	888.7 (± 948.8)
$\bar{x}$ # Taxa (± std. dev.)	18.6 (± 4.6)	19.2 (± 2.8)	19.3 (± 1.7)	18.3 (± 5.1)	18.8 (± 1.5)	18.3 (± 2.4)	15.3 (± 10.0)	16.8 (± 4.8)
$\bar{x}$ Shannon-Weaver diversity (± std. dev.)	2.8 (± 0.8)	3.0 (± 0.4)	2.8 (± 0.3)	3.1 (± 0.4)	3.0 (± 0.7)	3.2 (± 0.7)	2.7 (± 1.2)	2.8 (± 0.5)
Percent Composition								
Cyanophyta	12.7	9.4	15.3	9.1	13.4	23.1	16.3	9.0
Chlorophyta	8.5	7.9	3.8	5.9	7.1	14.2	6.3	2.9
Bacillariophyta	78.8	82.5	80.9	84.9	79.5	62.4	77.2	88.1
Chlorophyll a (mg/mm^2) (± std. dev.)	3.9 (± 4.7)	3.9 (± 5.1)	5.7 (± 3.2)	3.2 (± 1.1)	7.0 (± 13.4)	3.9 (± 6.3)	2.7 (± 4.1)	9.8 (± 9.3)

TABLE 39. Periphyton abundance, chlorophyll a, species richness, diversity, and percent composition of major algal divisions for the sampling period of low flow (< 28 m^3/s), Ochlockonee River, April to October, 1986.

STATION	1	2	3	4	5	6	7	8
Number of samples	5	7	7	7	4	7	6	6
$\bar{x}$ Abundance (#/mm^2) (± std. dev.)	574.9 (± 153.2)	1138.3 (± 700.0)	443.6 (± 209.1)	1081.3 (± 512.0)	1417.3 (± 899.1)	901.3 (± 653.8)	986.3 (± 431.0	1421.8 (± 904.0)
$\bar{x}$ # Taxa (± std. dev.)	33.0 (± 4.4)	33.9 (± 7.3)	24.1 (± 5.5)	29.7 (± 11.9)	25.5 (± 8.2)	25.9 (± 7.9)	30.5 (± 8.8)	36.5 (± 7.9)
$\bar{x}$ Shannon-Weaver diversity (± std. dev.)	3.8 (± 0.4)	3.7 (± 0.7)	3.5 (± 0.7)	3.4 (± 1.2)	3.2 (± 0.8)	3.4 (± 0.7)	3.6 (± 0.7)	3.8 (± 0.8)
Percent Composition								
Cyanophyta	12.0	7.3	21.9	8.7	8.5	9.0	10.7	10.3
Chlorophyta	4.0	4.2	4.2	5.3	8.7	3.4	3.0	5.0
Bacillariophyta	82.4	88.1	71.2	85.5	82.7	87.3	86.2	84.5
Chlorophyll a (mg/mm^2) (± std. dev.)	5.6 (± 5.5)	13.5 (± 12.8)	2.1 (± 1.3)	12.6 (± 8.0)	20.4 (± 11.0)	8.3 (± 7.4)	9.7 (± 7.0)	10.8 (± 5.5)

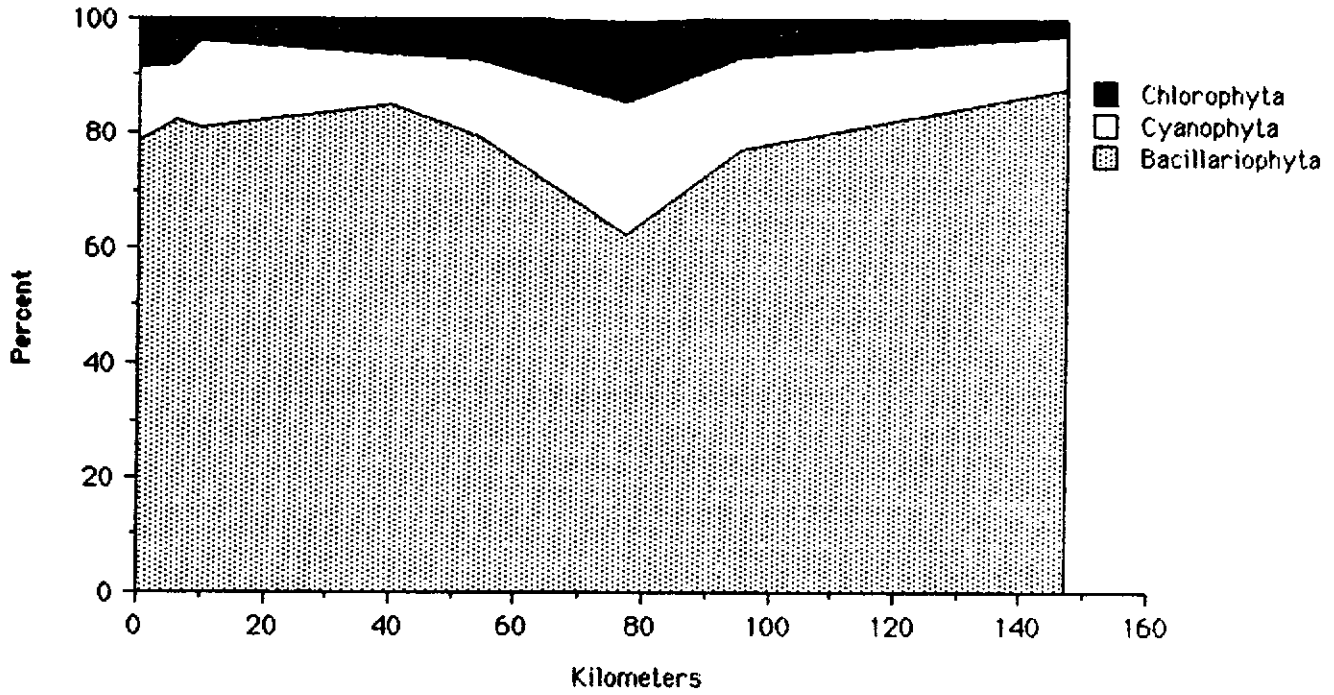


Figure 64. Mean percent composition of the three major algal divisions by river kilometer for the period of high flow.

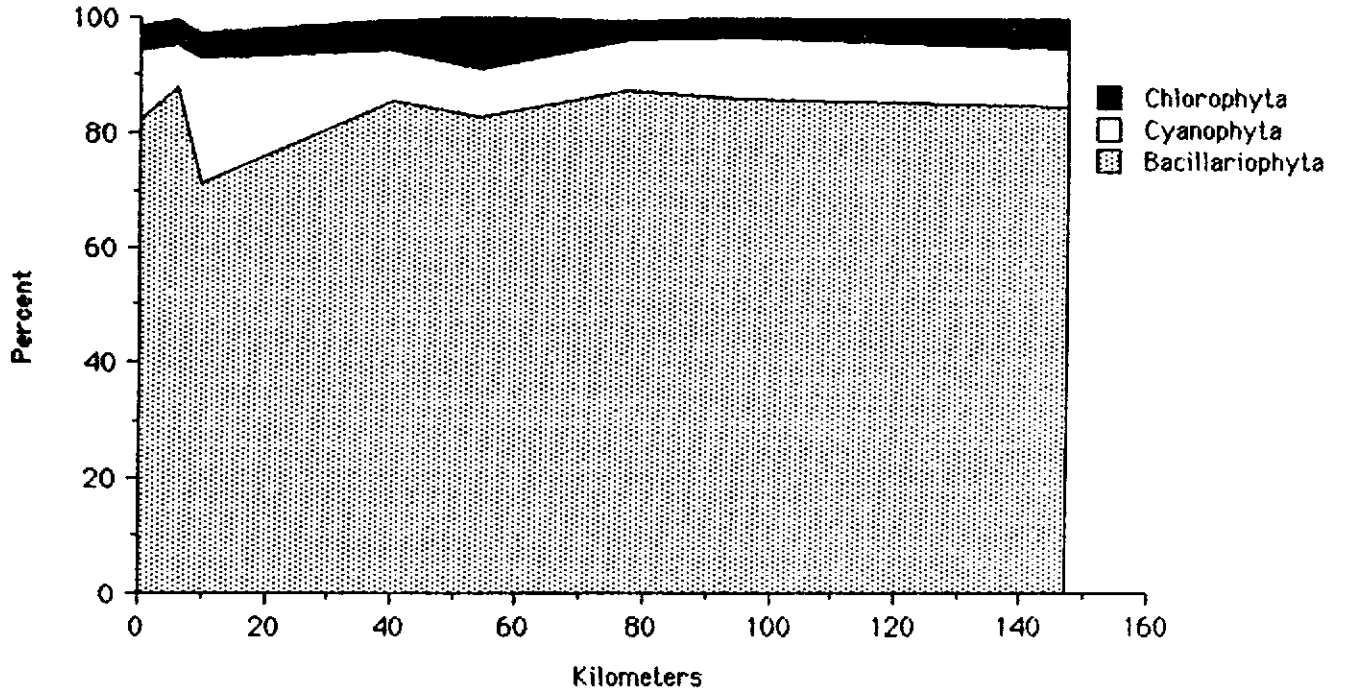


Figure 65. Mean percent composition of the three major algal divisions by river kilometer for the period of low flow.

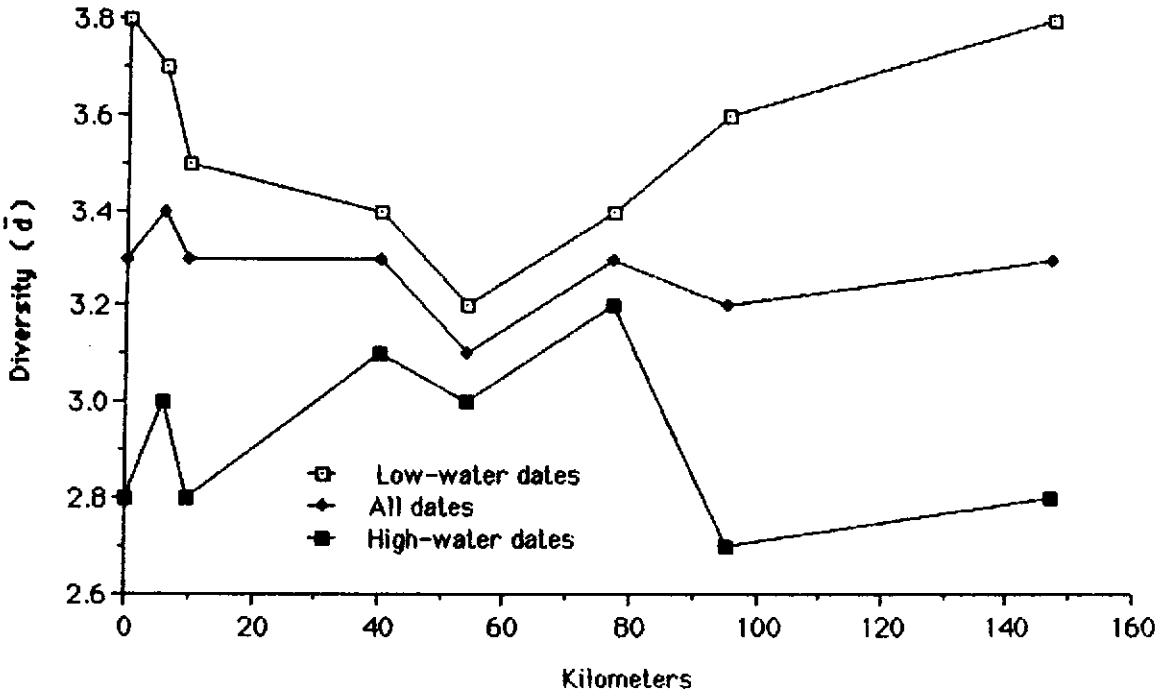


Figure 66. Mean periphyton Shannon-Weaver diversity by river kilometer.

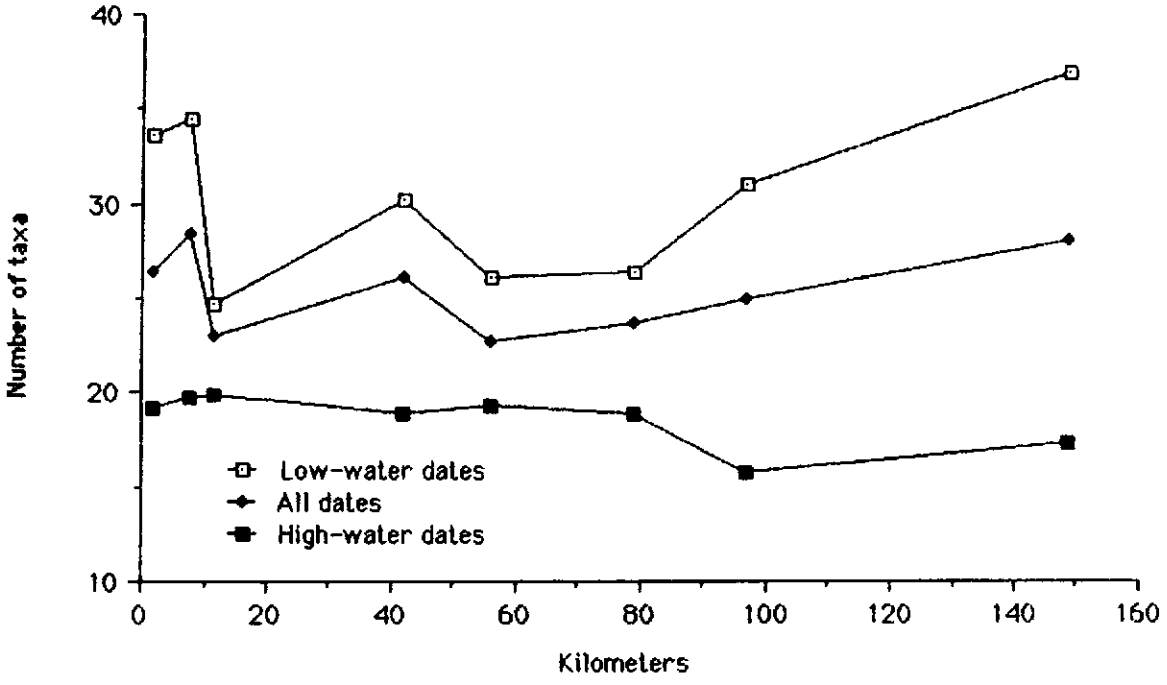


Figure 67. Mean number of periphyton taxa by river kilometer.

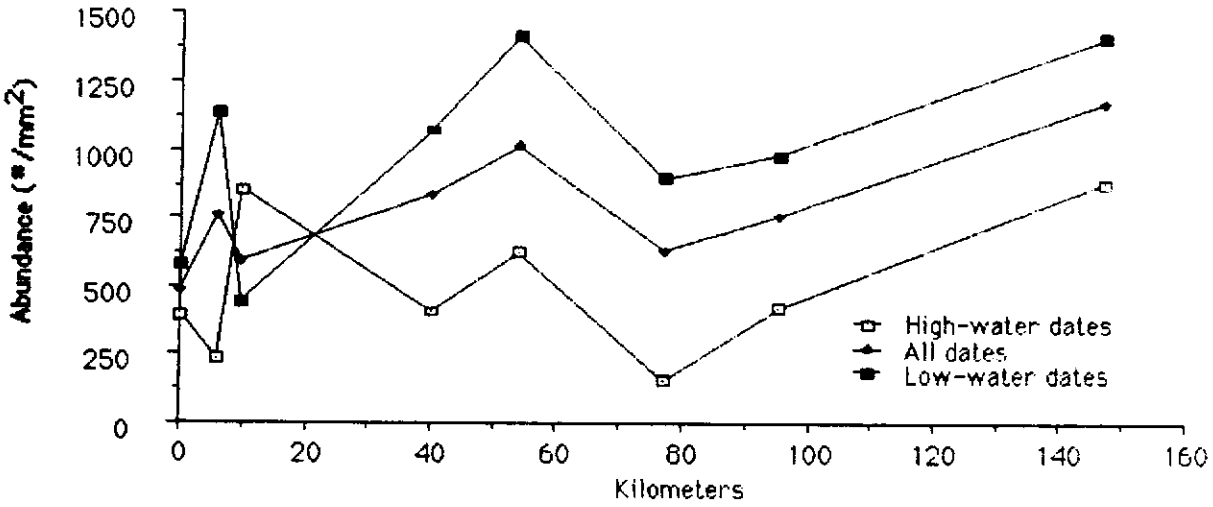


Figure 68. Mean periphyton abundance by river kilometer.

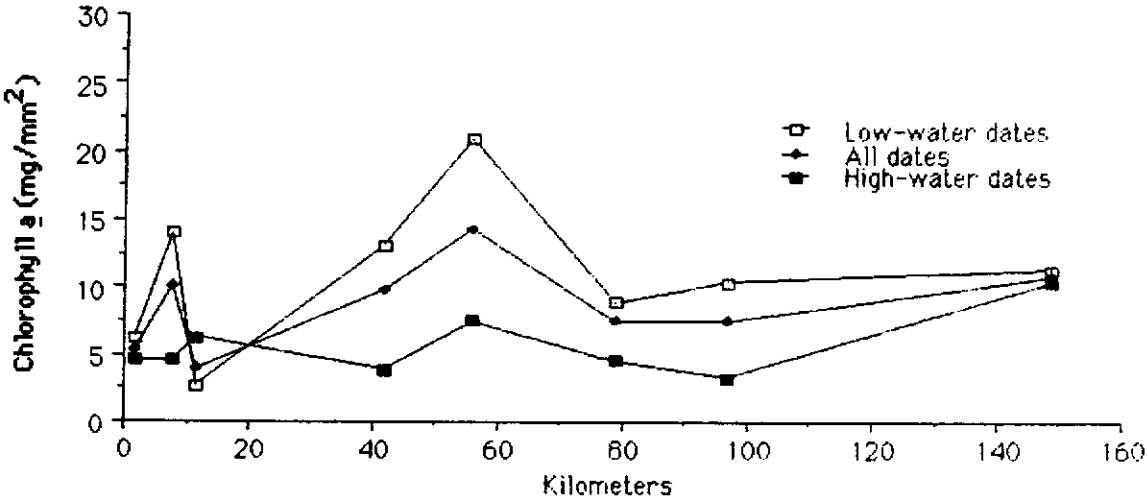


Figure 69. Mean periphyton chlorophyll a by river kilometer.

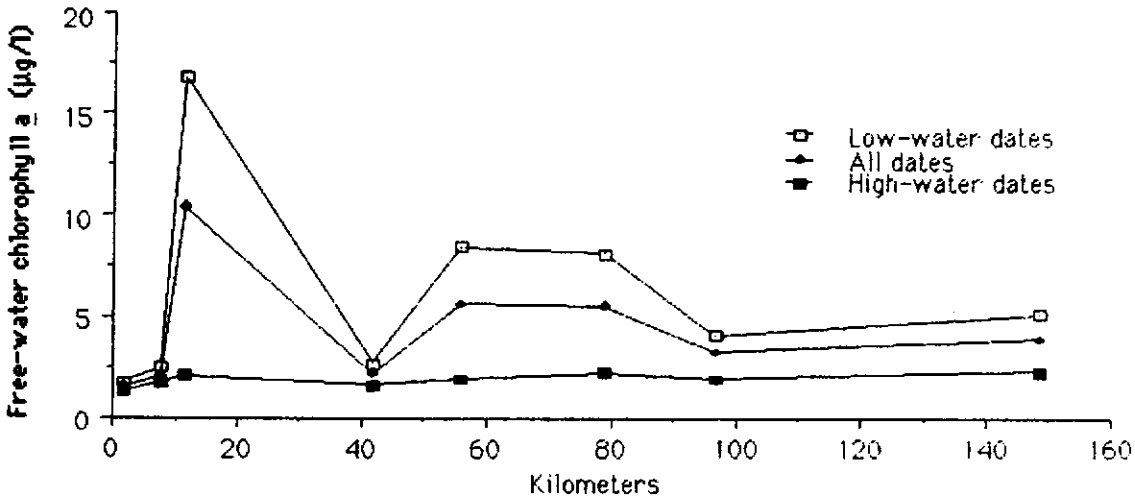


Figure 70. Mean free-water chlorophyll a by river kilometer.

During high flow conditions, free-water chlorophyll a values were so low at all stations that little difference could be discerned between them (Figure 70). The low water averages closely paralleled the yearly average, with a large peak at Station 3 and two smaller ones at Stations 5 and 6. For the most part, little variation in chlorophyll a according to flow regime was observed at the tributary stations (Table 40). The only exception to this was noted at Station 10, where chlorophyll a was nearly five times higher during low flow conditions.

Multivariate Techniques

Normal cluster analysis was performed on periphyton data from the high and low flow groups, as well as data comprising the entire sampling period. The stations were grouped differently during high and low flow conditions.

When data from the entire sampling period were analyzed, three station groups were indicated at the 70% level of similarity (Figure 71). Group A is made up of Stations 5 and 6, and Group B contains Stations 2 and 7. The remaining river stations (1, 4, 3, and 8) constitute Group C.

Multiple discriminant analysis was performed on several abiotic parameters which were thought to most likely account for periphyton distribution. This type of analysis is used as a means to indicate some of the abiotic factors that may have contributed to the station groupings derived from normal cluster analysis. The resulting scatterplot (Figure 72) illustrates the distribution of station groups in discriminant space. The first Discriminant Function (DF1) is primarily based on NO_2-NO_3 and turbidity, and explained 59.77% of the among-group variance. The addition of Discriminant Function 2 (DF2) increases the explained variance to 86.89%. The factor contributing the most to among-group separation in DF2 was PO_4. Groups A and B are clearly separated on the basis of NO_2-NO_3 and turbidity, although some values for Station 7 were relatively high. Stations 3 and 4 of Group C were the most dissimilar to the other river stations; this is probably due to high phosphorus levels.

Normal analysis of the low flow group (Figure 73) resulted in two station clusters. Group A consisted solely of Station 3, while the remaining seven stations constituted Group B.

Results of discriminant analysis of the low flow group were nearly identical to the group with all sample dates. Discriminant Function 1 (NO_2-NO_3 and turbidity) explained 58.96% of the among-group variance, and DF2 (PO_4) explained an additional 30.27%. The distribution of station groups in discriminant space (Figure 74), clearly demonstrates the separation of Station 3 from the others. At this station, the mean PO_4 and turbidity were highest during the low flow sampling period.

When the water level was high, the results of normal cluster analysis indicated three station groups, the first of which contained Stations 6 and 7 (Figure 75). The second cluster (Group B) was made up of the remaining stations (1, 2, 3, 4, 5, and 8).

TABLE 40. Mean free-water chlorophyll *a* for the entire sampling period and periods of high and low water, tributary stations.

Chlorophyll *a* (ug/l) ± std. dev.

STATION	High water dates	All dates	Low water dates
9	2.4 ± 1.4	3.4 ± 2.2	4.3 ± 2.4
10	5.1 ± 6.0	16.2 ± 19.4	24.5 ± 22.1
11	1.3 ± 0.8	2.3 ± 2.1	3.1 ± 2.4
12	1.6 ± 0.9	2.1 ± 1.1	2.4 ± 1.1
13	3.7 ± 2.6	3.6 ± 2.9	3.5 ± 3.2
14	8.7 ± 5.3	8.1 ± 4.8	7.7 ± 4.7
15	2.8 ± 2.2	2.3 ± 1.6	1.9 ± 0.8
16	2.3 ± 1.4	3.4 ± 3.9	4.2 ± 5.0
17	3.5 ± 2.4	3.7 ± 4.1	3.8 ± 5.2

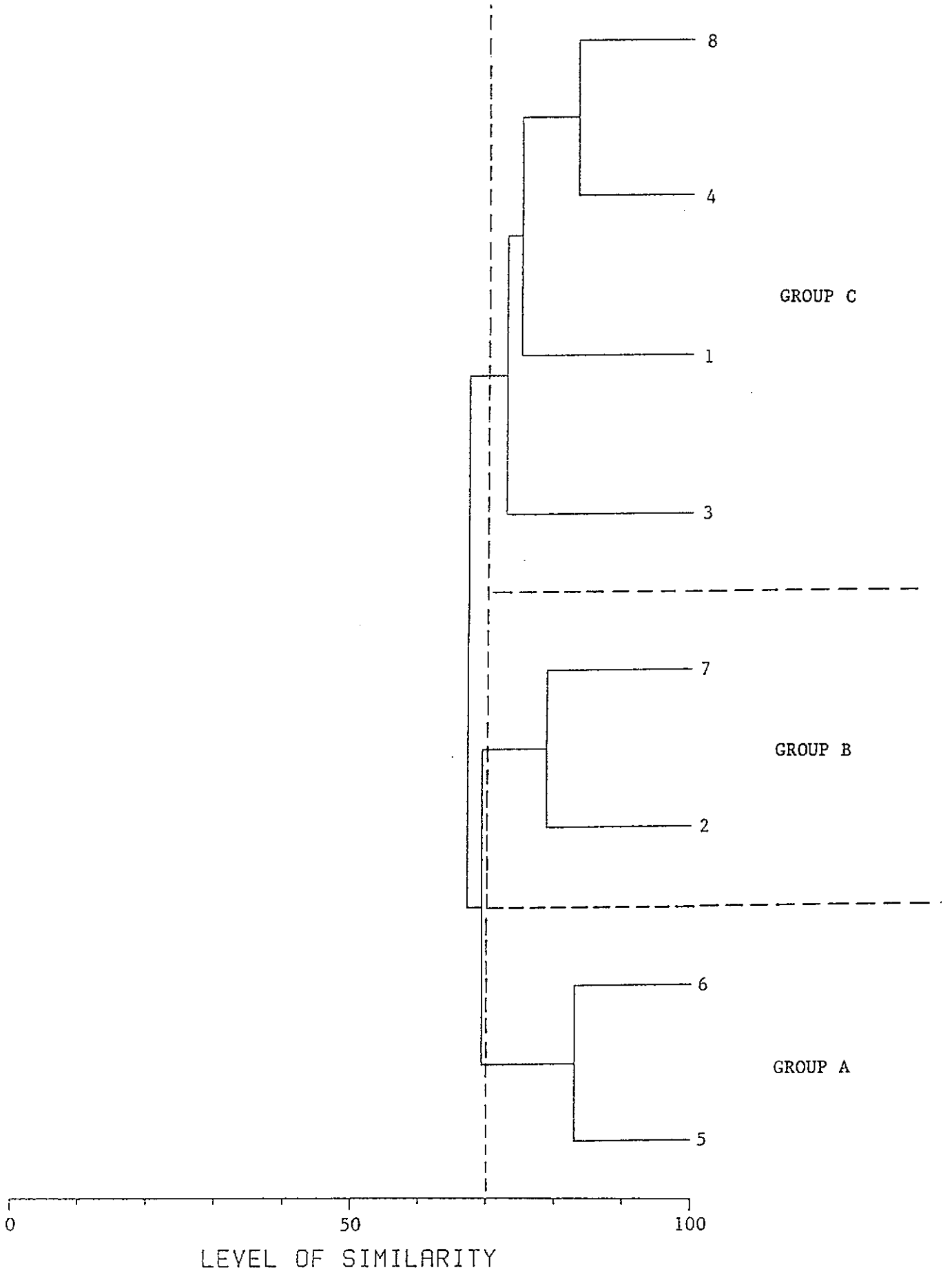


FIGURE 71. Station cluster of periphyton data for the entire sampling period.

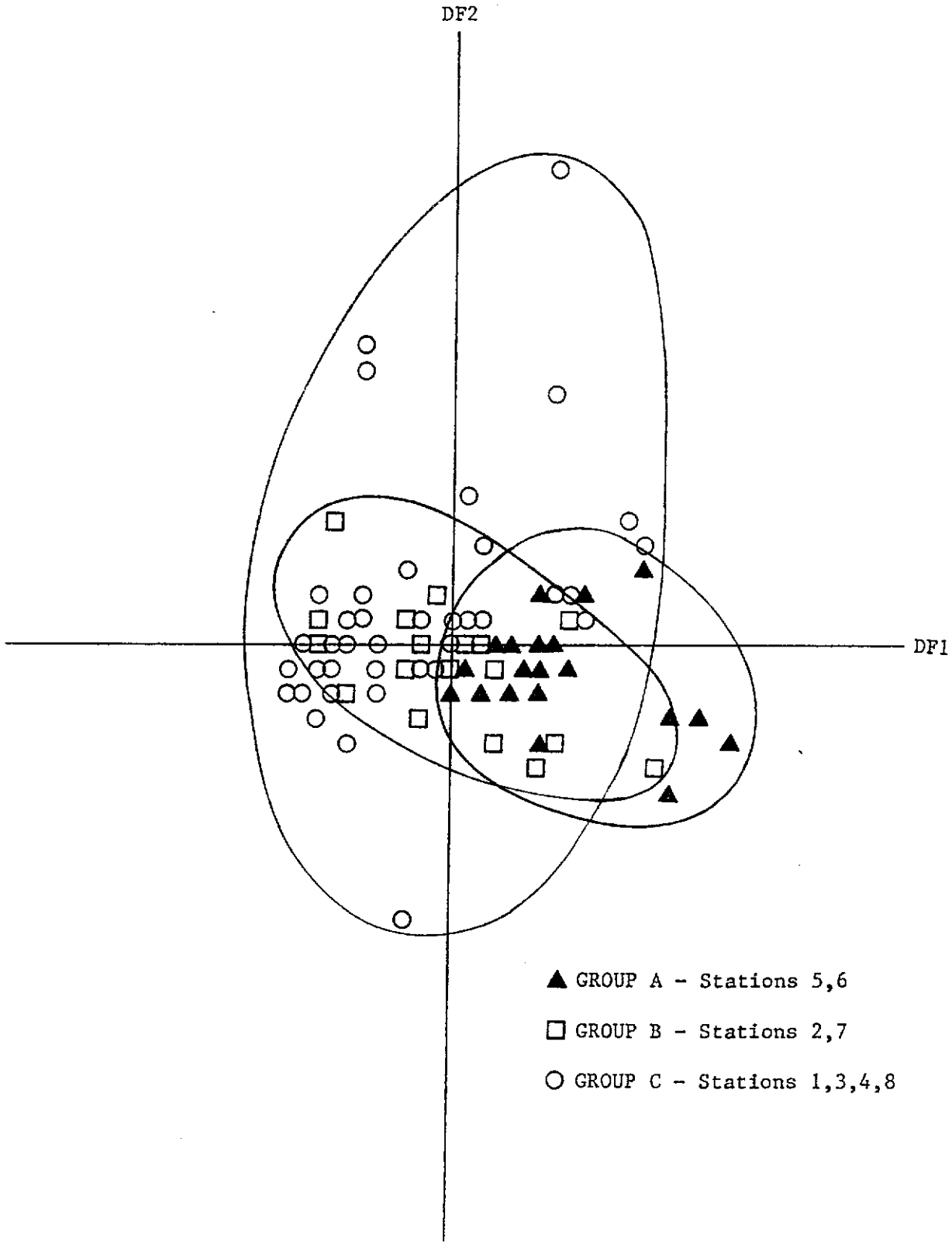


FIGURE 72. Orientation of periphyton station groups in discriminant space.

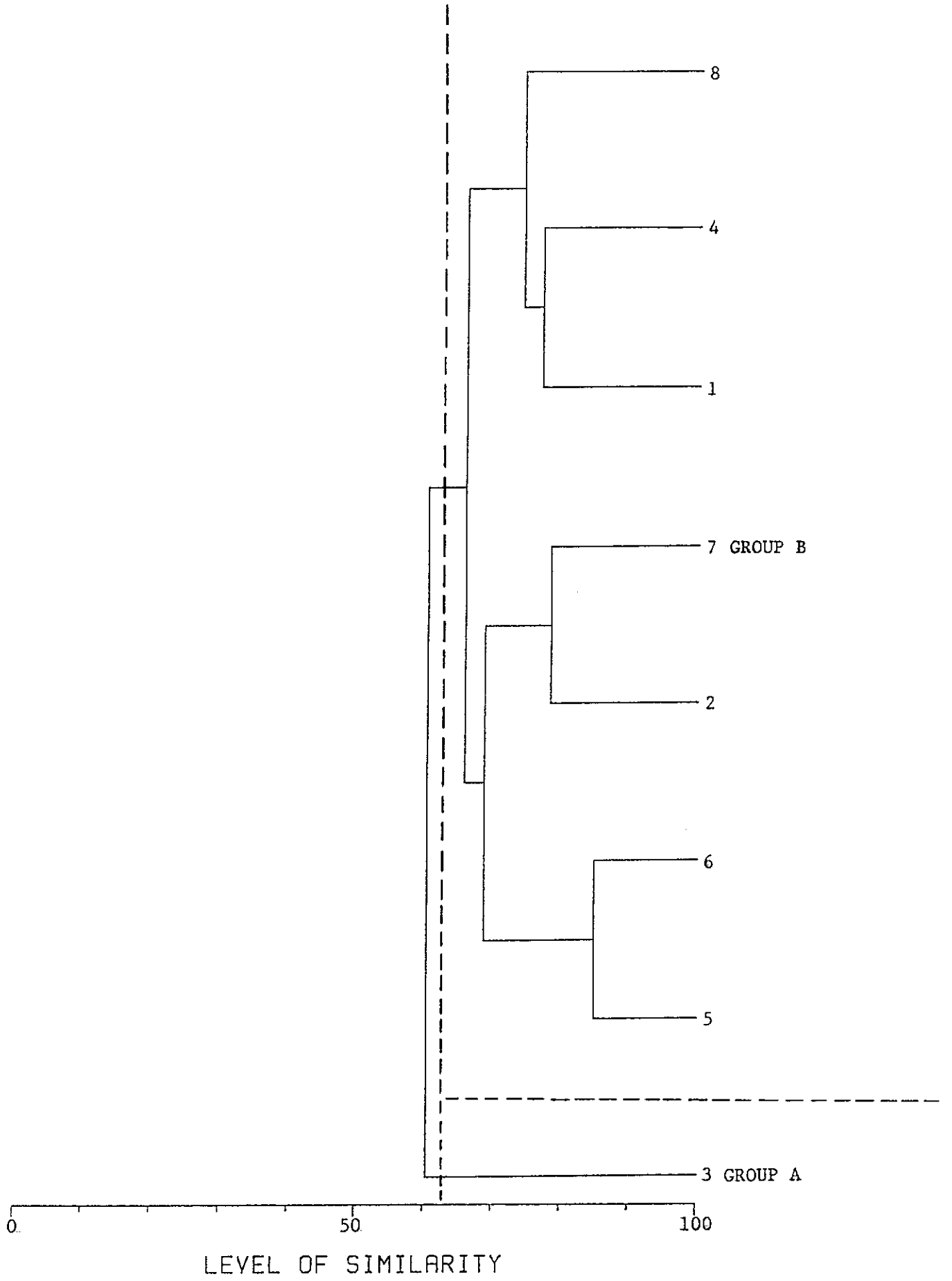


FIGURE 73. Station cluster of periphyton data for the period of low flow.

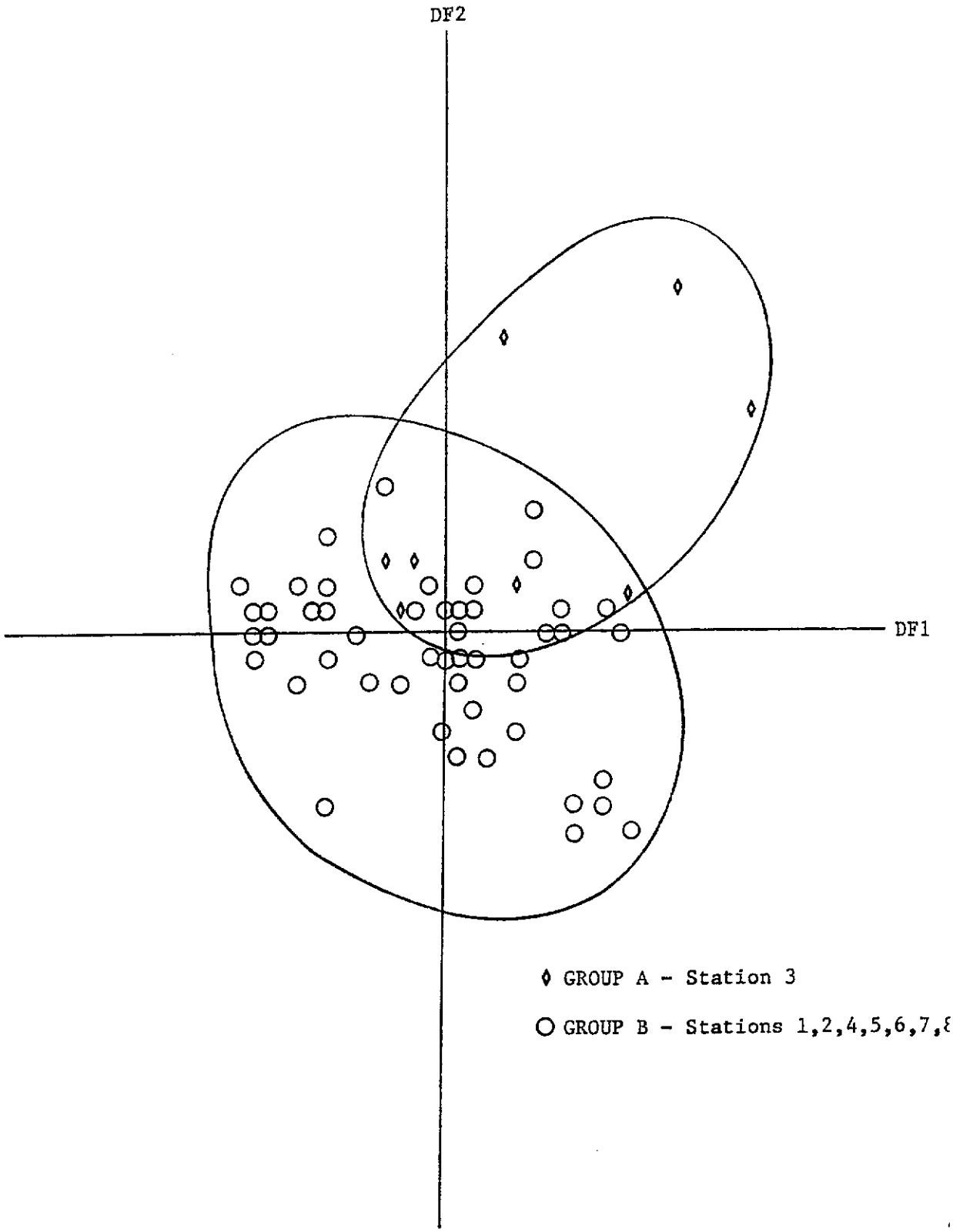


FIGURE 74. Orientation of periphyton station groups in discriminant space for the period of low flow.

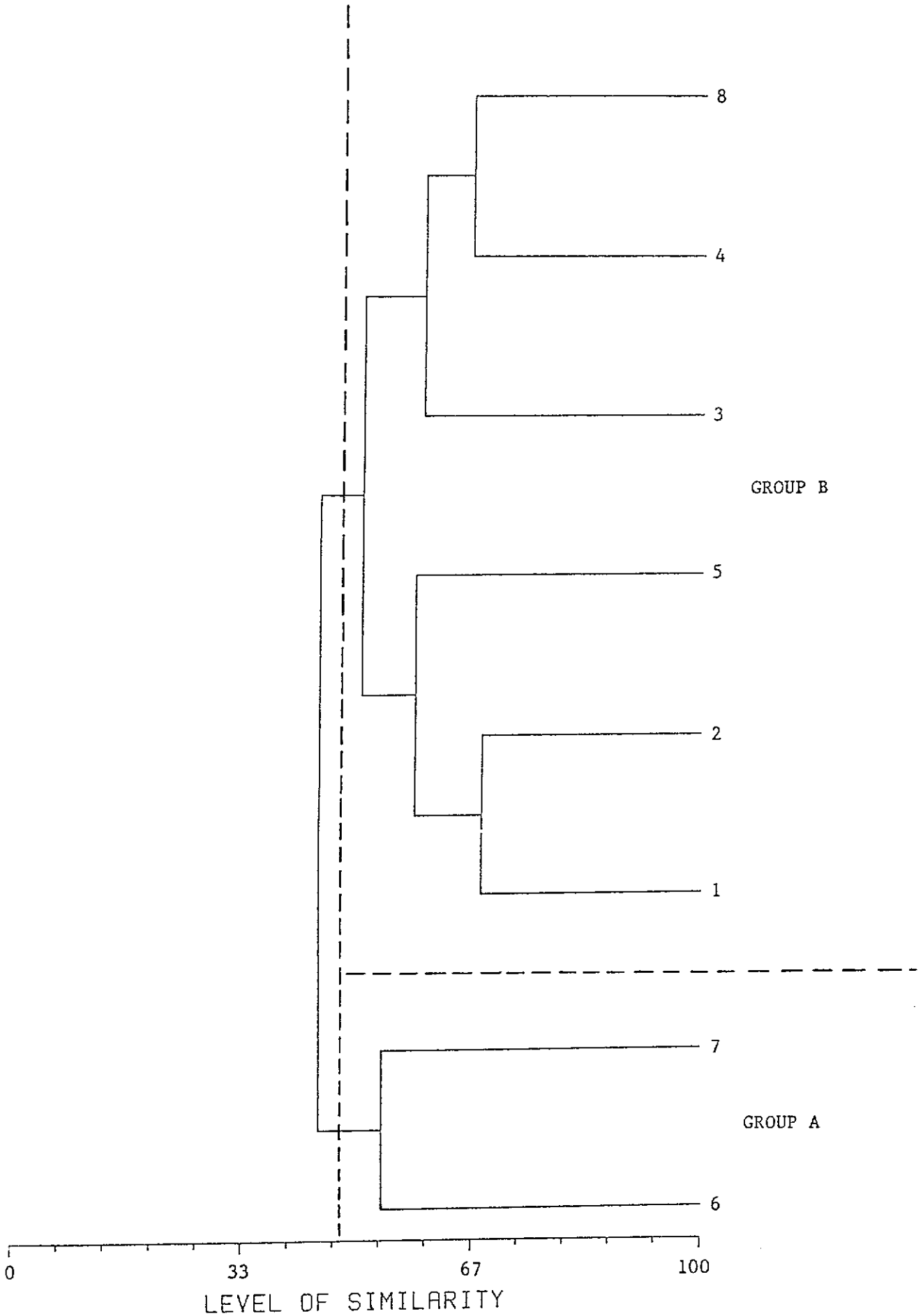


FIGURE 75. Station cluster of periphyton data for the period of high flow.

The scatterplot of the distribution of these station groups in discriminant space (Figure 76) does little to illustrate the separation of these station clusters. Turbidity and NO_2-NO_3 were the principal components of this first discrimiant function, which explained 65.51% of among-group variance. The second discriminant function was primarily based on PO_4 and conductivity, and explained an additional 19.25%.

The most abundant 50 algal taxa (93.1% of total) were used for inverse cluster analysis (Table 41). A dendrogram of the results of inverse cluster analysis revealed the presence of 14 species groups (Figure 77). These groups were distinguished at the same level of similarity (70%) as the normal cluster analysis in an attempt to more accurately reflect the observed station groupings. Several of these groups contained only one or a few taxa, but can be associated with similar groups to form assemblages which reflect certain stations or areas of the river.

The first group contained twelve taxa, and represented 80% of the entire algal population collected over the sampling period. Dominant taxa included Gomphonema parvulum, Achnanthes exigua, and Eunotia pectinalis, which were extremely abundant at all sampling stations. Cocconeis fluviatilis, the fourth most abundant taxon, was substantially less dense at the three upper river stations, and Synedra ulna was least common at Stations 6 and 7. The average abundance of these 12 taxa closely paralleled that of all taxa combined (Figure 78).

The second series of species groups was collected from all stations, but was conspicuously more abundant at some. This assemblage is made up of three specific groups. One group contained nine taxa, and was densest at Stations 2, 3, 4, and 8. Dominant members of this group included Frustulia rhomboides, Eunotia curvata, and several species of Navicula. Another group, containing four taxa, was most abundant at Stations 4, 6, and 7, and very scarce at Stations 3 and 5. Cocconeis hustedtii and Diploneis puella are typical members of this sub-group. Still another group, consisting of seven taxa, was found in most abundance at Stations 2, 4, and 8. It is interesting to note that more chlorophyte taxa (e.g., Chlamydomonas, Cosmarium, and Closterium) were members of this sub-group, and were particularly abundant at Station 8. Together, this assemblage included 20 taxa and 21% of the total of the algal population collected.

The third association of groups was made up of groups which were found at most stations, but which were completely (or nearly) absent from one or two sites. Two of these five groups had members representing every station except #1. One cluster was most abundant at Station 6; the most dominant taxon was Navicula viridula. Th other group had three taxa which were most abundant at Station 3 and were fairly evenly distributed between Stations 4, 5, and 8. Two species of Synedra and the green alga, Characium sp., were members of this group. Another group belonging to this assemblage, made up of the diatoms, Meridion circulare and Synedra filiformis, was collected at all but Station 8. Surirella tenera was absent from both Stations 1 and 8. The last group in this association

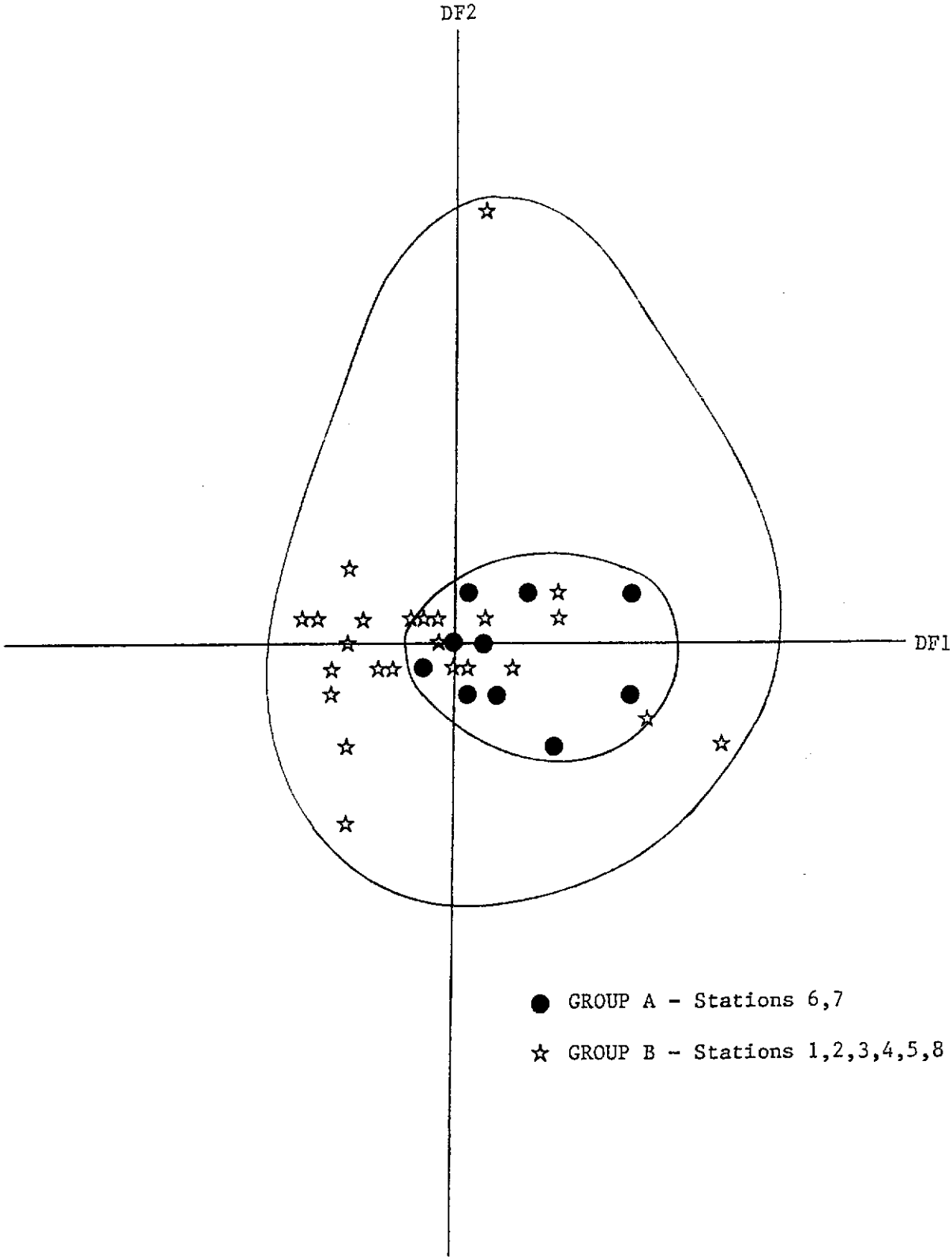


FIGURE 76. Orientation of periphyton station groups in discriminant space for the period of high flow.

TABLE 41. Total abundance of the top 50 periphyton taxa, Ochlockonee River, October 1985 to October 1986.

	1	2	3	4	5	6	7	8
Gomphonema parvulum	862	758	1623	1995	1736	317	542	3515
Achnanthes exigua	746	940	116	1339	1541	698	942	678
Eunotia pectinalis	713	1298	859	628	243	641	574	1925
Cocconeis fluviatilis	94	29	19	941	1944	1094	1872	834
Microcystis sp.	353	554	734	512	417	578	646	665
Synedra ulna	287	211	274	338	385	64	42	962
Achnanthes lanceolata	287	242	59	355	310	204	357	588
Achnanthes linearis	152	847	85	228	276	44	234	236
Melosira varians	51	732	58	237	67	158	47	171
Nitzschia palea	72	454	213	171	90	159	78	249
Navicula rhynchocephala	123	262	86	246	42	351	168	40
Bacillaria paradoxa	0	7	0	0	0	533	324	4
Cymbella minuta	22	146	40	16	24	55	29	435
Synedra amphicephala	0	17	397	208	22	8	0	91
Botryococcus sp.	75	77	167	128	66	80	66	40
Synedra rumpens	0	1	386	43	53	0	25	163
Navicula viridula	0	18	0	11	51	438	97	17
Dactylococcopsis sp.	8	4	8	1	2	1	379	184
Eunotia curvata	17	151	85	166	16	38	34	53
Navicula radiosa	25	240	12	36	6	85	25	113
Nitzschia filiformis	0	18	7	10	12	275	90	5
Navicula lateropunctata	0	200	9	31	6	91	17	57
Characium sp.	0	37	1	73	254	0	0	37
Gomphonema gracile	0	11	89	44	68	32	40	66
Cocconeis hustedtii	7	0	0	172	2	66	64	28
Frustulia rhomboides	8	160	51	23	3	38	11	37
Gomphonema affine	23	220	16	0	0	23	14	32
Navicula pupula	11	45	55	5	5	31	36	119
Phormidium sp.	54	53	107	14	10	12	9	39
Melosira granulata	0	1	0	0	0	0	0	268
Capartogramma crucicula	20	40	0	46	4	70	37	52
Oscillatoria sp.	19	30	33	48	36	14	20	45
Meridion circulare	70	8	123	20	10	8	5	0
Diploneis puella	26	7	3	63	0	68	59	5
Navicula capitata	48	82	16	43	5	17	7	9
Fragilaria crotonensis	0	87	3	9	0	5	0	88
Achnanthes hauckiana	45	27	2	48	20	10	19	20
Synedra filiformis	41	0	57	77	5	8	0	0
Eunotia neagelii	4	41	37	0	1	23	5	49
Gyrosigma spencerii	8	7	0	27	7	33	70	8
Biddulphia laevis	0	0	0	0	0	6	136	13

TABLE 41. Cont.

	1	2	3	4	5	6	7	8
Chlamydomonas sp.	14	40	2	13	28	9	5	39
Eunotia vanheurckii	7	16	10	15	2	3	11	79
Cosmarium sp.	16	14	10	20	12	2	15	49
Achnanthes minutissima	0	135	0	0	0	0	0	0
Nitzschia parvula	6	28	5	12	10	67	6	0
Surirella tenera	0	1	25	77	1	18	8	0
Anabaena sp.	13	19	2	20	19	5	19	32
Closterium sp.	8	6	3	13	9	0	12	76
Cyclotella meneghiniana	5	21	57	0	0	10	0	29

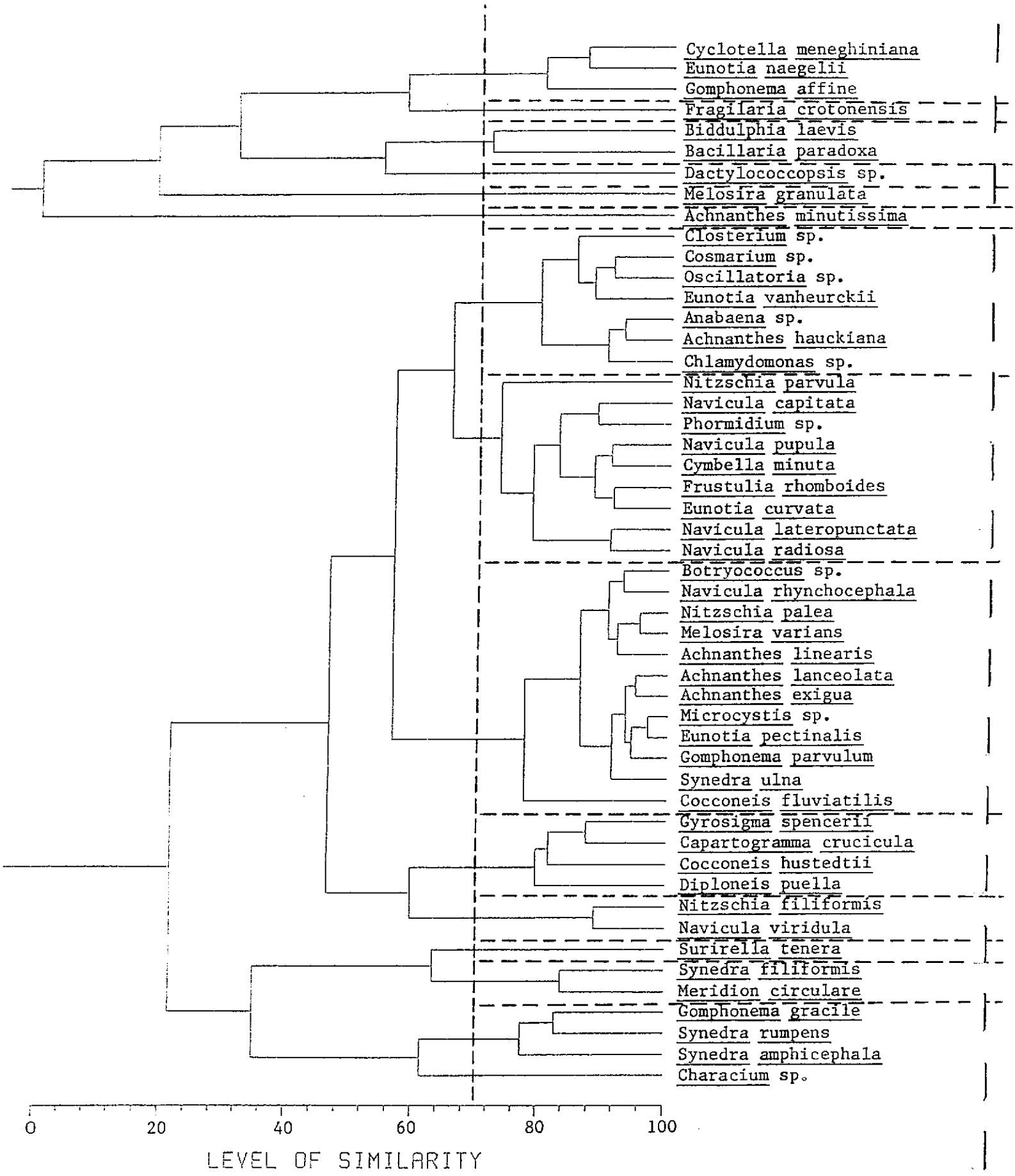


FIGURE 77. Species cluster of the top 50 periphyton taxa.

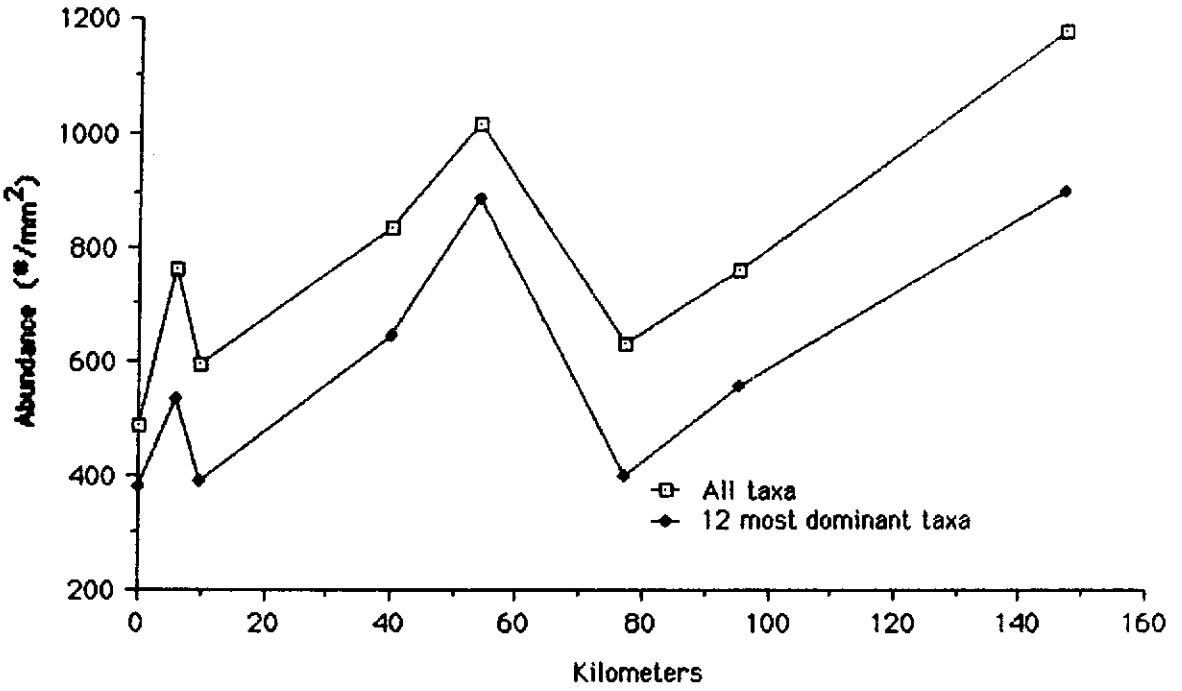


Figure 78. Mean abundance of all periphyton and taxa of the 12 most dominant taxa by river kilometer.

contained three taxa and was absent from Stations 4 and 5. The five groups which make up this assemblage accounted for 7.2% of the total abundance of taxa collected.

The final species group assemblage consisted of five groups but only 3.6% of the total. These groups were made up of one or two taxa which were associated with one or two particular stations. For example, the diatom, Melosira granulata, was collected almost exclusively from Station 8, and the cyanophyte, Dactylococcopis sp., from Stations 7 and 8. Bacillaria paradoxa and Biddulphia laevis were found chiefly at Stations 6 and 7. Fragilaria crotonensis was collected from Stations 2 and 8, and Achnanthes minutissima was found exclusively at Station 2.

Discussion

The community structure of periphyton in the Ochlockonee was found to be similar to that observed in other studies of river systems such as the Suwannee (FDER 1985), and the Latrobe (Chessman 1985). Although diatoms were consistently dominant, their displacement by blue-green algae at Stations 3 and 6 may be indicative of changes in conditions which proved to be disruptive to the algal community. Such changes could include elevated organic loading or increased turbidity levels, and their effects on the algal population were probably related to the stage height and flow regime of the river.

Diversity, in the form of d (Shannon-Weaver index) and species richness, were both notably higher during the period of low flow. This is not surprising, since flood conditions generally cause habitat disruption, increases in turbidity, and deposition of silt and detritis which could deter colonization of certain algal taxa (Patrick et al. 1954) or result in the scouring of others. During the low flow stage, conditions are usually more stable, and the more hospitable environment enables a wider variety of algal forms to become established.

Algal abundance was affected in a similar fashion. During the low flow period, abundance was up to five times higher than during the flood period. Pryfogle and Lowe (1979) found that a high flow rate had a great capacity to remove periphyton from the substrate by scouring, resulting in a decline in abundance, as was observed at Stations 3 and 6. Butcher (1946) reported that increased periphyton density in the summer months was due to low flow and decreased turbidity. Decrease in the current allows accumulation of dense periphytic growth, and greater light penetration is possible with a reduction in turbidity. The abundance patterns were different during flood stage, which was probably due to the disruptive nature of swiftly-moving water in certain areas of the river.

Periphyton chlorophyll a was well correlated with algal abundance. When chlorophyll a and abundance were regressed using data from each station separately, a non-significant correlation was observed at Stations 2 and 4. It is likely that the lack of correlation at these stations is related to algal community composition. Berman and Pollingher (1974) reported that species composition was the primary cause of chlorophyll a fluctuation in Lake Kinneret and Jones (1977) found that blue-green algae have a lower chlorophyll a content per unit volume than diatoms.

Free-water chlorophyll a did not follow the same trend as abundance or periphyton chlorophyll a, nor was it significantly correlated with either biomass estimator. This is not surprising, since the free-water chlorophyll a measurement is a reflection of one point in time, while the periphyton measurements are influenced by biotic and abiotic conditions for 28 days. Free-water chlorophyll a was, however, significantly correlated with algal growth potential and Total Soluble Inorganic Nitrogen (TSIN), and most of the chlorophyll a surges corresponded to increases in TSIN. As noted earlier, the river waters were mostly N-limited. Similar relationships were observed between algal growth potential and nutrient parameters (TSIN, PO_4) as well as a signficant correlation with abundance and periphyton chlorophyll a. This implies that algal growth potential may be a more useful indicator of productivity than free-water chlorophyll a in river systems.

At the tributary stations, free-water chlorophyll a values were quite higher and more variable than at the river stations, probably due to the more direct effects of anthropogenic inputs. The extreme increases observed at Station 10 may also be related to sediment nutrients and flow regime. For example, the phosphorus and nitrogen content of the sediments at Stations 9 and 10 (Figures 8 and 9, respectively) were markedly higher than that at Stations 11 and 12, which are nearby and believed to be the receiving waters of similar types of nutrient loadings. The flow regimes at Stations 9 and 10 were different in that, at Station 9, water flowed more rapidly, enabling the nutrients to be flushed out. The flow was more sluggish at Station 10, though, and water backed up to form pools. This condition could have caused an accumulation of sediment nutrients that were periodically released into the water, and the high chlorophyll a values seem to reflect this. Additionally, values were highest during the periods of lowest flow.

Abundance and periphyton chlorophyll a were both negatively correlated with turbidity. This can be associated with the flooding and increased turbidity during the first six months of the study. The inhibitory effect of turbidity has been well-documented (Patrick 1948, Verduin 1951, Roy 1955, Luttenton et al. 1986). The increase in water velocity which accompanies flood conditions has also been shown to cause decreases in algal abundance (Antoine and Benson-Evans 1982) and to interfere with diatom colonization (Oemke and Burton 1986).

Normal cluster analysis indicated three station groupings, and the basis for this separation was made partially apparent by discriminant analysis. The level of similarity based on periphyton distribution was relatively high (70%), and thus a strong distinction between these groups based on abiotic parameters would not necessarily be expected. Discriminant analysis did indicate the factors by which the eight river stations were distinguished, namely, turbidity, NO_2-NO_3, and PO_4. These multivariate techniques also served to illustrate the differences or similarities in biotic and abiotic water quality measurements between high and low flow conditions.

Although inverse cluster analysis did not appear to indicate the specific reasons for the station groupings observed in normal cluster analysis, certain species-station associations may provide some explanations for the distribution patterns of the periphyton along the Ochlockonee River. Generally, the river was dominated by several diatom species. Three of these, Gomphonema, Achnanthes, and Cocconeis, were found to be typical genera of fast-flowing streams by Patrick (1948) because of their ability to attach themselves to the substrate by gelatinous masses or stalks. Gomphonema parvulum was most abundant from spring to midsummer, while Achnanthes exigua, A. lanceolata, and Cocconeis fluviatilis made up most of the fall assemblage. Both Gomphonema sp. and Cocconeis sp. have been associated with organic pollution (Hynes 1960). Oemke and Burton (1986) reported these two genera to be fast reproducers that displace other genera (e.g., Synedra) after initial colonization. Gomphonema parvulum was abundant at all stations except Stations 6 and 7 during the flood period, and C. fluviatilis was most dense from Stations 4 to 7. Achnanthes exigua, a cosmopolitan diatom species, was prevalent all down the river in late summer and fall but was least abundant at Station 3. Achnanthes lanceolata, which usually does not appear in large numbers under conditions of heavy organic enrichment (Patrick and Reimer 1966), was uncommon at Station 3. Synedra ulna, another cosmopolitan diatom species, was common at all stations except for 6 and 7. Seasonal distribution of S. ulna was very spotty but this diatom was abundant when present. Oemke and Burton (1986) found that S. ulna has a facility for immigration and attachment. The six genera listed above represented the majority of organisms collected from the river stations. They were present at all stations, though abundance of some taxa was decreased at certain stations. This is probably why there was such similarity among all of the stations and, thus, why normal cluster analysis failed to exhibit more distinctive station groups.

A few taxa were associated with one or two stations. For example, Melosira granulata was almost exclusively found at Station 8. Although sometimes associated with eutrophic waters, this species is also considered indicative of oligotrophic conditions by Patrick (1948) because blooms of Melosira often followed blooms of a diatom with high nutritive requirements, such as Synedra. Two other diatoms, Bacillaria paradoxa and Navicula viridula, were clearly most abundant at Station 6, and sometimes 7. Hynes (1960) lists N. viridula as a characteristic diatom of downstream eutrophic waters. Several other species of Navicula were more

prevalent at Station 6 than at the other stations. The displacement of other diatom taxa that were dominant upstream indicated a change in conditions in the area of Station 6 which appeared to inhibit algal abundance as well as alter species composition.

The water quality of the Ochlockonee River in Georgia, along with many of its tributaries, was assessed in 1972 by the Georgia Department of Natural Resources (G.E.P.D. 1973). A qualitative comparison of river stations reveals both similarities and differences. Most often, the dominant periphytic organism in 1972 was a green filamentous alga, Spirogyra sp., while in the present study this species was encountered very infrequently. Although diatoms did not appear to predominate in the Georgia study, the most common genera listed were Synedra sp. and Melosira sp. These two genera were collected in the present study with great frequency, particularly Synedra ulna.

Conclusions

The periphyton community of the Ochlockonee River was similar to that found in other river studies. Diatoms were dominant, making up 81.8% of the total collected, followed by blue-green algae (12.1%) and then green algae (5.7%).

A great deal of variation in periphyton community characteristics was observed over the sampling period. These changes can be mostly attributed to seasonal and flow regime effects. Abundance and chlorophyll *a* values were low in winter and increased to a fall maximum. Species richness and diversity were low in winter and spring, and highest in summer. Substantial differences were observed in the periphyton community between the high and low flow periods. During flood conditions, Shannon-Weaver diversity ($\bar{d}$) and species richness were both notably reduced. The same trend was observed for abundance and chlorophyll *a* values.

Certain tributary inputs may be having a detrimental effect on periphyton algae along the river. Although much variation in community characteristics can be explained by natural occurrences, abrupt changes between adjacent stations may be indicative of habitat disruption. These changes included a decreased proportion of diatoms, accompanied by an increase in blue-green algae, severe reductions in abundance and chlorophyll *a* measurements, and decreases in species richness. Most of these alterations were observed at Stations 3 and 6, and sometimes Station 5. Stations 3 and 5 are downstream of tributaries which are receiving municipal and industrial discharges, and Stations 6 and 3 were observed to be highest in sediment organic content and nutrient concentration. Additionally, the highest sediment silt/clay fraction was noted at Station 6. Although the evidence for detrimental consequences on the river algal community due to tributary inputs is not conclusive, municipal and industrial discharges from Oquina Creek may be responsible for the abrupt changes noted at Station 3. Ultimately, differences in nutrient concentration and fine sediments appear to be the major influence on periphyton distribution.

BENTHIC MACROINVERTEBRATES

Introduction

Aquatic macroinvertebrate communities have been shown to be very sensitive to stress and, therefore, can serve as useful indicators of environmental perturbations resulting from introduced contaminants (Gaufin and Tarzwell 1952, Beck 1954, Hynes 1959, Butcher 1959, U.S. EPA 1973, Bauer et al. 1980). Benthic macroinvertebrates are an integral part of the aquatic food web, and thus the relative health of this community is reflected in the well-being of higher trophic levels such as fish (Sterba 1962, Scott and Crossman 1973, Tippets and Moyle 1978). The sedentary nature of benthic macroinvertebrates, coupled with the phenomenon of "biological magnification", makes them susceptible to contaminants (e.g., pesticides, radioactive materials, and metals) which may be present in undetectable concentrations, but which can be absorbed over time and produce adverse impacts on the benthic community (U.S. EPA 1973).

To adequately assess possible pollution sources, it is desirable to accentuate spatial differences in water quality (upstream and downstream of a discharge) while controlling for other factors which affect benthic community composition such as current speed and the substrate. Many authors state that the single most important factor influencing macroinvertebrate distribution and community structure is the substrate (Cummins and Lauff 1969, de March 1976, Ruggiero and Merchant 1979, Wise and Molles 1979). When spatial comparisons are desired in streams with hard or variable substrate quality or deep water, the use of artificial substrates for sampling benthic macroinvertebrates is a preferred method (Anderson and Mason 1968, Hilsenhoff 1969). By using artificial substrates, the major variable, sediment quantity and quality, is eliminated and differences in the benthos due to differences in water quality become more apparent.

The objectives of this part of the study were to quantitatively characterize the aquatic benthic macroinvertebrates of the Ochlockonee River in terms of abundance and taxonomic composition to: 1) determine ambient conditions; and 2) determine the biological effects of point source and nonpoint source discharges with regard to present and future regulatory concerns.

Methods

A modification of the method of Parsons and Tatum (1974) was selected, which consists of mounting 4 Hester-Dendy multiplate samplers (as modified by U.S. EPA 1973) on a concrete block. The concrete blocks were then placed at a depth of approximately 0.5m. Extreme care was taken to locate the samplers in areas of similar water velocity and microhabitat. Each Hester-Dendy sampler has a total surface area of 0.11 m^2. The samplers were incubated for 28 days, which, according to previous studies (Rosenberg and Resh 1982), is adequate to allow macroinvertebrate colonization of the samplers to reach equilibrium. Upon

retrieval, the incubated samplers were placed in separate Whirl Pak® bags, partially filled with water from that particular station, and then stored on ice.

In the laboratory, the samplers were dismantled and the plates carefully brushed and washed with tap water over a 0.5 mm mesh stainless steel sieve. The sieved material was then stored in 70% ethanol, and later, the organisms separated from detritus under a 60X dissecting microscope and placed in fresh 70% ethanol. Organisms were then counted and identified, using either a dissecting or compound microscope, to the lowest possible taxonomic level using the taxonomic references listed in the Literature Cited.

To determine if point source or non-point source discharges within the Ochlockonee Basin were having adverse effects on the river's biota, longitudinal (upstream-downstream) data were emphasized, noting any changes due to tributary inputs. Several levels of data analysis have been utilized, including but not limited to, the techniques of Lenat et al. (1979) in their evaluation of pollution impacts on North Carolina streams and rivers. The multivariate techniques of classification and ordination (Bloom et al. 1977, Green and Vascotto 1979, Field et al. 1982, etc.) were also used, along with multiple discriminant analysis.

Results

Single number summaries include mean abundance or density, total number of taxa, mean number of taxa, Shannon-Weaver diversity index ($\bar{d}$), and a "pooled" variation of this index (pooled $\bar{d}$). Pooled $\bar{d}$ for a given station is calculated with the Shannon-Weaver equation, using the sum of individuals and total taxa found for all samplings at a given station. Where applicable, a range of values from minimum to maximum for each parameter has been provided. A reduction (or increase) of these single number summaries between stations is useful in interpreting how tributary discharges may affect general trends of the benthic communities. Table 42 provides analysis criteria for evaluating these data in relation to controls.

Benthic macroinvertebrate mean abundance was lowest at the upper three river stations, averaging less than 200 organisms per station (Table 42, Figure 79). Abundance increased at Station 4 and was highest at Station 5, with 543 organisms. A dramatic, 63% decrease in abundance from the levels observed at Station 5 occurred at Station 6 ($\bar{x}$ = 201). However, the abundance at Station 7 ($\bar{x}$ = 473) was again similar to that found at Station 5. There was a 30% decrease in abundance between Stations 7 and 8.

The average taxa per station followed a trend almost identical to the abundance curve (Figure 79, Table 43). Mean number of taxa was low in the upper river ($\bar{x}$ = 23), increased at Station 4, and peaked at Station 5 (35 taxa). A notable 30% decrease in mean number of taxa occurred at Station 6. The average number of taxa at Station 7 was closer to that at Station 5, while a slight drop in mean number of taxa was noted at Station 8.

TABLE 42. Analysis Criteria for Evaluating Data in Relation to Controls.

A. Reduction in Density (N) (from Lenat et al. 1979)

1. < 30%: Unstressed
2. 30%-60%: Moderate Stress
3. > 60%: Severe Stress

B. Reduction in Species (or Taxa) Richness (s) (from Lenat et al. 1979)

1. < 20%: Unstressed
2. 20%-50%: Moderate Stress
3. > 50%: Severe Stress

C. Diversity ($\bar{d}$) (from Wilhm 1970)

1. > 3: Clean
2. 2-3: Moderate Stress
3. < 2: Severe Stress

D. Diversity ($\bar{d}$) (from FAC 17-3.121(7))

1. 25% reduction in d (compared to the control) is a violation.

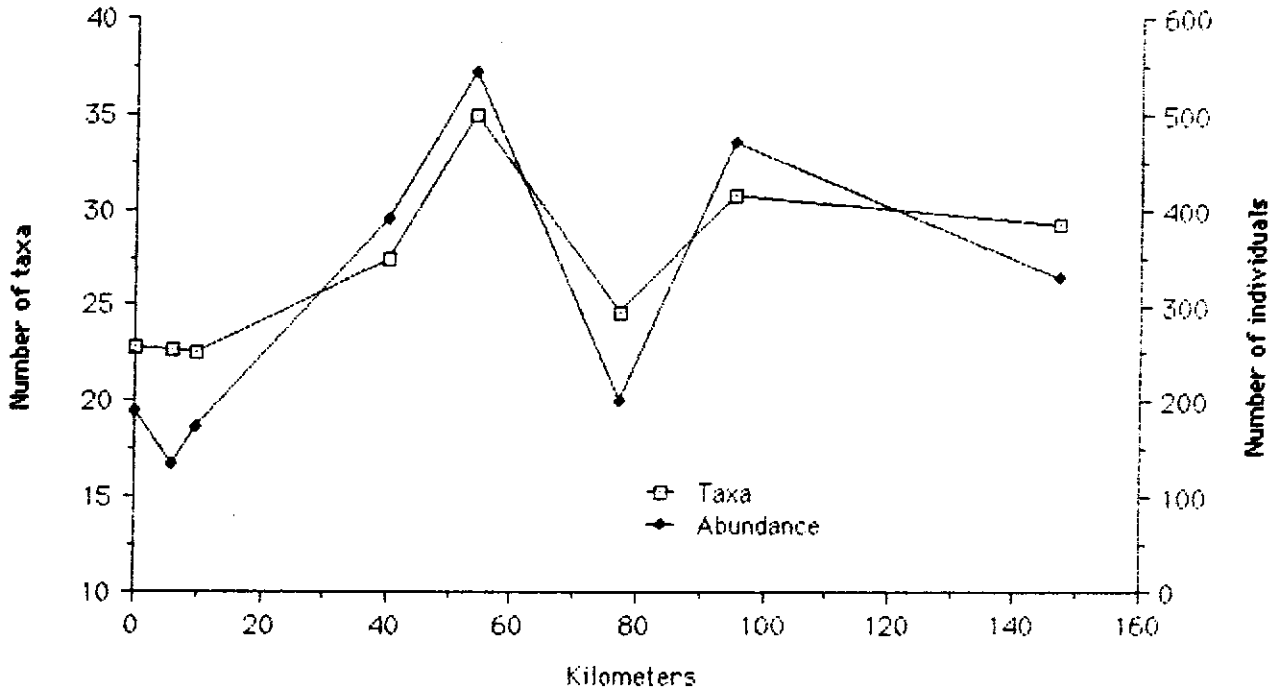


Figure 79. Mean abundance and mean taxa by river kilometer.

TABLE 43. Benthic macroinvertebrate mean abundance, mean taxa, total taxa, mean Shannon-Weaver diversity index, the "pooled" variation of this index, mean turbidity, sediment silt-clay and organic fraction, and mean number of individuals in selected taxonomic groups for the Ochlockonee River, October 1985 to October 1986.

STATION	1	2	3	4	5	6	7	8
$\bar{x}$ Abundance (± Std. dev.)	191 (± 181)	134 (± 99)	172 (± 168)	392 (± 291)	543 (± 123)	201 (± 123)	473 (± 425)	329 (± 269)
$\bar{x}$ Taxa (± Std. dev.)	23 (± 9)	23 (± 6)	23 (± 14)	28 (± 12)	35 (± 11)	25 (± 8)	31 (± 11)	29 (± 8)
Total Taxa	91	84	83	83	93	98	106	98
$\bar{x}$ Shannon-Weaver Diversity (± Std. dev.)	3.4 (± 0.5)	3.5 (± 0.5)	3.4 (± 0.7)	3.3 (± 0.5)	3.6 (± 0.5)	3.3 (± 0.4)	3.4 (± 0.6)	3.6 (± 0.5)
Pooled Shannon-Weaver Diversity	4.8	4.4	4.9	4.4	4.2	4.5	4.5	4.4
$\bar{x}$ Turbidity (NTU)	11.0	15.6	20.6	21.3	18.9	18.9	16.2	8.1
Sediment Silt-Clay Fraction (%)	0.03	8.05	4.45	0.55	6.7	22.7	0.07	0.04
Organic Fraction (%)	0.15	0.15	2.1	0.2	1.5	7.5	0.1	0.1
$\bar{x}$ Individuals								
Acarina	0.4	0.0	0.5	0.2	3.0	0.3	0.8	0.3
Coleoptera	7.9	2.1	2.8	4.6	10.3	4.4	2.0	1.3
Diptera	104.2	97.3	108.3	258.6	277.5	141.3	248.8	145.0
Ephemeroptera	12.0	18.1	30.3	62.1	117.7	24.2	118.6	100.8
Gastropoda	27.7	6.0	8.3	0.8	6.6	8.5	3.0	2.6
Malacostraca	0.3	0.1	0.4	0.5	0.2	0.6	0.7	10.8
Megaloptera	0.1	0.4	0.2	1.0	5.2	0.0	3.4	0.1
Odonata	13.7	2.7	2.4	3.7	1.5	4.8	2.4	9.8
Oligochaeta	1.3	2.1	3.8	0.5	0.5	1.4	0.2	0.7
Plecoptera	0.2	0.0	4.2	1.5	4.6	0.8	7.6	0.9
Trichoptera	19.8	3.5	10.7	57.6	115.1	13.3	85.3	52.7

Longitudinal trends in total taxa were different from those observed for mean number of taxa (Figure 80). A slight (8%) decrease in total taxa occurred between both Stations 1 and 2 and Stations 7 and 8. Stations 2 and 3 had the lowest total taxa (83 per station) while Station 7 had the highest total taxa with 106.

Mean Shannon-Weaver diversity ($\bar{d}$) was fairly similar at all stations, ranging from a low of 3.3 at Stations 4 and 6, to a high of 3.6 at Station 5 (Figure 81, Table 43). The "pooled" value of this diversity index was lowest at Station 5 (4.2) and highest at Station 3 (4.9).

Certain samples collected during the study had unusually low abundance or species richness. In January, 1986, only 16 individuals from seven taxa were found at Station 3. Again in August, 1986, only four animals from four taxa were found at this same station. In March, 1986, unusual values for these parameters were noted at three stations: (1) Station 1 produced 16 individuals from seven taxa, (2) Station 6 had 53 organisms and 11 taxa, and (3) Station 7 had 79 animals and 11 taxa.

Abundance, species richness, and diversity values for all river stations were combined and averaged by season to determine variation in these parameters over the duration of the project. All three parameters exhibited similar seasonal trends: lowest in the winter and highest in the summer (Figures 82, 83, and 84). Abundance averaged 135 organisms per station during the winter, increasing to 210 in the spring and 410 in the summer. Fall abundance was just slightly lower at 405. An average of 19 taxa was collected during the winter months, increasing to 24 in the spring and 33 in the summer. Species richness during the fall was 30, again just slightly lower than the summer value. Not unexpectedly, mean diversity followed a pattern similar to the abundance and taxa curves. Diversity averaged 3.1 in the winter, rising to 3.3 in the spring and 3.6 in the summer, and decreasing slightly to 3.4 in the fall.

The Ochlockonee River flooded during this study and data from high flow months (defined as greater than 28 m^3/s) were compared with the low flow period (usually much less than 28 m^3/s). Abundance was much higher during the low flow period for all stations except Station 2, where the mean number of organisms collected was similar for both high and low flow months (Figure 85). The greatest variation of flow related abundance values was at Stations 5 and 8. Species richness was also higher at low water for all stations (Figure 86). The largest difference in average taxa for the two flow periods was at Stations 5 and 7. Note that inter-station (longitudinal) trends for abundance and taxa were usually quite consistent regardless of the flow regime. Again, during low flow conditions, diversities were highest at all stations, except at Station 8, where they were identical (Figure 87). Diversities at Stations 1 and 7 exhibited the greatest variation between low and high flow periods.

The mean density of individuals belonging to the major taxonomic groups has been tabulated. These data are somewhat more detailed than the single number summaries, in that the reduction or elimination of certain

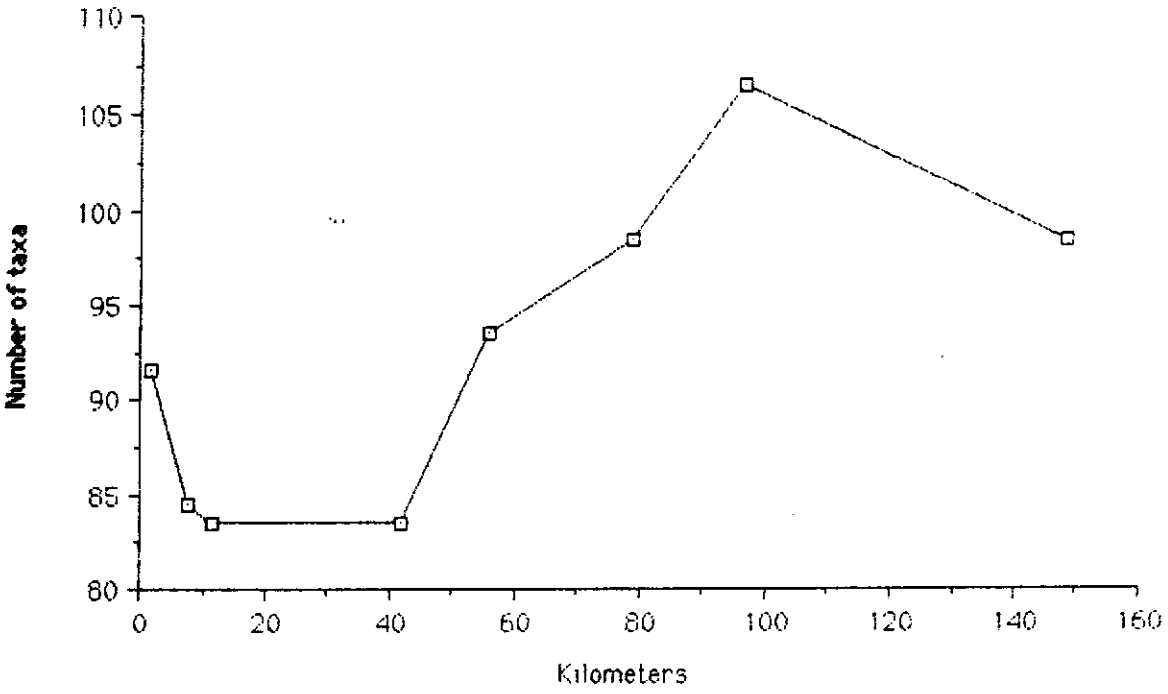


Figure 80. Total macroinvertebrate taxa by river kilometer

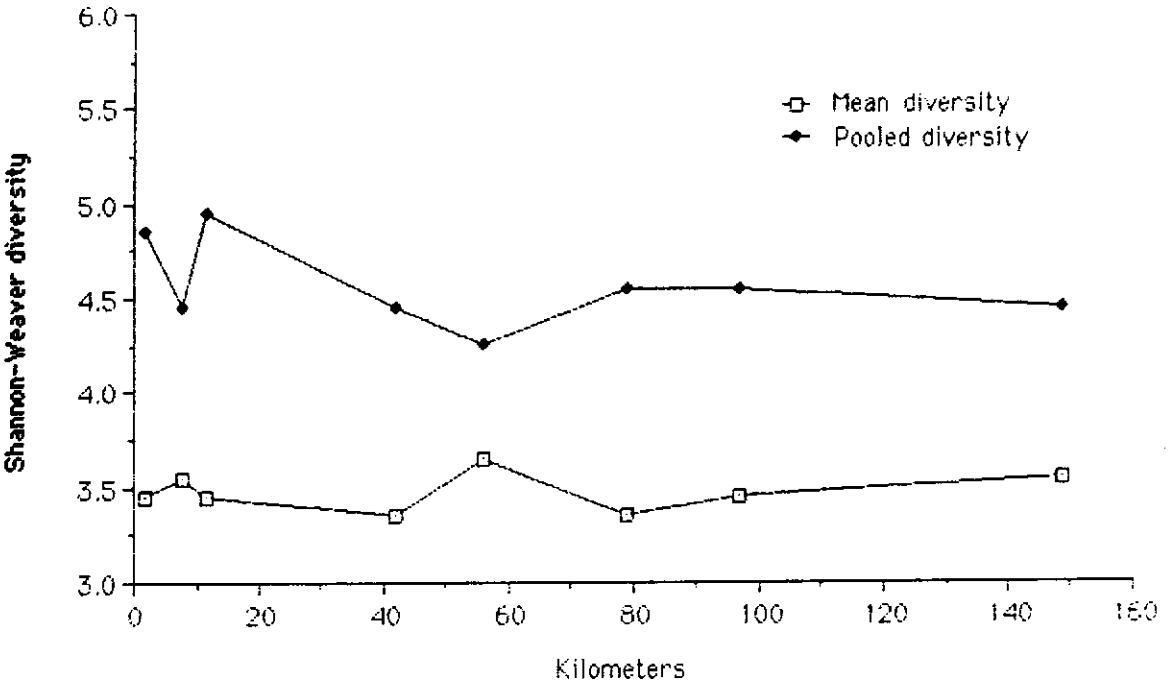


Figure 81. Pooled and mean macroinvertebrate diversity by river kilometer.

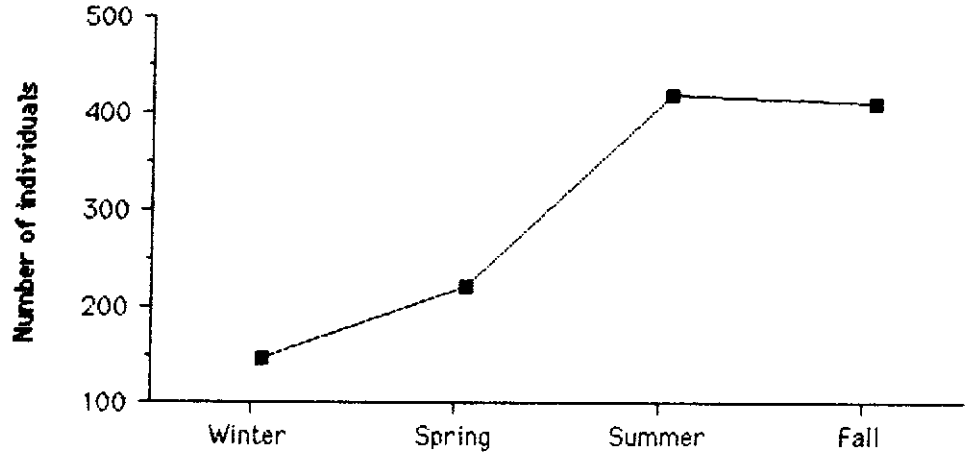


Figure 82. Mean macroinvertebrate abundance by season.

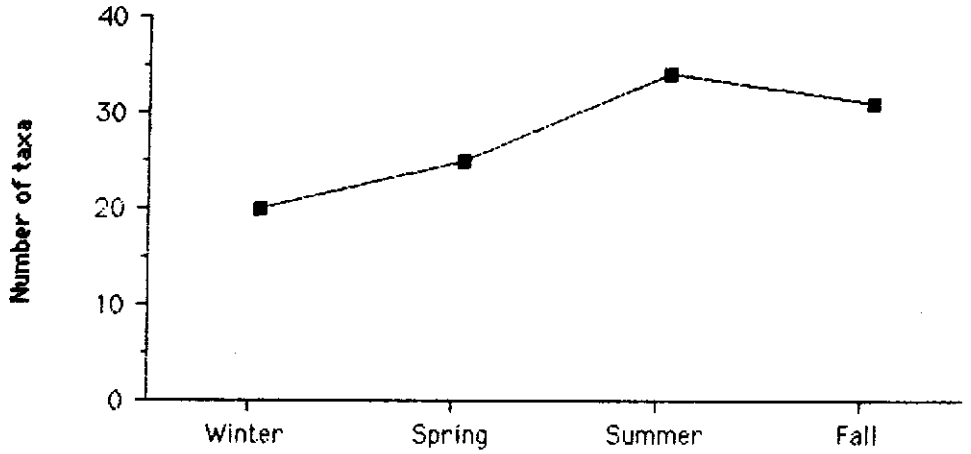


Figure 83. Mean number of macroinvertebrate taxa by season.

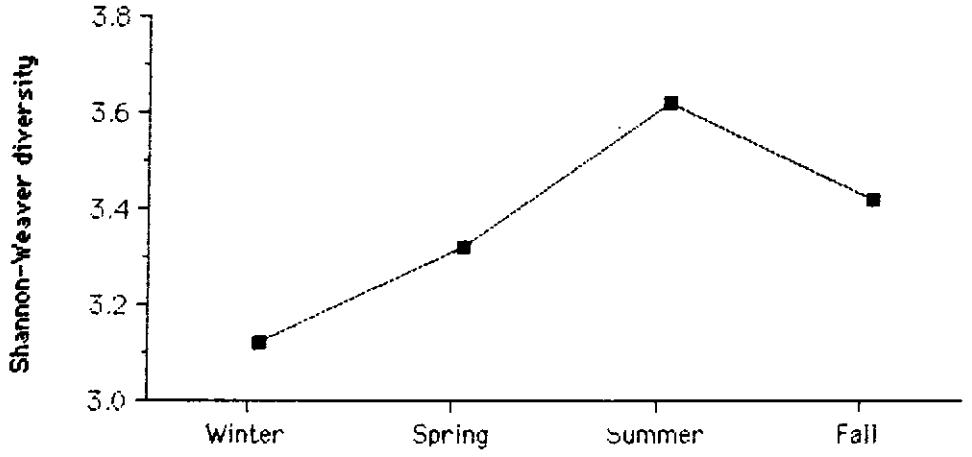


Figure 84. Mean macroinvertebrate diversity by season.

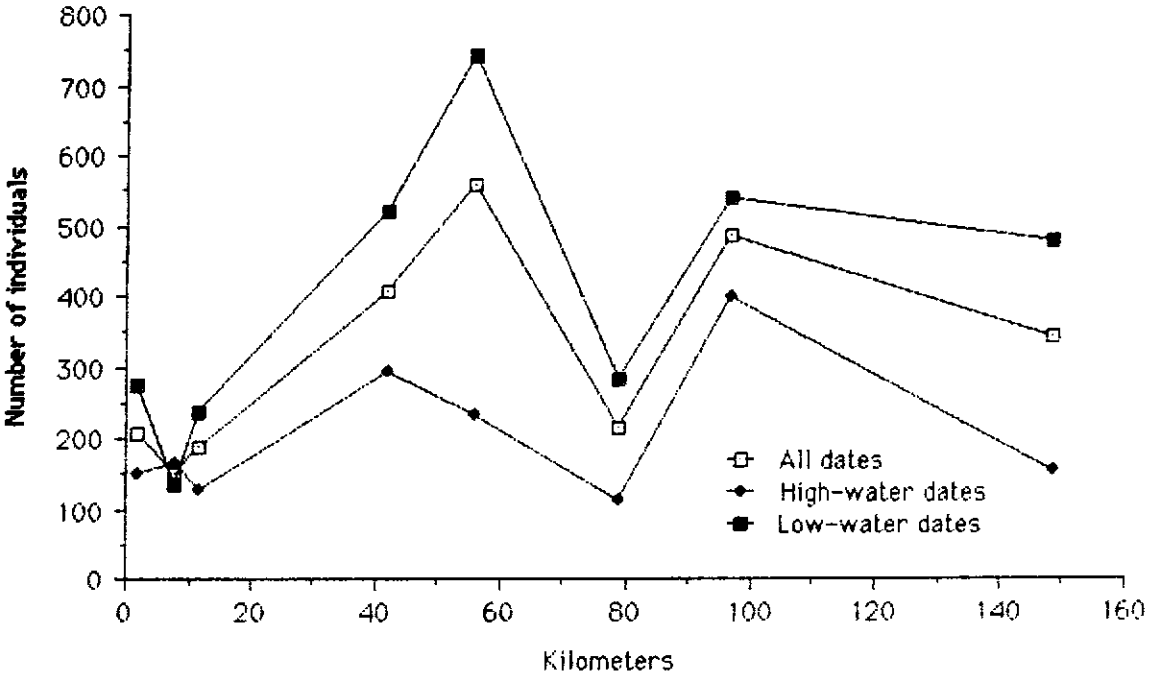


Figure 85. Mean macroinvertebrate abundance by river kilometer.

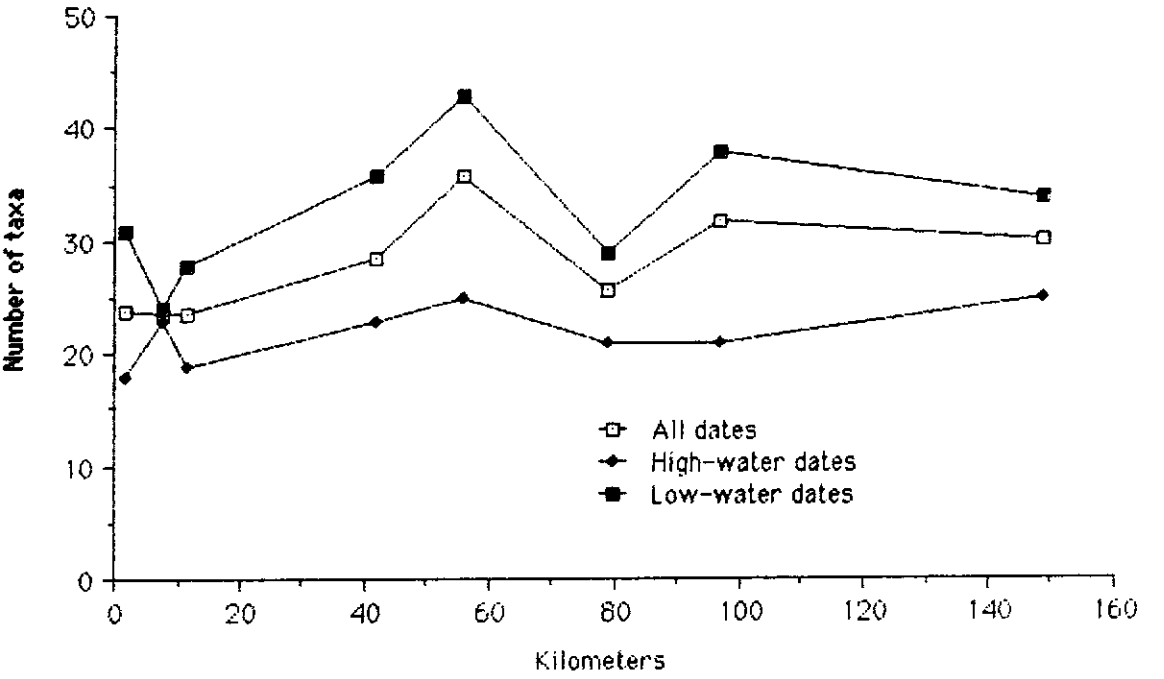


Figure 86. Mean number of macroinvertebrate taxa by river kilometer.

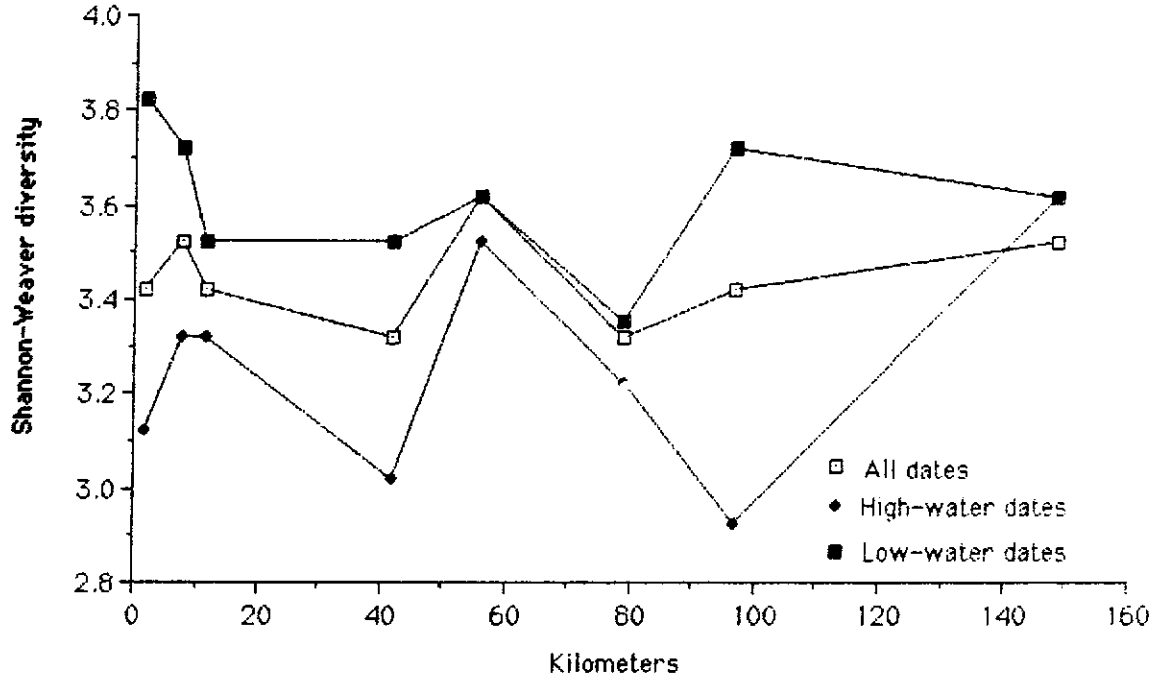


Figure 87. Mean macroinvertebrate diversity by river kilometer.

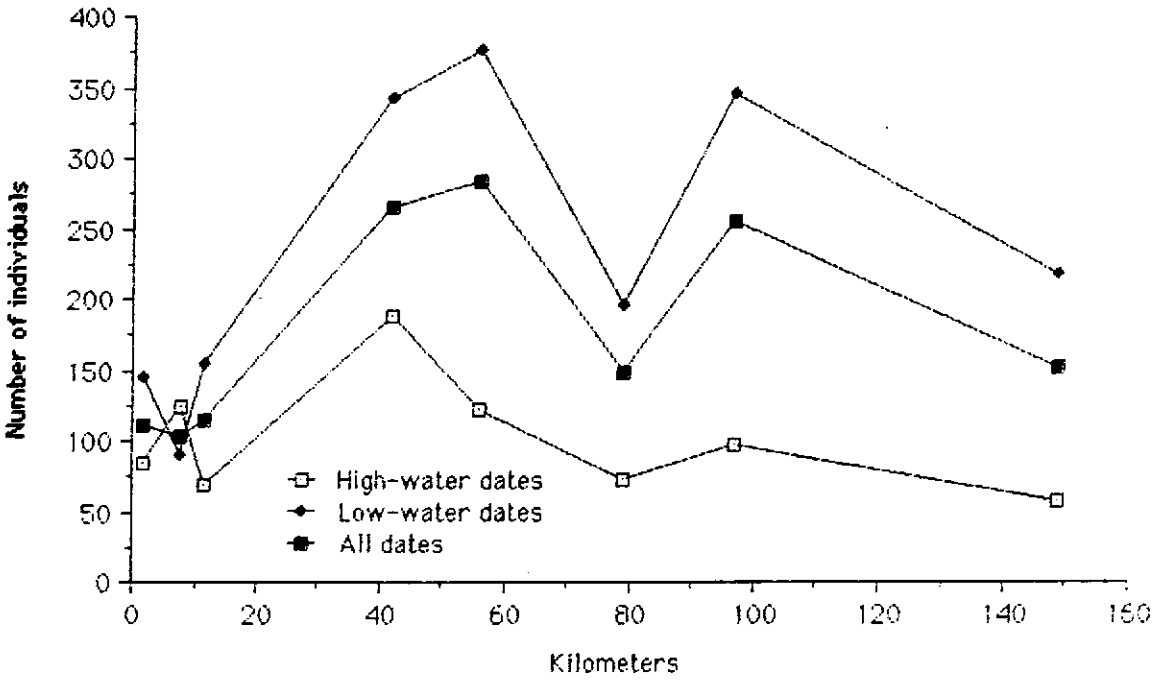


Figure 88. Mean dipteran abundance by river kilometer.

sensitive groups of organisms (e.g., Plecoptera, Trichoptera) are documented. Reduction or elimination of sensitive groups between an upstream station and an impacted station would represent a perturbation. Conversely, an increase of known tolerant groups (e.g., certain Oligochaeta) may also indicate stress.

A comparison of the mean abundances of organisms belonging to eleven different and important taxonomic groups indicated some interesting differences among stations (Table 43). Groups such as the Acarina (water mites), Megaloptera (dobsonflies), and Plecoptera (stoneflies) were not common at most stations (usually less than 5 organisms collected per month), but were slightly more abundant at Stations 5 and 7. Gastropod (snail) and odonate (dragonfly and damselfly) abundance was highest at Station 1, with an average of 27.7 and 13.7 organisms, respectively. Odonates were also fairly common at Station 8, with a mean abundance of 9.8, as were malacostracans (mainly Hyalella azteca) ($\bar{x}$ abundance = 10.8). Malacostracans were uncommon at other stations. Coleopteran (beetle) abundance was highest at Stations 1 and 7, with 7.9 and 10.3 animals, respectively. Oligochaetes (segmented worms) were not common in the river but were most abundant at Stations 2 and 3 with means of 2.1 and 3.8, respectively.

Out of 26,884 organisms collected during the study, 24,572 or 92% belonged to three groups, the Diptera (midges, 57%), Ephemeroptera (mayflies, 20%), and Trichoptera (caddisflies, 15%). Not unexpectedly, these three major groups contributed most to between-station differences in macroinvertebrate abundance. Stations 1, 2, and 3 all had an average midge population per station of around 100 organisms (Figure 88, Table 43). The abundance of this group increased at Station 4 and nearly tripled at Station 5 ($\bar{x}$ = 277.5). A 49% decrease in the midge population occurred at Station 6, but it rebounded to 248.8 by Station 7. A 42% decrease in dipteran abundance occurred at Station 8.

The ephemeropteran mean abundance increased dramatically between Stations 1 and 5 (Figure 89), though a substantial (79%) decrease in mayfly abundance was noted at Station 6. The average numbers of mayflies collected at Stations 7 and 8, however, were back to the levels noted at Station 5. The trichopteran mean abundance curve followed the mayfly abundance curve very closely (Figure 90), except for an 84% decrease in caddisflies observed between Stations 1 and 2. The trichopteran population at Station 5 was highest ($\bar{x}$ = 115.1), while this group was reduced at Station 6 ($\bar{x}$ = 13.3, an 88% decrease). Averages of 85.3 and 52.7 caddisflies were found at Stations 7 and 8, respectively. These values were considerably higher than the mean abundance of trichopterans at Station 6, but not quite as high as that found at Station 5.

As was the case with total abundance, the mean number of dipterans was generally much higher at low water levels. However, this did not always hold true for the mayfly and caddisfly populations. The most mayflies were noted at Stations 3, 5, 6, and 8 during low water conditions. More ephemeropterans were collected at Stations 4 and 7 at

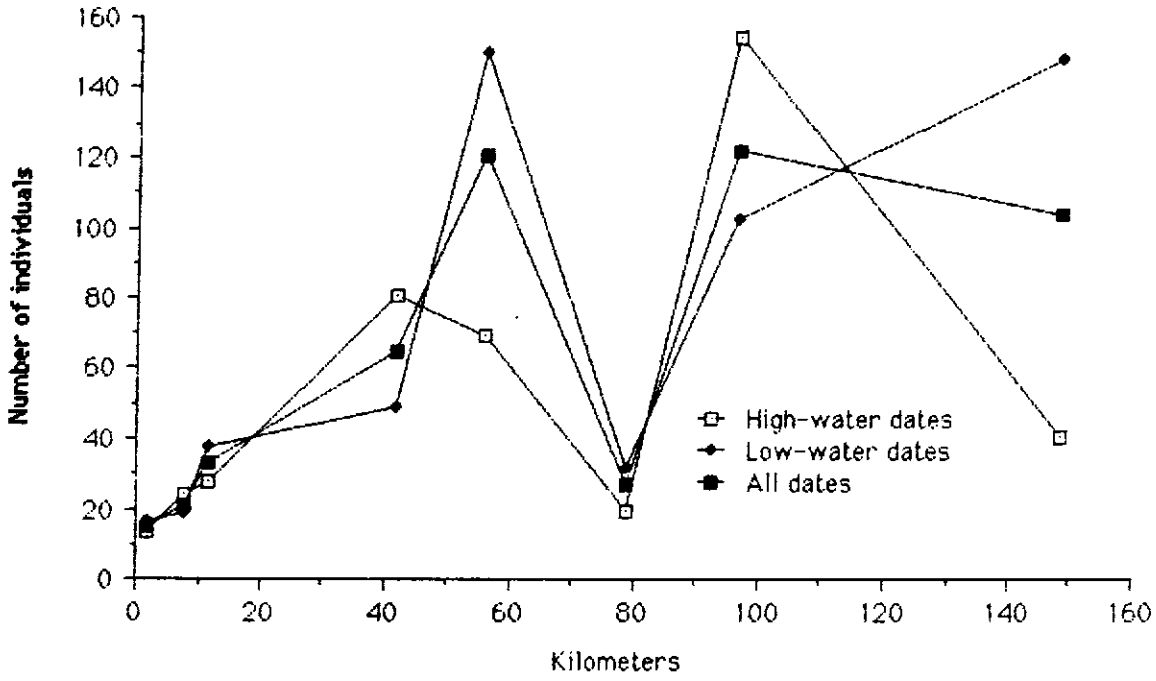


Figure 89. Mean ephemeropteran abundance by river kilometer.

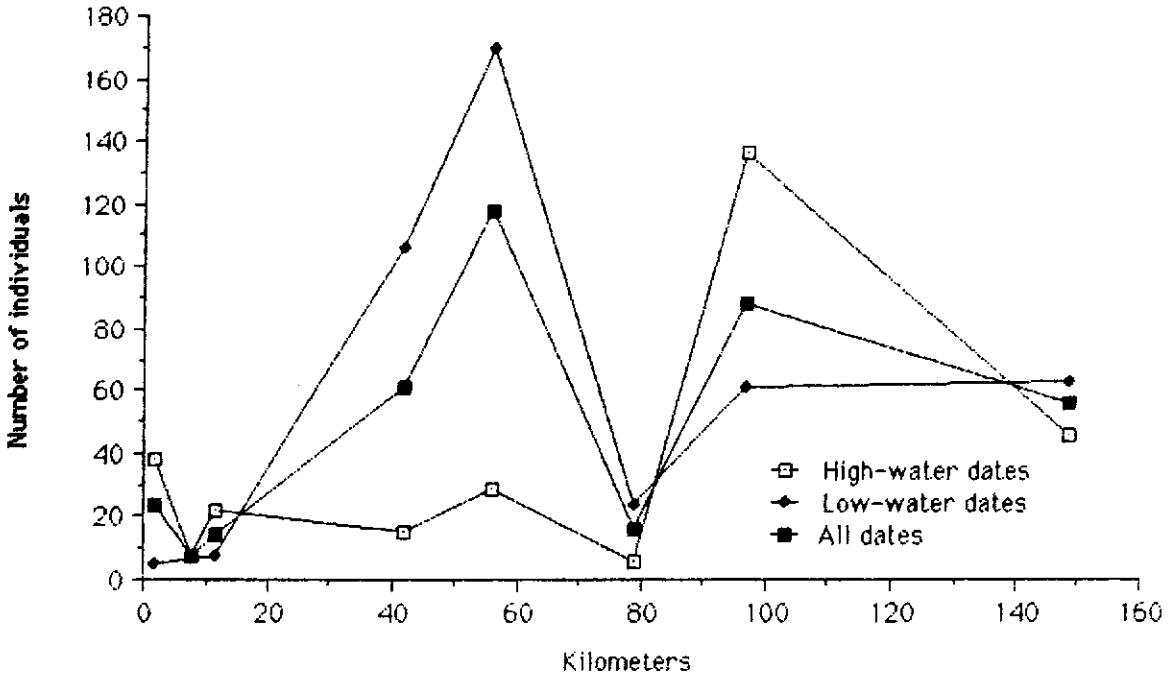


Figure 90. Mean trichopteran abundance by river kilometer.

high water, while water level evidently had little effect on this population at Stations 1 and 2. Trichopterans were more numerous at Stations 4, 5, 6, and 8 during low water, and more numerous at Stations 1, 3, and 7 at high water. Again, the abundance of caddisflies at Station 2 was the same regardless of water level. It is interesting to note that longitudinal trends in abundance of the top three groups (i.e. increasing between 1 and 5, dropping at 6 and rebounding at 7) were generally the same despite extreme differences in flow conditions.

Species level data can be utilized to show reductions in occurrence or complete elimination of taxa collected at a station downstream of a suspect tributary. The complete elimination of a certain species between two stations would suggest a rather sudden alteration in habitat and/or other water quality parameter(s) necessary for the species to survive.

A total of 204 different benthic macroinvertebrate taxa were collected from the Ochlockonee River during this study. Kinds of organisms occurring in 50% or more of the samplings for a given station were examined for spatial differences (Table 44). Two midges, Rheotanytarsus sp. and Tanytarsus sp., and one mayfly, Stenonema exiguum, were found quite frequently at all stations. These three organisms represented 30% of all individuals collected. Several other taxa occurred frequently at all except one or two stations. These were the caddisfly, Cyrnellus fraternus, the mayflies, Stenonema smithae and Stenacron interpunctatum, and the midges Ablabesmyia parajanta and Polypedilum convictum. Some taxa were conspicuously rare or totally absent from certain stations, while occurring frequently at others. For example, Cheumatopsyche sp., a net-spinning trichopteran, was normally found in moderately large quantities at Stations 1, 4, 5, and 7. In contrast, at Stations 2 and 8, a total of only three and seven Cheumatopsyche sp., respectively, were found, while none were collected at Station 6. Similarly, the filter feeding mayfly, Isonychia sicca, occurred frequently and abundantly at Stations 5 and 7, while few were found at most other stations and none at Station 6. The predatory megalopteran, Corydalis cornutus (known locally as "gator flea"), followed this same pattern of distribution. Other organisms which were usually rare in the upper river and at Station 6, but occurred frequently elsewhere (especially Stations 5 and 7) were the midges, Thienemanniella xena and Corynoneura taris, and the gastropod Ferrissia hendersoni (which was also often found at Station 1).

Some organisms were representative of only one particular station. Station 5 had many such frequently occurring organisms, including the midges, Cricotopus bicintus and Pentaneura inconspicua, the caddisfly, Hydropsyche mississippiensis, the mayfly, Heptagenia flavescens, the water mite, Hygrobates sp., and the elmid beetle, Macronychus glabratus. The trichopterans, Macronema carolina and Neotrichia sp., were usual components of the fauna at Station 7, as was the stonefly, Perlesta placida, which was also abundant at Station 4. Organisms which were found in excess of half the samples recovered from Station 8 were the amphipod, Hyalella azteca, the caddisfly, Neureclipsis sp., the dragonfly,

TABLE 44. Benthic macroinvertebrate taxa and number of occurrences at each station, Ochlockonee River, October, 1985 to October, 1986.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
CNIDARIA								
Hydra sp.	2	3	1	3	1	1	1	4
PLATYHELMINTHES								
Dugesia tigrina	2	4	1	-	-	5	1	2
RYNCHOCOELA								
Prostoma rubra	-	-	-	-	-	1	1	1
NEMATODA								
Unknown nematod	1	-	1	1	1	1	-	-
OLIGOCHAETA								
Chaetogaster diaphanus	1	-	-	-	-	-	-	-
Dero sp.	-	1	-	-	-	-	-	-
D. obtusa	1	2	2	1	-	3	-	1
Eclipidrilus sp.	-	-	2	-	-	-	-	-
Limnodrilus hoffmeisteri	-	-	4	-	-	1	-	-
Unknown lumbriculid	1	1	-	-	-	-	-	-
Nais communis	-	-	-	1	-	-	-	1
N. elinguis	2	1	2	1	-	1	1	3

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
N. pseudobtusa	-	3	-	-	-	1	-	-
Quistadrilus multisetosus	-	1	-	-	-	-	-	-
Slavina appendiculata	2	4	1	-	2	3	-	1
Unknown tubificid	-	-	1	-	-	-	1	-
HIRUDINEA								
Helobdella triserialis	2	1	-	-	-	1	-	-
MALACOSTRACA								
Asellus sp.	2	-	2	-	-	3	1	1
Hyalella azteca	-	1	-	3	1	1	-	10*
Oronectes sloanii	-	-	-	-	-	1	-	-
Procambarus sp.	1	-	1	2	1	2	3	1
ACARINA								
Albia sp.	-	-	-	-	-	-	-	1
Arrenurus sp.	-	-	-	-	-	1	-	-
Atractides sp.	-	-	-	-	-	-	1	-
Unknown halacarid	-	-	-	-	-	1	-	-
Hygrobates sp.	1	-	3	1	7*	-	4	1
Lebertia sp.	1	-	-	-	1	-	2	1
Mideopsis sp.	1	-	-	-	-	-	-	-
Neumania sp.	-	-	-	-	-	1	-	-
Sperchonopsis sp.	-	-	-	-	2	-	-	-
Unknown water mite	-	-	-	-	-	1	-	-
Sperchon sp.	-	-	-	1	-	-	-	-

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
PLECOPTERA								
Neoperla sp.	-	-	-	2	1	-	1	-
N. clymene	-	-	-	-	2	1	2	-
Perlesta placida	-	-	6*	2	4	2	6*	4
Taeniopteryx leta	-	-	1	1	1	-	-	-
EPHEMEROPTERA								
Baetis sp.	-	-	-	1	4	-	2	-
B. intercalaris	1	-	-	2	2	-	1	-
B. propinquus	-	-	-	1	2	-	-	-
Caenis hilaris	3	2	3	4	6*	7*	6*	8*
Centroptilum hobbsi	-	-	-	-	-	-	1	-
C. viridocularis	-	-	-	1	-	1	2	-
Eurylophella temporalis	-	1	1	-	1	-	-	-
Habrophlebiodes brunniepennis	-	-	1	-	-	-	-	-
Heptagenia flavescens	-	-	-	1	6*	-	5	2
Hexagenia sp.	-	1	-	1	-	-	-	-
H. munda	-	-	-	-	-	1	1	-
Isonychia sicca	1	-	2	4	9*	-	7*	1
Neoephemera youngi	-	-	-	-	-	-	1	1
Stenonema exiguum	4*	6*	8*	9*	11*	8*	11*	11*
S. integrum	-	-	-	-	-	-	1	1
S. smithae	3	6*	7*	9*	11*	5	11*	6*
Stenacron interpunctatum	6*	8*	8*	9*	10*	10*	10*	2
Tricorythodes albilineatus	-	-	-	-	6*	2	5	6*

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
ODONATA								
Argia sp.	4	4	3	3	2	5	3	2
A. fumipennis	-	-	-	-	-	-	-	1
A. moesta	-	-	-	1	-	4	-	4
A. tibialis	5*	5	3	5*	3	5	-	10*
Boyeria vinosa	-	-	-	-	-	-	1	-
Unknown corduliid	-	-	-	-	-	-	-	1
Dromogomphus spinosus	1	-	-	-	-	-	-	-
Enallagama sp.	1	-	-	-	-	-	-	-
E. cardenium	-	-	-	-	-	1	-	1
Erythrodiplax connata minuscula	-	-	-	-	-	-	-	1
Neurocordulia virginiensis	1	1	-	2	3	-	5	7*
HEMIPTERA								
Hydrometra sp.	1	-	-	-	-	-	-	-
Mesovelia amoena	1	-	-	-	-	-	-	-
MEGALOPTERA								
Corydalus cornutus	1	-	1	4	6*	-	6*	1
Nigronia serricornis	-	-	-	-	-	-	1	-
Sialis sp.	-	3	1	1	-	-	-	-
S. mohri	-	-	-	1	-	-	-	-

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
TRICHOPTERA								
Cheumatopsyche sp.	5*	2	5	5*	10*	-	7*	4
Chimarra sp.	-	-	-	-	5	-	5	-
Cyrnellus fraternus	1	8*	6*	8*	9*	7*	7*	12*
Hydropsyche sp.	-	-	-	3	5	1	4	1
H. incommoda	-	-	-	-	-	1	4	4
H. mississippiensis	-	-	-	-	6*	-	1	5
H. simulans	-	-	-	-	-	-	-	2
Hydroptila sp.	-	-	-	3	5	1	4	1
Lepidostoma sp.	-	-	-	-	-	-	1	-
Macronema carolina	-	-	-	-	1	-	6*	2
Mayatrichia sp.	-	-	-	-	-	-	-	1
Nectopsyche sp.	-	-	-	-	1	-	1	1
N. candida	-	-	-	-	-	-	1	-
Neotrichia sp.	-	2	-	3	7*	3	5	-
Neureclipsis sp.	-	-	-	-	4	1	4	8*
Oecetis sp.	-	-	-	-	1	-	1	1
O. cinerascens	-	-	-	-	5	-	2	4
O. inconspicua	1	-	-	-	-	-	-	-
Orthotrichia sp.	1	-	-	-	1	-	1	2
Oxyethira sp.	-	-	1	-	1	-	2	-
Phylocentropus sp.	-	-	-	-	-	-	1	-
Polycentropus sp.	-	6*	1	-	1	6	5	1
Unknown trichopteran	1	-	-	1	5	1	2	7*
Trianodes sp.	1	-	-	-	-	-	-	-
T. tardus	-	-	-	-	-	-	1	-

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
COLEOPTERA								
Agabetes acuductus	1	-	-	-	-	-	-	-
Ancyronyx variegatus	8*	3	5	2	8*	7*	2	5
Berosus sp.	-	-	1	-	-	2	-	-
Celina sp.	-	1	1	-	-	1	-	-
Dineutus sp.	1	5	1	2	3	1	1	4
Dubiraphia sp.	1	-	-	-	1	-	-	-
D. bivittata	-	1	-	2	1	4	2	-
Hydrobiomorpha casta	1	-	-	-	-	-	-	-
Hydroporus sp.	-	4	-	1	-	4	-	1
DIPTERA								
Ablabesmyia sp.	2	3	3	2	-	2	2	2
A. cinctipes	-	1	-	-	-	-	-	-
A. mallochi	2	3	4	2	1	1	3	4
A. ornata	3	7*	4	5*	1	8*	6*	5
A. parajanta	3	8*	7*	6*	5	9*	6*	11*
A. tarella	2	4	-	-	1	1	-	-
Atherix lantha	-	-	1	-	-	-	-	-
Atrichopogon sp.	2	1	-	-	3	-	1	-
Bezzia sp.	1	1	1	2	1	5	1	2
Chaoborus punctipennis	-	-	-	-	-	-	-	2
Unknown chironomid	3	8*	5	7*	6*	5	5	8*
Chironomus sp.	-	3	-	1	-	-	-	-
C. attenuatus	-	2	-	-	-	-	-	1
C. riparius	1	4	2	-	-	-	1	1
C. stigmaterus	-	1	1	-	-	-	-	-
Cladotanytarsus sp.	-	-	-	-	-	1	-	-

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
Conchapelopia sp.	3	5	4	3	5	–	–	–
Corynoneura taris	2	5	6*	7*	8*	4	7*	5
Cricotopus sp.	–	–	1	6*	7*	6	2	2
C. bicinctus	1	–	1	4	6*	2	3	1
Cryptochironomus sp.	–	–	1	–	–	–	–	–
C. blarina	–	–	1	–	–	–	–	–
C. fulvus	–	–	1	–	–	–	1	3
Dicrotendipes sp.	–	1	1	2	–	1	–	–
D. modestus	–	–	1	–	–	–	–	–
D. neomodestus	3	3	–	4	5	6	4	4
D. nervosus	4	7*	4	5*	6*	9*	3	7*
Endochironomus nigricans	1	1	2	–	–	–	–	2
Glyptotendipes sp.	1	1	–	–	–	–	–	1
G. lobiferus	–	2	–	–	–	–	–	2
G. meridionalis	–	1	–	–	–	–	–	–
G. paripes	–	1	–	–	–	–	–	1
Harnischia sp.	1	–	–	–	–	3	–	1
H. curtilamellata	–	–	–	1	–	1	–	2
Hemerodromia sp.	1	1	3	4	9*	1	4	2
Kiefferulus dux	–	1	–	–	–	–	–	–
Labrundinia sp.	–	–	1	–	–	–	1	–
L. floridana	1	–	3	4	3	3	5	4
L. neopilosella	–	–	–	–	–	–	1	–
L. virescens	1	–	–	–	2	–	–	–
Nanocladius sp.	1	1	4	2	3	2	3	6*
Nilothauma sp.	3	2	3	3	7*	3	4	4
Nilotanypus sp.	–	–	–	–	–	–	1	–
N. fimbriatus	–	–	–	–	1	–	1	–
Odontomesa sp.	–	–	1	–	–	–	–	–
Parachironomus sp.	–	2	1	–	1	1	–	–
P. directus	–	–	–	–	–	1	–	–
P. schneideri	1	–	–	–	–	1	–	1
Pentaneura inconspicua	2	–	1	4	8*	1	2	–

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
P. directus	–	–	–	–	–	1	–	–
P. schneideri	1	–	–	–	–	1	–	1
Pentaneura inconspicua	2	–	1	4	8*	1	2	–
Phaenopsectra obediens	–	2	–	–	–	–	–	1
Parakiefferiella sp.	2	3	1	2	3	2	2	3
Paralauterborniella nigrohalteralis	–	–	1	–	–	1	–	–
Polypedilum convictum	6*	6*	7*	9*	11*	6	9*	8*
P. fallax	3	6*	4	3	–	6	3	8*
P. halterale	3	8*	5	5*	4	6	5	7*
P. illinoense	4	2	6*	7*	4	8*	4	2
Potthastia sp.	–	1	–	–	1	–	1	–
Procladius bellus	3	3	2	–	–	–	–	–
Parametriocnemus lundbecki	–	–	–	–	1	1	–	–
Pseudochironomus fulviventris	–	–	–	–	1	1	–	–
P. richardsoni	–	–	–	1	–	1	–	–
Unknown dipteran pupae	9*	11*	9*	10*	11*	6	9*	8*
Rheocricotopus sp.	1	–	–	–	–	–	–	–
R. robackii	3	1	7*	5*	8*	2	2	1
Rheotanytarsus sp.	6*	7*	10*	9*	11*	10*	9*	7*
Simulium sp.	2	–	1	2	2	–	2	4
Stenochironomus sp.	–	–	–	1	1	–	1	–
S. hilaris	1	–	–	1	3	2	1	2
Stelechomyia sp.	–	–	–	3	1	–	1	–
Tanytarsus sp.	7*	12*	10*	9*	10*	13*	11*	10*
Thienemanniella xena	4	4	7*	8*	10*	4	8*	8*
Tanypus sp.	–	–	–	–	–	1	–	–
Tribelos sp.	–	1	–	–	–	–	–	–
T. fuscicornus	4	7*	1	4	2	7*	5	7*
T. jucundis	–	4	2	–	–	1	–	–

TABLE 44. Continued.

	Number of Occurrences							
	1	2	3	4	5	6	7	8
GASTROPODA								
Cincinnatia sp.	-	1	-	-	-	-	-	-
Ferrissia sp.	-	-	1	1	1	-	-	-
F. hendersoni	5*	5	5	3	10*	6	7*	6*
Fossaria sp.	1	-	-	-	-	-	-	-
Gyraulus sp.	-	-	-	-	-	2	-	-
G. parvus	-	-	-	-	-	1	-	-
Unknown hydrobiid	-	2	-	-	-	5	-	-
Micromenetus dilatus	4	4	2	-	1	4	1	4
Physella heterostropha pomila	3	7*	2	-	1	10*	1	6*
Promenetus sp.	-	1	-	-	-	-	-	-
Unknown gastropod	-	1	-	-	-	-	-	-
PECECYPODA								
Corbicula manilensis	1	-	-	-	-	1	-	-
Musculium sp.	-	-	-	-	-	1	-	-
Unknown sphaeriid	3	1	1	-	-	2	1	4
Total*	10	17	15	21	30	14	19	24

Neurocordulia virginiensis, and Nanocladius sp., a midge. Tricorythodes albilineatus (a mayfly) was common at Stations 8 and 5, and the chironomid, Tibelos fuscicornis was representative of Stations 8, 6, and 1. An ephemeropteran, Caenis hilaris, occurred frequently only in the lower river from Stations 5 through 8. Finally, a few taxa usually occurred frequently only at the middle river stations (3, 4, 5, and/or 6). These were the beetles, Stenelmis sp. and Ancyronyx variagata, and the midges, Cricotopus sp. and Polypedilum illinoense. Interestingly, no organism appeared to be unique to only the upper (1-3) river stations.

Multivariate techniques (similarity indices and ordination) are standard analytical tools in community ecology (Bloom 1981). Put simply, these methods place either similar sampling stations (Q or normal analysis) or taxa (R or inverse analysis) into groups with similar attributes and therefore link these groups. Quite often, the geographically closest sampling stations (assuming a continuous aquatic system) will group together. When two geographically separated stations group together, rather than with nearby stations, some type of environmental perturbation is suggested. The clustering of certain species groups (e.g., those restricted to either "healthy" or "impacted" stations) may also help explain apparent differences in the biota sampled from dissimilar stations.

Normal cluster analysis of all months of species composition and abundance data for the most abundant 50 taxa indicated the presence of three station groups at the level of 70% similarity (Figure 91). One consisted of Stations 5 and 7. Another group consisted of Stations 1, 3, 4, 2, and 6, while Station 8 was the only member of the third group.

Normal cluster analysis was also performed on data from high and low flow periods. Cluster analysis performed on combined data from high flow months indicated the existence of five station groups at the 70% similarity level (Figure 92). Stations 2 and 6 comprised one group. A second consisted of Stations 1, 3, and 4. The remaining three groups consisted of the single Stations 5, 7, and 8.

Cluster analysis on combined data from the low flow period yielded four groups at the 67% similarity level (Figure 93). Again, Stations 5 and 7 were linked to form a single group. Another consisted of Stations 1 and 2. Stations 3, 4, and 6 comprised a third group, while Station 8, once again, remained in isolation.

Inverse cluster analysis of the most abundant 50 taxa (94% of all organisms collected) yielded 14 groups at the 70% similarity level (Figure 94). The 70% similarity level was chosen to more accurately reflect the station groupings apparent from normal analysis. The first group represented the most abundant organisms in the river, accounting for 72.2% of all animals collected. Dominant members of this group included Stenonema exiguum, Caenis hilaris, Rheotanytarsus sp., Tanytarsus sp., and Cyrnellus fraterus. Not unexpectedly, the spatial distribution of this group was descriptive of the mean abundance curve for the entire system, notably increasing between Stations 1 and 5, decreasing at Station 6, and once again increasing at Stations 7 and 8.

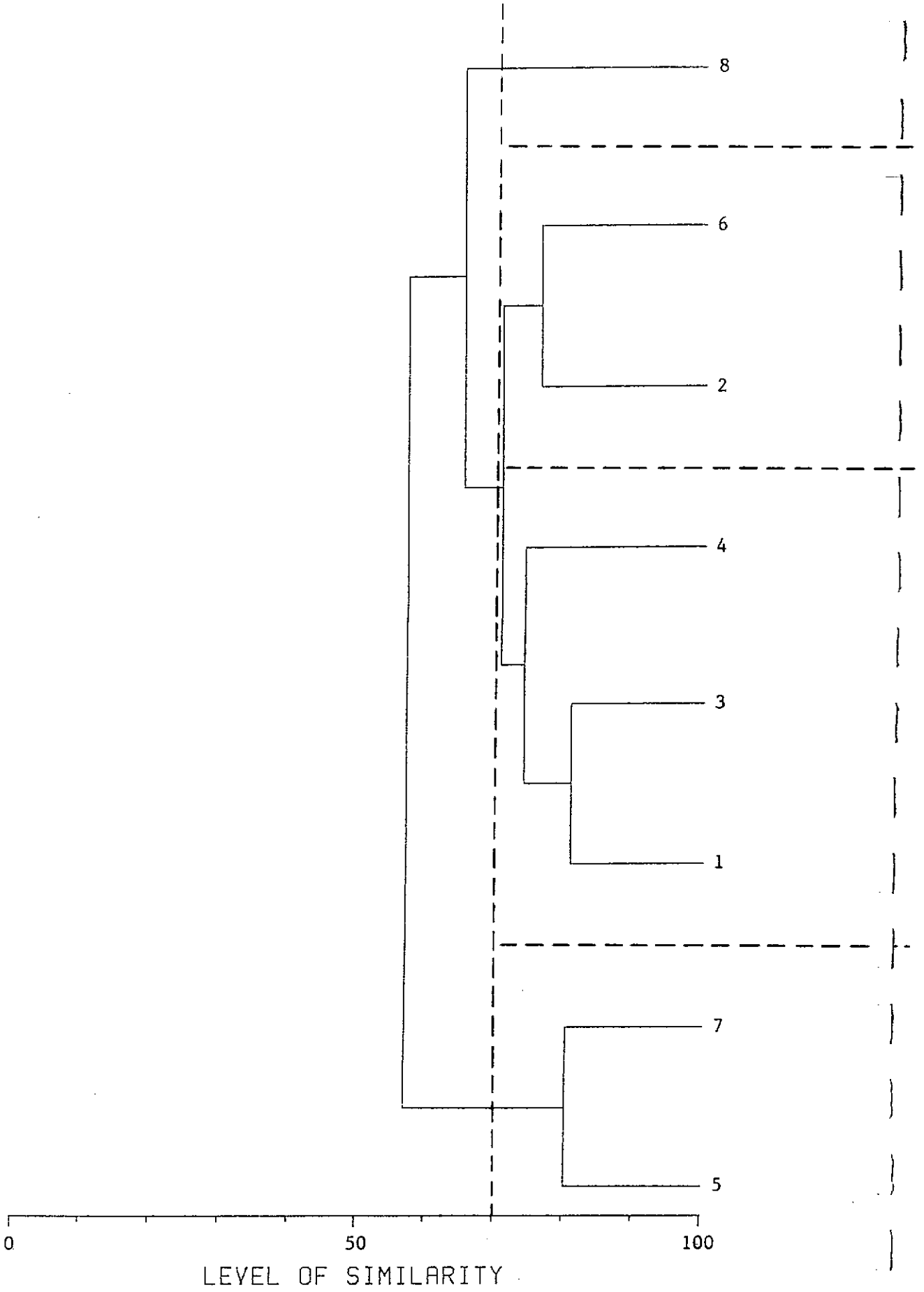


FIGURE 91. Station cluster of benthic macroinvertebrate data for the entire sampling period.

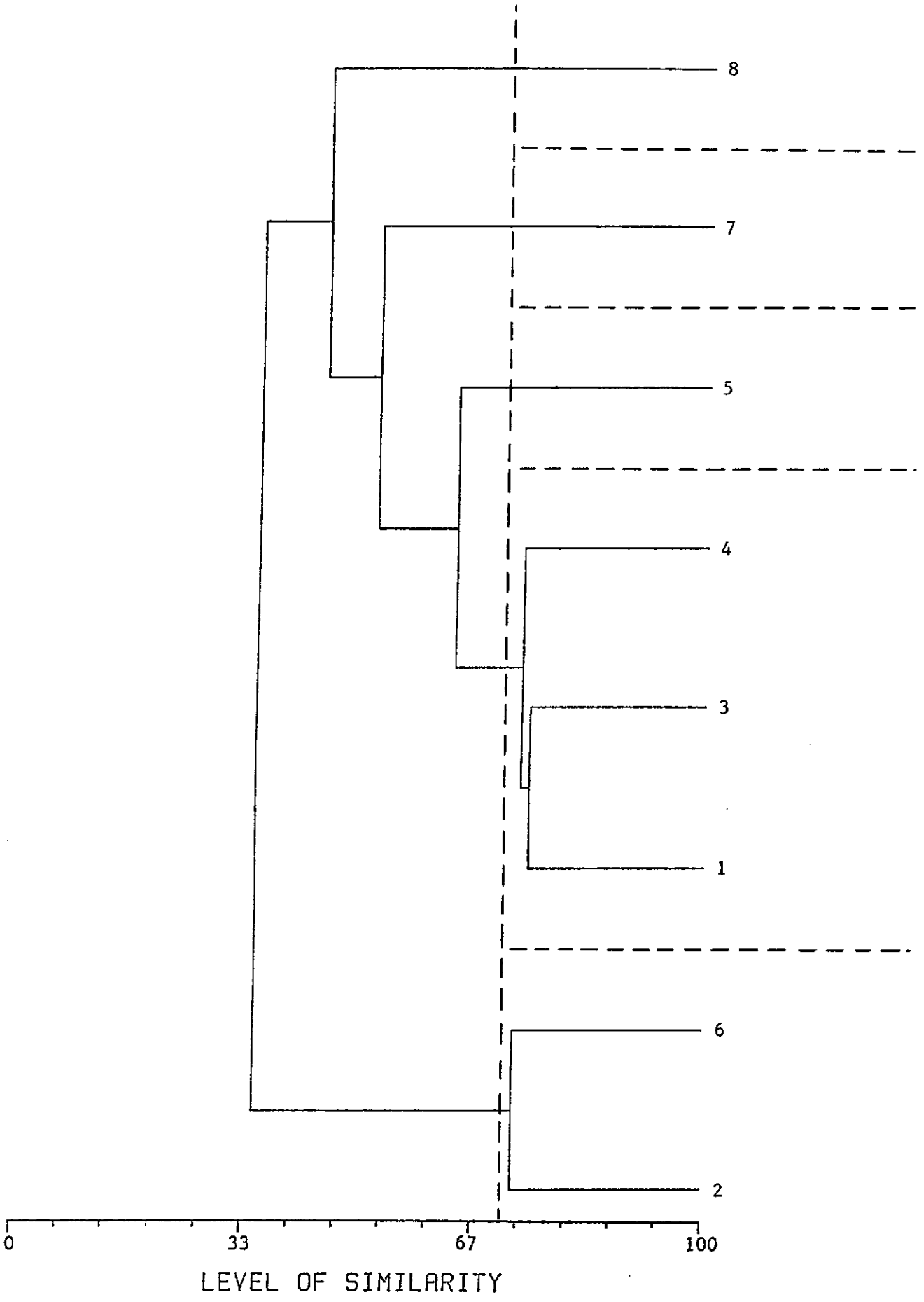


FIGURE 92. Station cluster of benthic macroinvertebrate data for the period of high flow.

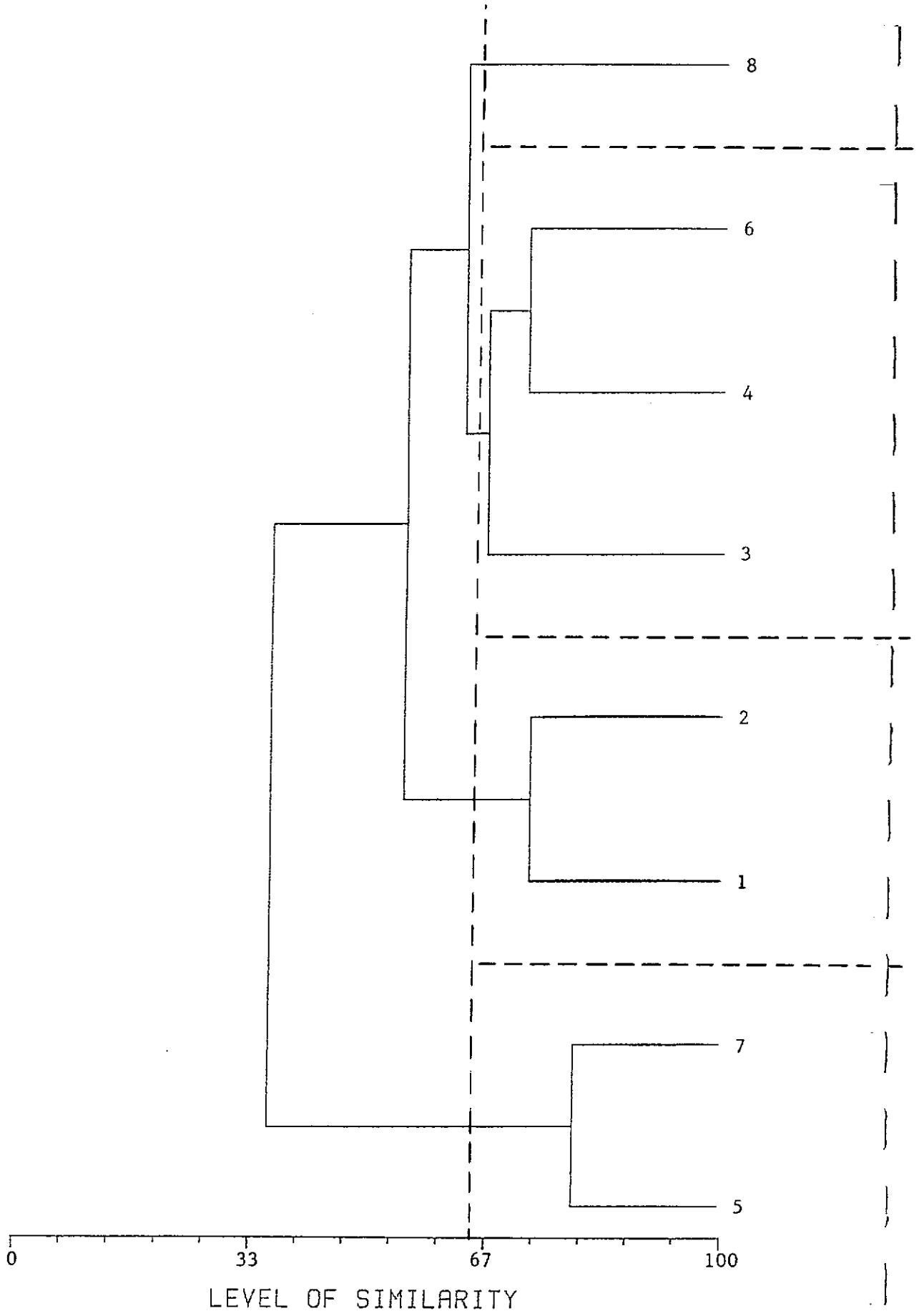


FIGURE 93. Station cluster of benthic macroinvertebrate data for the period of low flow.

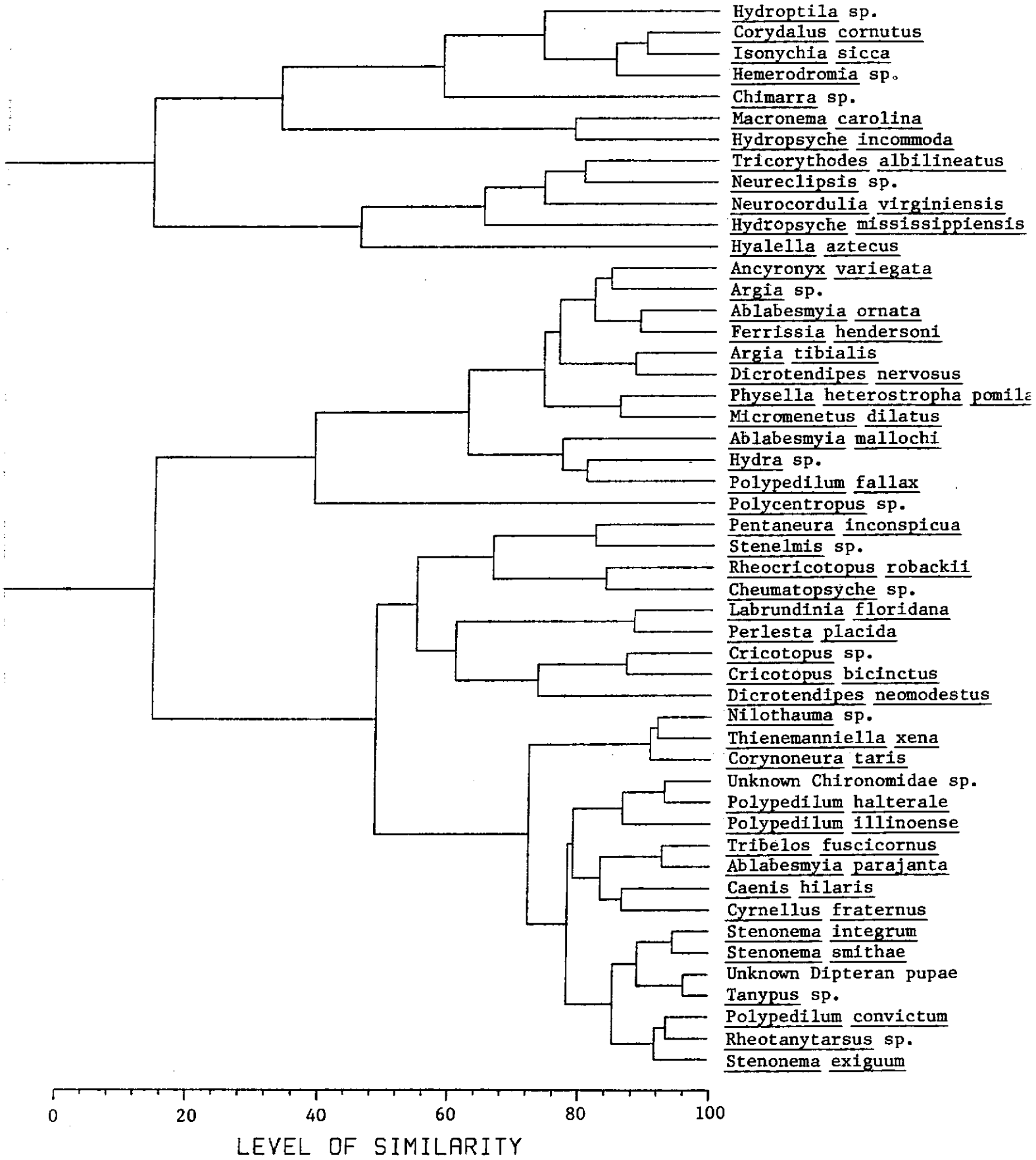


FIGURE 94. Species cluster of the top 50 benthic macroinvertebrate taxa.

Two groups peaked at Station 6, where Dicrotendipes neomodestus, Crictopus bicinctus, and Polycentropus sp. were most often found. These groups were small, and together accounted for 4% of the total population.

Perlesta placida and Labrundinia floridana were the two members of another small group (1.2% of the total), which was most numerous at Stations 3 and 7.

Four different groups were most abundant at Stations 5 and 7, which probably influenced the clustering of those two stations in normal analysis. Of all organisms collected, 9.6% belonged to these four groups, including the caddisflies, Cheumatopsyche sp., Chimarra sp., Hydropsyche incommoda, and Macronema carolina. Other important members of these groups were Isonychia sicca, Corydalis cornutus, and Rheocricoptopus robackii.

Four other groups of organisms were usually dominant at Station 8, but sometimes were also found at Stations 5 and/or 7. Descriptive of these sets were invertebrates such as Hyalella azteca, Polypedilum fallax, Hydropsyche mississippiensis, Neureclipsis sp., and Neurocordulia virginiensis. The animals in these four similar groups accounted for 4.1% of the total population.

The smallest cluster (only 0.8% of the total) was represented by Stenelmis sp. and Pentaneura inconspicua, which were most numerous at Stations 4 and 5.

One last cluster consisted mainly of gastropods and odonates, and exhibited peaks at Stations 1 and 4 and noticeable decreases at Stations 5 and 7. Organisms such as Micromenetus dilatus, Physella heterostropha pomila, Ferrissia hendersoni, and Argia tibialis comprised this group, which numerically contained 7.8% of the total benthic community.

Discriminant analysis was used to isolate the abiotic factors that exert the most influence on the benthic community. These results were compared to the results from the cluster analysis to attempt to correlate the environmental parameters responsible for the station clusters.

Multiple discriminant analysis was performed using the entire data set (all months), and for months with high and low flows. Chemical parameters included in the analysis were total suspended solids, dissolved oxygen, pH, conductivity, and turbidity, since these were thought to be critical to benthic community distribution.

The results using the entire data set indicated that Discriminant Function I (turbidity) was responsible for 54.6% of the among-group variance, while DFII (total suspended solids) accounted for an additional 22.7% of the variance (Figure 95). Similarly, the analysis performed using data from low flow months showed that turbidity (DFI = 58.3%) and total suspended solids (DFII = 25.2%) were again the most important parameters in contributing to among-group separation (Figure 96).

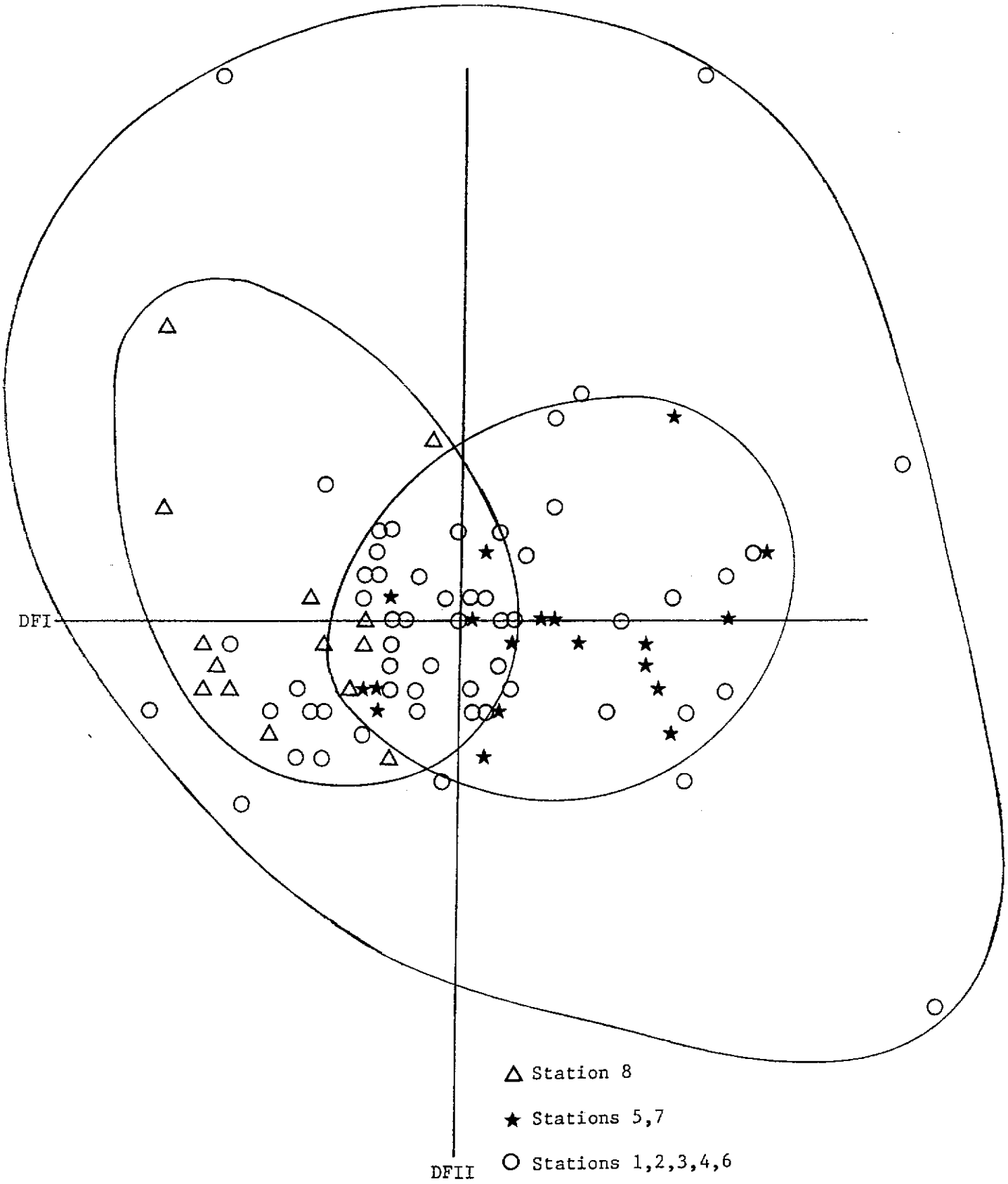


FIGURE 95. Orientation of benthic macroinvertebrate station groups in discriminant space.

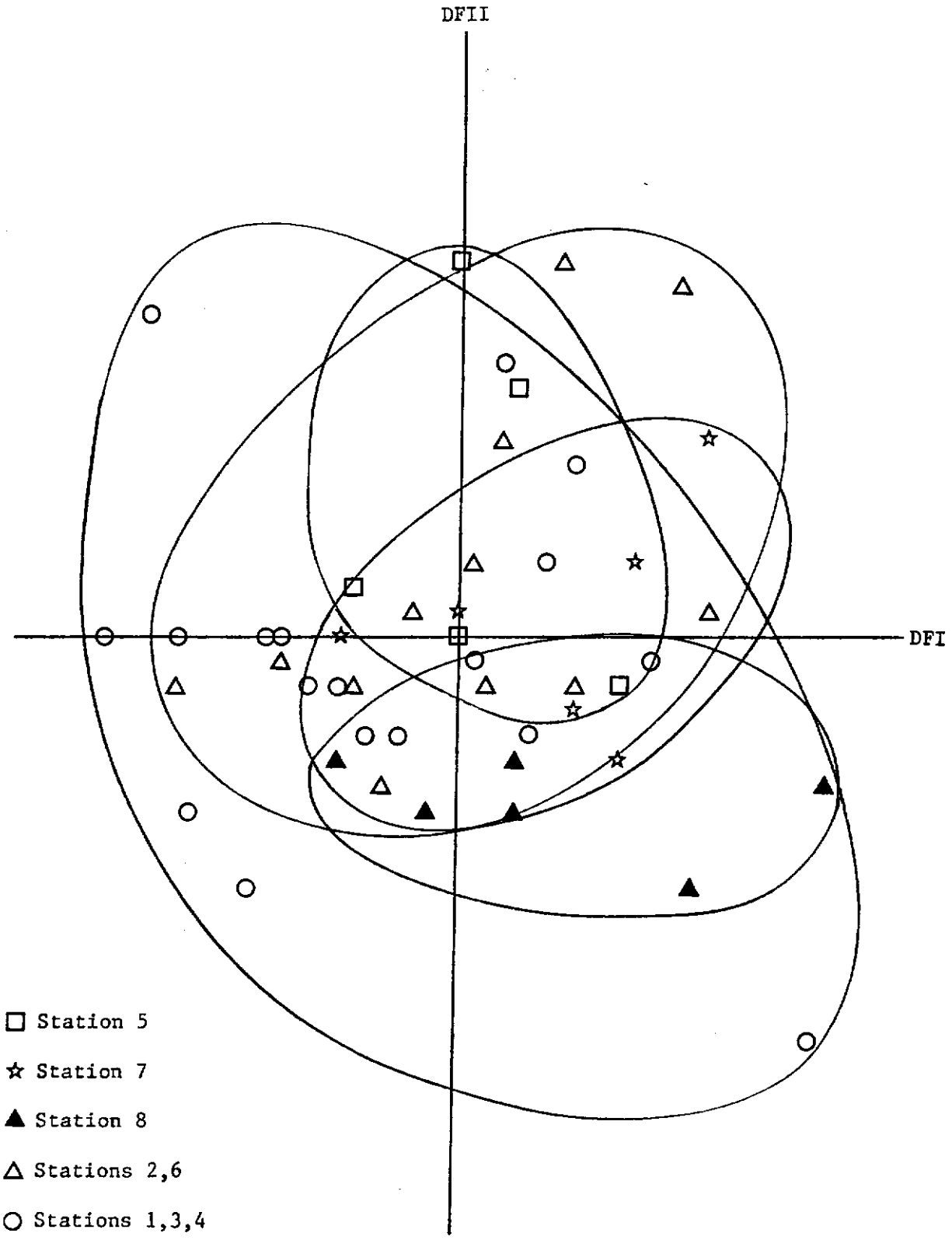


FIGURE 96. Orientation of benthic macroinvertebrate station groups in discriminant space for the period of high flow.

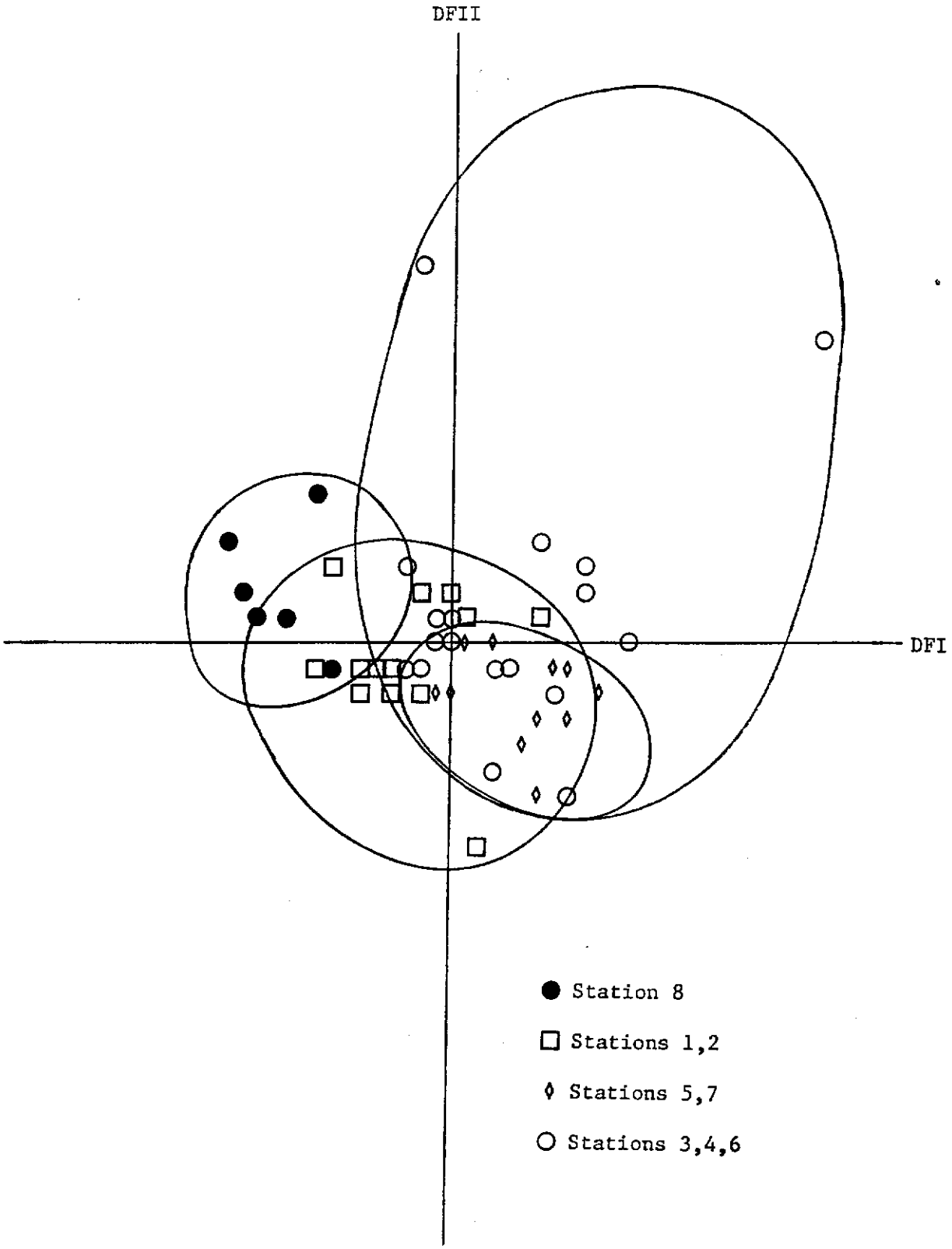


FIGURE 97. Orientation of benthic macroinvertebrate station groups in discriminant space for the period of low flow.

The results of discriminant analysis for high flow (= winter) months, however, were different from the results using data for all months and low flow months (Figure 97). At high flow, 51.8% of the among group variance could be explained by DFI or pH. The addition of DFII increased the explained variance to 90.1%. Conductivity and turbidity were the most important components of the high flow DFII.

Discussion

Sampling stations were primarily situated to determine the effects of tributaries or point source discharges on the biota of the river. Longitudinal (upstream-downstream) differences were emphasized, while seasonal variations or changes due to hydrologic conditions were presented mainly to help explain the variability in spatial trends.

Typical current velocities associated with average discharge measurements (see text table below) indicate that conditions throughout the portions of the river we studied were hospitable to rheophilic organisms (Mr. Paul Meadows, Mr. Marvin Franklin, and Mr. Roger McFarland, U.S.G.S., personal communications).

River kilometer	17.3	91.8	146.9
Location relative to present Stations	Below Station 3	Above Station 7	Above Station 8
Mean discharge (CFS)	501 CFS	1036 CFS	1675 CFS
Period of record	33 years	61 years	61 years
Velocity range at mean discharge (ft/sec)	0.8 to 1.1 ft/sec	1.3 to 1.5 ft/sec	0.7 to 1.2 ft/sec

The Hester-Dendy multiplate sampler was chosen because it simulates the "snag" habitat, which has been shown to support the greatest number and diversity of benthic invertebrates of any southeastern river habitat (Benke *et al.* 1984). Therefore, our study should represent the "best-case" situation for macroinvertebrate production at each station.

Macroinvertebrate mean abundance and mean taxa at the first three stations appeared to be relatively low, compared to the upper reaches of both the Suwannee River (FDER 1985) and the Satilla River (Benke *et al.* 1984). These two rivers should be directly comparable to the Ochlockonee since they are adjacent systems. There are however, major differences in land use at the headwaters of these rivers (see Land Use Section). While

both the Suwannee and Satilla drain undeveloped areas, the headwaters of the Ochlockonee drain mainly agricultural lands. Four sewage treatment plants also discharge to the upper Ochlockonee River. These factors, to be discussed in greater detail later, may have contributed to the low abundance and species richness observed in the upper Ochlockonee.

Significant increases in abundance and species richness occurred at Station 4, peaking at Station 5. This is important in that it suggests that mining operations (discharging through Barnetts Creek above Station 4) and assorted wastes from the Cairo area (discharging through Tired Creek above Station 5) were not adversely affecting the macroinvertebrates at these stations. Although toxicity was noted some miles downstream from both the Roddenberry and Cairo WPCP discharges (see Toxicity Section), dilution or stream purification processes may have occurred in the 10 mile stretch of Tired Creek before its confluence with the river.

Reductions in both density and taxa richness at Station 6 are indicative of moderate to severe stress (Table 42). This finding is unusual in that there is only one former point source discharge (non-toxic) between Stations 5 and 6 (an abandoned mining operation). The river basin is heavily forested between this station and the state line to the north, with little other human activity. Siltation effects may provide a possible explanation for the decline in the benthic community at Station 6 (discussed in the Sediment Section and later in this section).

The values for mean abundance and mean taxa at Station 7 were much higher than at Station 6, and indicate a recovery from conditions (i.e, excessive silt) prevalent at Station 6. Since Lake Talquin is situated between Stations 7 and 8, one would attribute most differences in the benthic communities found at Stations 7 and 8 to the presence of the impoundment (Baxter 1977, FDER 1986b). Decreases in benthic density and species richness between Stations 7 and 8 however, are slight enough for Station 8 to be considered "unstressed" (Tables 42 and 43).

Increases in total taxa between the upper river and Station 7 may have been due in part to the recruitment of drifting invertebrates from tributaries and associated habitat changes because of an increase in stream order (Vannote et al. 1980, Bruns et al. 1984, FDER 1985). In contrast, the low mean taxa present at Station 6 may again indicate that conditions at this station were inhospitable to many of these would-be colonizers, forcing them to continue drifting in search of suitable habitat.

Stations 6 and 4 had the lowest average diversity (3.3) for the Ochlockonee River. Although the absolute value is not necessarily alarming, the relatively low diversity at Station 6, coupled with low abundance and species richness values for this station, indicates perturbation.

Abnormally low abundance, species richness, and diversity values found at certain stations on various months may be explained. Station 3, where these parameters were unusually low twice, is subject to acutely toxic discharges from Oquina Creek. In fact, this was the only river station where both chronic and acute toxicity to aquatic invertebrates was observed, which may be attributed to two point sources, the Thomasville Water Pollution Control Plant and Sunnyland Meat Processors (see Toxicity Section). This toxicity was probably intermittent, since the benthic community did not always appear to be this stressed. Abnormally low abundance, species richness, and diversity values noted at three stations in March, 1986, were probably the result of the extreme water level fluctuations which occurred during sampler incubation.

Mean density, taxa, and diversity were lowest during winter (= flood conditions) and highest in summer and fall (= low water). These parameters may have been low during flood stage due to the high water velocities, abrasion, and sheer forces to which the benthic organisms would have been subjected, resulting in "castastrophic drift" (Waters 1972). A full discussion of seasonal variations in the benthic communities is beyond the scope of this report. It is notable, however, that the longitudinal trends in density and taxa were the same regardless of water discharge, suggesting that factors other than water velocity were responsible for the distribution of the benthic organisms.

The densities and distributions of three taxonomic groups, the Diptera, Ephemeroptera, and Trichoptera, were largely responsible for the observed longitudinal trends in macroinvertebrate mean abundance. All three groups displayed similar spatial trends, that is, low abundance at Stations 1 through 3, increasing abundance at Station 4 peaking at Station 5, a dramatic decrease in abundance at Station 6, then a substantial increase in abundances at Station 7, and finally, a slight decrease in abundance at Station 8.

These same groups were also most common in a similar study of the Suwannee River. However, the distribution pattern and total abundance of these groups were quite different in the Suwannee (FDER 1985). The abundances of these three groups were generally much lower in the Ochlockonee, especially in the upper river and at Station 6. For example, the trichopteran population in the upper Ochlockonee, as well as at Station 6 (with a mean abundance < 20), appears to be significantly depressed when compared to the mean caddisfly abundance (approximately 250) in the upper Suwannee. A comparison such as this provides further evidence that the benthic populations in certain areas of the Ochlockonee are disturbed.

The distributions of other taxonomic groups in the Ochlockonee also warrant mention. Acarina, Megaloptera, and Plecoptera were most numerous at Stations 5 and 7, but conspicuously rare or absent at Station 6. Col. Nick Lester has remarked that the "gator flea" (the megalopteran, Corydalis cornutus), which is widely used by anglers as bait, was once abundant at Station 6. Coleopterans, gastropods, and odonates were

abundant at Station 1 but not at Stations 2 and 3. Conversely, the oligochaete population (including worms such as Limnodrilus hoffmeisteri, a well known saprophile) increased at Station 2, and was most abundant at Station 3. These observations may possibly be related to additional inputs of organic matter from the Pelham Water Pollution Control Plant and Meigs Water Pollution Control Plant (upstream of Station 2, via the Little Ochlockonee River) and the Thomasville Water Pollution Control Plant (upstream of Station 3, via Oquina Creek), as well as other inputs from agricultural areas. Malacostracans (mainly Hyallela azteca, which is often considered a lake form) may have drifted to Station 8 from Lake Talquin.

The total number of different macroinvertebrate taxa collected in one year from the Ochlockonee (204) was somewhat lower than, but comparable to the 265 total taxa collected from the Suwannee. The latter system, however, was sampled for two years. Many of the more frequently occurring organisms in the Ochlockonee River were also common in the Satilla and Suwannee systems (Benke et al. 1984, FDER 1985). These were eight ubiquitous taxa which are usually found in riverine snag habitats (see Results). Several other taxa which were common in the Satilla and Suwannee rivers and in some parts of the Ochlockonee, were conspicuously rare or absent from particular Ochlockonee stations. For example, two filter feeding taxa which cannot tolerate siltation (Cheumatopsyche sp. and Isonychia sicca) were especially rare or absent from Stations 2, 3, and 6. Other sensitive organisms, which are also Class I indicators in the Florida Index system, including Corydalis cornutus, Thienemaniella xena, and Corynoneura taris, were usually rare or absent from the upper river and Station 6, but common at other areas, especially Stations 5 and 7. The Florida Index System is a DER refinement of Beck's Biotic Index (Beck 1954) which quantifies the environmental health of a stream based on the quality of the specific benthic macroinvertebrates present. Several other Class I or II Florida Index indicators were frequently present at Stations 5, 7, and 8 suggesting, along with previously presented data, that the water quality at these stations was good to excellent. The absence of such indicators of good water quality at the upper stations (especially Stations 2 and 3) and at Station 6, along with previously presented data, suggests that water quality problems exist in those areas.

It has been previously established in the Erosion and Land Use sections of this report that a substantial quantity of sediments, resulting mainly from agricultural run-off, is entering the river. Time-series analysis (see Chemistry Section) indicates that there has been a significant increase in the solids content of the river since the mid 1950's associated with increased agricultural activity in the basin and to a lesser extent, mining operations. The high turbidities in the river and its tributaries (see Chemistry Section) also attest to the existence of this suspended sediment load. The abnormally high sediment silt/clay fraction observed at Station 6 during both high and low flow conditions (24.7% and 20.7%, respectively), suggests that a portion of this suspended silt is accumulating in this area (see sediment section).

Numerous benthic biologists have concluded that siltation effects have adverse impacts on macroinvertebrate communities, including decreased abundance and species diversity, and changes in community structure (for a review, see Minshall 1984). Silt may signficantly reduce the habitability of an area by decreasing food quality and oxygen availability (Cordone and Kelley 1961, Chutter 1969). DeMarch (1976) found distinct groupings of insects based on the presence or absence of silt, but abundance and taxa were limited by the presence of silt. Everhart and Duchrow (1970) stated, "Benthic organisms, a major link in the food chain, may be smothered by solids which settle out as stream velocity decreases." It appears that the observed reductions in several benthic community parameters in Florida at Station 6 may be the result of siltation caused primarily by agricultural run-off originating in Georgia.

The results of normal cluster analysis are consistent with the previously discussed single number summary, taxonomic trend, and species level trend results. Stations which were considered "stressed" in terms of the biological parameters almost consistently grouped together in cluster analysis. Conversely, "healthy" stations clustered together as well. For example, Station 6 consistently grouped with the upper river stations, regardless of water level, while Stations 5, 7, and 8 were always distinctly separate from the upper river.

An important aspect of inverse cluster analysis was that groups of good to excellent water quality indicators were found at Stations 5, 7, and 8. Conversely, the group of organisms characteristic of Station 6 was somewhat tolerant of degraded water quality. For example, Polycentropus sp. (contained in the Station 6 cluster), is often characteristic of muddy sediments where it is frequently associated with another silt-tolerant saprophile, Chironomus sp. (Wiggins 1977). Another notable group of organisms, which consisted mainly of certain gastropods (considered indifferent to water quality), was characteristic of the upper river.

Although the station clusters were not obviously defined in discriminant space, the overriding importance of total suspended solids and turbidity in the distribution of station groups is noteworthy. Only during flood stage did other factors (pH and conductivity) become as important as turbidity in among-group separation. This is additional evidence to isolate siltation as the major physical/chemical phenomenon regulating the distribution of the biota in the Florida section of the Ochlockonee River.

Historical Benthic Data

The Georgia Environmental Protection Division (1973) documented the water quality of the Ochlockonee Basin and established "a record of the flora, fauna, and chemistry of the basin with which future studies may be compared to determine enhancement or degradation of water quality". Establishing similarities in the benthic communities between those sampled in the fall of 1972 and the present improves the confidence and reliability of both data sets. There is, in fact, fair to good agreement between both data sets with one exception. There is a good probability that this one exception represents a genuine change in the biota.

It should be noted that these 1972 samplings occurred during extreme low flow conditions as measured at the U.S.G.S. Station #02327500 near Thomasville on September 25, 1972 (flow = 15 cfs). However, rheophilic taxa were well represented in these samples and Georgia EPD assigned "healthy" ratings to most stations. This is further evidence to indicate that low flow (= low current velocity) is not as significant as other factors in regulating the distribution of the biota.

Station 1 (Ochlockonee River at Highway 202, EPD #0141.7) was classified "healthy" based on a sampling on October 3, 1972 (GEPD 1973). There has been a noticable decline in the mayfly, caddisfly, and stonefly populations at this station since then. For example, the pollution intolerant taxa, Chimarra sp., Neoperla clymene, Tricorythodes sp., and Habrophlebiodes sp., which were present in 1972 and which contributed to this station's "healthy" rating, were totally absent at Station 1 during our study. In addition, 147 Cheumatopsyche sp., and eight Corydalis cornutus were collected during a single sampling in 1972, while 170 of the former and only one of the latter were collected in nine samplings in 1986. The crayfish population has also decreased at this station.

Oquina Creek (GEPD #0136.4-2.6) was considered "polluted" in 1973 due to discharge from the Thomasville WPCP. Our study showed that the benthic community downstream of Oquina Creek at our Ochlockonee Station 3 still exhibited symptoms of stress.

Station 4 (EPD #D 118.0) was assigned a "healthy" rating in 1973, based on the presence of 28 taxa including the intolerant organisms, Neoperla clymene, Isonychia sp., and Chimarra sp. (GEPD 1973). Although our study also found a mean taxa of 28, Neoperla clymene and Chimarra sp. were not collected at this station. The benthic community at Station 4 did show considerable improvement over the first three river stations, and has probably changed only slightly since 1973.

Station 5 (EPD #0109.1), located 1.8 miles downstream from the confluence of the Ochlockonee and Tired Creek, was considered "healthy" based in part on the presence of 34 taxa and the intolerant species, Isonychia sp. (GEPD 1973). Our data agree with this assessment since the mean number of taxa at Station 5 was 34, and Isonychia sp. was a major component of the benthic community. The 1972 and 1986 species lists for this station are very similar. There has been no major change in the benthos at this station, except that no clams were collected in 1986. Hester-Dendy samplers are, however, less than ideal for collecting clams.

Conclusions

Macroinvertebrate mean abundance and species richness values were abnormally low at the first three stations and at Station 6. These parameters at Stations 4, 5, 7, and 8 were suggestive of normal to healthy conditions. Taxonomic group and species level data indicated that sensitive and intolerant taxa were often conspicuously rare or absent from Stations 1, 2, 3, and 6 but generally present to abundant at the remaining stations. The results of multivariate cluster analyses were consistent with these findings.

Acutely toxic discharges from both the Thomasville WPCP and Sunnyland Meat Processing Plant are believed to have been primarily responsible for the reductions in the benthic community observed at Station 3. It is unknown whether the three other WPCP's which discharge in the vicinity of Stations 1 and 2 are exerting this profound an effect on the benthic communities at these stations. Other factors, such as nonpoint-source run-off from extensive agricultural operations or periodic episodes of low dissolved oxygen concentrations may also have major impacts on the stream biota of this area.

Although discharges from Thor Mining, Roddenberry Company, and the Cairo WPCP probably affect the macroinvertebrates of the receiving tributaries, they seem to have no negative effect on the macroinvertebrates in the Ochlockonee River. The reductions in benthic community parameters observed at Station 6 appear to be the result of siltation effects caused by nonpoint-source (agricultural) run-off originating primarily in Georgia.

Results from discriminant analysis provided evidence that suspended solids and turbidity were the major physical chemical parameters regulating the distribution of the biota.

FISHERY RESOURCES

Introduction

Fish usually occupy higher trophic levels, and thus are sensitive to perturbations which upset the food web beneath them. For this and other reasons (e.g., biological magnification) fish populations integrate many environmental variables and may therefore indicate the health of an aquatic ecosystem as reflected in quantities of desirable game species produced. As part of a statewide river monitoring program, the Florida Game and Freshwater Fish Commission (G.F.C.) sampled fish communities of nine Florida rivers in 1983 and 1984 (Bass and Yeager 1985). Data from the Ochlockonee River (station locations presented in Figure 98) and comparisons with other rivers in the state are reported here.

Methods

Fish samples were collected from two to four stations in each river with standard D.C. electrofishing boats. Sampling was conducted at night at all stations. Standard electrofishing effort (catch per pedal time or CPT) was ten minutes of actual shocking time (pedal time) per sub-area. Most stations consisted of three sub-areas representing different habitat types, thus standard electrofishing time per station was 30 minutes. Field data were analyzed for relative abundance by number and biomass, species composition, and mean weights (Bass and Yeager 1985).

Results

Two years of data specific to the Ochlockonee River were available for this report. A total of 32 species of fish were collected from the only Ochlockonee River locations sampled (G.F.C. Stations 1 and 2) in the fall of 1983 (Appendix). By weight, 60% of the fish collected were sport/commercial fish, 33% were rough fish and 6% were miscellaneous fish. At the lower G.F.C. station (1), 19 species were collected, while 27 species were captured at the upper G.F.C. station (2). Not only was the total number of taxa higher at G.F.C. Station 2 (which is located at DER's Station 7), but the total weight of sport/commercial fish produced was 44% more than at G.F.C. Station 1.

During 1984, sampling was conducted at four stations (Figure 98) and 49 total species were collected (Appendix). However, this year, only 49% were sport/commercial fish by weight, while 47% were rough fish and 3% were miscellaneous fish. The mean catch per minute of pedal time for all four stations yielded 928 grams of sport/commercial fish, 889 grams of rough fish, and 61 grams of miscellaneous fish.

A station-by-station analysis of the 1984 sampling yielded some longitudinal trends. The number of taxa collected at the three upper stations was identical (23) with 35 collected at the farthest downstream station. These additional taxa at the lowest station were marine in origin. The total number of sport/commercial fish was again highest at

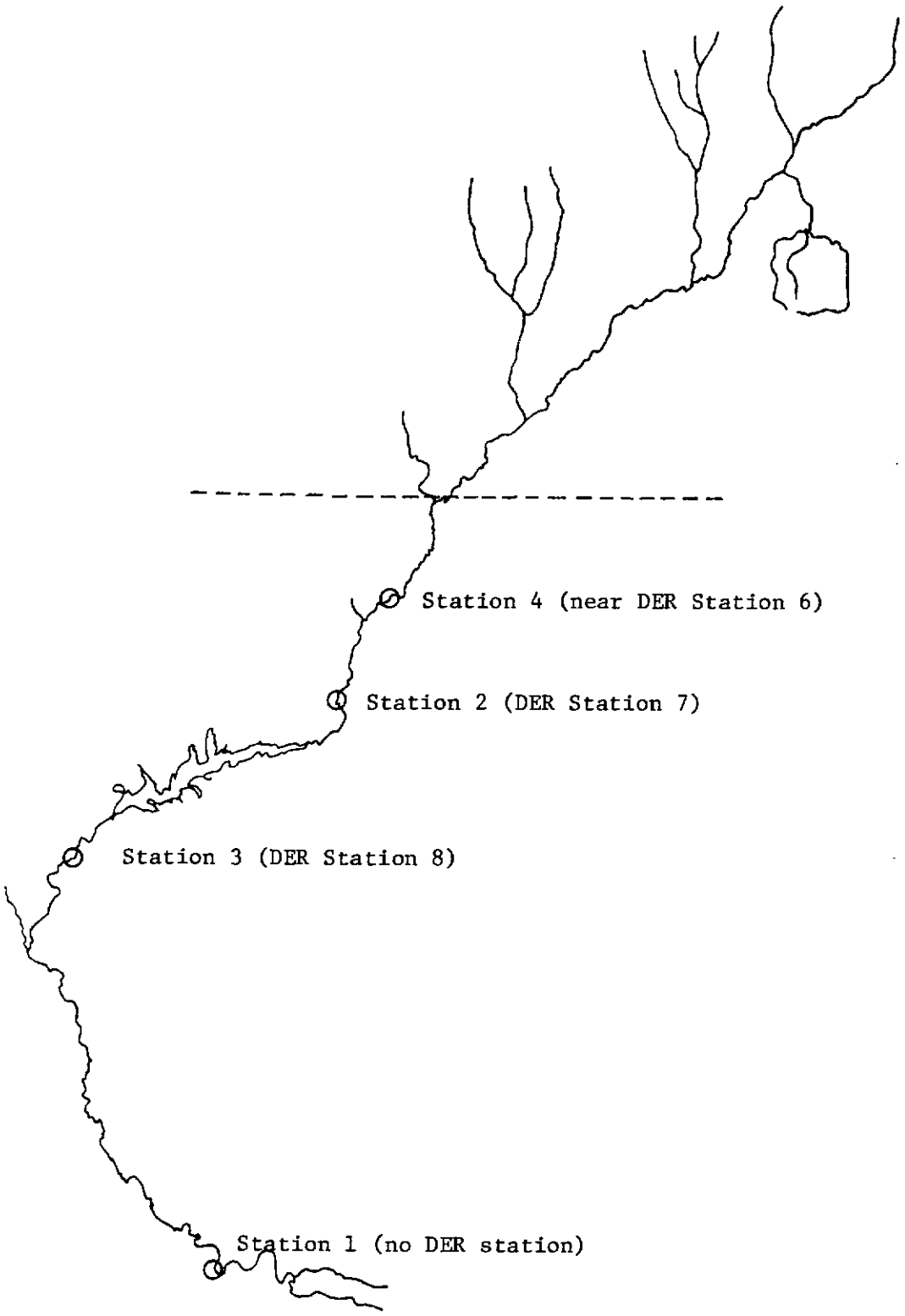


Figure 98. Electroshock sampling locations for fisheries investigations.

G.F.C. Station 2 (DER Station 7) with 627 individuals, and lowest at G.F.C. Station 1 with 215 (Figure 99). Waters at G.F.C. Station 4 (near DER Station 6) produced the lowest biomass of sport/commercial fish, while those from G.F.C. Station 3 (DER Station 8) had the highest (Figure 99). The total number of rough fish was lowest at G.F.C. Station 3 (DER Station 8) and highest at G.F.C. Station 1 (no DER Station 6). The biomass of rough fish was also highest at Station 1, but was lowest at Station 4 (near DER Station 6) (Figure 97).

The miscellaneous fish collected were most numerous at G.F.C. Station 3 (DER Station 8) with 1728, and least numerous at G.F.C. Station 1 with 96. Total biomass of miscellaneous fish followed a very similar pattern (Figure 98).

Discussion

The North Florida streams monitoring program was designed and carried out by the Game and Fresh Water Fish Commission to detect trends in riverine fish communities. A total of ten lotic systems were sampled, including the Escambia, Choctawhatchee, Apalachicola, Ochlockonee, Suwannee, Withlacoochee, Oklawaha, St. Johns, and Peace Rivers, as well as Holmes Creek. Comparison of fish populations between river systems is possible based upon the first two years of data (Bass and Yeager 1985). Of the rivers studied, the Ochlockonee River produced the highest total taxa per unit effort (Appendix). However, the Ochlockonee ranked fifth in total biomass yeild. Although the Oklawaha River and St. John's River produced the most sport/commercial fish by both numbers of individuals and total biomass, the Ochlockonee River had the third highest sport/commercial fishery (Appendix). This same trend existed for centrarchids (Appendix).

It is noteworthy that, in 1984, the Ochlockonee River produced the highest catch per effort (by number and weight) of largemouth bass of any North Florida stream studied. The presence of Lake Talquin may have a substantial influence on fish populations in the Ochlockonee River, as fish tend to congregate around the outfalls of major impoundments (Dan Dobbins, G.F.C., personal communication). As previously mentioned, the biomass of game fish in the Ochlockonee was highest at DER Station 8, located several kilometers downstream of Lake Talquin. Perhaps the high yield of sport fish in this area is related to the presence of the lake.

In 1983, only two stations were sampled by G.F.C., one of which corresponded to Station 7 of the present study. This station supported a larger number of taxa and a greater total weight of sport/commerical fish than the station located near Ochlockonee Bay.

In 1984, the G.F.C. sampled two additional stations. One of these stations (Figure 98) was within a few miles of DER Station 6 in the present study, and the other corresponds to DER Station 8. Therefore, a comparison of the fish population in the vicinity in our Stations 6, 7, and 8 is of particular interest. For convenience and clarity, DER station numbers will be used in this discussion. The number of sport/commercial

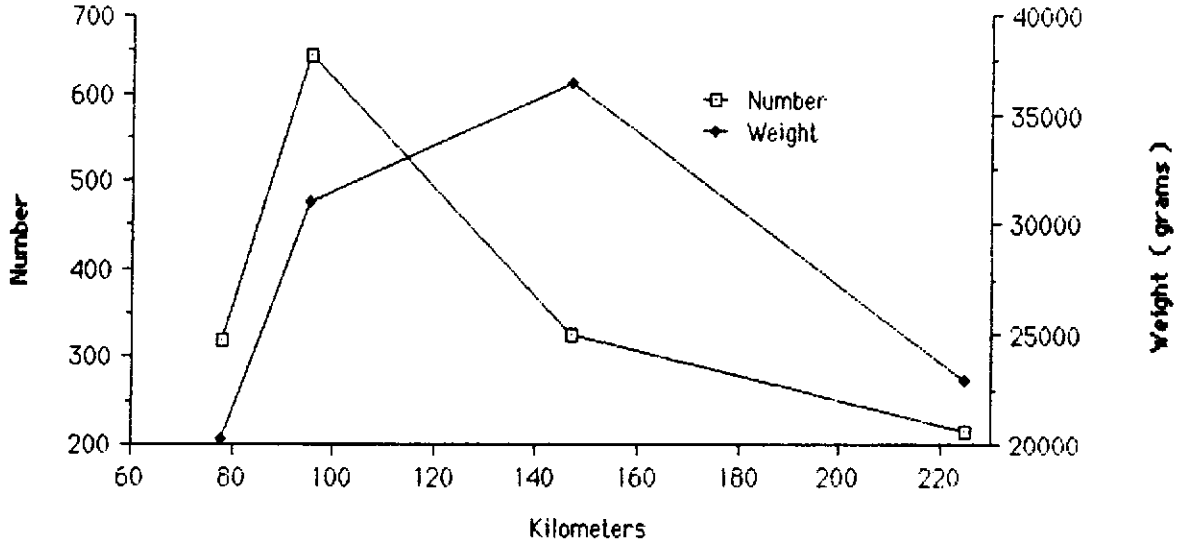


Figure 99. Weight and number of sport fish by river kilometer (1984).

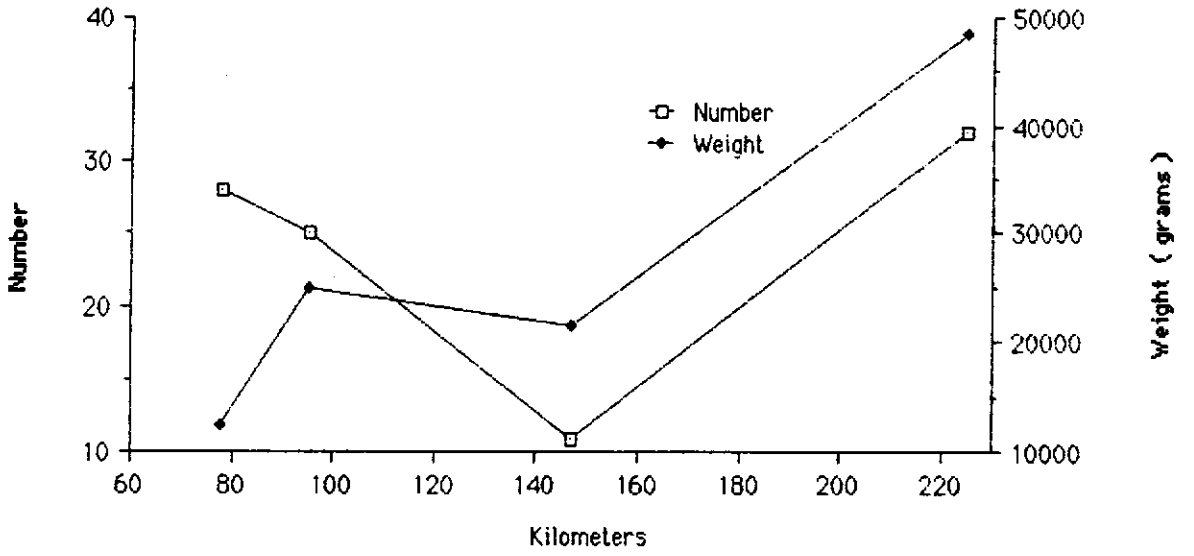


Figure 100. Weight and number of rough fish by river kilometer (1984).

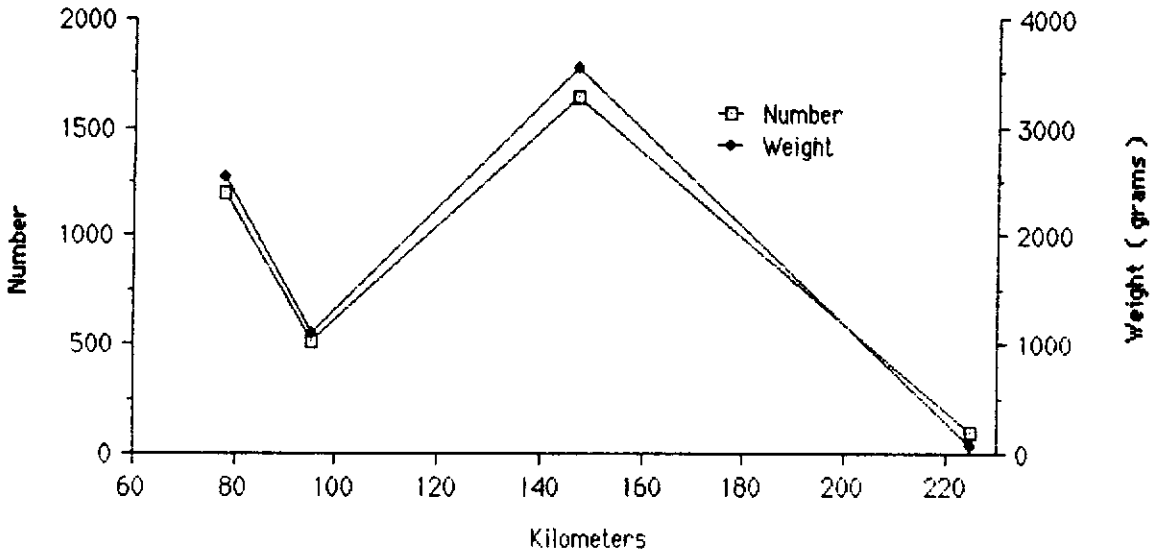


Figure 101. Weight and number of miscellaneous fish by river kilometer (1984).

fish collected from Station 7 was twice that of Stations 6 and 8. In terms of weight of sport/commercial fish, the samples from Stations 7 and 8 yielded significantly more biomass than Station 6 (34% and 44%, respectively). It is interesting to note, that a low abundance of macroinvertebrate "fish food" organisms also occurred at Station 6. Conversely, macroinvertebrates were abundant at Stations 7 and 8. Since many sport fish species (centrarchids) are "benthophagic", that is they feed on benthic organisms during part of their life cycle, the depressed population of sport fish near Station 6 is not surprising. This decrease in abundance of benthic macroinvertebrates, and thus of benthophagic fish, may be related to siltation effects observed at Station 6. Benthic organisms, as well as fish eggs and alevin, may be smothered by solids which settle out as stream velocity decreases (Everhart and Duchrow 1970). Many authors have documented detrimental effects of siltation on stream biota, including fish populations (Cordone and Kelley 1961, Hynes 1970). The reproductive success of centrarchids, including sunfish and bass, is particularly impaired when fine sediments settle on egg masses, resulting in anoxic conditions and subsequent embryonic death (Gray Bass, personal communication).

Conclusions

Although siltation effects may certainly contribute to the alleged decline in the sport fishery in certain portions of the Ochlockonee River, available data are not sufficient to draw any definite conclusions. Preliminary data indicate that the Ochlockonee River in the vicinity of Station 6 yielded less biomass of sport/commercial fish and rough fish than other stations sampled. The number of individuals belonging to these groups of fish at Station 6 however, were comparable to other stations sampled. Station 6 had the second highest miscellaneous fish population (both by number and weight). Further research on the fishery resources may indicate if siltation indeed is the specific cause for any reductions in sport fish populations and provide information by which proper action may be taken for restoration. The Florida Game and Freshwater Fish Commission is presently involved in further investigation of the Ochlockonee River fishery resources.

LITERATURE CITED

Adema, D. M. M. 1978. Daphnia magna as a test animal in acute and chronic toxicity tests. Hydrobiol. 52(2): 125-134.

American Public Health Assoc., American Water Works Assoc., and Water Pollution Control Federation. 1985. Standard methods for the examination of water and wastewater, 16th ed. New York, N.Y. 1268 p.

Anderson, J. B. and W. T. Mason. 1968. A comparison of benthic macroinvertebrates collected by dredge and basket sampler. J. Water Poll. Cont. Fed. 40(2): 252-259.

Antoine, S. E. and K. Benson-Evans. 1982. The effect of current velocity on the rate of growth of benthic algal communities. Int. Revue Ges. Hydrobiol. 67(4): 575-583.

Barnes. 1959. Apparatus and methods of oceanography. Geo. Allen and Unwin, Ltd, London. 341 p.

Bass, G and D. Yeager. 1985. North Florida streams research project. Fed. Wallop-Breaux Performance Report. Project No. F-36-5. 8 p.

Bates M. H. and Neafus N. E. 1980. Phosphorus release from sediments from Lake Carl Blackwell, Oklahoma. Wat. Res. 14: 1477-1491.

Bauer, G., E. Echimff, W. Thomas, and R. Herrmann. 1980. Relations between the decline of the freshwater pearl mussel (Margaritifera margaritifera) in the Fichtelgebirge and the water quality. Arch. Hydrobiol. 88(4): 505-513.

Baxter, R. M. 1977. Environmental effects of dams and impoundments. Ann. Rev. Ecol. Syst. 8: 255-283.

Beck, W. M., Jr. 1954. Studies in stream pollution biology. I. A simplified ecological classification of organisms. Quart. J. Fla. Acad. Sci. 17(4): 211-227.

Benke, A. C., T. C. VanArsdall, Jr., and D. M. Gillespie. 1984. Invertebrate productivity in a subtropical blackwater river: the importance of habitat and life history. Ecol. Monog. 54(1): 25-63.

Berman, T. and U. Pollingher. 1974. Annual and sesonal variations of phytoplankton chlorophyll, and photosynthesis in Lake Kinneret. Limnol. and Oceanogr. 19(1): 31-54.

Bloom, S. A., S. L. Santos, and J. G. Field. 1977. A package of computer programs for benthic community analyses. Bull. Mar. Sci. 27(3): 577-580.

Bloom, S. A. 1981. Similarity indices in community studies: potential pitfalls. Mar. Ecol. Prog. Sers. 5: 125-128.

Bouwer, H. 1978. Groundwater hydrology. McGraw-Hill., New York. 480 p.

Brown, B. W. Jr., and M. Hollander. 1977. Statistics: a biomedical introduction. John Wiley and Sons. New York.

Brown, H. D. 1976. A comparison of the attached algal communities of a natural and an artificial substrate. J. Phycol. 12(3): 301-306.

Bruns, D. A., G. W. Minshall, C. E. Cushing, K. W. Cummins, J. T. Brock, and R. L. Vannote. 1984. Tributaries as modifiers of the river continuum concept: analysis by polar ordination and regression models. Arch. Hydrobiol. 99(2): 208-220.

Buell, G. R. and S. C. Grams. 1985. The Hydrologic Bench-Mark Program - a standard to evaluate time-series trends in selected water-quality constituents for streams in Georgia. U. S. Geol. Surv. Wat. Res. Invest. Rep. 84-4318. 36 p.

Butcher, R. W. 1946. Studies on the ecology of rivers. VI: The algal growth in certain highly calcareous streams. J. Ecol. 33: 268-283.

_____. 1947. Studies in the ecology of rivers. VII: The algae of organically enriched waters. J. Ecol. 35(1,2): 186-191.

_____. 1959. Biological assessment of river pollution. Proc. Linn. Soc. London. 170(2): 159-165.

Cahn, R. D. 1967. Detergents in membrane filters. Sci. 155: 195-196.

Cain, J. R., R. L. Klotz, F. R. Trainor, and R. Costello. 1979. Algal assay and chemical analysis: a comparative study of water quality assessment techniques in a polluted river. Environ. Pol. 0013-9327/79/0019-0215. 215-223 p.

Chapin, J. D., and P. D. Uttormark. 1973. Atmospheric contributions of nitrogen and phosphorus. Tech. Rep. Wat. Resources Ctr. Univ. Wis., 73-2, 35 p.

Chessman, B. C. 1985. Artificial-substratum periphyton and water quality in the lower Latrobe River, Victoria. Aust. J. Mar. Freshw. Res. 36: 855-71

Chutter, F. M. 1969. The effects of silt and sand on the invertebrate fauna of streams and rivers. Hydrobiol. 34: 57-76.

Claesson, A. 1980. Variation in cell composition and utilization of N and P for growth of Selenastrum capricornutum. Physiol. Plant. 48: 59-64.

Cordone, A. J. and D. W. Kelley. 1961. The influence of inorganic sediment on the aquatic life of streams. Calif. Fish and Game. 47: 189-228.

Cowgill, U. W., K. I. Keating, and I. T. Takahashi. 1985. Fecundity and longevity of Ceriodaphnia dubia/affins in relation to diet at two different temperatures. J. Crust. Bio. 5(3): 420-429.

Cummins, K. W. and G. H. Lauff. 1969. The influence of substrate particle size on the microdistribution of stream macrobenthos. Hydrobiol. 34: 145-154.

Dance, K. W. and H. B. N. Hynes. 1980. Some effects of agriculture land use on stream insect communities. Environ. Poll. (Series A) 22: 19-28.

deMarch, B. G. E. 1976. Spatial and temporal patterns in macrobenthic stream diversity. J. Fish. Res. Bd. Can. 33: 1261-1270.

Devey, D. G. and H. Harknes. 1973. The significance of man-made sources of phosphorus: detergents and sewage. p. 35-54 In: S. H. Jenkins and K. J. Ives (eds.), Phosphorus in freshwater and the marine environment. Pergamon Press, Oxford

Dorris, T. C. and B. J. Copeland. 1963. Limnology of the middle Mississippi River. IV. Physical and chemical limnology of river and chute. Limnol. Oceangr. 8: 79-88.

Duda, A. M. 1985. Environmental and economic damage caused by sediment from agricultural nonpoint sources. Wat. Res. Bull. 21(2): 225-234.

Dunnett, C. W. 1955. Multiple comparison procedure for comparing several treatments with a control. J. Amer. Statist. Assoc. 50: 1096-1121.

Dye, C. W. and D. A. Jones. 1978. A review of eutrophication, nutrient regulation, and the impacts of nutrients on water quality. Fla. Dept. Envir. Reg. Tech. Ser. 4(1): 1-34.

Dye, C. W., D. A. Jones, L. T. Ross, and J. L. Gernert. 1980. Diel variations of selected physico-chemical parameters in Lake Kissimmee. Hydrobiol. 71: 51-60.

Elwood, J. W., J. D. Newbold, A. F. Trimble, and R. W. Stark. 1981. The limiting role of phosphorus in a woodland stream ecosystem: effects of P enrichment on leaf decomposition and primary producers. Ecol. 62(1): 146-158.

Everhart, W. H. and R. M. Duchrow. 1970. Effects of suspended sediment on aquatic environment. U. S. Bureau of Reclamation Report. 14-06-D-6596. 72 p.

Field, J. G., K. R. Clarke, and R. M. Warwick. 1982. A practical strategy for analysing multispecies distribution patterns. Mar. Ecol. Prog. Ser. 8: 37-52.

Finney, D. J. 1948. The Fisher-Yates test of significance in 2x2 contingency tables. Biometrika 35: 145-156.

Fjerdingstad, E. 1964. Pollution of streams estimated by benthal phytomicro-organisms I. A saprobic system based on communities of organisms and ecological factors. Int. Rev. Gesamt. Hydrobiol. 49(1): 63-131.

Flemer, D. A. 1970. Primary productivity of the north branch of the Raritan River, New Jersey. Hydrobiol. 35: 273-293.

Flora, D. and P. C. Rosendahl. 1982. The response of specific conductance to environmental conditions in the everglades. Wat. Air Soil Poll. 17: 51-59.

Florida Department of Environmental Regulation. 1982. Biological fixed station monitoring program. FDER, Tallahassee. 32 p.

_____. 1983. Bioassay program final report FFY 82-83. Bureau of Water Analysis, Biology Section. 8 p.

_____. 1984. Bioassay program final report FFY 83-84. Bureau of Laboratories and Special Programs, Biology Section. 22 p.

_____. 1985. Limnology of the Suwannee River, Florida. FDER, Tallahassee. 407 p.

Florida Department of Environmental Regulation. 1986a. Bioassay program final report FFY 84-85. Bureau of Laboratories and Special Programs, Biology Section. 25 p.

_____. 1986b. Stream impoundments: an investigation of effects on water quality in North Florida. FDER, Tallahassee. 361 p.

Fogg, G. E. 1971. Nitrogen fixation in lakes. Plant Soil (Spec. Vol.), 1971: 393-401.

Ford, J. B. 1962. The vertical distribution of larval Chironomidae (Diptera) in the mud of a stream. Hydrobiol. 19(3): 262-272.

Fritz, E. S. 1980. Potential impacts of low pH on fish and fish populations. U.S. Fish Wildl. Serv., Biol. Serv. Prog., Power Plant Project, FWS/OBS-80/40.2. 14 p.

Gardner, W. S., T. F. Nalepa, D. R. Slavens, and G. A. Laird. 1983. Patterns and rates of nitrogen release by benthic Chironomidae and Oligochaeta. Can. J. Fish. Aquat. Sci. 40: 259-266.

Gaufin, A. R. and C. M. Tarzwell. 1952. Aquatic invertebrates as indicators of stream pollution. Publ. Health Repts. 67(1): 57-64.

Geldreich, E. E., L. C. Best, B. A. Kenner, and D. J. VanDonsel. 1968. The bacteriological aspects of stormwater pollution. J. Wat. Poll. Con. Fed. 40(11) Part I: 1861-1872.

Georgia Environmental Protection Division. 1973. Ochlockonee River Basin water quality investigation. Georgia Department of Natural Resources Environmental Protection Division. 58 p.

Gerhart, D. Z. and G. E. Likens. 1975. Enrichment experiments for determining nutrient limitation: four methods compared. Limnol. Oceanog. 20(4): 649-653.

Gerloff, G. C. and F. Skoog. 1957. Nitrogen as a limiting factor for the growth of Microcystis aeruginosa in southern Wisconsin lakes. Ecol. 38(4): 556-561

Gianessi, L. P., H. M. Peskin, P. Crosson, and C. Puffer. 1986. Nonpoint-source pollution: Are cropland controls the answer? J. Soil Wat. Conserv. 41(4): 215-218.

Golterman, H. L. 1966. Influence of mud on the chemistry of water in relation to productivity. p. 297-313 In: H. L. Golterman and R. S. Clymo (eds.), Chemical environment in the aquatic habitat. North Holland.

Golterman, H. L. 1966. Influence of mud on the chemistry of water in relation to productivity. p. 297-313 In: H. L. Golterman and R. S. Clymo (eds.), Chemical environment in the aquatic habitat. North Holland.

_____. 1975. Physiological Limnology. Elsevier, Amsterdam.

Green, R. H. and G. L. Vascotto. 1978. A method for the analysis of environmental factors controlling patterns of species composition in aquatic communities. Wat. Res. 12: 583-490.

Greene, J. C., W. E. Miller, T. Shiroyama, R. A. Soltero, and K. Putman. 1975. Use of algal assays to assess the effects of municipal and smelter wastes upon phytoplankton production. p. 327-336. Proceedings of the symposium on terrestrial and aquatic ecological studies of the Northwest. Eastern Washington State College Press.

Harvey, H. W. 1940. Nitrogen and phosphorus required for the growth of phytoplankton. J. Mar. Biol. Assoc. U.K. 241: 115-123.

Henry, R., J. G. Tundisi and P. R. Curi. 1984. Effects of phosphorus and nitrogen enrichment on the phytoplankton in a tropical reservoir (Lobo Reservoir, Brazil). Hydrobiol. 118: 177-185.

Hilsenhoff, W. L. 1969. An artificial substrate device for sampling benthic stream invertebrates. Limnol. Oceanogr. 14(3): 465-471.

Hohn, M. H. 1961. The relationship between species diversity and population density in diatom populations from Silver Springs, Florida. Trans. Amer. Micro. Soc. 80(2): 140-165.

Hooper-Reid, N. M. and G. G. Robinson. 1978. Seasonal dynamics of epiphytic algal growth in a marsh pond: composition, metabolism, and nutrient availability. Can. J. Bot. 56: 2441-2448.

Horning, W. B., III and C. I. Weber. 1985. Short-term methods for estimating the chronic toxicity of effluents and receiving waters to freshwater organisms. U.S. Envir. Prot. Agency. EPA-600/4-85/014. 162 p.

Hufford, T. L. and G. B. Collins. 1976. Distribution patterns of diatoms in Cedar Run. Ohio J. Sci. 76(4): 172-183.

Hutchinson, G. E. 1957. A treatise on limnology. Vol. II. John Wiley and Sons, N.Y. 1015 p.

Hynes, H. B. N. 1959. The use of invertebrates as indicators of river pollution. Proc. Linn. Soc. London 170(2): 165-169.

_____. 1960. The biology of polluted waters. Univ. of Toronto Press, Toronto, 201 p.

_____. 1970. The ecology of running waters. Univ. of Toronto Press, Toronto, 201 p.

Jacoby, J. M., D. D. Lynch, E. B. Welch, and M. A. Perkins. 1982. Internal loading in a shallow eutrophic lake. Wat. Res. 16: 911-919.

Jones, R. I. 1977. Factors controlling phytoplankton production and succession in a highly eutrophic lake (Kinnego Bay, Lough Neagh). J. Ecol. 65: 547-559.

Jordan, R.A. and M. E. Bender. 1973a. Stimulation of phytoplankton growth by mixtures of phosphate, nitrate plus organic chelators. Wat. Res. 7: 189-195.

_____. 1973b. An in situ evaluation of nutrient effects in lakes. U. S. Envir. Prot. Agency. EPA-R3-73-108. 151 p.

Keeney, D. R., J. G. Konrad, and G. Chesters. 1970. Nitrogen distribution in some Wisconsin lake sediments. J. Water Poll. Control Fed. 42: 411-417.

Keup, L. E., 1968. Phosphorus in flowing waters. Wat. Res. 2: 373-386.

Kholdebarin, B. and J. J. Oertli. 1977. Effect of suspended particles and their sizes on nitrification in surface water. J. Water Poll. Control Fed. July: 1963-1967.

Konrand, J. G., D. R. Keeney, G. Chesters, and K. L. Chen. 1970. Nitrogen and carbon distribution in sediment cores of selected Wisconsin lakes. J. Water Poll. Control Fed. 42: 2094-2101.

Lean, D. R. S. and C. Nalewajko. 1976. Phosphate exchange and organic phosphorus excretion by freshwater algae. J. Fish. Res. Bd. Can. 33: 1312-1323.

Lee, G. F. and A. W. Hoadley. 1967. Biological activity in relation to the chemical equilibrium composition of natural waters. p. 319-338. Equilibrium concepts in natural water system. Am. Chem. Soc. Advances in Chemistry Ser. 67.

Lenat, R. D., D. L. Penrose, and K. W. Eagleson. 1979. Biological evaluation of non-point source pollutants in North Carolina streams and rivers. N. C. Dept. Nat. Resources and Comm. Dev. Biological Series 102. 168 p.

Likens, G., F. Bormann, and N. Johnson. 1972. Acid rain. Environment 14: 33-40.

Linduska, J. P. 1942. Bottom type as a factor influencing the local distribution of mayfly nymphs. Can. Entomol. 74: 26-30.

Lowrance, R., J. K. Sharpe, and J. M. Sheridan. 1986. Long-term sediment deposition in the riparian zone of a coastal plain waterhsed. J. Soil Wat. Conserv. 41(4): 266-271.

Lowe, R. L. 1974. Environmental requirements and pollution tolerance of freshwater diatoms. U.S. Envir. Prot. Agency. EPA-670/4-74-005. 333 p.

Luttenton, M. R., J. B. Vansteenburg, and R. G. Rada. 1986. Phyco-periphyton in selected reaches of the upper Mississippi River: community composition, architecture, and productivity. Hydrobiol. 136: 31-46.

McCormick, J. H., S. J. Broderius, and J. T. Fiandt. 1984. Toxicity of ammonia to early life stages of the green sunfish Lepomis cyanellus. Environmental Pollution (Series A) 36: 147-163.

McLachlan, A. J. 1969. Substrate preferences and invasion behavior exhibited by larvae of Nilodrum brevibucca Freeman (Chironomidae) under experimental conditions. Hydrobiol. 33: 237-249.

MacIsaac, J. J. and R. C. Dugdale. 1972. Interactions of light and inorganic nitrogen in controlling nitrogen uptake in the sea. Deep Sea Res. 19: 209-232.

Mason, B. 1952. Principles of geochemistry. New York, John Wiley and Sons, 310 p.

Matisoff, G., J. Benton-Fisher and S. Matis. 1985. Effects of benthic macroinvertebrates on the exchange of solutes between sediments and freshwater. Hydrobiol. 122: 19-33.

Miller, W. E., T. E. Maloney. 1971. Effects of secondary and tertiary wastewater effluents on algal growth in a lake-river system. J. Wat. Pol. Cont. Fed. 43(12): 2361-2365.

Miller, W. E., T. E. Maloney, and J. C. Greene. 1974. Algal productivity in 49 lake waters as determined by algal assays. Wat. Res. 8: 667-679.

Miller, W. E., J. C. Greene and T. Shiroyama. 1978. The Selenastrum capricornutum Printz algal assay bottle test. U.S. Envir. Prot. Agency. EPA-600/9-78-018. 126 p.

Minshall, G. W. 1984. Aquatic insect-substratum relationships. In: V. H. Resh and D. M. Rosenberg (eds). The ecology of aquatic insects, Proaeger Publishers, New York. 625 p.

Morris, I. 1974. Nitrogen assimilation and protein synthesis, p. 583-609. In: W.D.P. Stewart (ed.), Algal physiology and biochemistry. Univ. Calif. Press, Berkley, 989 p.

Moss, B. 1969. Limitation of algal growth in some Central African waters. Limnol. Oceanogr. 14: 591-601.

Mount, D. and T. Norberg. 1983. Ceriodaphnia life cycle test protocol. Seminar on Aquatic Toxicity Testing. U.S. EPA, Athens, Georgia, September 28-29.

Odum, E. P. 1959. Fundamentals of ecology, 2nd ed. W. B. Saunders Co., Philadelphia. 546 p.

_____. 1971. Fundamentals of ecology, 3rd ed. W. B. Saunders Co., Philadelphia. 574 p.

Oemke, M. P. and T. M. Burton. 1986. Diatom colonization dynamics in a lotic system. Hydrobiol. 139: 153-166.

Parsons, D. S. and J. W. Tatum. 1974. A new shallow water multi-plate sampler. Prog. Fish. Cult. 36: 179-180.

Pascale, A. and J. R. Wagner. 1982. Water resources of the Ochlockonee River area, Northwest, Florida. U.S. Geol. Surv. Open File Rep. 81-1121, p. 10-13.

Patrick, R. 1948. Factors affecting the distribution of diatoms. Bot. Rev. 14(8): 473-524.

Patrick, R., M. H. Hohn, and J. H. Wallace. 1954. A new method for determining the pattern of the diatom flora. Not. Nat. 259: 1-12.

Patrick, R. and C. W. Reimer. 1966. The diatoms of the United States, Vol. 1 Monog. Acad. Nat. Sci. Philadelphia. 688 p.

Pearson, E. S. and T. O. Hartley. 1962. Biometrika tables for statistians. Vol. 1. Cambridge University Press, England.

Peltier, W. and C. I. Weber. 1978. Methods for measuring acute toxicity of effluents to aquatic organisms. U.S Envir. Prot. Agency. EPA-600/4.78-012. 52 p.

Pryfogle, P. A. and R. L. Lowe. 1979. Sampling and interpretation of epilithic lotic diatom communities, p. 77-89. In R. L. Weitzel (ed.), Methods and measurements of periphyton communities: review. Amer. Soc. Test. Mat. STP 690, Philadelphia.

Puri, H. S. and R. O. Vernon. 1964. Summary of the geology of Florida and a guidebook to the classic exposures. Florida Division of Geology Special Publication No. 5, 312 p.

Ram, N. M. and I. S. Plotkin. 1983. Assessing aquatic productivity in the Housatonic River using the algal assay bottle test. Wat. Res. 17(9): 1095-1106.

Robarts, R. D. and G. S. Southall. 1977. Nutrient limitation of phytoplankton growth in seven tropical man-made lakes with special reference to Lake McIlwaine, Rhodesia. Arch. Hydrobiol. 79: 1-35.

Roll, M. L. 1981. Investigations of algal inhibition in Lake Okeechobee Florida, using algal assay techniques. Fla. Dept. Envir. Reg., Biol. Section. 58 p.

Rosenberg, D. M. and V. H. Resh. 1982. The use of artificial substrates in the study of freshwater benthic macroinvertebrates, p. 175-235. In John Cairns, Jr. (ed.), Artificial substrates. Ann Arbor Science, Ann Arbor, Mich. 279 p.

Round, F. E. 1964. The ecology of benthic algae. In: D. F. Jackson (ed.), Algae and man. Plenum Press, N.Y. 434 p.

Roy, H. K. 1955. Plankton ecology of the river Hooghly at Palta. Ecol. 36: 169-175.

Ruggiero, M. A. and H. C. Merchant. 1979. Water quality, substrate and the distribution of macroinvertebrates in the Patuxent River, Maryland. Hydrobiol. 64: 183-189.

Ruttner, F. 1953. Fundamentals of limnology. Univ. of Toronto Press, Toronto, Canada. 295 p.

Schindler, D. W., H. Kling, R. V. Schmidt, J. Prokopowich, V. E. Frost, R. A. Reid, and M. Capel. 1973. Eutrophication of Lake 227 by addition of phosphate and nitrate: the second, third, and fourth years of enrichment, 1970, 1971, and 1972. J. Fish Res. Bd. Can. 30: 1415-1440.

Scott, W. B. and E. J. Crossman. 1973. Freshwater fishes of Canada. Fish. Res. Bd. Can. Bull. 184: 1-966.

Shampine, W. J. 1975. Hardness of the water from the upper part of the Floridian Aquifer in Florida. U.S. Geol. Surv. Map Ser. No. 13.

Shannon, E. E. and P. L. Brezonik. 1972. Relationship between lake trophic state and nitrogen and phosphorus loading rates. Envir. Sci. and Tech. 6: 719-725.

Shiroyama, T., W. E. Miller, and J. C. Greene. 1975. Effect of nitrogen and phosphorus on the growth of Selenastrum capricornutum. U.S. Envir. Prot. Agency. EPA-660/3-75-034. 11 p.

Slack, L. J. and M. I. Kaufman. 1975. Specific conductance of water in Florida streams and canals. U.S. Geol. Surv. Map Ser. No. 58.

Sládeček, V. and A. Sladeckova. 1964. Determination of the periphyton production by means of the glass slide method. Hydrobiol. 23: 125-158.

Sládečková, A. 1962. Limnological investigation methods of the periphyton ("Aufwuchs") community. Bot. Rev. 28(2): 286-350.

Spodniewska, I. 1978. Phytoplankton as the indicator of lake eutrophication, I. Summer situation in 34 Masurian Lakes in 1973. Ekol. Pol. 26(1): 53-70.

State of Florida. 1966. Gazeteer of Florida Streams. Florida State Board of Conservation, Division of Water Resources.

_____. 1983. Game and Freshwater Fish Commission. North Florida Streams Research Project.

State of Georgia. 1978. Georgia Water quality nonpoint source control program. Department of Natural Resources. 205 p.

_____. 1980a. Resource conservation program and action plan, Flint River Soil and Water Conservation District. 39 p.

_____. 1980b. Resource conservation program and action plan, Middle South Georgia Soil and Water Conservation District. 36 p.

_____. 1985. Georgia Agricultural Facts. Department of Agriculture. 216 p.

Sterba, G. 1962. Freshwater fishes of the world. Studio Vista Books, London. 877 p.

Strickland, J. H. and T. R. Parsons. 1972. A practical handbook of seawater analysis, 2nd ed. J. Fish Res. Bd. Can. 310 p.

Stumm, W. and J. J. Morgan. 1970. Aquatic chemistry. John Wiley and Sons Inc., New York 583 p.

Swift, D. R. 1981. Preliminary investigations of periphyton and water quality relationships in the Everglades Water Conservation Areas. Tech. Publ. #81-5, South Fla. Water Management Dist., West Palm Beach, Fla. 83 p.

Talling, J. F. 1966. The annual cycle of stratification and phytoplankton growth in Lake Victoria (East Africa). Int. Revue Ges. Hydrobiol. 51: 545-621.

Technican Methods Manual. 1978. Technican instrument corporation.

Thompson, A. R., R. B. Frydenborg, C. A. Biederman, C. W. Dye, and L. T. Ross. 1982. Phytoplankton and periphyton community dynamics in detention/retention wetlands, Kissimmee River Basin, Florida. Final Report to Coordinating Council on the Restoration of the Kissimmee River Valley and Taylor Creek-Nubbin Slough Basin. 50 p.

Tippets, W. E. and P. B. Moyle. 1978. Epibenthic feeding by rainbow trout (Salmo gairdneri) in the McCloud River, California. J. Anim. Ecol. 47: 549-559.

Tuchman, M. 1979. Comparison of attached algal communities on natural and artificial substrata along a thermal gradient. Brit. Phyco. J. 14: 243-254.

United States Department of Agriculture. 1982. Southwest Georgia land and water resource cooperative study. Southwest Georgia Main Report. 114 p.

_____. 1984. Erosion report: a special resource inventory, problems and solutions, Leon County, Florida. 40 p.

_____. 1985. Erosion report: a special resource inventory and cooperative river basin study, problems and solutions, Gadsden County, Florida. 42 p.

United States Environmental Protection Agency. 1973. Biological field and laboratory methods for measuring the quality of surface waters and effluents. EPA-670/4-73-001. Office of Research and Development, Cincinnati, Ohio.

_____. 1975. Process design manual for nitrogen control. 450 p.

_____. 1977. Current practices in water microbiology - Training Manual. Office of Water Programs Operations, Cincinnati, Ohio.

United States Environmental Protection Agency. 1978. Microbiological methods for monitoring the environment. EPA 600/8-78-017. Cincinnati, Ohio.

_____. 1979. Methods for chemical analysis of water and wastes. EPA 600/4-79-020. 298 p.

Vannote, R. L., G. W. Minshall, K. W. Cummins, J. R. Sedell and C. E. Cushing. 1980. The river continuum concept. Can. J. Fish. Aquat. Sci. 37: 130-37.

Verduin, J. 1951. Comparison of spring diatom crops of western Lake Erie in 1949 and 1950. Ecol. 32(4): 662-668.

Vollenweider, R. A. (ed). 1974. A manual on methods for measuring production in aquatic environments. IBP Handbook No. 12, Blackwell Scientific Publications, Oxford. 225 p.

Waters, T. F. 1972. The drift of stream insects. Am. Rev. Ent. 17: 253-272.

Welch, E. B. 1977. Nutrient diversion: resulting lake trophic status and phosphorus dynamics. Ecol. Res. Ser. EPA 6001/3-88-003. 91 p.

Welch, E. B., P. Sturtevant and M. S. Perkins. 1978. Dominance of phosphorus over nitrogen as the limiter to phytoplankton growth rate. Hydrobiol. 57: 209-215.

Wetzel, R. G. 1975. Limnology. W. B. Saunders Co., Philadelphia. 743 p.

White, F. C., J. R. Hairston, W. N. Musser, H. F. Perkins, and J. F. Reed. 1981. Relationship between increased crop acreage and nonpoint-source pollution: a Georgia case study. Soil Wat. Conserv. 36(3): 172-177.

Wiggins, G. B. 1977. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto. 401 p.

Wise, D. H. and C. Molles, Jr. 1979. Colonization of artificial substrates by stream insects: influence of substrate size and diversity. Hydrobiol. 65(1): 69-74.

Wolk, C. P. 1973. Physiology and cytological chemistry of blue-green algae. Bacteriol. Rev. 37:32-101.

Wood, E. J. 1965. Marine microbial ecology. Chapman and Hall, Ltd., London. 243 p.

Yount, J. L. 1956. Factors that control species numbers in Silver Springs, Florida. Limnol. Oceanogr. 1(4): 286-295.

Periphyton Identification References

Forest, H. S. 1954. Handbook of Algae. Univ. Tenn., Knoxville. 467 p.

Hustedt, F. 1930. Bacillariophyta (Diatomeae), p. 1-466. In: A. Pascher (ed.). Die Susswasser-flora Mitteluropas. Bd. 10. Gustav Fisher, Jena.

Patrick, R. and C. W. Reimer. 1966. The diatoms of the United States, Vol. 1. Monog. Acad. Nat. Sci. Philadelphia. 688 p.

_____. 1975. The diatoms of the United States, Vol. 2(1). Monog. Acad. Nat. Sci. Philadelphia. 213 p.

Prescott, G. W. 1961. Algae of the western great lakes region. Brown Co. Publ., Dubuque. 977 p.

_____. 1970. The freshwater algae. Brown Co., Dubuque. 348 p.

Smith, M. 1950. The freshwater algae of the United States. McGraw-Hill, New York. 719 p.

Van Landingham, S. L. 1982. Guide to the identification, environmental requirements, and pollution tolerance of freshwater blue-green algae (Cyanophyta). U.S. Environ. Prot. Agency, EPA 600/3-82-073. 341 p.

Vinyard, W. C. 1979. Diatoms of North America. Mad River Press, Eureka, Calif. 120 p.

Weber, C. I. 1966. A guide to the common diatoms at water pollution surveillance system stations. U.S. Envir. Prot. Agency, Analytical Quality Control Lab., Cincinnati, Ohio. 98 p.

Whitford, L. A. and G. J. Schumacher. 1984. A manual of freshwater algae. Sparks Press, Raleigh, NC. 337 p.

Benthic Macroinvertebrate Identification References

Beck, W. M. 1979. Biology of the larval chironomids. Fla. Dept. Envir. Reg. Tech. Ser. 2(1): 1-58.

Berner, L. 1950. The mayflies of Florida. Univ. Fla. Press, Gainesville. 267 p.

Brinkhurst, R. O. and B. G. M. Jamieson. 1971. Aquatic Oligochaeta of the world. Univ. Toronto Press, Toronto. 860 p.

Brown, H. P. 1976. Aquatic dryopoid beetles (Coleoptera) of the United States. U.S. Envir. Prot. Agency Wat. Poll. Contr. Res. Ser. 18050, EZD/04/72. 82 p.

Burch, J. B. 1982. Freshwater snails (Mollusca: Gastropoda) of North America. U.S. Envir. Prot. Agency. EPA-600/3-82-026. 294 p.

Byers, C. F. 1930. A contribution to the knowledge of Florida Odonata. Univ. Fla. Biol. Sci. Ser. 1(1): 1-327.

Edmondson, W. T. 1959. Freshwater biology. J. Wiley and Sons, New York. 1248 p.

Edmunds, G. F., Jr., S. L. Jensen, and L. Berner. 1979. The mayflies of north and central America. Univ. Minn. Press, Minneapolis. 330 p.

Hiltunen, J. K. and D. J. Klemm. 1980. A guide to the Naididae (Annelida: Clitellata: Oligochaeta) of North America. U.S. Envir. Prot. Agency. EPA-600/4-80-031. 48 p.

Johannsen, O. A. 1934. Aquatic diptera. Cornell Univ. Agric. Exp. Sta. Mem. Reprinted by Entomological Reprint Specialists, Los Angeles. 369 p.

Kenk, R. 1976. Freshwater planarians (Turbellaria) of North America. U.S. Envir. Prot. Agency Wat. Poll. Contr. Res. Ser. 18050 EZD/02/72. 81 p.

Klemm, D. J. 1982. Leeches (Annelida: Hirudinea) of North America. U.S. Envir. Prot. Agency. EPA-600/3-82-025. 177 p.

Mason, W. T., Jr. 1973. An introduction to the identification of chironomid larvae. U.S. Envir. Prot. Agency. 90 p.

Merritt, R. W. and K. W. Cummins. 1978. An introduction to the aquatic insects of North America. Kendall/Hunt Publ., Dubuque. 441 p.

Morihara, D. K. and W. P. McCafferty. 1980. The Baetis larvae of North America (Ephemeroptera: Baetidae). Trans. Amer. Entomol. Society. 105: 139-221.

Oliver, D. R., D. McClymont, and M. E. Roussel. 1978. A key to some larvae of Chironimidae (Diptera) from the MacKenzie and Porcupine River watersheds, Canadian Fisheries and Marine Service Technical Report, No. 791. 72 p.

Parrish, F. E. 1975. Keys to water quality indicative organisms of the Southeastern United States. U.S. EPA Office of Research and Development, Environmental Monitoring and Support Laboratory, Cincinnati. 195 p.

Pennak, R. W. 1978. Freshwater invertebrates of the United States. John Wiley and Sons, New York. 803 p.

Ross, H. H. 1944. The caddisflies or Trichoptera, of Illinois. State of Illinois Natural History Survey Division. 23(1): 1-326.

Simpson, K. W. and R. W. Bode. 1980. Common larvae of Chironomidae (Diptera) from New York State streams and rivers. New York State Museum Bull. No. 439. 103 p.

Starke, B. P. and A. R. Gaufin. 1979. The stoneflies (Plecoptera) of Florida. Trans. Am. Entomol. Society. 104: 391-433.

Stimpson, K. S., D. J. Klemm, and J. K. Hiltunen. 1982. A guide to the freshwater Tubificidae (Annelida: Clitellata: Oligochaeta) of North America. U.S. Environ. Prot. Agency, EPA-600/3-82-033. 61 p.

Thompson, F. G. 1983. An identification manual of the freshwater snails of Florida. Florida State Museum, Gainesville. 55 p.

Usinger, R. L. 1968. Aquatic insects of California. University of California Press, Berkeley. 508 p.

Wiederhalm, T. (ed). 1983. Chironomidae of the Holarctic region. Keys and diagnoses. Part 1. Larvae. Entomologica Scandinavica Supplement No. 19. 457 p.

Wiggins, G. B. 1977. Larvae of the North American caddisfly genera (Trichoptera). University of Toronto Press, Toronto. 401 p.

Young, F. N. 1954. The water beetles of Florida. University of Florida Press, Gainesville. 238 p.

A P P E N D I X

Figure Electrofishing CPT, all species,

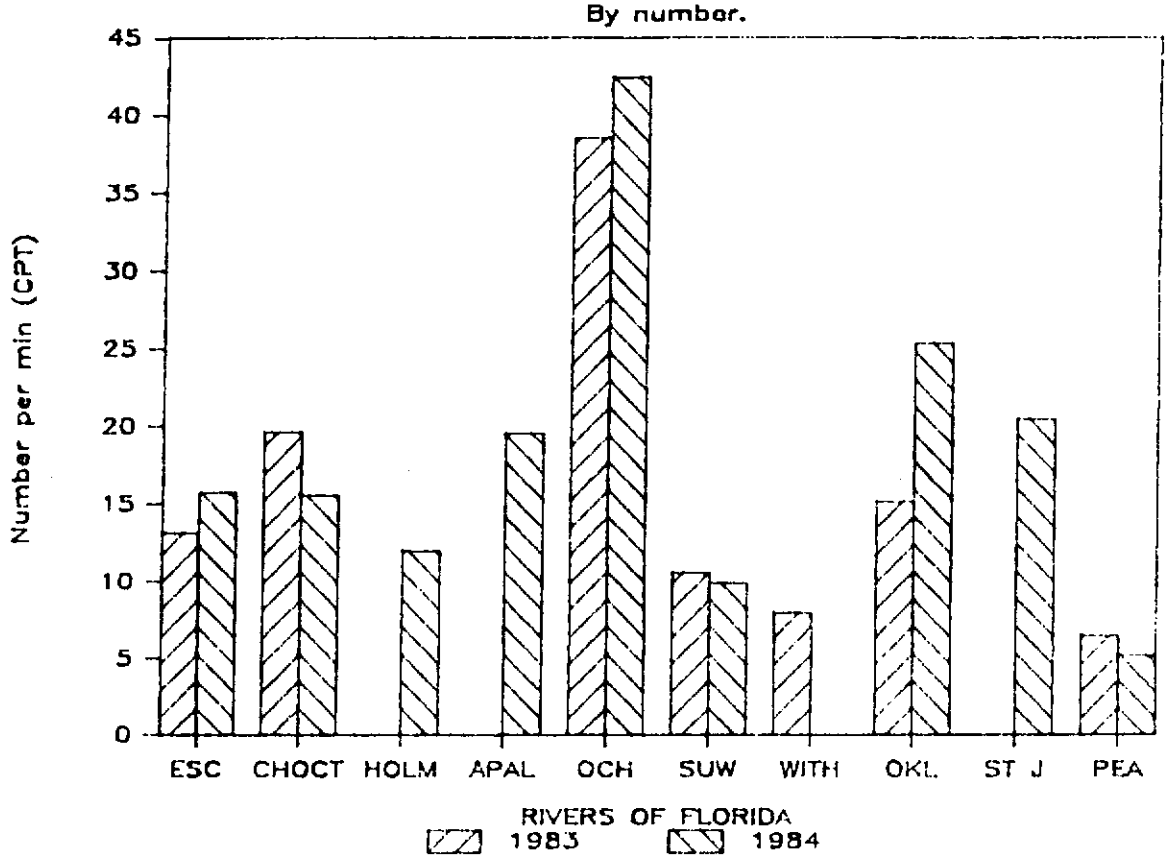


Figure Electrofishing CPT, all species.

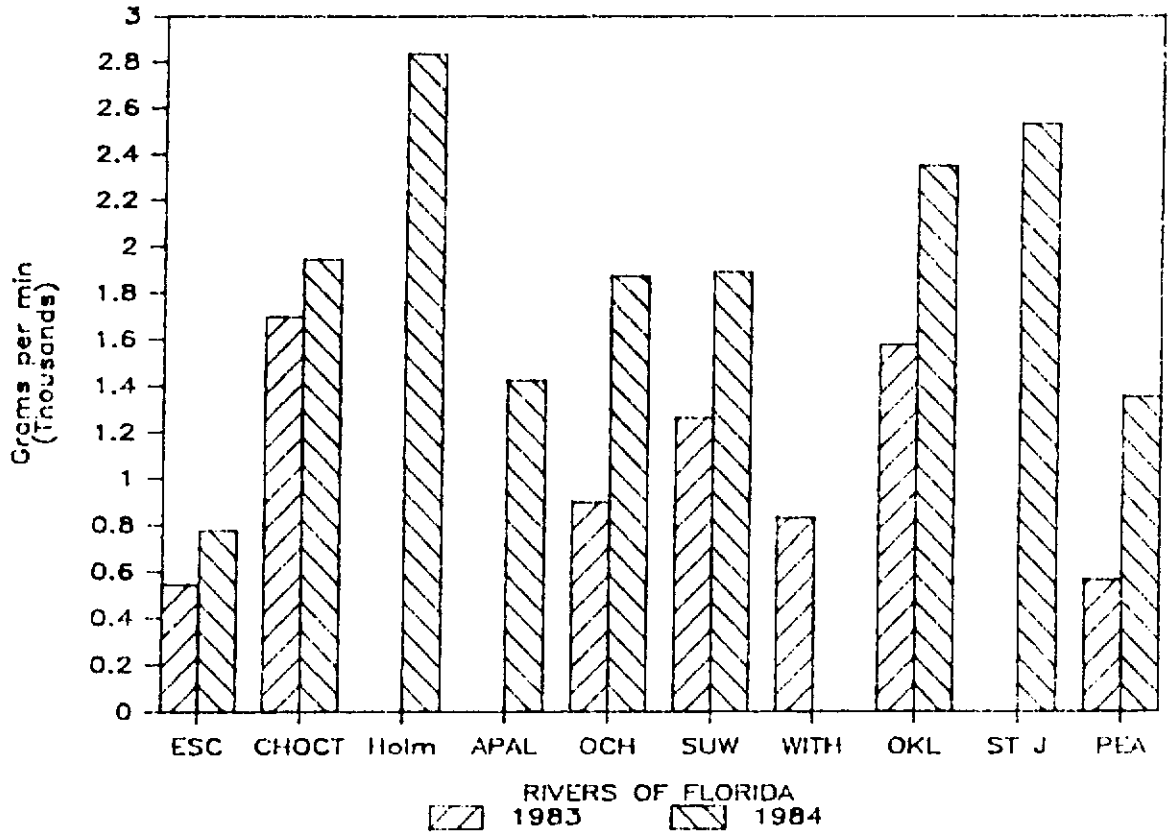


Figure Electrofishing CPT, Sport/Comm

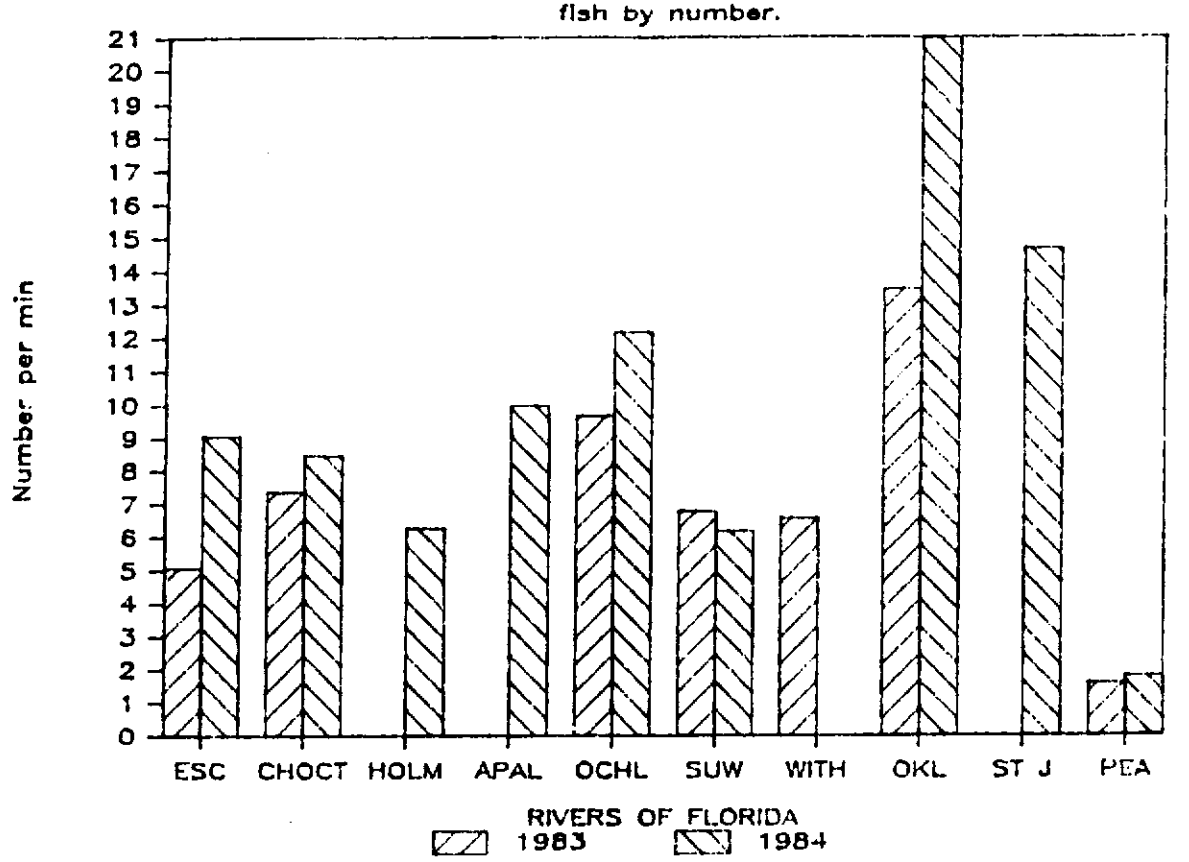


Figure Electrofishing CPT, Sport/Comm

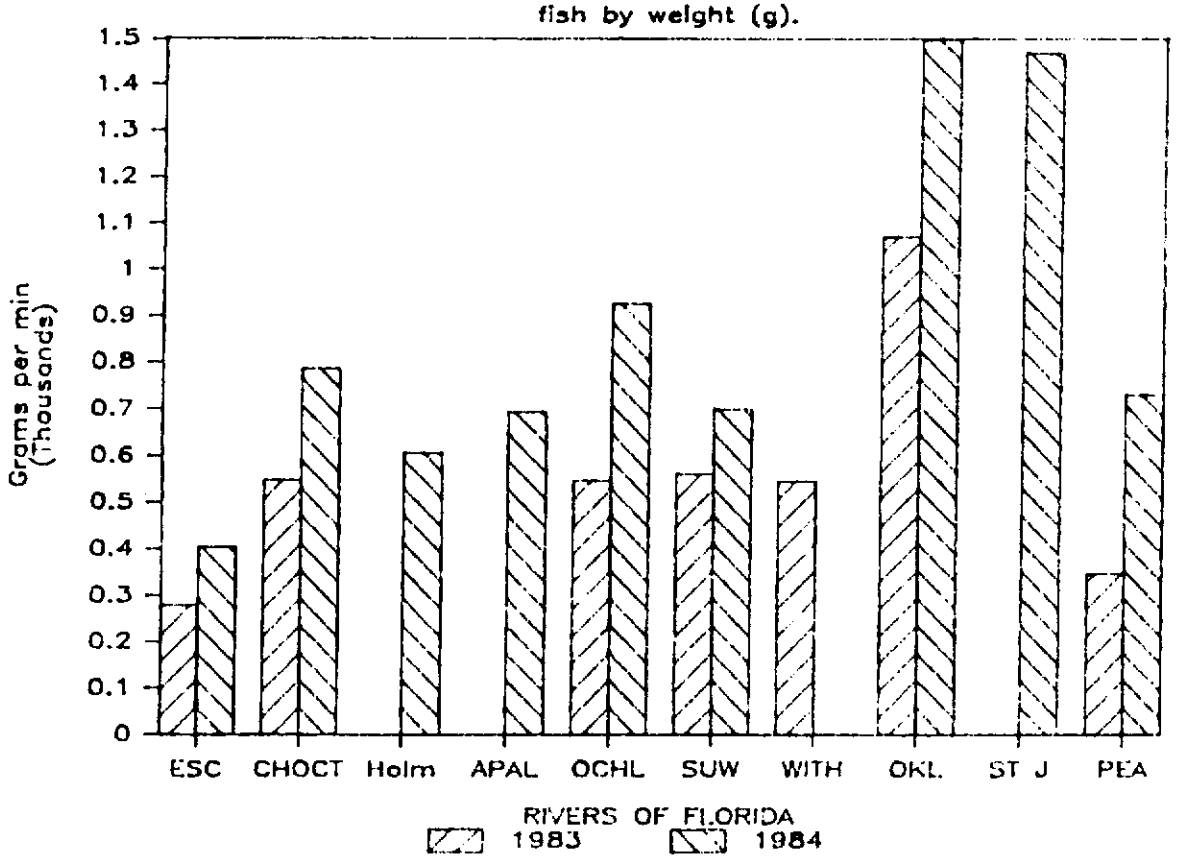


Figure Electrofishing catch per unit effort,

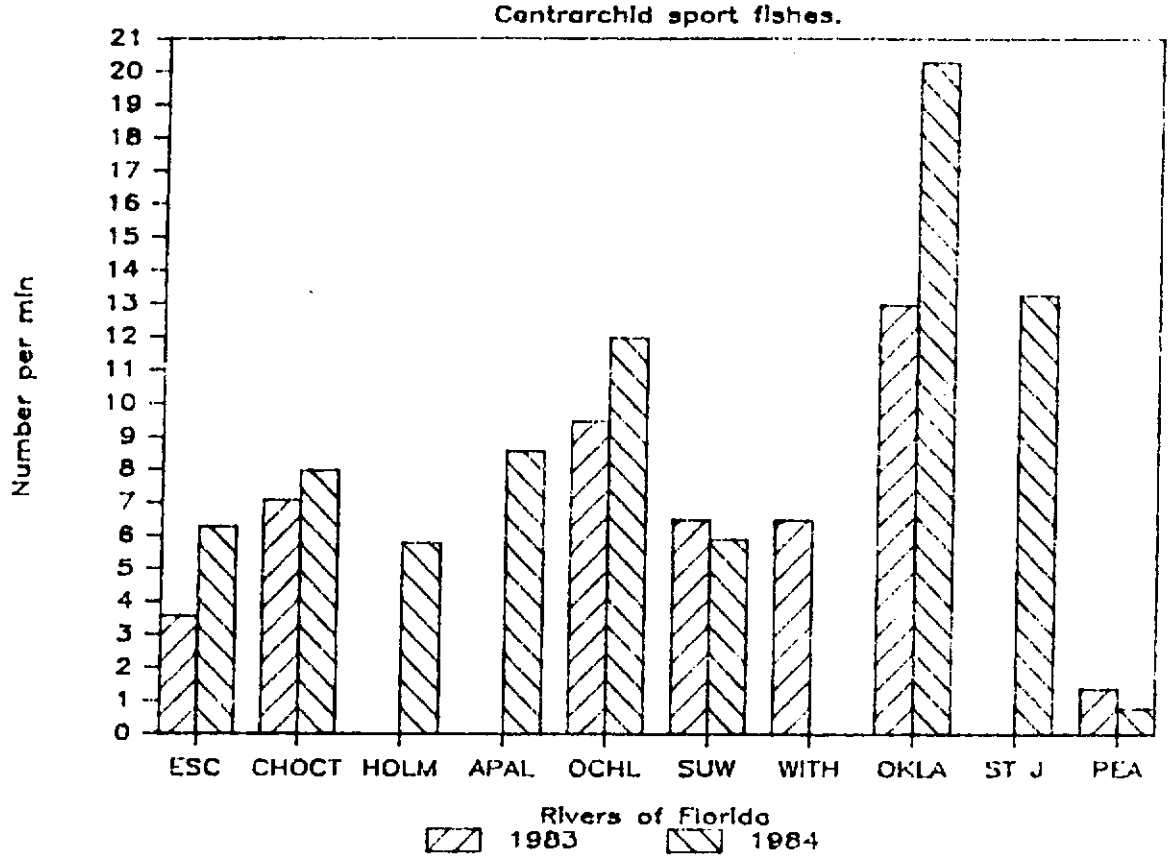


Figure Electrofishing catch per unit effort,

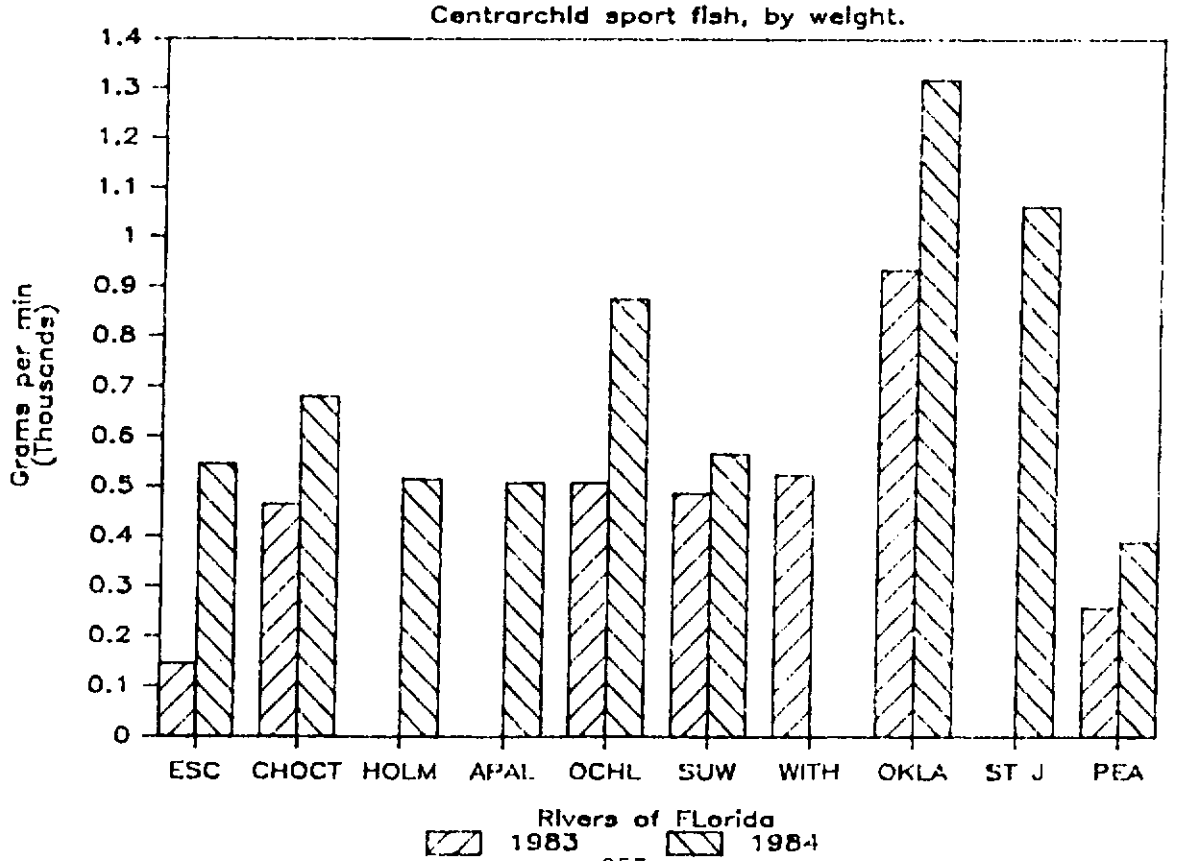


Figure Electrofishing catch per unit effort,

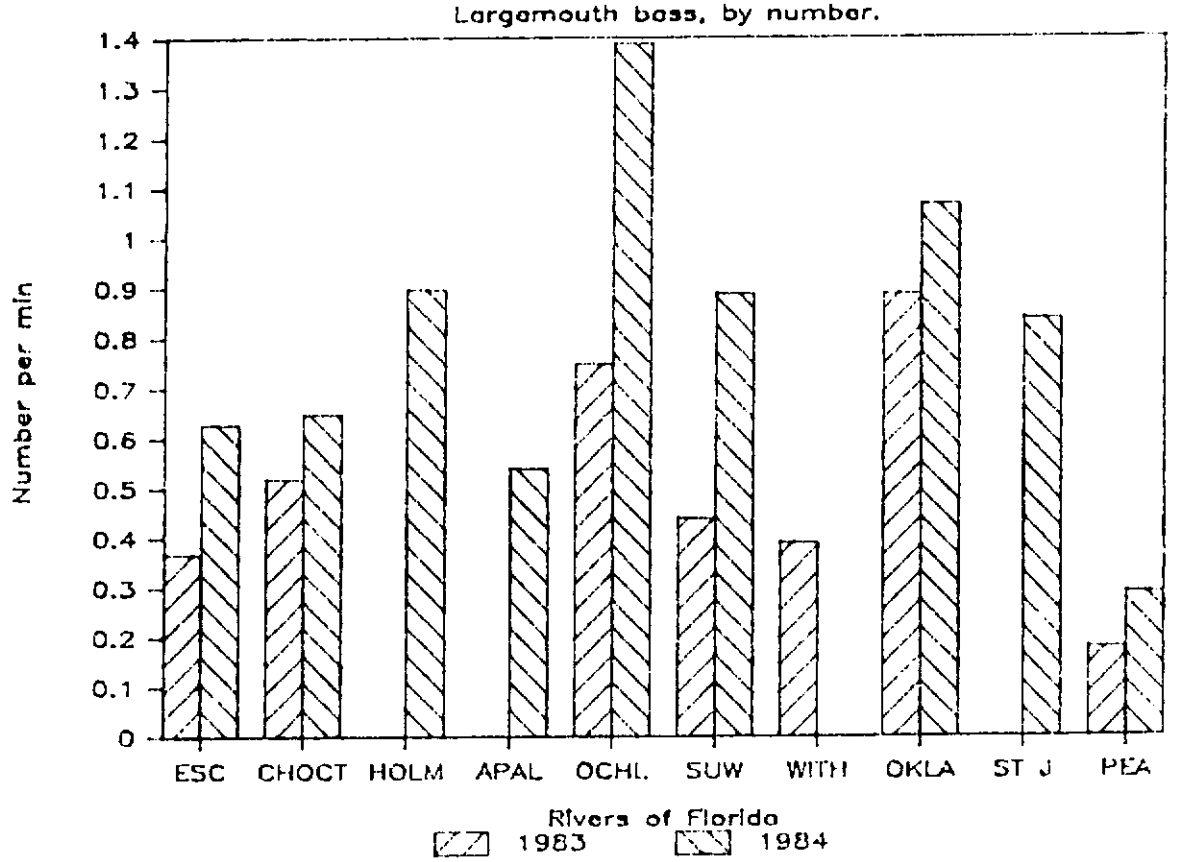
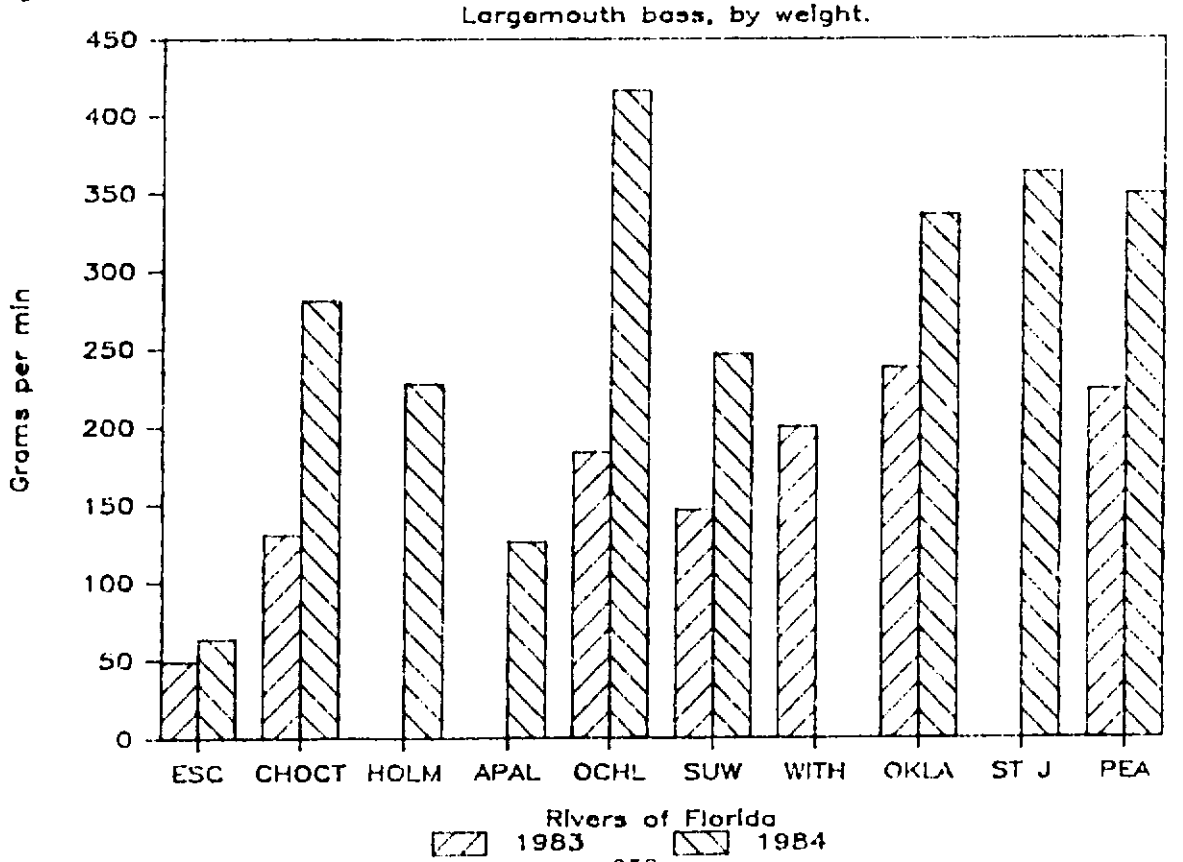


Figure Electrofishing catch per unit effort,



Figure

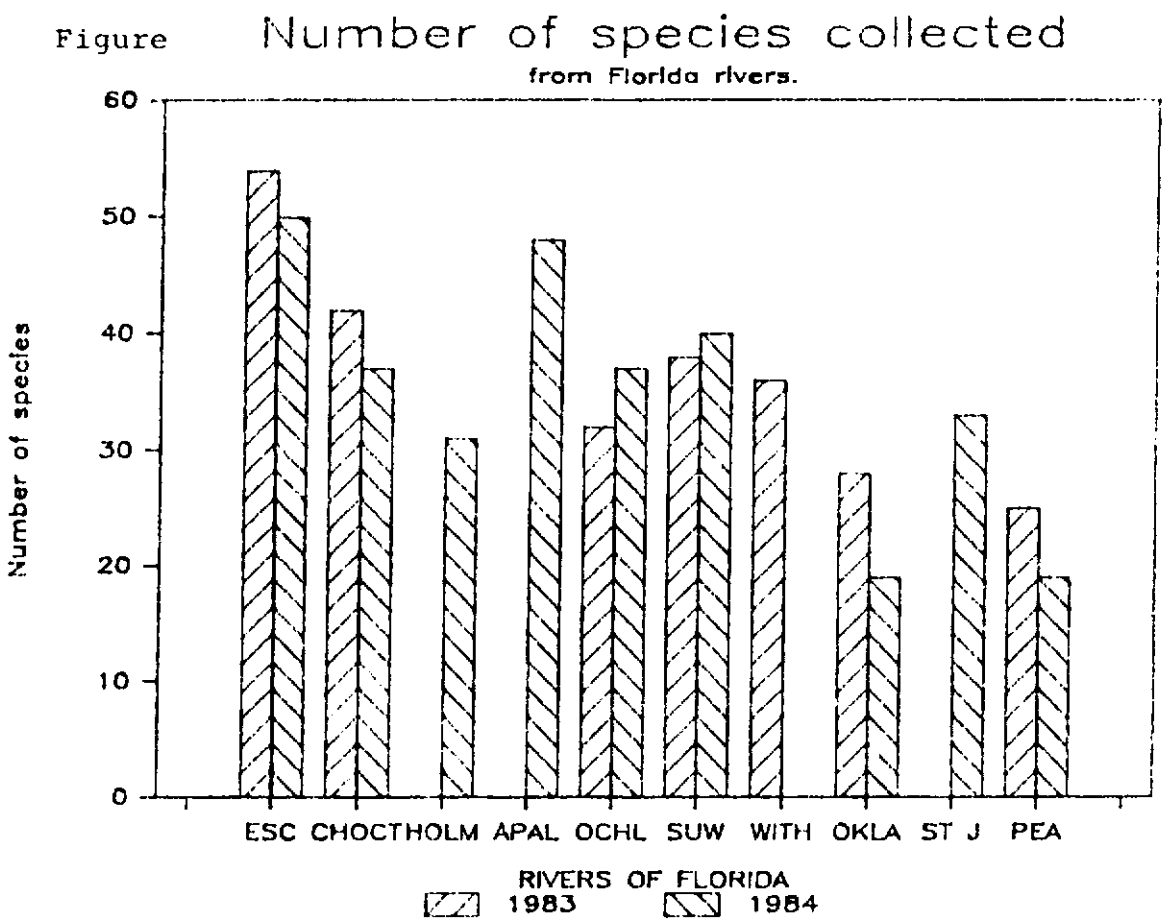

Number of species collected
from Florida rivers.
Number of species
60
50
40
30
20
10
0
ESC CHOCTHOLM APAL OCHL SUW WITH OKLA ST J PEA
RIVERS OF FLORIDA
1983
1984

Table Statewide stream monitoring project summary, 1983. Ochlockonee River.

Species	No.	%No.	Wt(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Longnose gar	3	0.1	302.0	0.7	0.05	5.0	100.7
Bowfin	2	0.1	6430.0	11.9	0.03	107.2	3215.0
American eel	4	0.2	1335.0	2.5	0.07	22.3	333.8
Gizzard shad	246	10.6	1629.0	3.0	4.10	27.2	6.6
Threadfin shad	2	0.1	4.0	0	0.03	0.1	2.0
Chain pickerel	1	0	24.0	0	0.02	0.4	24.0
Pugnose minnow	19	0.8	21.0	0	0.32	0.4	1.1
Coastal shiner	17	0.7	24.0	0	0.28	0.4	1.4
Blacktail shiner	16	0.7	84.0	0.2	0.27	1.4	5.3
Weed shiner	1078	46.6	2518.0	4.7	17.97	42.0	2.3
Bannerfin shiner	83	3.6	338.0	0.6	1.38	4.6	4.1
Notropis spp.	104	4.5	42.0	0.1	1.73	0.7	0.4
Carp	1	0	6804.0	12.6	0.02	113.4	6804.0
Spotted sucker	1	0	1814.0	3.4	0.02	30.2	1814.0
Greyfin redhorse	1	0	930.0	1.7	0.02	15.5	930.0
Channel catfish	3	0.1	69.0	0.1	0.05	1.2	23.0

Table Continued.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Pirate perch	6	0.3	10.0	0	0.10	0.2	1.7
Longnose killifish	1	0	2.0	0	0.02	0	2.0
Pygmy killifish	1	0	2.0	0	0.02	0	2.0
Mosquitofish	1	0	1.0	0	0.02	0	1.0
Brook silverside	131	5.7	185.0	0.3	2.18	3.1	1.4
Warmouth	15	0.6	796.0	1.5	0.25	13.3	53.1
Redear sunfish	28	1.2	1374.0	2.5	0.47	22.9	49.1
Spotted sunfish	53	2.3	1700.0	3.1	0.88	28.3	32.1
Bluegill	145	6.3	3838.0	7.1	2.42	64.0	26.5
Redbreast sunfish	257	11.1	10039.0	18.6	4.28	167.3	39.1
Largemouth bass	45	1.9	11060.6	20.4	0.75	184.3	245.8
Black crappie	28	1.2	1707.0	3.2	0.47	28.5	61.0
Blackbanded darter	12	0.5	18.0	0	0.20	0.3	1.5
Brown darter	1	0	1.0	0	0.02	0	1.0
Spotfin mojarra	6	0.3	24.0	0	0.10	0.4	4.0
Striped mullet	2	0.1	972.0	1.8	0.03	16.2	486.0

Table Continued.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Hogchoker	2	0.1	3.0	0	0.03	0.1	1.5
Total	2315	99.7	54100.6	100.0	38.58	901.7	23.4
Sport/Commercial	581	25.1	32914.6	60.8	9.68	548.6	56.7
Rough fish	256	11.1	17913.0	33.1	4.27	298.6	70.0
Miscellaneous	1478	63.8	3273.0	6.0	24.63	54.6	2.2
Total	2315	100.0	54100.6	99.9	38.58	901.7	23.4
Number of species	32						

Table Ochlockonee River. Station 1 .

Date: 12/07/83 Pedal time: *30 min.

Work time: 85 min. Max./Min. VDC: 670.

Max./Min. Amp: 6-7 Cond.: ? uhos/cm.

*Estimated for one substation.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Longnose gar	1	0.2	30.0	0.2	0.03	1.6	30.0
Gizzard shad	238	43.3	1315.0	10.8	7.73	43.8	5.5
Chain pickerel	1	0.2	24.0	0.2	0.03	0.8	24.0
Pugnose minnow	4	0.7	4.0	0	0.13	0.1	1.0
Coastal shiner	17	3.1	24.0	0.2	0.57	0.8	1.4
Channel catfish	1	0.2	60.0	0.5	0.03	2.0	60.0
Pirate perch	4	0.7	7.0	0.1	0.13	0.2	1.8
Longnose killifish	1	0.2	2.0	0	0.03	0.1	2.0
Pygmy killifish	1	0.2	2.0	0	0.03	0.1	2.0
Brook silverside	7	1.3	10.0	0.1	0.23	0.3	1.4
Warmouth	11	2.0	594.0	4.9	0.37	19.8	54.0
Redear sunfish	14	2.5	558.0	4.6	0.47	18.6	39.9
Spotted sunfish	45	8.2	1496.0	12.3	1.50	49.9	33.2
Bluegill	85	15.5	1966.0	16.2	2.83	65.5	23.1

Table Continued.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Redbreast sunfish	91	16.5	3307.0	27.2	3.03	110.2	36.3
Largemouth bass	11	2.0	2547.0	21.0	0.37	84.9	231.5
Black crappie	11	2.0	175.0	1.4	0.37	5.8	15.9
Spotfin mojarra	6	1.1	24.0	0.2	0.20	0.8	4.0
Hogchoker	1	0.2	2.0	0	0.03	0.1	2.0
Total	550	100.1	12147.0	99.7	18.33	404.9	22.1
Sport/Commercial	270	49.1	10727.0	88.3	9.00	357.6	39.7
Rough fish	239	43.5	1345.0	11.1	7.97	44.8	5.6
Miscellaneous	41	7.5	75.0	0.6	1.37	2.5	1.8
Total	550	100.1	12147.0	100.0	18.34	404.9	22.1
Number of species	19						

Table Ochlockonee River. Station: 2

Date: 12/08/83 Pedal time: 30 min.

Work time: 78 min. Max./Min. VDC: 504-670

Max./Min. Amp.: 4-7 Cond.: 80 uhos/cm.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Longnose gar	2	0.1	272.0	0.6	0.07	9.1	136.0
Bowfin	2	0.1	6430.0	15.3	0.07	214.3	3215.0
American eel	4	0.2	1335.0	3.2	0.13	44.5	333.8
Gizzard shad	8	0.5	314.0	0.7	0.27	10.5	39.3
Threadfin shad	2	0.1	4.0	0	0.07	0.1	2.0
Blacktail shiner	16	0.9	84.0	0.2	0.53	2.8	5.3
Weed shiner	1078	61.1	2518.0	6.0	35.93	83.9	2.3
Pugnose minnow	15	0.8	17.0	0	0.50	0.6	1.1
Bannerfin shiner	83	4.7	338.0	0.8	2.77	11.3	4.1
Carp	1	0.1	6804.0	16.2	0.03	226.8	6804.0
Notropis spp.	104	5.9	42.0	0.1	3.47	1.4	0.4
Spotted sucker	1	0.1	1814.0	4.3	0.03	60.5	1814.0
Greyfin redhorse	1	0.1	930.0	2.2	0.03	31.0	930.0

Table Continued.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Channel catfish	2	0.1	9.0	0	0.07	0.3	4.5
Pirate perch	2	0.1	3.0	0	0.07	0.1	1.5
Mosquitofish	1	0.1	1.0	0	0.03	0	1.0
Brook silverside	124	7.0	175.0	0.4	4.13	5.8	1.4
Redear sunfish	14	0.8	816.0	1.9	0.45	27.2	58.3
Warmouth	4	0.2	202.0	0.5	0.13	6.7	50.5
Spotted sunfish	8	0.5	204.0	0.5	0.27	6.8	25.5
Bluegill	60	3.4	1872.0	4.5	2.00	62.4	31.2
Redbreast sunfish	166	9.4	6732.0	16.0	5.53	224.4	40.6
Black crappie	17	1.0	1532.0	3.7	0.57	51.1	90.1
Largemouth bass	34	1.9	8513.6	20.3	1.13	283.8	250.4
Blackbanded darter	12	0.7	18.0	0	0.40	0.6	1.5
Brown darter	1	0.1	1.0	0	0.03	0	1.0
Striped mullet	2	0.1	972.0	2.3	0.07	32.4	486.0
Hogchoker	1	0.1	1.0	0	0.03	0	1.0
Total	1765	100.2	41953.6	99.7	58.83	1398.5	23.8

Table Continued.

Species	No.	%No.	Wt.(g)	%Wt.	C/pt(No.)	C/pt(Wt.)	$\bar{x}$ Wt.
Sport/Commercial	311	17.6	22187.6	52.9	10.37	739.6	71.3
Rough fish	17	1.0	16568.0	39.5	0.57	552.3	974.6
Miscellaneous	1437	81.4	3198.0	7.6	47.90	106.6	2.2
Total	1765	100.0	41953.6	100.0	58.83	1398.5	23.8
Number of Species	27						

Table Abundance and biomass of fish.

Ochlockonee R. Station No.1-4 Date:1984

Species	No.	Wt.(g)
LEAST BROOK LAMPREY	1	4.1
FLORIDA GAR	3	3840
LONGNOSE GAR	19	36352
BOWFIN	7	22180
AMERICAN EEL	2	918
GIZZARD SHAD	31	6960
THREADFIN SHAD	1	4.7
BAY ANCHOVY	2	1
CARP	2	11860
PUGNOSE MINNOW	173	139.8
COASTAL SHINER	37	30
WEED SHINER	1935	3433.7
GOLDEN SHINER	13	212
BLACKTAIL SHINER	293	1200.4
CLEAR CHUB	19	47.2
TAILLIGHT SHINER	1	.1
BANNERFIN SHINER	527	1462.9
SPOTTED SUCKER	33	25900.8
CHANNEL CATFISH	8	2935.7
PIRATE PERCH	21	101.2
SEMINOLE KILLIFISH	5	8
BLUEFIN KILLIFISH	1	.1
BROOK SILVERSIDE	444	477.7
STRIPED BASS	4	2160
LARGEMOUTH BASS	167	50228.6
REDEAR SUNFISH	156	14892
BLUEGILL	302	12009.4
SPOTTED SUNFISH	95	2660.1
WARMOUTH	41	2226.3
REDBREAST SUNFISH	489	14673.8
BLACK CRAPPIE	200	7100
DOLLAR SUNFISH	2	12
SUWANNEE BASS	4	1940
BLACKBANDED DARTER	70	103.2
GULF DARTER	3	1.4
SOUTHERN FLOUNDER	2	36
HOGCHOKER	13	95.5
Total	5126	226207.7

Table Continued

Sport/Commercial species		
AMERICAN EEL	2	918
CHANNEL CATFISH	8	2935.7
STRIPED BASS	4	2160
LARGEMOUTH BASS	167	50228.6
REDEAR SUNFISH	156	14892
BLUEGILL	302	12009.4
SPOTTED SUNFISH	95	2660.1
WARMOUTH	41	2226.3
REDBREAST SUNFISH	489	14673.8
BLACK CRAPPIE	200	7100
SUWANNEE BASS	4	1940
SOUTHERN FLOUNDER	2	36
Total	1470	111779.9
Rough fish		
Total	96	107097.5
Misc. fish		
Total	3560	7330.301

Table Percentage by number and weight, and mean weight (grams).

Species	%No.	%Wt.	MeanWt.
LEAST BROOK LAMPREY	1.950839E-02	1.812493E-03	4.1
FLORIDA GAR	5.852517E-02	1.697555	1280
LONGNOSE GAR	.3706594	16.07019	1913.263
BOWFIN	.1365587	9.805147	3168.572
AMERICAN EEL	3.901678E-02	.4058217	459
GIZZARD SHAD	.6047601	3.076818	224.5161
THREADFIN SHAD	1.950839E-02	2.077736E-03	4.7
BAY ANCHOVY	3.901678E-02	4.420716E-04	.5
CARP	3.901678E-02	5.242969	5930
PUGNOSE MINNOW	3.374951	6.180161E-02	.8080925
COASTAL SHINER	.7218104	1.326215E-02	.8108108
WEED SHINER	37.74873	1.517941	1.774522
GOLDEN SHINER	.2536091	9.371917E-02	16.30769
BLACKTAIL SHINER	5.715958	.5306627	4.096929
CLEAR CHUB	.3706594	2.086578E-02	2.484211
TAILLIGHT SHINER	1.950839E-02	4.420716E-05	.1
BANNERFIN SHINER	10.28092	.6467065	2.775901
SPOTTED SUCKER	.6437768	11.45001	784.8728
CHANNEL CATFISH	.1560671	1.29779	366.9625
PIRATE PERCH	.4096762	4.473764E-02	4.819048
SEMINOLE KILLIFISH	9.754194E-02	3.536572E-03	1.6
BLUEFIN KILLIFISH	1.950839E-02	4.420716E-05	.1
BROOK SILVERSIDE	8.661724	.2111776	1.075901
STRIPED BASS	7.803356E-02	.9548746	540
LARGEMOUTH BASS	3.257901	22.20464	300.7701
REDEAR SUNFISH	3.043309	6.58333	95.46154
BLUEGILL	5.891534	5.309015	39.76623
SPOTTED SUNFISH	1.853297	1.175955	28.00105
WARMOUTH	.799844	.9841839	54.30001
REDBREAST SUNFISH	9.539602	6.48687	30.00777
BLACK CRAPPIE	3.901678	3.138708	35.5
DOLLAR SUNFISH	3.901678E-02	5.304859E-03	6
SUWANNEE BASS	7.803356E-02	.8576188	485
BLACKBANDED DARTER	1.365587	4.562179E-02	1.474286
GULF DARTER	5.852517E-02	6.189002E-04	.4666667
SOUTHERN FLOUNDER	3.901678E-02	1.591458E-02	18
HOGCHOKER	.2536091	4.221783E-02	7.346154
Total			44.12948

Table Percentage by number and weight, and mean weight (grams): sport/commercial, rough, and miscellaneous fishes.

Ochlockonee R. Station No.1-4 Date:1984

	% Number	%Weight	Mean weight(grams)
Sport/comm.	28.67733	49.41471	76.04075
Rough fish	1.872805	47.34476	1115.599
Misc. fish	69.44987	3.240518	2.059073

Table
Electrofishing catch per unit effort (C/PT).
Ochlockonee R. Station No.1-4 Date:1984

Species	By Number	By Weight
LEAST BROOK LAMPREY	8.298756E-03	.0340249
FLORIDA GAR	2.489627E-02	31.86722
LONGNOSE GAR	.1576764	301.6764
BOWFIN	5.809129E-02	184.0664
AMERICAN EEL	1.659751E-02	7.618257
GIZZARD SHAD	.2572614	57.75934
THREADFIN SHAD	8.298756E-03	3.900415E-02
BAY ANCHOVY	1.659751E-02	8.298756E-03
CARP	1.659751E-02	98.42323
PUGNOSE MINNOW	1.435685	1.160166
COASTAL SHINER	.307054	.2489627
WEED SHINER	16.05809	28.49544
GOLDEN SHINER	.1078838	1.759336
BLACKTAIL SHINER	2.431535	9.961826
CLEAR CHUB	.1576764	.3917013
TAILLIGHT SHINER	8.298756E-03	8.298756E-04
BANNERFIN SHINER	4.373444	12.14025
SPOTTED SUCKER	.2738589	214.9444
CHANNEL CATFISH	6.639005E-02	24.36266
PIRATE PERCH	.1742739	.839834
SEMINOLE KILLIFISH	4.149378E-02	6.639005E-02
BLUEFIN KILLIFISH	8.298756E-03	8.298756E-04
BROOK SILVERSIDE	3.684647	3.964316
STRIPED BASS	3.319502E-02	17.92531
LARGEMOUTH BASS	1.385892	416.8349
REDEAR SUNFISH	1.294606	123.5851
BLUEGILL	2.506224	99.66307
SPOTTED SUNFISH	.7883818	22.07552
WARMOUTH	.340249	18.47552
REDBREAST SUNFISH	4.058091	121.7743
BLACK CRAPPIE	1.659751	58.92116
DOLLAR SUNFISH	1.659751E-02	9.958506E-02
SUWANNEE BASS	3.319502E-02	16.09959
BLACKBANDED DARTER	.5809129	.8564315
GULF DARTER	2.489627E-02	1.161826E-02
SOUTHERN FLOUNDER	1.659751E-02	.2987552
HOGCHOKER	.1078838	.7925311
Total	42.53942	1877.242

Table . Continued.

Sport/Comm.	12.19917	927.634
Rough fish	.7966805	888.7759
Misc. fish	29.54357	60.83237

Table Abundance and biomass of fish.

Ochlockonee R. Station No.1 Date:11/14/84

Species	No.	Wt.(g)
LONGNOSE GAR	18	36330
BOWFIN	1	2400
AMERICAN EEL	1	800
GIZZARD SHAD	9	692
BAY ANCHOVY	2	1
CARP	1	5860
PUGNOSE MINNOW	13	6.1
COASTAL SHINER	37	30
WEED SHINER	29	37
SPOTTED SUCKER	2	2780
CHANNEL CATFISH	5	254
PIRATE PERCH	4	10
SEMINOLE KILLIFISH	5	8
BLUEFIN KLLIFISH	1	.1
BROOK SILVERSIDE	1	.1
LARGEMOUTH BASS	21	13862
REDEAR SUNFISH	25	3070
BLUEGILL	59	2396
SPOTTED SUNFISH	27	1080
WARMOUTH	5	533
REDBREAST SUNFISH	62	852
BLACK CRAPPIE	8	298
SOUTHERN FLOUNDER	2	36
HOGCHOKER	4	6
Total	342	71341.31

Table Continued

Sport/Commercial species		
AMERICAN EEL	1	800
CHANNEL CATFISH	5	254
LARGEMOUTH BASS	21	13862
REDEAR SUNFISH	25	3070
BLUEGILL	59	2396
SPOTTED SUNFISH	27	1080
WARMOUTH	5	533
REDBREAST SUNFISH	62	852
BLACK CRAPPIE	8	298
SOUTHERN FLOUNDER	2	36
Total	215	23181
Rough fish		
Total	31	48062
Misc. fish		
Total	96	98.29999

Table Percentage by number and weight, and mean weight (grams).

Species	%No.	%Wt.	MeanWt.
LONGNOSE GAR	5.263158	50.92422	2018.333
BOWFIN	.2923977	3.36411	2400
AMERICAN EEL	.2923977	1.12137	800
GIZZARD SHAD	2.631579	.969985	76.88889
BAY ANCHOVY	.5847954	1.401713E-03	.5
CARP	.2923977	8.214036	5860
PUGNOSE MINNOW	3.80117	8.550446E-03	.4692308
COASTAL SHINER	10.81871	4.205138E-02	.8108108
WEED SHINER	8.479532	5.186337E-02	1.275862
SPOTTED SUCKER	.5847954	3.896761	1390
CHANNEL CATFISH	1.461988	.356035	50.8
PIRATE PERCH	1.169591	1.401713E-02	2.5
SEMINOLE KILLIFISH	1.461988	.0112137	1.6
BLUEFIN KLLIFISH	.2923977	1.401713E-04	.1
BROOK SILVERSIDE	.2923977	1.401713E-04	.1
LARGEMOUTH BASS	6.140351	19.43054	660.0952
REDEAR SUNFISH	7.309942	4.303258	122.8
BLUEGILL	17.25146	3.358503	40.61017
SPOTTED SUNFISH	7.894737	1.51385	40
WARMOUTH	1.461988	.7471128	106.6
REDBREAST SUNFISH	18.12866	1.194259	13.74194
BLACK CRAPPIE	2.339182	.4177103	37.25
SOUTHERN FLOUNDER	.5847954	5.046166E-02	18
HOGCHOKER	1.169591	8.410275E-03	1.5
Total			208.6003

Table Percentage by number and weight, and mean weight (grams): sport/commercial, rough, and miscellaneous fishes.

Ochlockonee R. Station No.1 Date:11/14/84

	% Number	%Weight	Mean weight(grams)
Sport/comm.	62.8655	32.4931	107.8186
Rough fish	9.064328	67.36911	1550.387
Misc. fish	28.07018	.1377883	1.023958

Table
Electrofishing catch per unit effort (C/PT).
Ochlockonee R. Station No.1 Date:11/14/84

Species	By Number	By Weight
LONGNOSE GAR	.590164	1191.148
BOWFIN	3.278688E-02	78.68853
AMERICAN EEL	3.278688E-02	26.22951
GIZZARD SHAD	.295082	22.68853
BAY ANCHOVY	6.557377E-02	3.278688E-02
CARP	3.278688E-02	192.1312
PUGNOSE MINNOW	.4262295	.2
COASTAL SHINER	1.213115	.9836066
WEED SHINER	.9508197	1.213115
SPOTTED SUCKER	6.557377E-02	91.14754
CHANNEL CATFISH	.1639344	8.327869
PIRATE PERCH	.1311475	.3278689
SEMINOLE KILLIFISH	.1639344	.2622951
BLUEFIN KLLIFISH	3.278688E-02	3.278689E-03
BROOK SILVERSIDE	3.278688E-02	3.278689E-03
LARGEMOUTH BASS	.6885246	454.4918
REDEAR SUNFISH	.8196721	100.6557
BLUEGILL	1.934426	78.55738
SPOTTED SUNFISH	.8852459	35.40984
WARMOUTH	.1639344	17.47541
REDBREAST SUNFISH	2.032787	27.93443
BLACK CRAPPIE	.2622951	9.770492
SOUTHERN FLOUNDER	6.557377E-02	1.180328
HOGCHOKER	.1311475	.1967213
Total	11.21312	2339.059

Table Continued.

Sport/Comm.	7.049181	760.0328
Rough fish	1.016393	1575.803
Misc. fish	3.147541	3.222951

Table Abundance and biomass of fish.

Ochlockonee R. Station No.2 Date:12/19/84

Species	No.	Wt.(g)
BOWFIN	2	9980
GIZZARD SHAD	9	1738
GOLDEN SHINER	13	212
WEED SHINER	324	458
BLACKTAIL SHINER	63	231
PUGNOSE MINNOW	42	39
CLEAR CHUB	1	1.5
TAILLIGHT SHINER	1	.1
SPOTTED SUCKER	14	13420
CHANNEL CATFISH	1	980
PIRATE PERCH	8	39
BROOK SILVERSIDE	62	76
BLACK CRAPPIE	171	4188
REDEAR SUNFISH	88	7084
BLUEGILL	69	3264.1
REDBREAST SUNFISH	190	5026
WARMOUTH	21	1211.5
SPOTTED SUNFISH	42	1403.5
DOLLAR SUNFISH	1	4
SUWANNEE BASS	2	996
LARGEMOUTH BASS	43	6936
BLACKBANDED DARTER	22	34.5
GULF DARTER	1	.1
Total	1190	57322.31

Table Continued

Sport/Commercial species		
CHANNEL CATFISH	1	980
BLACK CRAPPIE	171	4188
REDEAR SUNFISH	88	7084
BLUEGILL	69	3264.1
REDBREAST SUNFISH	190	5026
WARMOUTH	21	1211.5
SPOTTED SUNFISH	42	1403.5
SUWANNEE BASS	2	996
LARGEMOUTH BASS	43	6936
Total	627	31089.1
Rough fish		
Total	25	25138
Misc. fish		
Total	538	1095.2

Table Percentage by number and weight, and mean weight (grams).

Species	%No.	%Wt.	MeanWt.
BOWFIN	.1680672	17.41033	4990
GIZZARD SHAD	.7563026	3.031979	193.1111
GOLDEN SHINER	1.092437	.3698386	16.30769
WEED SHINER	27.22689	.7989909	1.41358
BLACKTAIL SHINER	5.294118	.4029845	3.666667
PUGNOSE MINNOW	3.529412	6.803635E-02	.9285714
CLEAR CHUB	8.403362E-02		
		2.616783E-03	1.5
TAILLIGHT SHINER	8.403362E-02		
		1.744522E-04	.1
SPOTTED SUCKER	1.176471	23.41148	958.5714
CHANNEL CATFISH	8.403362E-02		
		1.709631	980
PIRATE PERCH	.672269	6.803635E-02	4.875
BROOK SILVERSIDE	5.210084	.1325837	1.225807
BLACK CRAPPIE	14.36975	7.306057	24.49123
REDEAR SUNFISH	7.394959	12.35819	80.5
BLUEGILL	5.79832	5.694293	47.3058
REDBREAST SUNFISH	15.96639	8.767966	26.45263
WARMOUTH	1.764706	2.113488	57.69048
SPOTTED SUNFISH	3.529412	2.448436	33.41667
DOLLAR SUNFISH	8.403362E-02		
		6.978086E-03	4
SUWANNEE BASS	.1680672	1.737544	498
LARGEMOUTH BASS	3.613446	12.1	161.3023
BLACKBANDED DARTER	1.84874	.060186	1.568182
GULF DARTER	8.403362E-02		
		1.744522E-04	.1
Total			48.17001

Table
Electrofishing catch per unit effort (C/PT).
Ochlockonee R. Station No.2 Date:12/19/84

Species	By Number	By Weight
BOWFIN	6.666667E-02	332.6667
GIZZARD SHAD	.3	57.93334
GOLDEN SHINER	.4333334	7.066667
WEED SHINER	10.8	15.26667
BLACKTAIL SHINER	2.1	7.7
PUGNOSE MINNOW	1.4	1.3
CLEAR CHUB	3.333334E-02	.05
TAILLIGHT SHINER	3.333334E-02	3.333334E-03
SPOTTED SUCKER	.4666667	447.3334
CHANNEL CATFISH	3.333334E-02	32.66667
PIRATE PERCH	.2666667	1.3
BROOK SILVERSIDE	2.066667	2.533333
BLACK CRAPPIE	5.7	139.6
REDEAR SUNFISH	2.933334	236.1333
BLUEGILL	2.3	108.8033
REDBREAST SUNFISH	6.333334	167.5333
WARMOUTH	.7	40.38334
SPOTTED SUNFISH	1.4	46.78334
DOLLAR SUNFISH	3.333334E-02	.1333333
SUWANNEE BASS	6.666667E-02	33.2
LARGEMOUTH BASS	1.433333	231.2
BLACKBANDED DARTER	.7333334	1.15
GULF DARTER	3.333334E-02	3.333334E-03
Total	39.66667	1910.744

Table Continued.

Sport/Comm.	20.9	1036.303
Rough fish	.8333333	837.9334
Misc. fish	17.93333	36.50667

Table Percentage by number and weight, and mean weight (grams): sport/commercial, rough, and miscellaneous fishes.

Ochlockonee R. Station No.2 Date:12/19/84

	% Number	%Weight	Mean weight(grams)
Sport/comm.	52.68908	54.23561	49.5839
Rough fish	2.10084	43.85379	1005.52
Misc. fish	45.21009	1.9106	2.035688

Table Abundance and biomass of fish.

Ochlockonee R. Station No.3 Date:10/29/84

Species	No.	Wt.(g)
LONGNOSE GAR	1	22
FLORIDA GAR	2	3000
BOWFIN	4	9800
AMERICAN EEL	1	118
THREADFIN SHAD	1	4.7
CARP	1	6000
BLACKTAIL SHINER	29	131.9
BANNERFIN SHINER	453	1159
WEED SHINER	894	1834.2
PUGNOSE MINNOW	88	66.3
SPOTTED SUCKER	2	3000
PIRATE PERCH	1	2.2
BROOK SILVERSIDE	239	267.1
REDEAR SUNFISH	23	3740
BLUEGILL	65	4448.7
REDBREAST SUNFISH	124	4656.3
WARMOUTH	12	421.8
SPOTTED SUNFISH	21	132
DOLLAR SUNFISH	1	8
BLACK CRAPPIE	11	1612
LARGEMOUTH BASS	61	21783.5
BLACKBANDED DARTER	15	25.6
HOGCHOKER	9	89.5
Total	2058	62322.8

Table Continued

Sport/Commercial species		
AMERICAN EEL	1	118
REDEAR SUNFISH	23	3740
BLUEGILL	65	4448.7
REDBREAST SUNFISH	124	4656.3
WARMOUTH	12	421.8
SPOTTED SUNFISH	21	132
DOLLAR SUNFISH	1	8
BLACK CRAPPIE	11	1612
LARGEMOUTH BASS	61	21783.5
Total	319	36920.3
Rough fish		
Total	11	21826.7
Misc. fish		
Total	1728	3575.8

Table Percentage by number and weight, and mean weight (grams).

Species	%No.	%Wt.	MeanWt.
LONGNOSE GAR	4.859087E-02		
		3.530008E-02	22
FLORIDA GAR	9.718173E-02		
		4.813648	1500
BOWFIN	.1943635	15.72458	2450
AMERICAN EEL	4.859087E-02		
		.1893368	118
THREADFIN SHAD	4.859087E-02		
		7.541381E-03	4.7
CARP	4.859087E-02		
		9.627296	6000
BLACKTAIL SHINER	1.409135	.21164	4.548276
BANNERFIN SHINER	22.01166	1.859673	2.558499
WEED SHINER	43.44024	2.943064	2.051678
PUGNOSE MINNOW	4.275996	.1063816	.7534091
SPOTTED SUCKER	9.718173E-02		
		4.813648	1500
PIRATE PERCH	4.859087E-02		
		3.530008E-03	2.2
BROOK SILVERSIDE	11.61322	.4285751	1.117573
REDEAR SUNFISH	1.11759	6.001014	162.6087
BLUEGILL	3.158406	7.138159	68.44155
REDBREAST SUNFISH	6.025268	7.471262	37.55081
WARMOUTH	.5830905	.6767988	35.15
SPOTTED SUNFISH	1.020408	.2118005	6.285714
DOLLAR SUNFISH	4.859087E-02		
		1.283639E-02	8
BLACK CRAPPIE	.5344995	2.586533	146.5455
LARGEMOUTH BASS	2.964043	34.9527	357.1066
BLACKBANDED DARTER	.728863	4.107646E-02	1.706667
HOGCHOKER	.4373178	.1436072	9.944444
Total			30.28319

Table Percentage by number and weight, and mean weight (grams): sport/commercial, rough, and miscellaneous fishes.

Ochlockonee R. Station No.3 Date:10/29/84

	% Number	%Weight	Mean weight(grams)
Sport/comm.	15.50049	59.24044	115.7376
Rough fish	.5344995	35.02201	1984.245
Misc. fish	83.96501	5.737548	2.069329

Table
Electrofishing catch per unit effort (C/PT).
Ochlockonee R. Station No.3 Date:10/29/84

Species	By Number	By Weight
LONGNOSE GAR	3.333334E-02	.7333334
FLORIDA GAR	6.666667E-02	100
BOWFIN	.1333333	326.6667
AMERICAN EEL	3.333334E-02	3.933334
THREADFIN SHAD	3.333334E-02	.1566667
CARP	3.333334E-02	200
BLACKTAIL SHINER	.9666666	4.396667
BANNERFIN SHINER	15.1	38.63334
WEED SHINER	29.8	61.14
PUGNOSE MINNOW	2.933334	2.21
SPOTTED SUCKER	6.666667E-02	100
PIRATE PERCH	3.333334E-02	7.333334E-02
BROOK SILVERSIDE	7.966667	8.903334
REDEAR SUNFISH	.7666666	124.6667
BLUEGILL	2.166667	148.29
REDBREAST SUNFISH	4.133333	155.21
WARMOUTH	.4	14.06
SPOTTED SUNFISH	.7	4.4
DOLLAR SUNFISH	3.333334E-02	.2666667
BLACK CRAPPIE	.3666667	53.73334
LARGEMOUTH BASS	2.033333	726.1166
BLACKBANDED DARTER	.5	.8533334
HOGCHOKER	.3	2.983333
Total	68.6	2077.427

Table Continued.

Sport/Comm.	10.63333	1230.677
Rough fish	.3666667	727.5566
Misc. fish	57.6	119.1934

Table Abundance and biomass of fish.

Ochlockonee R. Station No.4 Date:10/30/84

Species	No.	Wt.(g)
LEAST BROOK LAMPREY	1	4.1
FLORIDA GAR	1	840
GIZZARD SHAD	13	4530
PUGNOSE MINNOW	30	28.4
BLACKTAIL SHINER	201	837.5
CLEAR CHUB	18	45.7
WEED SHINER	688	1104.5
BANNERFIN SHINER	74	303.9
SPOTTED SUCKER	15	6700.8
CHANNEL CATFISH	2	1701.7
PIRATE PERCH	8	50
BROOK SILVERSIDE	142	134.5
STRIPED BASS	4	2160
WARMOUTH	3	60
BLUEGILL	109	1900.6
REDEAR SUNFISH	20	998
REDBREAST SUNFISH	113	4139.5
SPOTTED SUNFISH	5	44.6
BLACK CRAPPIE	10	1002
LARGEMOUTH BASS	42	7647.1
SUWANNEE BASS	2	944
BLACKBANDED DARTER	33	43.1
GULF DARTER	2	1.3
Total	1536	35221.31

Table Continued

Sport/Commercial species		
CHANNEL CATFISH	2	1701.7
STRIPED BASS	4	2160
WARMOUTH	3	60
BLUEGILL	109	1900.6
REDEAR SUNFISH	20	998
REDBREAST SUNFISH	113	4139.5
SPOTTED SUNFISH	5	44.6
BLACK CRAPPIE	10	1002
LARGEMOUTH BASS	42	7647.1
SUWANNEE BASS	2	944
Total	310	20597.5
Rough fish		
Total	29	12070.8

Table Percentage by number and weight, and mean weight (grams).

Species	%No.	%Wt.	MeanWt.
LEAST BROOK LAMPREY	6.510417E-02	1.164068E-02	4.1
FLORIDA GAR	6.510417E-02	2.38492	840
GIZZARD SHAD	.8463542	12.86153	348.4616
PUGNOSE MINNOW	1.953125	8.063301E-02	.9466667
BLACKTAIL SHINER	13.08594	2.377822	4.166667
CLEAR CHUB	1.171875	.129751	2.538889
WEED SHINER	44.79167	3.135886	1.605378
BANNERFIN SHINER	4.817708	.8628301	4.106757
SPOTTED SUCKER	.9765625	19.02485	446.72
CHANNEL CATFISH	.1302083	4.831451	850.85
PIRATE PERCH	.5208334	.1419595	6.25
BROOK SILVERSIDE	9.244791	.3818712	.9471831
STRIPED BASS	.2604167	6.132652	540
WARMOUTH	.1953125	.1703514	20
BLUEGILL	7.096354	5.396166	17.4367
REDEAR SUNFISH	1.302083	2.833512	49.9
REDBREAST SUNFISH	7.356771	11.75283	36.63275
SPOTTED SUNFISH	.3255208	.1266279	8.92
BLACK CRAPPIE	.6510416	2.844869	100.2
LARGEMOUTH BASS	2.734375	21.71158	182.0738
SUWANNEE BASS	.1302083	2.680196	472
BLACKBANDED DARTER	2.148438	.1223691	1.306061
GULF DARTER	.1302083	3.690948E-03	.65
Total			22.93054

Table Percentage by number and weight, and mean weight (grams): sport/commercial, rough, and miscellaneous fishes.

Ochlockonee R. Station No.4 Date:10/30/84

	% Number	%Weight	Mean weight(grams)
Sport/comm.	20.18229	58.48023	66.44355
Rough fish	1.888021	34.2713	416.2345
Misc. fish	77.92969	7.248454	2.132832

Table
Electrofishing catch per unit effort (C/PT).
Ochlockonee R. Station No.4 Date:10/30/84

Species	By Number	By Weight
LEAST BROOK LAMPREY	3.333334E-02	.1366667
FLORIDA GAR	3.333334E-02	28
GIZZARD SHAD	.4333334	151
PUGNOSE MINNOW	1	.9466667
BLACKTAIL SHINER	6.7	27.91667
CLEAR CHUB	.6	1.523333
WEED SHINER	22.93333	36.81667
BANNERFIN SHINER	2.466667	10.13
SPOTTED SUCKER	.5	223.36
CHANNEL CATFISH	6.666667E-02	56.72333
PIRATE PERCH	.2666667	1.666667
BROOK SILVERSIDE	4.733333	4.483333
STRIPED BASS	.1333333	72
WARMOUTH	.1	2
BLUEGILL	3.633334	63.35334
REDEAR SUNFISH	.6666667	33.26667
REDBREAST SUNFISH	3.766667	137.9833
SPOTTED SUNFISH	.1666667	1.486667
BLACK CRAPPIE	.3333334	33.4
LARGEMOUTH BASS	1.4	254.9033
SUWANNEE BASS	6.666667E-02	31.46667
BLACKBANDED DARTER	1.1	1.436667
GULF DARTER	6.666667E-02	4.333334E-02
Total	51.2	1174.044

Table Continued.

Sport/Comm.	10.33333	686.5833
Rough fish	.9666666	402.36
Misc. fish	39.9	85.1