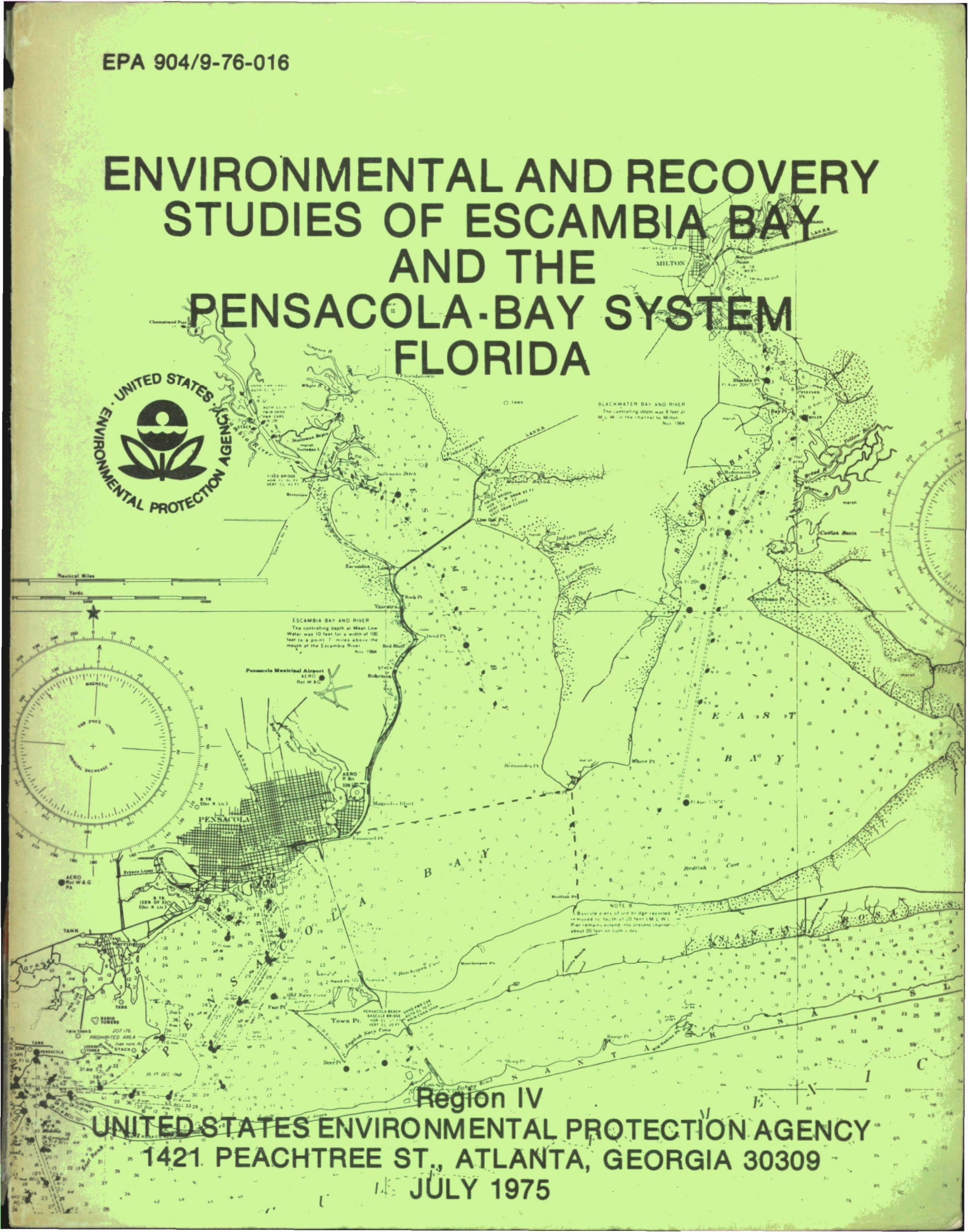
EPA 904/9-76-016

ENVIRONMENTAL AND RECOVERY STUDIES OF ESCAMBIA BAY AND THE PENSACOLA-BAY SYSTEM FLORIDA



Region IV

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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JULY 1975

ENVIRONMENTAL AND RECOVERY STUDIES OF ESCAMBIA BAY AND THE PENSACOLA BAY SYSTEM, FLORIDA

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July 1975

REVIEW NOTICE

This report has been reviewed by the Environmental Protection Agency, Region IV, and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Foreward

The studies represented in this report indicate that an environmentally damaged estuary can improve rapidly when wastewater discharges are reduced. The effort expended to abate pollution appears worthwhile, and the additional pollution abatement efforts recommended in the report are necessary for continued recovery of the system.

The Escambia Bay Recovery Study was initiated as a result of concern over the degraded condition of Escambia Bay. The success of the Study was due to the cooperation of conservation and sportsmens groups, academic institutions, industries, government agencies, and concerned citizens. The studies indicated that environmental protection is not an impossible goal.

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1 - INTRODUCTION

GENERAL

The Escambia Bay Recovery Study (EBRS) was established when public concern over the degradation of the waters of Escambia Bay, Florida - exemplified by massive fish kills, abrupt declines in commercial and sports fisheries, and waters closed to body contact sports - was translated into action by Federal and State governments. ERBS consisted of a multidisciplinary team of Federal scientists, located at the U.S. Environmental Protection Agency (USEPA), Gulf Breeze Environmental Research Laboratory, Gulf Breeze, Florida, who were under the direction of the USEPA, Region IV, Surveillance and Analysis Division, Athens, Georgia. A steering committee made up of groups concerned with problems in Escambia Bay assisted (Appendix 1-1).

The major goal of the study was to determine methods of accelerating the recovery of Escambia Bay over and above reducing waste discharges into the bay. The specific objectives of the Escambia Bay Recovery Study were to:

- Document conditions in the Pensacola Bay system under various environmental situations,
- Determine the significant mechanisms causing degradation to the ecosystem of Escambia Bay,
- Determine the feasibility of restoration schemes such as diverting a portion of the Escambia River into northeast Escambia Bay, removing sediments from Escambia Bay, revegetating the bay, and altering portions of the sediments.

BACKGROUND

General

Within the past 25 years aquatic conditions in the Escambia River have changed from healthy to stressed, and have subsequently improved. Before major industrial plants located in the area, the lower Escambia River exhabited a healthy aquatic condition, free from the effects of pollution (Academy of Natural Sciences of Philadelphia, 1953). By 1962, after the establishment of major industrial waste discharges, fish kills and Sphaerotilus growths near the Florida State line were related to industrial waste discharges (Wastler and Kittrell, 1962). Between 1960 and 1968, stressed aquatic conditions, as indicated by declining fisheries and altered macroinvertebrate communities

in the Escambia River, continued to exist (Schneider, 1964, Florida State Board of Health, 1963, 1966, 1968; Blanchard, 1968). Signs of improvement were noted in 1972 when the water quality of the Escambia River was found comparable to unpolluted northwest Florida streams (USEPA, 1972).

Stressed aquatic conditions in Escambia Bay have been of considerable concern during the past few years. In 1958, bioassays indicated industrial waste discharges in northeast Escambia Bay adversely affected aquatic organisms (Florida State Board of Health, 1958). Hopkins (1969, 1973) concluded the assimilative and exchange capacities of Escambia Bay have been exceeded, causing excessive phytoplankton organisms and diurnal depletion of dissolved oxygen which have led to fish kills. Weak circulation in the bay and waste discharges were found to have contributed to stressed aquatic conditions by USDI (1970); USEPA (1971d); and Florida State Board of Health (1969). High concentrations of PCB were found in bay oysters during April 1969 (Duke et al., 1970; Nimmo et al. 1971a, 1971b) and, consequently, stresses due to toxic materials also contribute to problems in the bay. A systems model of Escambia Bay developed by Schomer (1975), which required many assumptions, indicated that man-induced inputs to the system are likely to remain for a long time.

Weak circulation occurs throughout the entire Pensacola Bay system due to low tidal energy (Ellis, 1969). Strong vertical stratification was found to contribute to weak circulation and low dissolved oxygen concentrations in bottom waters of the Pensacola Bay system during a study by Gallagher (1971). Aquatic conditions in most of Pensacola Bay were acceptable, but degraded conditions were found near the Pensacola waterfront (Florida State Board of Health, 1969, and Baseline Incorporated, 1973). A study of near-shore waters of the Gulf of Mexico, including limited work in the Pensacola Bay system, indicated better flushing in Pensacola Bay than in other components of the bay system (Escarosa I, 1973).

The most massive fish kills have occurred in Mulatto Bayou and Bayou Texar. In Mulatto Bayou, low dissolved oxygen and possible algal toxicity, resulting from disturbances such as dredging and filling and artifically enriched waters, were considered major factors in the fish kills (USDI, 1969; USDI, 1970, and Livingston et al., 1972). Bayou Texar receives silt, overflow from sewage lift stations, and runoff from fertilized lawns and is rapidly becoming a shallow system unfit for recreational and aesthetic purposes (Moshiri et al., 1972; and Hannah et al., 1973).

Federal Involvement

The historical responsibility of the Federal Government in dealing with environmental problems in Escambia Bay led to the establishment of EBRS within USEPA. Federal involvement first

occurred in 1962 when the Conference on Interstate Pollution of the Conecuh-Escambia River was convened by the U.S. Public Health Service (USPHS, presently USEPA) at the request of the State of Florida (USPHS, 1962). The major conclusion of the conference was that the pollution of interstate waters, as subject to abatement under the Federal Water Pollution Control Act, was not occurring in the Conecuh-Escambia River system at the time of the conference. Solutions to the problems were indicated to be the responsibility of official State water pollution control agencies, and assistance from the USPHS was offered.

The Federal Water Pollution Control Administration (FWPCA presently USEPA) was again involved with Escambia Bay when in August 1969 the Southeast Region's technical assistance was requested in evaluating interstate and intrastate pollution from waste sources entering the Conecuh-Escambia River downstream from Brewton, Alabama, and Escambia Bay near Pensacola, Florida. An investigation of waste sources in Florida and Alabama, and a detailed study of the receiving waters, were conducted during the period of September 23 - 25, 1969 and October 22 - 30, 1969. Based on the results of these studies, a conference in the matter of pollution of the interstate waters of the Escambia River Basin (Alabama - Florida) and the intrastate portions of the Escambia Basin within the State of Florida, was convened under the provisions of Section 10 of the Federal Water Pollution Control Act, as amended (33 USC 466 et seq). Three sessions of the conference were held in January 1970 (USDI, 1970a), February 1971 (USEPA, 1971c), and January 1972 (USEPA, 1972e). The recommendations of the conference are presented in Appendix 1-2.

ACKNOWLEDGMENTS

We thank the following individuals, institutions, and agencies:

Surveillance and Analysis Division, EPA, Region IV, for their assistance in planning the study, analyzing samples, and for reviewing the report. The Enforcement and Water Divisions, EPA, Region IV, for providing field personnel during studies.

Dr. Tom Duke, Director, Gulf Breeze Environmental Research Laboratory and Staff for the infinite amount of assistance provided during our stay at their facility.

Dr. Tom Hopkins, Chairman, Faculty of Biology, University of West Florida, Messrs. Ken Adams and Mike Ziegler, Ms. Debby Reik and other Sea Grant Staff members who assisted us in the field studies and in the laboratory.

Mr. Bob Dillard, Region Administrator, Mr. Phil Doherty, Regional Engineer, and Mr. Walt Flanigan, Florida Department of Environmental Regulation and the Staff for cooperation and assistance in field studies and laboratory assistance.

The Bream Fisherman Association of Pensacola for their assistance in the revegetation studies and the stocking of striped bass fry in the Escambia River.

Mr. Bill Young, Florida Department of Environmental Regulation, for supplying us with historical records of fish kills in the Pensacola Bay system.

The South Carolina Wildlife and Marine Resources Department for providing the Striped Bass fry that were stocked in the Escambia River.

The U.S. Geological Survey, Tallahassee, Florida for providing provisional streamflow data and water quality data.

Dr. Marian H. Pettibone, U. S. National Museum; Dr. E. L. Bousfield, National Museum of Canada; Dr. Henry Kritzer, FSU Marine Laboratory, Dr. W. H. Heard, FSU Biological Science Department; and Mr. John R. Hall, NMFS, Panama City, Florida for assistance in the confirmation and identification of certain macroinvertebrate species.

Monsanto Chemical Corporation, Air Products and Chemicals, Inc., and American Cyanamid Co. for providing their water quality data.

Dr. Ralph D. Harkins, Environmental Protection Agency, Robert S. Kerr Environmental Research Laboratory, Ada, Oklahoma for providing the basic computer program used in the calaculation of PNI values.

Mr. Don Lawhorn, EBRS, for assisting in field studies and for maintaining field equipment in excellent condition.

Mrs. Cathrine Willard, EBRS, for typing this report and performing secretarial duties for the project. Mrs. Veronica O'Hearn, EBRS, for performing secretarial duties. Mrs. Elizabeth Korhonen, SAD, and Mrs. Elizabeth Dempsey, Water Division, for assisting in typing this report.

Mr. Roy Weimert (SAD) for preparing drawings for the report.

The following part time employees of EBRS:

John C. Wright	Cynthia Nametz
Mahlon Doug Sellers	Marvin Kaplan
Diane C. Ricksecker	James A. Harper
Paul G. Johnson	William L. Howell
Steven B. Dubose	Rodney A. Smith
James E. Pritchett	William T. Dungan

2 - SUMMARY

The major goal of this study was to determine methods of accelerating the recovery of Escambia Bay over and above reducing waste discharges into the bay. To accomplish this, studies were performed in the entire Pensacola Bay system. The study period was October 1972 through September 1974.

AREA DESCRIPTION

Escambia Bay is part of the Pensacola Bay system which also includes East, Blackwater, and Pensacola Bays (Figure 4-1). The total surface area of the bay system is 373 km^2 (144 mi^2). The drainage area of the bay system consists of 17,550 km^2 (6,778 mi^2) in Alabama and Florida. Major tributaries to the system are the Escambia, Blackwater, and Yellow Rivers.

Seasonal variation of wind, air temperature, and precipitation have a significant effect on the bay system. Prevailing winds during the study period were from the northeast with velocities between 8.4 and 17.6 km/hr (4.5 to 9.5 k). Annual precipitation was above normal during the first year of the study period and about normal during the second year of the study period. Mean monthly temperatures were slightly higher than normal during the study period.

POLLUTION SOURCES

Pollution discharges are classified as point and non-point sources. Point sources include effluents from municipal-private domestic wastewater treatment plants and from industrial plants. Non-point sources include urban stormwater runoff, agricultural runoff, forest and swamp drainage, and runoff and groundwater seepage into surface waters.

The massive quantities of point source waste previously discharged into the Pensacola Bay system between 1955 and 1964 have been significantly reduced. Based on surveys by USEPA and its predecessor agencies, the combined quantity of waste discharged by the four major dischargers into the Escambia Bay drainage area--Container Corporation of America, Monsanto Chemical Co., American Cyanamid Co., and Air Products and Chemicals plants--has been reduced between September 1969 and January 1975 by 40 percent for BOD_5, 71 percent for total nitrogen, and 96 percent for total phosphorus. Based on discharge limitations in NPDES permits (as of January 1975), Escambia Bay received the largest portion of the BOD_5 (34 percent) and total nitrogen (43 percent) loads discharged by point sources. The largest portion of the total phosphorus load (44 percent) entered Pensacola Bay.

Pensacola Bay received the greatest quantity of BOD_5 and significant amounts of total nitrogen and phosphorus from non-point sources entering the estuarine reaches of the Pensacola Bay

system. Escambia Bay received the lowest quantities of BOD_5, total nitrogen, and total phosphorus because the bluff on the western shore causes most urban stormwater runoff to enter Bayou Texar instead of Escambia Bay.

HYDRODYNAMICS

Circulation in an estuary depends on many factors including river inflow, tides, and wind. The relationships among these factors are extremely variable and complex. The estimated mean annual discharge into the Pensacola Bay system is 311 m^3/sec (11,000 cfs), and the estimated seven-day low flow that occurs once every ten years (seven-day, 10-year low flow), which is usually used to describe critical streamflow conditions, is 61 m^3/sec (2160 cfs). This is about 20 percent of the mean annual flow.

Higher than normal river discharges occurred during the periods when EBRS performed field studies. The mean annual discharge of the Escambia River at Century, Florida from 1935 to 1974 was 170 m^3/sec (6016 cfs) and the mean annual discharges at this location for water years 1973 and 1974 were 293 and 190 m^3/sec (10,350 and 6,708 cfs), respectively.

Extremely low flows occurred in the Escambia River during 1967, 1968 and 1969, when the mean annual flows at Century, Florida were 120, 100 and 82 m^3/sec (4,240, 3,530 and 2,895 cfs), respectively. Circulation in the Pensacola Bay system should have been considerably weaker during these years than was observed during the study period by EBRS because water year 1973 was an extremely high flow year and water year 1974 was an above average flow year.

Tidal energy in the Pensacola Bay system is relatively weak because of the low mean tidal range of 0.5 m (1.5 ft). In addition, there is rarely more than one tidal cycle per day. The tidal range also cycles approximately every two weeks from 0.8 m (2.5 ft) during tropic tides, to 0.2 m (0.5 ft), during equatorial tides. Circulation is extremely weak when equatorial tides occur.

Circulation in the Pensacola Bay system varied between two-layer flow with entrainment and two-layer flow with vertical mixing. Mean water transport over a tidal cycle was normally seaward in the upper layer of the Pensacola Bay system and riverward in the lower layer. Consequently, the system was usually vertically stratified and there was little exchange between the outflowing upper layer and inflowing lower layer. An analysis using the Two Layer Model, described by Bowden (1967), indicated that under slightly less than average flow (148 m^3/sec) and average tide conditions, the flushing time for the Pensacola Bay system was about 34 days. The model indicated a 60 day reduction in flushing time was caused by tidal mixing. If it is assumed that tidal mixing would also cause a 60-day reduction in

flushing time during low flow conditions, the flushing time would be about 200 days when river inflow is equal to the seven-day, ten-year low flow of 61 m^3/sec.

Under certain meteorological conditions, current reversals occur in the bay; hence, inflow takes place in the upper layer and outflow occurs in the lower layer. This means that waste discharges into the bay are sometimes transported riverward and remain in the system for a longer period than the flushing time suggests. Wind is probably the most influential factor in causing these current reversals.

Salinity data and the August 1973 dye study indicated that more freshwater flows down the western sides of Escambia and East Bays than the eastern sides. This appeared to be due to the Coriolis force which is caused by the earth's rotation.

Based on the August 1973 dye study, the L and N Railroad bridge pilings did not appear to significantly hinder circulation in upper Escambia Bay after excess pilings had been removed. The dye study also indicated that the time of travel of the major dye peak was 2.3 days from the mouth of the Escambia River to the mouth of Escambia Bay when Escambia River inflow was about average annual flow (190 m^3/sec).

Based on field flow estimations, about 25 percent of the total flow of the Escambia River basin entered the northwestern section of upper Escambia Bay through the Little White and Simpson Rivers. This freshwater inflow traveled seaward along the Escambia River delta, not throughout the entire northeast section of the upper bay.

Discharges from American Cyanamid Co. and Air Products and Chemicals, Inc. plants tended to accumulate in the vicinity of the Air Products outfall (based on dye study results). The effluent from Air Products and Chemicals, Inc. stayed close to the shore north and south of the outfall.

The existing Main Street Wastewater Treatment Plant outfall terminates at a location where currents transport the effluent into Bayous Chico and Grande.

Circulation in the Pensacola Bay system was weak and not conducive to a high assimilative capacity. Although currents in some areas were stronger than in others, all currents were relatively weak. Currents in the lower layer were extremely weak.

Circulation in the northeast arm and in the dredged finger canals of Mulatto Bayou was weak during June and July 1974. Dead fish caused an algae bloom in the unused finger canals of the bayou, and, later, the algae were transported to the main area of the bayou by wind.

BAY SEDIMENTS

The composition of the sediments in the Pensacola Bay system and in northeast Gulf bays (Choctawhatchee Bay and Panama City bays) was compared during this study.

Sediments in Escambia Bay consisted of sandy material near the shore grading into mud in the central portion of the bay. The sand shelf ended rather abruptly, with a change in slope into the transition zone which consisted of a sand mud mixture on a relatively steep slope down to the mud plain. The mud plain was almost flat and extended throughout the central bay area. Particle size classification at stations on the sand shelf was sand, whereas size classification at transition zone stations ranged from sand to clayey silt. Mud plain station sediment size classifications ranged from sand to clay. The sand shelf on the western shore was narrow and the gradient down to the mud plain was steep. On the eastern side of the bay, the shelf was wider, oyster beds were present, and the slope down to the mud plain was more gradual. Water depth over the mud plain increased seaward. Mud percentage increased with water depth throughout the Pensacola Bay system.

Total phosphorus, organic nitrogen, and organic carbon concentrations in sediments throughout the Pensacola Bay system increased with water depth, and, therefore, mud content. Total phosphorus and organic nitrogen concentrations were generally higher in Escambia Bay sediments when compared to East Bay sediments. Escambia Bay tended to have slightly lower organic carbon concentrations than East Bay. Concentrations of total phosphorus, organic nitrogen, and organic carbon were higher in Choctawhatchee Bay and Panama City bays than in Escambia Bay.

Volatile organic sediment material in Escambia Bay was distributed with highest concentrations in deeper waters. Escambia and East Bays have similar concentrations in like sediments; however, concentrations were higher in Pensacola Bay than in East Bay. When compared to several northeast Gulf bays, volatile organic material in Escambia Bay sediments had a similar distribution.

The area of higher BOD_5 concentrations in Escambia Bay sediments coincided with the zone of maximum mixing of fresh and saline waters. Flocculation of dissolved organics occurred in this mixing zone with ultimate deposition in bay sediments.

Concentrations of BOD_5 were highest near industrial discharges. Compared to the other bays studied, BOD_5 concentrations in Escambia Bay sediments were not unusually high except around the industrial waste discharges.

Polychlorinated biphenyl (PCB) leaked into the Pensacola Bay system from the Monsanto Chemical Co. plant in 1969. Aroclor 1254 (a trade name of a type of PCB) was found in sediments

throughout the Pensacola Bay system, with higher concentrations in the finer sized particles. Stations with high PCB concentrations include those in the channel and near the industrial waste discharges in the northeast portion of Escambia Bay. This study, plus previous work (Nimmo, et al., 1975; US-EPA, unpublished data), indicated that the Aroclor 1254 was being removed from the sediments at a rate of about 90 percent per year between 1969 and 1974.

Dieldrin was the only pesticide, among the 21 investigated, that was detected in Escambia Bay. Use of this highly toxic pesticide will soon be greatly restricted.

Eleven of the twelve metals analyzed in sediments of the Pensacola Bay system were most concentrated in the finer grained sediments. There were seven metals that had similar concentrations in both East Bay and Escambia Bay. These metals were lead, zinc, chromium, manganese, nickel, aluminum, and iron. Four metals--cadmium, copper, cobalt, and vanadium--had greater concentrations in Escambia Bay than in East Bay. Titanium was equally distributed throughout all bays of the system regardless of sediment type.

The dredged channel in Escambia Bay acted as a sink for silt and clay particles and fine organics. Consequently, mud content and volatile organic material concentrations were higher at channel stations within the bay. In the Escambia River portion of the dredged channel, these two constituents had low values. Nutrient concentrations were also low in the dredged river channel and high in the bay channel sediments. Total phosphorus and organic nitrogen were higher in the bay channel sediments than in sediments at stations adjacent to the channel on the mud plain. Metal and PCB concentrations were also higher in channel sediments than in the adjacent muds.

Microbial activity (as determined anaerobically by the reduction of triphenyltetrazolium chloride) in the sediments of Blackwater Bay, East Bay, and Pensacola Bay was similar to that observed in the sediments of Escambia Bay. Northeast Escambia Bay sediments near the industrial outfalls had microbial activity that was similar to sediments at other location in the Pensacola Bay system. Sediments from the river stations and shallow bay stations which were high in percent sand and low in percent volatile organic matter had low values of microbial activity. As the percent volatile organics increased, a corresponding increase in microbial activity usually occurred until a plateau near the one percent level was reached. A concomitant increase in microbial activity with percent volatile organics was not observed above a one percent organic content.

Significant amounts of total nitrogen, and negligible amounts of total phosphorus, were released from Escambia Bay sediments during a sediment nutrient release study performed under aerobic conditions. The quantity of nitrogen released was directly

proportional to volatile organic content of the sediments. A larger amount of nitrogen was released from sediments located near the industrial and sewage outfalls.

WATER QUALITY

Total organic carbon (TOC) concentrations were uniformly distributed in the waters of the Pensacola Bay system during the 1974 study period and they consistently exceeded 2.0 mg/l (a maximum concentration to avoid nutrient enrichment, derived from Water Quality Criteria, 1972). Based on limited data, total organic carbon concentrations in Escambia Bay appeared to decrease by 12 percent between 1969 and 1974. Pensacola and Choctawhatchee Bay systems had about the same TOC concentrations under similar hydrological conditions in 1974.

Total nitrogen concentrations in the waters of Escambia Bay were significantly higher than in the rest of the Pensacola Bay system during 1974. Escambia Bay had mean total nitrogen concentrations that exceeded 0.360 mg/l, a recommended maximum level to avoid nutrient enrichment in marine waters (Water Quality Criteria, 1972), during 10 of the 12 surveys performed in 1974. The remainder of the Pensacola Bay system had mean concentrations lower than this value. Total nitrogen concentrations in the Pensacola Bay system were significantly higher than those in Choctawhatchee Bay under similar hydrological conditions in 1974. Total nitrogen concentrations in upper Escambia Bay appeared to decrease by 50 percent between 1969 and 1974, based on a two-day survey in 1969.

Total phosphorus concentrations were also distributed uniformly throughout the Pensacola Bay system in 1974, and they were consistently below the 0.05 mg/l recommended maximum level to avoid nutrient enrichment in marine waters (Water Quality Criteria, 1972). Based on limited data, total phosphorus in Escambia Bay appeared to decrease by 75 percent between 1969 and 1974. Choctawhatchee and Pensacola Bay systems had about the same total phosphorus concentrations under similar hydrological conditions in 1974.

A nonparametric statistical classification procedure was used to combine total organic carbon, total nitrogen, and total phosphorus data into a single value designated the Principal Nutrient Index (PNI). A PNI value of 9.0 (based on statistical manipulation of 2.0 mg/l - total organic carbon, 0.36 mg/l - total nitrogen, and 0.05 mg/l - total phosphorus) was used to distinguish between excessive nutrient enrichment and acceptable aquatic conditions. During the September 1969 survey, 91 percent of the PNI values in Escambia Bay were greater than 9.0. The mean PNI value of pooled data for upper Escambia Bay during the summer of 1974 was 10.6, which was a 41 percent decrease from the 1969 value. Values of PNI near waste discharges and in Bayou Texar and Mulatto Bayou were higher than those at adjacent locations.

Dissolved oxygen concentrations in Escambia Bay appeared to improve between 1969 and 1973 through 1974. The high diurnal variation in dissolved oxygen observed in 1969 was not observed in 1973. During the 1974 study period, there were two periods of low dissolved oxygen, one in the early spring and another in late summer. The period in early spring occurred after high river inflows and the one in summer occurred when salinities in the system were high and river inflow was low (indicating poor flushing). During both periods lower bottom dissolved oxygen concentration occurred near the industrial discharges in northeast Escambia Bay (Station EGLY). The available data for Pensacola Bay during 1974 indicated that low dissolved oxygen concentrations in Escambia and East Bays during the spring of 1974 were not caused by a water mass from Pensacola Bay entering these systems. Benthic oxygen demand from the sediments appeared to be a significant factor in causing low bottom dissolved oxygen concentrations.

Vertical stratification in the system was observed in the salinity data and also in the dissolved oxygen data. Bottom dissolved oxygen concentrations were always lower than surface concentrations. This occurred because the dissolved oxygen removed from the lower layer by benthic demand was not continuously replaced when the system was stratified, since there was very little exchange between reaerated upper layer water and lower layer water.

Based on dissolved oxygen concentrations measured in East Bay, low dissolved oxygen concentrations occur during critical periods (high temperatures, low river inflow) in bays that do not receive direct point source waste discharges. Consequently, due to naturally poor circulation and non-point source discharges in the Pensacola Bay system, the assimilative capacity of the system with respect to oxygen resources should be extremely limited.

Ultimate BOD values during the 1974 study period were approximately the same as 1973 values. Ultimate BOD concentrations in northeast Escambia Bay near the industrial outfalls were higher than in the Escambia River.

Total and fecal coliform densities were greatest in the Escambia River and upper Escambia Bay. These densities decreased as the river water dispersed into the upper bay and diminished progressively in a seaward direction. Natural die-off and increasing salinity also contributed to decreased bacterial densities. Total and fecal coliform densities were higher following periods of heavy rainfall and increased river flow, which indicated that the higher densities observed were due to runoff and swamp drainage. All of the Class III waters (recreation - fish and wildlife) in the Pensacola Bay system except the tributaries, were within the mean total coliform and fecal coliform limitations specified in the Florida water quality standards.

Waters in Escambia Bay and East Bay complied (in most instances) with the mean coliform shellfish standard in areas opened to harvesting oysters. Violations of the maximum standard occurred more than ten percent of the time at most stations in Class II waters (shellfish harvesting).

The highest turbidities in Pensacola Bay system waters were measured during winter and spring when rainfall in the drainage area was high, and the lowest values were measured in summer during low river inflow periods. Higher turbidities were measured in the Conecuh-Escambia River than in the Blackwater and Yellow Rivers. This occurred because most of the Conecuh-Escambia River drainage basin is an area with clay soils. Most of the drainage basins of the Blackwater and Yellow Rivers are areas with sandy soils. Mean turbidities in Blackwater and East Bays were considerably lower than those in Escambia Bay. None of the turbidity values measured in the bays during the 1974 surveys exceeded the State of Florida water quality standard of 50 jtu for Class II and III waters.

Point sources of waste contributed the greatest portions of the BOD_5, total nitrogen, and total phosphorus loads to the Pensacola Bay system (based on allowable discharges in NPDES permits in effect during January 1975 and critical (60-day, 10-year) low flows in the rivers tributary to the bay system, and average annual non-point discharges). Tributary rivers and non-point sources of waste followed point-sources with decreased pollutant contributions. Low flow conditions were used to determine the pollutant loading from tributary rivers because low flow periods generally occur in late summer and early fall when the water temperature of the bays is highest, the bottom dissolved oxygen concentrations lowest, the chlorophyll a concentrations (phytoplankton) highest, and when most of the fish kills occur. Under allowable discharges in NPDES permits in effect during January 1975 and low flow conditions, it was estimated that 38, 41, and 21 percent of the BOD_5 loads discharged into the Pensacola Bay system were from tributary rivers, point sources and non-point sources, respectively. At a later time, when final NPDES limitations will be in effect, and under low flow conditions, it is estimated that 50, 22, and 28 percent of the BOD_5 loadings will be from tributary rivers, point sources, and non-point sources, respectively. Point source discharges will still be the greatest contributor of total phosphorus, 45 precent, when final NPDES effluent limitations are in effect. Accordingly, the theory held by many, that point source discharges are insignificant compared to contributions from tributary rivers and non-point sources, is incorrect.

PLANKTON

Plankton studies were performed by the University of West Florida (UWF) and EBRS in the Pensacola Bay system. The University's work on primary productivity indicated that Escambia Bay and East Bay had similar production. Comparing Escambia Bay

with Port Royal Sound, South Carolina, shows that Escambia Bay was several times less productive. Escambia Bay, when compared to several systems throughout the Gulf Coast, had a low primary productivity. All counts of, and seasonal succession of, phytoplankton were similar in Escambia Bay and East Bay; however, because of river inflow, Escambia Bay had a less uniform distribution of phytoplankton than East Bay.

Seasonal trends and total counts of zooplankton were similar in Escambia and East Bays. No differences were noted between the bays within the dominant groups of organisms. Acartia tonsa was the dominant organism in both bays.

Chlorophyll a concentrations were compared throughout the Pensacola Bay system. Escambia Bay had higher concentrations than other bays in the system, with concentrations higher in the upper estuary and decreasing toward the Gulf inlet. Mulatto Bayou and Bayou Texar had the highest concentrations of chlorophyll a in the bay system and most of the time bloom conditions were present.

FISHES

Investigation of the fish fauna was directed toward developing a pertinent and reproducible data base for future assessment and to ascertain the present status of the finfishes and penaeid shrimps.

During the year, a total of 79,373 fishes, representing 57 species and 32 families, was taken in the otter trawl and seine collections at 15 stations throughout the estuary. The average trawl catch was 568 individuals per collection.

The dominant pelagic fishes in both the trawl and seine collections were the bay anchovy (Anchoa mitchilli), Gulf menhaden (Brevoortia patronus), striped anchovy (A. hepsetus), tidewater silverside (Menidia beryllina), and Atlantic bumper (Chloroscombrus chrysurus); whereas the most abundant benthic species were the spot (Leiostomus xanthurus), Atlantic croaker (Micropogon undulatus), and sand seatrout (Cynoscion arenarius). An additional fifty other species were represented in the catches.

Fish kills are visible indications of conditions of poor water quality. In the past, pollution-caused kills were linked with excessive amounts of nutrients, polychlorinated biphenyls, sewage, oils, phenols, toxic metals, pesticides, and other industrial by-products. In general, reductions in industrial waste discharges paralleled similar declines in the number of fish kills. From 1970 through 1974, the frequency of fish kills in Escambia Bay and associated bayous dropped by 86 percent; in the entire Pensacola Bay system, the number of kills was reduced by 75 percent. In addition, there were no massive kills in the Pensacola area in 1974.

Freshwater angling in the lower Escambia River and delta tributaries is a popular sport. The most sought after and most frequently caught species were bluegill (Lepomis macrochirus), redear sunfish (L. microlophus), and largemouth bass (Micropterus salmoides). Based on a comparison of the catch rates between the 1970 and 1974 creel surveys (both approximately 1.0 fish per angling hour), there has been no significant improvement in this fishery.

An analysis of the diversity of the fish communities provided a technique for ascertaining the effects of pollution or environmental stress. In Escambia Bay, species diversity (Shannon-Weaver formula, H') was inversely correlated with the nutrient concentrations (PNI) in the water column. In other words, higher nutrient concentrations contributed to lower species diversity, whereas low nutrient levels resulted in higher species diversity in various areas of the bay and bayous. Overall, nutrients contributed 42 percent of the variance of diversity. It is apparent that further reductions in waste discharges will contribute to the well-being of fish populations.

Both the relative abundance and species diversity of the fish populations in Escambia Bay were similar to, and in some instances superior to, many estuaries in the northern Gulf of Mexico. In general, the finfish populations and the nursery grounds (for fishes) were judged to be in an intermediate stage of recovery.

The decline in shrimp fishery was attributed to the deterioration in the bottom habitat by various pollutants. However, persistent pollutant residues in the sediments, such as PCB, and associated materials in the water column continue to obstruct the development of a viable shrimp fishery. Further leaching of various foreign substances from the sediments should lead to improved conditions on the bottom. At present, both the shrimp fishery and nursery grounds are in the early stages of recovery.

In some estuaries, the bottom environment might be altered to improve conditions. In Escambia Bay, an intensive study of utilization of two major substrates (compact shell and soft mud) revealed that both bottom areas were quite productive. Large-scale changes in the existing substrates, at least in the open bay, would not enhance bottom nursery habitat for young fishes and penaeid shrimps.

Historically, the anadromous striped bass (Morone saxatilis) inhabited the waters of Escambia Bay and River. The feasibility of re-establishing this valuable sport fishery was enhanced due to the overall improvement in environmental quality. In April 1975, five million fry, descendants of the famed striped bass population in the tail waters of the Santee-Cooper Reservoir in South Carolina, were stocked in the tributary streams of the lower Escambia River.

BENTHIC MACROINVERTEBRATES

Benthic macroinvertebrates at sand shelf, mud plain, and transition zone stations were compared for biomass, species number, and numbers of individuals. All three parameters increased from mud to transition to sand stations. The same trend applied for diversity (Shannon - Weiner formula, H'); that is, H' increased from mud to transition to sand. There was no significant difference within sand shelf stations between values for biomass, species number, number of individuals, and diversity for the upper bay compared to the lower bay and for the east side compared to the west side. The same is true for the transition zone and mud plain stations. In all cases except one, the winter samples within like sediments had higher biomass, species numbers, and numbers of individuals than did the summer samples. Biomass was higher in the summer at sand shelf stations.

Oyster bed stations had the highest number of species, diversity, and biomass of any other habitat in Escambia Bay.

Grass beds were the second most productive habitat in Escambia Bay. East Bay grassbed sample data were similar to the data for an Escambia Bay grassbed.

Near the Northeast Wastewater Treatment Plant discharge, the assemblage of organisms observed was similar to that found in other sediments with similar physical characteristics. However, samples at this station were taken a year later than those at comparable sediment stations, and the annual variation must be considered in evaluating the data.

At the industrial discharge stations, there was a shift in species types from mullusca and crustacea to polychaete worms. The species number, biomass, and numbers of individuals of organisms around the industrial discharges were altered only in a narrow band nearshore at the discharge from Air Products and Chemicals, Inc.

Deep water mud sediments in Escambia, East, and Pensacola Bays generally had similar assemblages, except Pensacola Bay which had two high salinity species that were not found in the other two bays.

The high salinity area assemblage sampled in Santa Rosa Sound produced by far a higher number of species, biomass, diversity, and number of individuals than found in the Pensacola Bay system.

Escambia Bay had diversity (H') values lower than values from Hillsborough Bay and Galveston Bay within comparable mud sediments during the summer, indicating stressed macroinvertebrate populations in Escambia Bay.

In general, Escambia Bay sediments supported a population of benthic macroinvertebrates similar to that in East Bay.

BENTHIC MACROFLORA

Seagrasses are an especially important component of an estuary, since they function as a nursery ground for finfish and shellfish. There has been extensive vegetation loss throughout the Pensacola Bay system. All seagrasses (Thalassia and Halodule) were gone except one bed on the northeast shore of East Bay, and this bed has diminished significantly. The shoreline near this bed is the least altered by man in the system and seems to have the least beach erosion. A persistent freshwater specie, Vallisneria americana, is growing well in Blackwater Bay but declined in upper Escambia Bay prior to 1974. However, in 1974 and 1975, there has been an expansion of Vallisneria in the Escambia River delta area.

Major causes of this vegetation loss were sewage and industrial waste discharges, dredging and filling, beachfront alteration, and changing watershed characteristics. In the Pensacola Bay system many factors have synergistically affected the entire system with certain factors having an increased local effect. For instance, the loss of vegetation around the Northeast STP was caused first by laying the discharge pipe directly through the bed and later by sewage effluents. Along the southern shore of East Bay, bulkheads and groins likely caused changes in nearshore water movements and, therefore, erosion of seagrass beds. Industrial discharges, no doubt, caused the loss of vegetation in the northeast section of Escambia Bay since these effluents remain near shore in that area. Dredging and filling of the Port of Pensacola caused turbidities which affected the vegetation in addition to the actual removal of the grassbeds in some instances.

In neighboring Santa Rosa Sound, seagrasses have remained relatively stable. This area should be considered as endangered, however, and every effort should be made to preserve the integrity of these seagrass beds.

Transplants of Halodule wrightii were taken from East Bay and introduced into Escambia Bay during July and September 1974. One-hundred plugs of H. wrightii were placed at each of four sites in depths from 0.3 to 1.0 m.

Observation of the plants in May 1975, after overwintering, revealed green leaves on 37 percent at one site, 10 percent at another site, and two sites were covered with 12 cm of sand. Additional leaves may have developed later in the spring as water temperature increased. In June 1975, additional transplanting was performed at two new sites and near two old sites. One month after transplanting, green leaves were observed on 23, 43, 61, and 78 percent of the plugs. Continued evaluation of the revegetation program will be performed by the Bream Fisherman Association of Pensacola and a UWF student as a special course project.

3 - CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

As evidenced by an improved dissolved oxygen regime, a reduction in frequency and intensity of fish kills, and attritional losses of toxic materials from the sediments, aquatic conditions in Escambia Bay were considerably improved during 1973 and 1974. These improvements resulted from a combination of higher than normal annual river inflows and accelerated pollution abatement efforts. Conditions will continue to fluctuate as a function of freshwater inflow, but overall quality can be expected to improve further as point source waste inputs are reduced. In addition to waste reduction, restoration techniques such as revegetation of marine grasses, relocation of waste discharge sites, stocking of striped bass, and implementation of an areawide water quality management plan will protect gains made in improved aquatic conditions. The following conclusions elaborate further (including reasons for rejecting certain types of restoration techniques such as selective dredging and tributary flow pattern alteration).

Environmental Quality

- Physical and chemical characteristics of sediments from Escambia Bay are similar to sediments from other Florida bays. Finer grained sediments with the highest concentrations of organic material, nitrogen, and phosphorus occurred at mud plain locations in each bay at deep water depths. Most of the particulate material entering the Pensacola Bay system from point and non-point waste sources and tributary rivers are retained in the system. However, this material is distributed throughout the bays before sedimentation occurs. Thus, the effects of the waste discharges are bay-wide.

- Based on all water quality data collected, aquatic conditions are worse in Escambia Bay than in the other bays of the Pensacola Bay system and Choctawhatchee Bay. Conditions appear to have improved in upper Escambia Bay based on decreased nutrient concentration between a two-day study in 1969 and studies performed in 1973 and 1974 under similar hydrological conditions.

- Nutrient enrichment was greatest in Mulatto Bayou and Bayou Texar, and algal blooms occurred there during the summer months.

- Based on rates of primary production, phytoplankton cell counts, and zooplankton counts, during 1973 and 1974, Escambia Bay and East Bay were similar to other northern Florida bays.

- Estuarine waters were functioning as productive nurseries for young fishes. The most productive nursery grounds for finfishes were in the semi-protected bayous and not in the open bays. The dominant fishes in Escambia Bay were anchovies, clupeids, and scianids. Similar faunal assemblages are found in other nearby estuaries of the northern Gulf of Mexico. Annual shifts in the number of species of fishes were related to seasonal changes.

- Overall, the condition of the fish populations and fishery was judged to be in an intermediate recovery stage, whereas, the penaeid shrimp nursery and fishery showed indications of an early stage of recovery. No improvement was noted in the freshwater sport fisheries on the lower Escambia River between 1970 and 1974.

- Based on limited sampling in East Bay, macroinvertebrate species found in a given type of sediment are similar in both Escambia Bay and East Bay.

- Escambia Bay sediments support stressed populations of benthic macroinvertebrates.

- Algal blooms in the partially constructed finger canals of Mulatto Bayou are intensified by weak circulation.

Causes of Environmental Problems

- Because of poor circulation and flushing characteristics, the assimilative capacity of the Pensacola Bay system is extremely limited and the bay is barely able to assimilate natural inputs of nutrients and oxidizing materials.

- Circulation caused most of the discharge from the American Cyanamid plant to be transported north toward Floridatown instead of seaward during the September 1974 survey. Effluent from the Air Products and Chemicals Inc. plant remained concentrated in the nearshore zone north and south of the discharge point during the August 1974 survey. Both effluents entered Mulatto Bayou.

- Critical aquatic conditions in the Pensacola Bay system occur in late summer when:

  1) The system is vertically stratified and oxygen is not transported from the upper layer, which undergoes reaeration, to the lower layer which must satisfy the benthic oxygen demand.

  2) Water temperature is highest which increases the rates of biological growth processes.

3) Low river inflows occur which reduce flushing and weaken circulation.

4) Low turbidities promote phytoplankton growth.

- Point source wastewater discharges are the major cause of poor aquatic quality conditions during late summer. Non-point sources and tributary river inflow also contribute to poor aquatic quality conditions.

- Although nutrient levels decreased between 1969 and 1973-1974, nutrient enrichment still exists in Escambia Bay. Nutrient concentrations during 1973-1974 usually exceeded the levels recommended in Water Quality Criteria (1972) for marine waters.

- In the past, nutrient enrichment in the Pensacola Bay system caused high phytoplankton concentration during summer months and contributed to benthic oxygen demand. Phytoplankton were a food source and attracted numerous fish (Menhaden) into areas where phytoplankton concentrations were high. Phytoplankton respiration and benthic oxygen demand depressed dissolved oxygen concentrations and caused fish kills.

- Tributaries were the major source of total and fecal coliform bacteria to the Pensacola Bay system. Wastes discharged from the Pensacola sewage treatment plants did not contribute significantly to coliform densities observed in Escambia Bay or Pensacola Bay except in the vicinity of the outfalls. The potential for the presence of pathogens based on coliform densities was greatest in the tributaries, bayous, northern Escambia Bay, and Blackwater Bay.

- Under aerobic conditions, significant amounts of total nitrogen, and negligible amounts of total phosphorus, were released from Escambia Bay sediments. The highest amounts of nitrogen were released from sediments located near American Cyanamid and Air Products and Chemicals Inc. plants and Northeast Wastewater Treatment Plant outfalls.

- Diversity of the fish communities was inversely related to nutrient content in the water column. That is, species diversity was depressed in areas with high nutrient concentrations, whereas diversity was improved in waters with low nutrient levels. The numerical distribution of the fishes and penaeids was not related to the major point sources of pollution in the upper bay.

- The decline in the shrimp fishery, since 1970, in the Pensacola Bay system is attributed to persistent pollutant residues in the sediments.

- Man's influence (dredge and fill activities, waterfront alterations, and waste discharges) appears to be the cause for the reduction of seagrasses.

Restoration

- The circulation of upper Escambia Bay improved after the excess pilings under the L and N Railroad bridge were removed in 1970.

- There is no evidence that diverting freshwater into the Little White and Simpson Rivers would change the flow pattern in the vicinity of Floridatown and improve water quality. The possibility exists that such changes could damage a productive fishery.

- The soft mud and compact shell bottoms are nursery grounds for young fishes. Major changes in either substrate would not speed up the recovery processes.

- Techniques for transplanting Halodule wrightii (shoal grass) have been developed. The best period for transplanting Halodule wrightii is late May or early June; however, transplants can live through the winter when planted as late as September. The plug method of transplanting (as used in this study) cannot be evaluated in less than two to three years since the plant will be living on the original soil during the first one or two years.

- It was not possible to evaluate the success of the initial stocking of striped bass in the lower Escambia River because of the projects termination.

RECOMMENDATIONS

1. An areawide pollution abatement and management plan should continue to be developed for the Pensacola Bay system and should be adopted. The planning process should:

   - Prohibit municipal-private domestic wastewater discharges into Escambia and Pensacola Bays, their tributary bayous, and the lower Escambia River other than the discharge from the Main Street Plant, which shall receive advanced waste treatment and not exceed 77,500 m^3/day (20 mgd).

   - Allow only existing municipal-private domestic wastewater discharges into East and Blackwater Bays, their tributary bayous, and the lower Yellow and Blackwater Rivers after advanced waste treatment has been provided.

   - Not modify the final effluent limitations of currently issued NPDES permits to reflect less stringent effluent limits.

   - Prohibit new industries from discharging wastewaters into the Pensacola Bay system and the lower reaches of tributary rivers.

   - Provide for the use of alternate methods of wastewater disposal, such as land application, where practical and where potable groundwater supplies are not endangered.

   - Formulate comprehensive land use management practices (stressing preservation of environmental quality) for Escambia and Santa Rosa Counties in order to address the control of non-point sources.

   - Develop and design an integrated physical, chemical, and biological ambient and waste source monitoring program.

2. The Main Street Outfall should be extended to discharge about 1830 m from shore to improve dispersion of the waste.

3. Effluents from American Cyanamid Company and Air Products and Chemicals, Inc., should be discharged through outfalls extended to the vicinity of the barge channel in Escambia Bay. The American Cyanamid plant outfall would have to be extended about 1920 m.

4. A detailed evaluation of the effects of open water disposal of dredged material on the environment, which

includes a cost-benefit analysis containing the cost of environmental damage, should be performed before open water spoil disposal is allowed in Pensacola, East, and Blackwater Bays.

5. No open water disposal of dredged material should be allowed in Escambia Bay. No dredging should be performed in Escambia Bay during June through October.

6. Contained spoil areas with discharges into the Pensacola Bay system should be designed to minimize the discharge of fine sediment materials into the receiving waters.

7. A striped bass fishery should be established in the Escambia River under the auspices of a government agency to augment the sport fishery and to better utilize the abundant forage base.

8. Research grants, from the Environmental Protection Agency and others, should be be awarded for revegetation of seagrasses in Escambia Bay in May-June, 1976.

9. The productive nature of the bayous, as a habitat for young fishes, should be recognized, enhanced, and protected in the Pensacola Bay system.

10. Partially constructed finger canals in Mulatto Bayou should be sealed off from the remainder of the bayou.

11. The deep borrow pits in Mulatto Bayou should be eliminated if fish kills occur in the Bayou in the future.

12. Every effort should be made to preserve the integrity of the seagrass beds in East Bay and Santa Rosa Sound.

4 - AREA DESCRIPTION

The Pensacola Bay system is located in Escambia and Santa Rosa Counties in the extreme northwestern portion of the State of Florida (Figure 4-1). The river systems that feed the bay have extensive drainage areas totaling 17,550 km² (6,778 mi²). The Escambia, Yellow, and Blackwater Rivers, which are the major tributary rivers, extend to the northeast into Alabama. Most of the Escambia River drainage basin is in Alabama, and only the upper reaches of the Yellow and Blackwater River basins are in Alabama.

The area adjacent to the Pensacola Bay system that drains directly into it is 828 km² (320 mi²), and the land use of this area are about 7, 74, and 19 percent agricultural, forest, and urban-residential, respectively. The rest of the drainage area has agricultural and forest land use.

The rivers draining into the Pensacola Bay system have been considered point sources discharging into the estuarine reaches of the system. Thus, the study area of this report is the Pensacola Bay system.

CLIMATOLOGY

Climatic conditions have a significant effect on aquatic systems. Winds, air temperature, and precipitation are generally seasonal with short-term variation due to local disturbances.

Wind

Wind velocity and direction can affect a body of water like the Pensacola Bay system in a number of ways. Winds can cause water to "pile up" on one side of the system and in this way reverse normal circulation patterns. Wind velocity is an important factor with respect to reoxygenation; high velocity wind transfers dissolved oxygen into the water at a rapid rate. Conversely, high wind velocity may resuspend sediments which can exert a considerable oxygen demand on the water column.

Prevailing winds were from the north at Pensacola Regional Airport (Table 4-1). The data were obtained from U.S. Department of Commerce (1972 to 1974, a). During October 1972 through September 1973 the prevailing winds were from the north (34 percent of the time). Winds were from the south and east about 22 percent of the time. West winds occurred only 16 percent of the time and were the least frequent. Calm conditions occurred 5.2 percent of the time. During October 1973 through September 1974, winds from the north and south occurred about 29 percent of the time. Winds from the east and west occurred 21 and 12

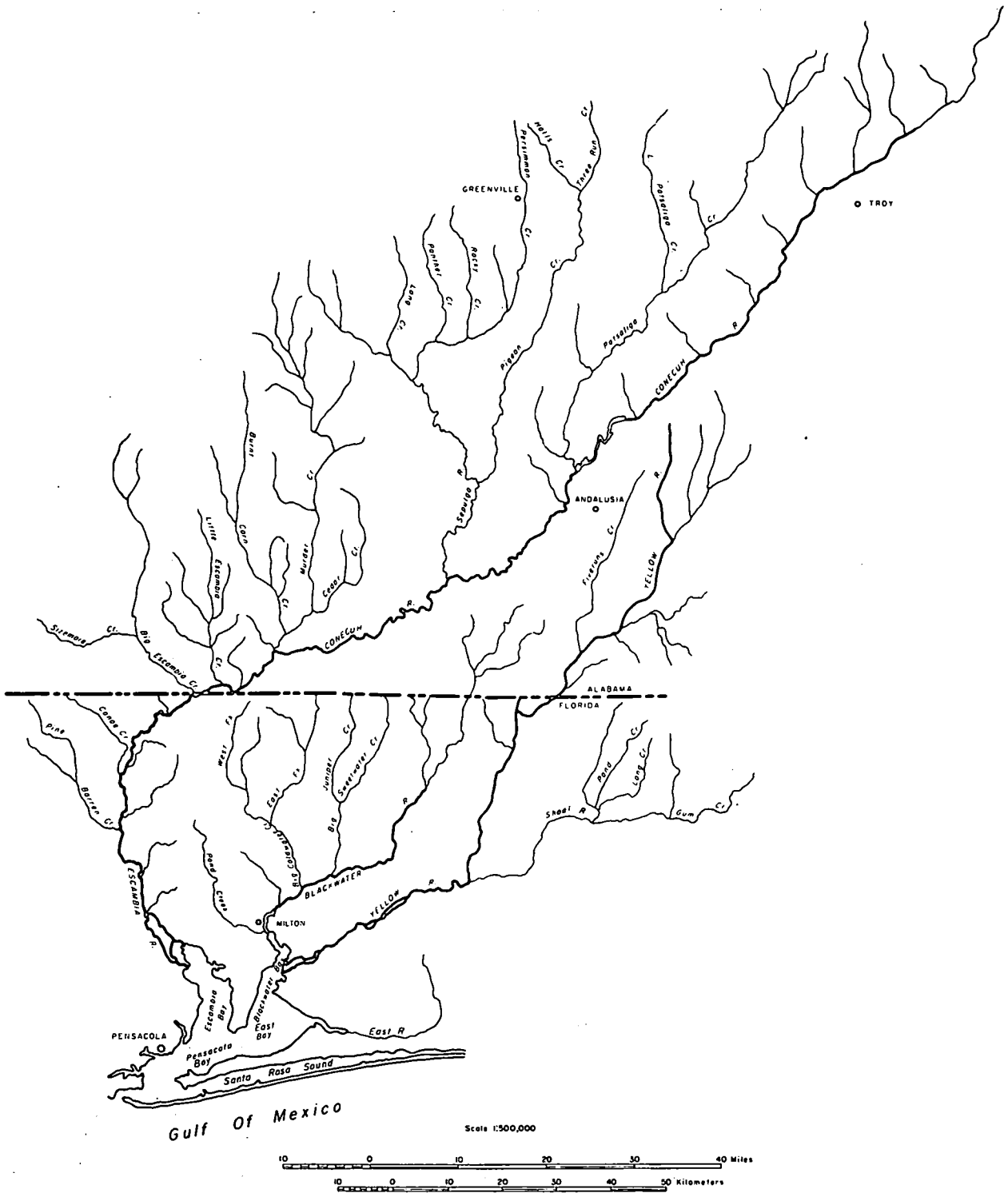


Figure 4-1. Map of drainage area.

Table 4 - 1. Frequency distributions of wind direction and velocity at Pensacola Regional Airport.

Direction		Date: Oct. 1972 to Sep. 1973	Oct. 1973 to Sep. 1974
		Percent of Time	
N (315 to 45)		34.2	29.2
E (46 to 135)		22.8	21.2
S (136 to 225)		21.7	29.9
W (226 to 315)		16.1	7.5
CALM		5.2	7.5
Velocity (km/hr)	(knots)		
CALM		5.2	7.5
1.2 to 8.3	0.5 to 4.5	19.8	12.2
8.4 to 17.6	4.6 to 9.5	54.5	52.3
17.7 to 26.8	9.6 to 14.5	23.7	24.1
>26.9	>14.6	5.8	3.9

percent of the time, respectively. Calm conditions existed 7.5 percent of the time. Data were not available to determine if the above conditions were normal.

The frequencies of wind velocities were similar during both periods, and velocities between 8.4 and 17.6 km/hr occurred slightly more than 50 percent of the time (Table 4-1).

Wind roses for conditions at Pensacola Regional Airport (Figure 4-2) indicate that winds with velocities between 8.4 and 17.6 km/hr occurred with the highest frequency in every direction, and that north and south winds generally have higher velocities than east and west winds. Winds from the northeast with velocities between 8.4 and 17.6 km/hr were the most frequent during both periods.

Mean wind velocities were about normal during the period when studies were performed by the Escambia Bay Recovery Study (Table 4-2). Lowest wind velocities (about 11 km/hr) normally occurred in July and August. During both years of the study period, mean wind velocities were slightly above normal in July and slightly below normal in August. Thus, the energy contributed by wind for circulation and reoxygenation was lowest during the summer months when critical conditions, with respect to dissolved oxygen, normally occur.

Precipitation

Surface water and groundwater discharges into rivers and estuaries are controlled by precipitation. The precipitation at Pensacola, Florida, and Andalusia, Alabama, (U.S. Department of Commerce, 1972 to 1974, b) is presented in Figure 4-3. Normal annual rainfall for Pensacola and Andalusia was 152 cm (60 in) and 145 cm (57 in), respectively. At Pensacola, Florida, during the period October 1972 to September 1973, the total annual rainfall was above normal at 188 cm (74 in), and during October 1973 to September 1974, the total annual rainfall was lower than normal at 140 cm (55 in). At Andalusia, Alabama, during October 1972 through September 1973, total annual precipitation was greater than normal at 196 cm (77 in), and during October 1973 through September 1974, total precipitation was 152 cm (60 in) which is greater than normal. Thus, the total annual rainfall during the first year of the study period was significantly above normal and during the second year about normal.

Air Temperature

Air temperature controls water temperature, which has a profound effect on the aquatic systems in an area. The saturation concentrations of dissolved gases in the water and the rates of respiration of organisms in the ecosystem are also affected by temperature. Mean monthly air temperature data for the Pensacola Regional Airport are presented in Figure 4-4 (U.S. Department of Commerce, 1972 to 1974, b). Normal mean monthly

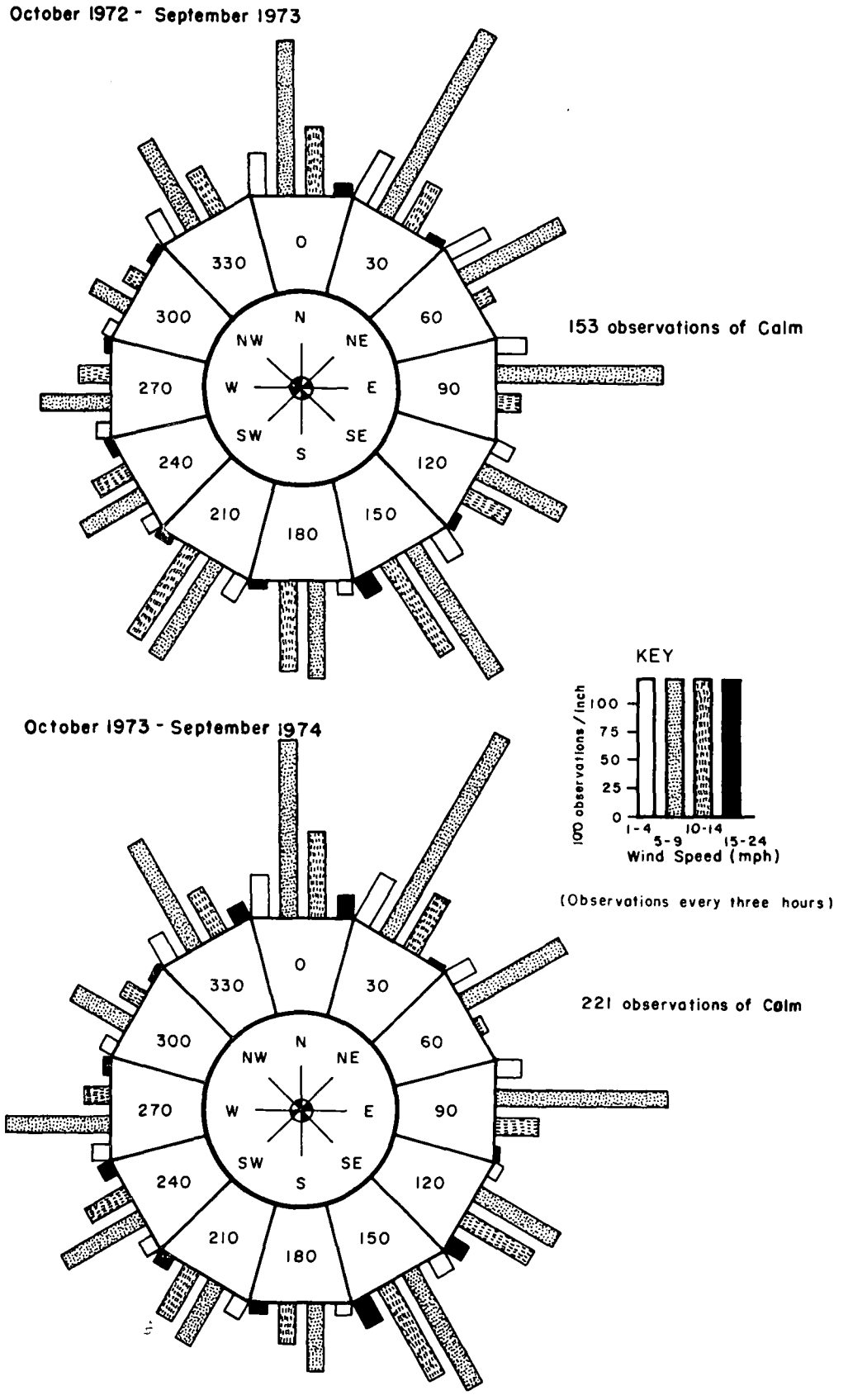


Figure 4-2. Wind roses at Regional Airport, Pensacola, Florida for October 1972 to September 1973, and October 1973 to September 1974.

Table 4 - 2. Mean monthly wind velocities (km/hr)** at Pensacola Regional Airport.

Month	Date		
	1972 to 1973	1973 to 1974	1941 to 1970*
October	13.2	12.1	12.9
November	15.8	13.2	12.9
December	15.3	17.2	14.5
January	15.6	13.3	14.3
February	15.4	15.9	15.1
March	17.2	15.3	15.3
April	17.9	15.9	15.1
May	16.1	14.2	13.8
June	12.2	12.7	12.1
July	11.1	11.1	10.8
August	9.5	9.8	10.5
September	13.2	13.5	12.4
Year	14.3	13.7	13.4

* Normals
** km/hr X 0.622 = mph

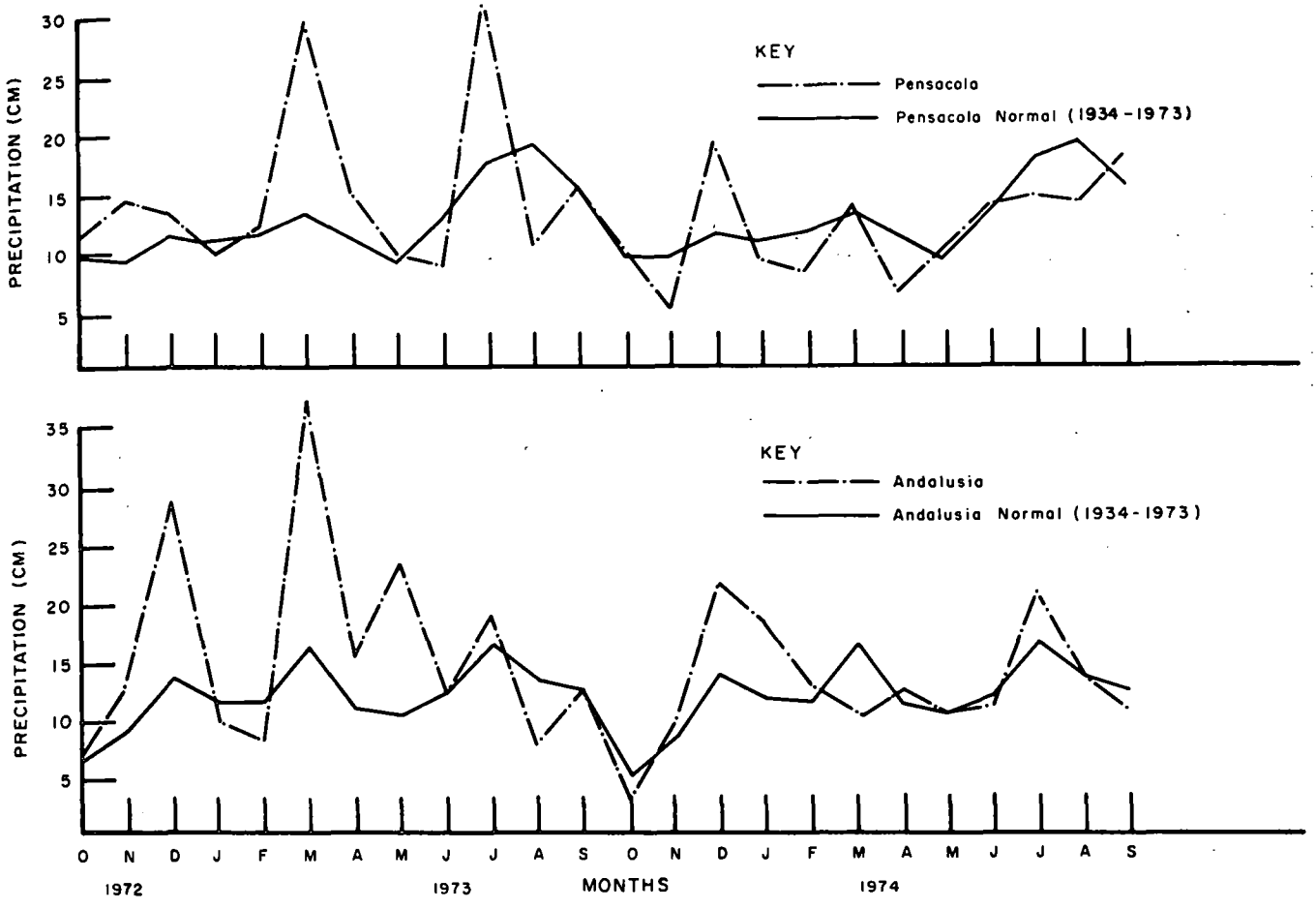


Figure 4-3. Total monthly precipitation records at Pensacola, Florida and Andalusia, Alabama for October 1972 - September 1974.

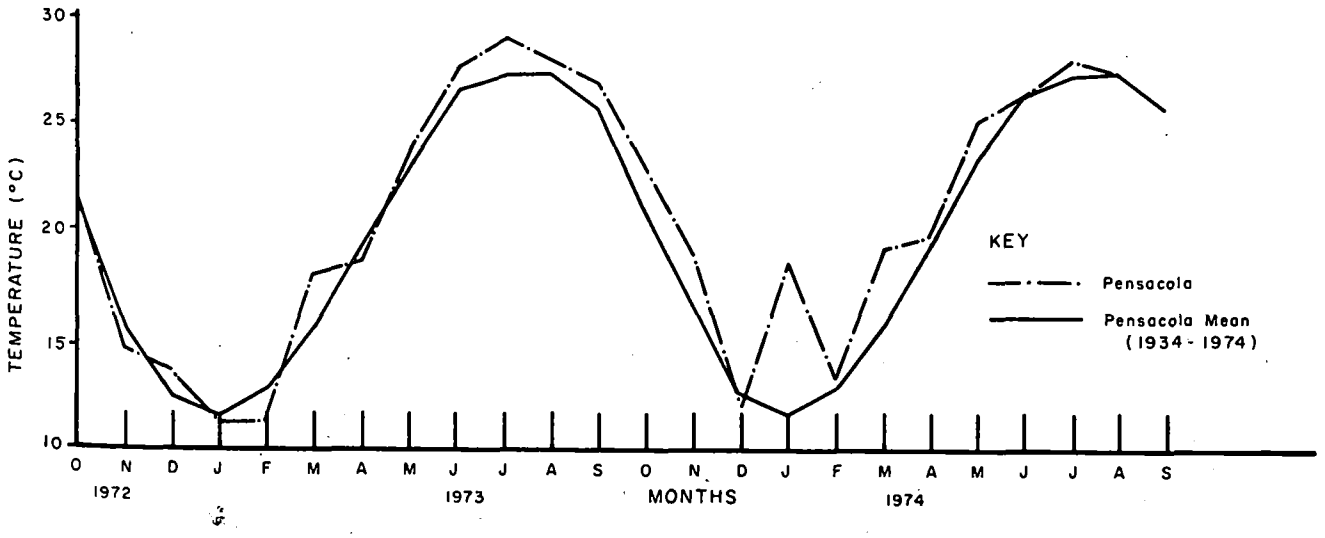


Figure 4-4. Mean monthly air temperature at Regional Airport, Pensacola Florida for October 1972 through September 1974.

temperature data for the period of 1934 through 1973 are also presented in the figure. Normally, January is the coldest month, with a mean temperature of about 12°C, and the highest mean temperature of about 27°C occurs in July and August. Mean monthly temperatures during October 1972 through September 1974 followed the same trend as the normal mean temperature, but were usually slightly higher.

POPULATION

The population of Escambia and Santa Rosa Counties is expected to more than double between 1970 and 2010. Population trends for this area between 1900 and 2010 are shown below:

Thousand persons (from Henningson, et al., 1975)

1940	1950	1960	1970	1980	1990	2010
91	131	203	244	327	427	570

ECONOMY

Pensacola Bay is an excellent, easily defended harbor and due to this, a military base and the City of Pensacola developed on its shores. In the late 1800's, Pensacola was a world timber center. Unfortunately, due to poor reforestation practices, this industry diminished in importance. Reforestation of the land led to the development of the paper industry in the area. Historically, agriculture and commercial fishing were extremely important to the economy of the area, but, at the present time manufacturing has surpassed them in importance. The Naval Air Station at Pensacola has been and is an important part of regional economy.

The proximity of Pensacola to the Gulf of Mexico and the abundance of historical landmarks has made this area a tourist attraction. The beautiful beaches and water resources of the area have contributed to the development of motels, restaurants, recreational related and travel oriented businesses. Unfortunately, Pensacola fell from the fifth to the thirteenth most visited city in Florida between 1961 and 1970. This adverse effect on tourism is believed to have been caused by a decline in water quality (Henningson, et al., 1975).

The economy of the area is characterized by a lack of industrial diversification, because there are only four major classifications of industries in the area: chemicals, lumber and wood products, food products, and stone, clay, and glass. These industries employ about 7,200, 2,400, 1,000 and 800 persons, respectively, (1967 census of manufacturing, p. 10-15, cited by Henningson, et al., 1975). The Pensacola Naval Air Station and outlying bases employ about 19,000 military and civilian personnel. Thus, of the 65,500 persons from this area that had

non-agricultural employment in 1969 (Henningson, et al., 1975), 22 percent or 14,300 were employed in manufacturing and 29 percent were employed by the military. Other employers besides industry and the military include retail stores, construction, and tourist-oriented trades and services.

RECREATION

Outdoor recreational opportunities in the Pensacola area are centered around water-borne and water-related activities. Water bodies available for recreation include large portions of the estuarine zone and the coastal waters of the Gulf of Mexico. These waters have become increasingly important as recreational resources because of the nearness of the major population center in northwest Florida. Popular features that attract people, both residents and visitors, include renowned, white-sand beaches, sparkling blue waters, picturesque bays, and mild climate.

Outdoor activities, enjoyed by all age groups, are generally similar in type, but often not in degree, to those in other sundrenched estuarine and coastal waters of Florida. Specific usage includes:

Boating (sail, motor, canoe)

Swimming and wading

Fishing (boat, pier, beach, and jetty)

Water skiing and surfing

Scuba diving and snorkeling

Picnicking and camping

Other shoreline activities (sunbathing, shelling, hiking, bird watching)

Waterfowl hunting

Aesthetic enjoyment.

The four most popular activities enjoyed by all age groups are swimming, sunbathing, boating, and fishing. Sailing has become increasingly popular, and a number of sailboat regattas, both local and regional in scope, are held in Pensacola Bay and offshore waters during the warmer months. In Florida, fishing was recently cited as the main reason that tourists return, but precise information is lacking on the monies generated by sport fishing activities in this area. During the warm summer months, crowds of people participate in swimming, sunbathing, and related shoreline activities.

In Escambia Bay, outdoor activities largely center around boating and fishing. Beach activities are limited, partly due to the lack of access points and to the less attractive brownish-sand shoreline that must compete with the famous Gulf beaches. Saltwater sport fishery in the bay and bayous and the popular freshwater fishery on the lower Escambia River and delta streams are major recreational outlets. In the fall, duck hunting is actively pursued along the shores and backwaters of the river.

Numerous water-oriented services and industries in the Pensacola area are dependent on the tourist industry, particularly those near the beaches. Included in this category are numerous motels, restaurants, boat agencies, marinas, tackle shops, charter boats, gasoline stations, and other related services. In turn, outdoor activities that attract people are interwoven and dependent on maintaining conditions of good water quality.

SPORT AND COMMERCIAL FISHERIES

Sportfishing in the Pensacola area may be divided, for discussion purposes, into three contiguous aquatic zones: Gulf waters, estuarine waters, and fresh waters. Fishermen must travel offshore, well beyond the sight of land to reach the more successful red snapper, grouper, and billfishing grounds. Billfishing is becoming increasingly popular and the established Pensacola International Billfishing Tournament is held each summer. In the inshore or coastal waters, those with smaller boats actively pursue the king mackerel, an extremely popular game and foodfish, from late spring until fall. Trolling with feather jigs and cigar minnows is a favorite and successful method for catching kings. In April, the fishing season is in full swing by the time the cobia (known locally as the ling) pass the area on their annual westward migration to Mississippi waters. Other species that are taken while trolling or casting include ladyfish, Spanish mackerel, and occasionally, dolphin, wahoo, and sailfish. Some spearfishing for groupers, flounders, and sharks occur around reefs and wrecks such as the U.S.S. Massachusetts which was sunk outside Pensacola entrance in 1922 during a demonstration of railroad artillery. Surf and pier fishermen take whiting (*Menticirrus* spp.), pompano, red drum, bluefish, and black drum; in addition to these species, king and Spanish mackerel and cobia are caught near the end of the beach pier.

In the estuarine waters of the bays, sounds, and bayous, the most sought after species is the speckled seatrout (or speck). Numerous fishermen will usually be found spin casting with jigs or lures or fishing with live shrimp over the grass beds for this popular fish. The best fishing period is late spring to early summer. In Escambia Bay, the L and N Railroad trestle, which spans the bay, is a favorite fishing site for specks in the fall and winter.

During the warmer months, schools of Spanish mackerel, crevalle jack, ladyfish, and Atlantic bonita, are found in the open waters of the estuary. Spin casting and trolling are the most used fishing methods for these pelagic fishes. Other sport fishes, that mainly frequent the more saline portions of the bays and bayous, include flounders, red drum, striped mullet, king mackerel, spot, spadefish, sheepshead, and pompano. The mullet is a fine food fish that is rarely taken by hook-and-line, but when schooling, they are readily caught with snag hooks or cast nets.

In Florida, when replacement bridges are built, the old structures are usually converted to stationary fishing platforms, such as the Pensacola Bay (three-mile bay bridge) and Santa Rosa Sound bridges. Maintaining old bridges for fishing purposes is not the case in some coastal states. Many avid bridge fishermen, often in family groups, travel long distances in order to bottom fish for white trout, Atlantic croaker, sheepshead, speckled seatrout, and flounder. Bridge fishing is such a popular and enjoyable pastime that many individuals camp and fish all night from these structures.

Lower reaches of the rivers, such as Escambia, Blackwater, Yellow, and East Bay Rivers, are frequented by freshwater fishing enthusiasts. The largemouth bass, warmouth, channel catfish, red ear, and spotted sunfish form the bulk of the catches. The last two species are more readily known in this region by their colorful vernacular names, which are "shell cracker" and "stump knocker," respectively. Results of two recent creel surveys on the lower Escambia River are analyzed in Chapter 10.

Although there are no statistics on the marine sport fisheries of the Pensacola area, the value and magnitude of this resource can be inferred from regional figures for the eastern Gulf of Mexico (Deuel, 1973). In the 1970 saltwater angling survey, the eastern Gulf was defined as the area along the Gulf Coast from the Florida Keys to the Mississippi River Delta. The estimated number of saltwater fishermen and their catches were:

	Fishing area		
	Ocean	Estuary	Total
	Thousands		
Number of fishermen	633	915	---
Number of fishes caught	42,352	146,336	188,888
Total weight of fishes	111,177	222,943	334,120

There was no firm total for the number of fishermen, because some anglers fished in both areas. However, approximately 1.5 million individuals participated in saltwater sport fishing in the eastern Gulf in 1970 and caught an estimated total of 189 million

fishes; the average catch rate was 122 fishes (or 216 lbs) per angler per year. Of the total saltwater catch, 78 percent of the fishes were caught in various bays, sounds, and tidal rivers of the estuarine zone. A recent survey revealed that a total of 349,000 private recreational boats were used in saltwater fishing in the Gulf of Mexico from November 1972 through October 1973 (Ridgely, 1975).

From different regions of the country, it has been estimated that 65 to 90 percent of the species in the commercial landings are estuarine-dependent (Sykes, 1968). Estuaries provide an essential and irreplacable habitat for finfish and shellfish species at various phases of their life cycle.

The importance of commercial fisheries to the economy of the Pensacola area can be judged from records of commercial landings in Escambia County during the past ten years (Florida Department of Natural Resources, 1964-72 and U.S. National Marine Fisheries Service, 1974). Annual landings are comparable in terms of either dollars or weights, or both (Figure 4-5). However, weights are generally preferred for evaluating fluctuations and trends because poundage is less influenced by inflationary increases than are dollars.

Not all of the finfishes in the landings by county were caught in nearby estuarine and coastal waters. Some may have been taken in distant waters, such as off Louisiana and Campeche, Mexico. However, more precise yields by area are kept for selected valuable species, such as shrimp and oysters.

Annual poundage of finfish and shellfish in the commercial landings of Escambia County steadily increased from a low of 3.2 million pounds in 1966 to a 10-year high of 5.6 million pounds in 1973. The five-year annual catch in the 1969-73 period represented a 21 percent increase over the previous 1964-68 period (Table 4-3).

The composition of the commercial landings in Escambia County in 1973 was:

Species	Pounds
Fishes	4,649,294
Blue Crab	69,451
Spanish lobster	62
Oysters	7,287
Shrimps (heads-on)	906,133
Squid	12,516

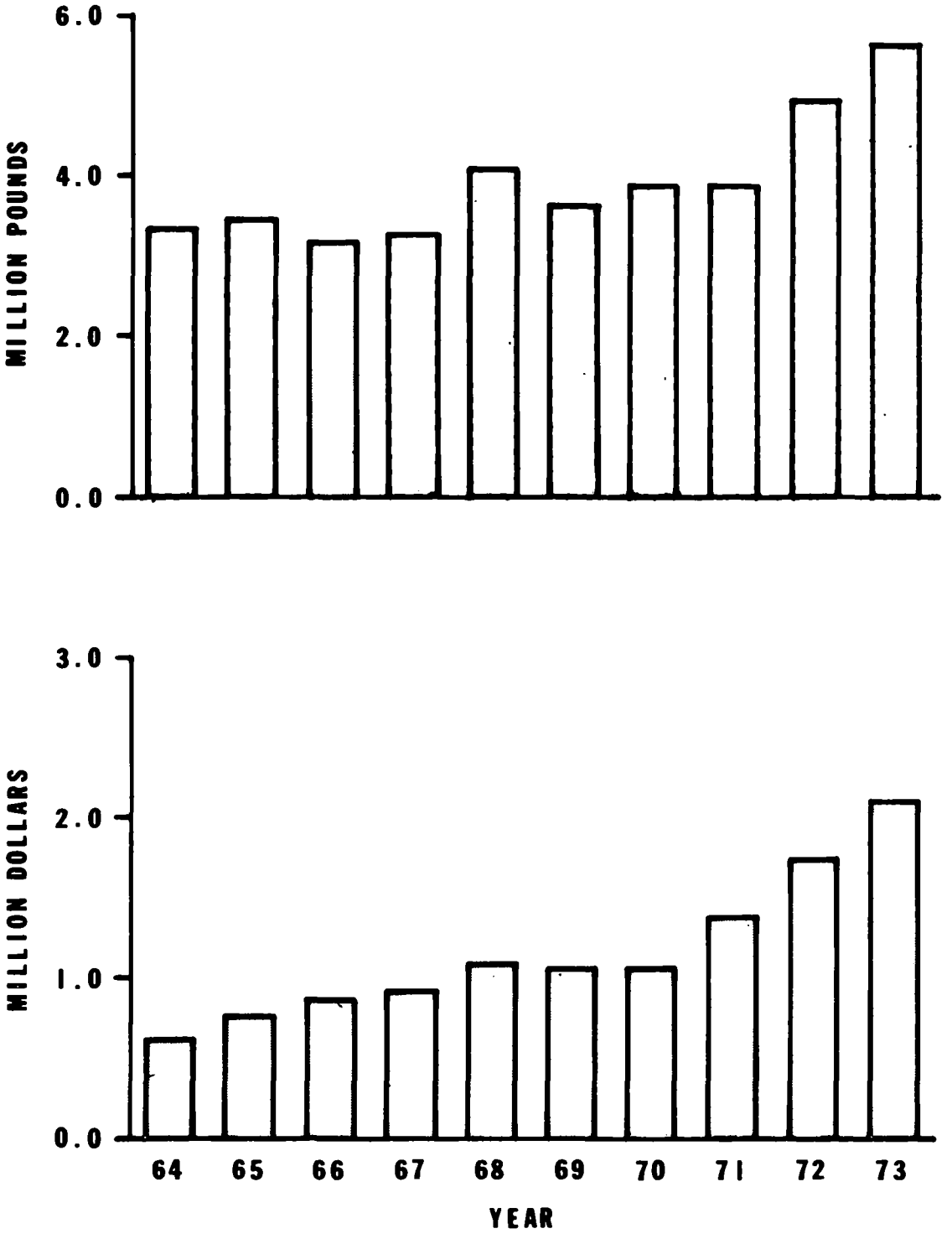


Figure 4-5. Trends in the commercial landing of finfish and shellfish in Escambia County, Florida, 1964-1973.

An additional 25,659 lbs of oysters were harvested from the beds in East Bay and landed in Santa Rosa County. Although the political boundary of Santa Rosa County encompasses the eastern half of Escambia Bay, all of East Bay, and portions of Pensacola Bay, 95 percent of the total catch from the Pensacola Bay system and adjacent offshore waters were landed in Escambia County. Therefore, the values presented in Figure 4-5 and Table 4-3 for the Pensacola area were depressed by roughly five percent.

During the past 10 years, the dollar value of the landings, which represented monies paid to the fishermen or wholesale value, increased from 643 thousand dollars in 1964 to 2.1 million dollars in 1973. This was more than a three-fold increase. However, no adjustments were made for inflationary increases since 1964. Processing, distribution and retailing create a two-fold increase in the retail price over the wholesale or dockside value. Thus, the commercial fishing industry generated over four million dollars in the local economy in 1973.

Table 4 - 3. Total commercial landings of finfish and shellfish in Escambia County, Florida from 1964 through 1973.

Year	Landings	
	Pounds	Dollars
1964	3,367,085	643,874
1965	3,480,821	772,822
1966	3,170,075	883,475
1967	3,291,330	923,668
1968	4,119,232	1,191,738
1969	3,626,588	1,039,101
1970	3,915,520	1,039,607
1971	3,916,007	1,395,483
1972	4,968,878	1,757,793
1973	5,644,743	2,115,015
Annual average	3,950,028	1,176,258
Five-year average (1964-1968)	3,485,709	883,258
Five-year average (1969-1973)	4,414,347	1,469,400

5 - POLLUTION SOURCES

POINT SOURCE DISCHARGES

Introduction

An aquatic estuarine ecosystem must have external energy sources to function at a productive level. For each estuary there is an optimum productivity level based on the bathymetry, hydrodynamics and climatology of the system. At this level, energy sources are utilized without causing water quality problems such as depressed dissolved oxygen. In some cases, waste discharges may provide energy sources that increase the productivity of a system to its optimum level; unfortunately, in the majority of cases, waste discharges cause over-production that results in water quality problems. Thus, a knowledge of waste discharges into the Pensacola Bay system is extremely important in evaluating the condition of the system.

Although the study area is the estuarine reaches of the Pensacola Bay system, information on waste discharges for the entire drainage area of Escambia Bay will be provided in this chapter.

Methods

Specific surveys of point source discharges were not performed by the Escambia Bay Recovery Study. The data discussed in this section were plant self monitoring reports obtained from the Florida Department of Environmental Regulation (FDER), Regional Office, Gulf Breeze, Florida; compliance monitoring conducted by the U.S. Environmental Protection Agency (USEPA) and its predecessor agency, the United States Department of Interior, Federal Water Pollution Control Administration (USDI, FWPCA).

Results

General

There are a total of 23 significant (wastewater flow greater than 378 m^3/day or 0.1 mgd) municipal-private domestic point sources and 10 significant industrial point sources discharging into the Pensacola Bay system and its tributaries, the Escambia, Blackwater, and Yellow Rivers. The locations of these point sources are shown in Figure 5-1.

To control point source discharges, the National Pollutant Discharge Elimination System (NPDES) was established by Public Law 92-500 (92nd Congress 5.2770, October 18, 1972, Federal Water Pollution Control Act Amendments of 1972, Section 402). Under this system, permits are issued to each point source specifying the quantities of pollutants that may be discharged into surface

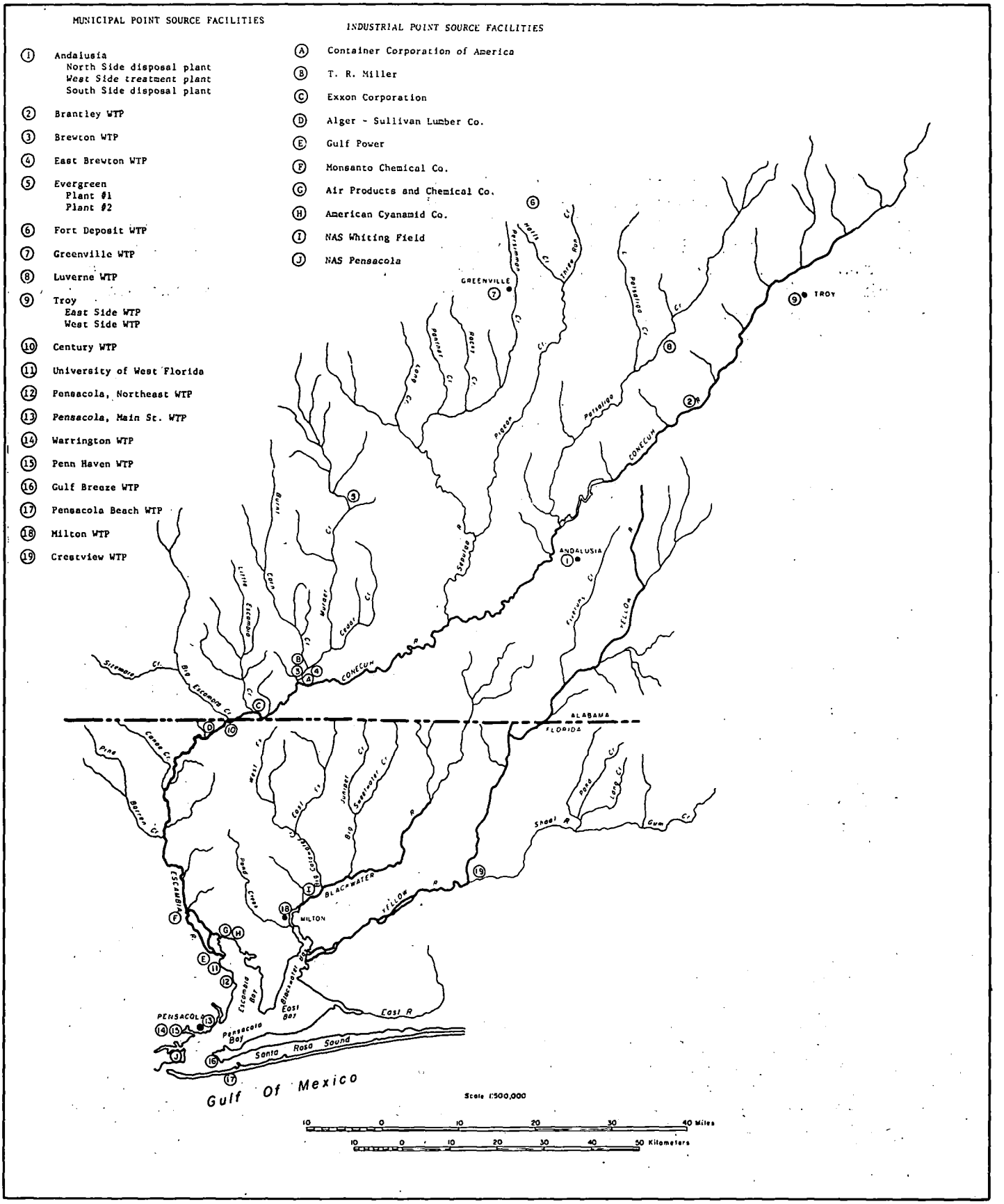


Figure 5-1. Map of location of point sources.

waters. Most of the permits issued contain interim and final effluent limits. The interim limits usually reflect the amount of waste water discharged when the permit was issued. The final limits are designed to reduce plant discharges to an amount that can be obtained after best practical treatment for a given industrial wastewater or to a lower amount in areas where water quality problems exist. Final effluent limits become effective after the discharger has had adequate time to construct facilities to meet the limits. The period of time required to meet the final limits is determined when the permit is issued. Information concerning NPDES permits for principal point sources discharging into the Pensacola Bay system and its tributary rivers is presented in Appendix 5-1.

Information on all significant point sources of waste in the tributary area to the Pensacola Bay system is provided in Appendices 5-2 and 5-3 for industrial discharges, and Appendix 5-4 for municipal-private domestic discharges into all rivers and bays.

Principal Industrial Point Sources

Container Corporation of America

The Container Corporation of America, Brewton, Alabama, integrated kraft mill began operation in December 1957 with an average daily production of 272 MT/day (300 tons/day) (Alabama Water Improvement Commission 1962), and production increased to 1043 MT/day (1150 tons/day) of paperboard in 1975, of which approximately 50 percent is bleached (USEPA compliance monitoring report for January 1975 study).

Wastewaters from this facility are from the unbleached pulp process, bleach plant, and wood yard. Unbleached pulp process wastewaters are treated in a clarifier, liquid oxygen applicator, aeration basin, and oxidation pond; and then they flow through a creek, swamp, and six natural lakes before discharging into the Conecuh River, about 80 km (50 mi) upstream of Escambia Bay. Bleach plant and woodyard effluents go directly to the creek, swamp, and lake system. Sanitary wastewaters are discharged into the clarifier to provide nutrients for treatment of unbleached pulp process wastewaters.

Effluent loadings from the Container Corporation of America Mill have decreased between 1969 and 1975 (Table 5-1). Using 1969 as a base, the BOD_5 effluent load discharged into the Conecuh River decreased between 1962 and 1969. The BOD_5 loading was 30 percent less than the 1969 base during the January 1975 survey.

Table 5 - 1. Effluent loadings from Container Corporation of America, Brewton, Ala.

Date	Flow		BOD_5		TSS		Reference
	tcmd (4) (mgd)	% change (1)	kg/day (lb/day)	% change (1)	kg/day (lb/day)	% change (2)	
1962	77.6 (21.0)	-43.7	6259 (13800)	+86.0	-	-	Nastler, T.A. and Kittrell, F.W. 1962
Sept. 1969	138.2 (36.0)	-	3365 (7420)	-	-	-	USDI, 1970
Aug., 1970	121 (32)	-12.5	3855 (8500)	+14.6	4444 (9800)	-	USEPA, 1971a
June, 1971	129.6 (34.5)	-6.2	1007 (2220)	-70.1	2204 (4860)	-50.4	USEPA, 1971b
Early 1973	138.2 (36.7)	0.0	2747 (6058)	-18.4	2221 (4897)	-50.0	NPDES permit application
Jan., 1975	172.8 (3) (44.8)	+25.	2370 (5230)	-29.6	1690 (3730)	-62.0	USEPA compliance monitoring report

(1) Percent change from Sept 1969

(2) Percent change from Aug 1970

(3) Unusually high flow due to rainfall during the study

(4) thousand cubic meters per day

Monsanto Chemical Company

The Monsanto Chemical Company Pensacola Plant began manufacturing nylon in December 1953 (USEPA, 1972a). Nylon production increased by 300 percent during the period 1953 through 1962 and by an additional 400 percent during 1963 to 1972. The principal products of the plant include nylon intermediates and finished nylon.

Concentrated wastes generated at the plant are collected in a separate system and disposed of by deep well injection. Other waste streams, reported by the company to contain cooling water and materials from spills, are discharged through two outfalls into the Escambia River. The north outfall receives effluents from the yarn manufacturing area and the research and development building. The main outfall receives effluents from the remainder of the plant. Sanitary wastes are treated by a primary treatment plant and then discharged into a lagoon, which supplies makeup water for cooling towers.

In the past, Monsanto Chemical Company Pensacola Plant discharged a large quantity of waste into the Escambia River. The chemical oxygen demand load discharged by the Pensacola Plant from 1954 to 1972 is presented in Figure 5-2 (Monsanto Chemical Corporation self monitoring data). An extremely high average annual load of 61,200 kg/day (135,000 lbs/day) was discharged into the Escambia River in 1955. The waste load decreased until 1959, and then increased until 1963, when a peak average annual load of 33,100 kg/day (73,000 lbs/day) was discharged. Waste injection wells were installed after 1963 and the discharge to the Escambia River decreased steadily after that time.

The five-day biochemical oxygen demand (BOD_5) load discharged by the Pensacola Plant has decreased by 92.6 percent between September 1969 and January 1975 based on USEPA monitoring studies (Table 5-2). Mean monthly BOD_5 waste loadings (self-monitoring data) indicate discharges vary considerably, but a general downward trend is evident (Figure 5-3). The exception to this is relatively large discharges in May and July 1972, and small discharges in September and November 1972, and January 1973.

Total nitrogen and phosphorus discharges have decreased by 93.8 and 96.5 percent, respectively, between September 1969 and January 1975, based on USEPA monitoring data (Table 5-2). Mean monthly self-monitoring data (Figure 5-4) indicated the quantity of total nitrogen discharged was relatively constant during 1971 through 1974. During the same period, the mean monthly total phosphorus effluent load was extremely variable and no trends were obvious.

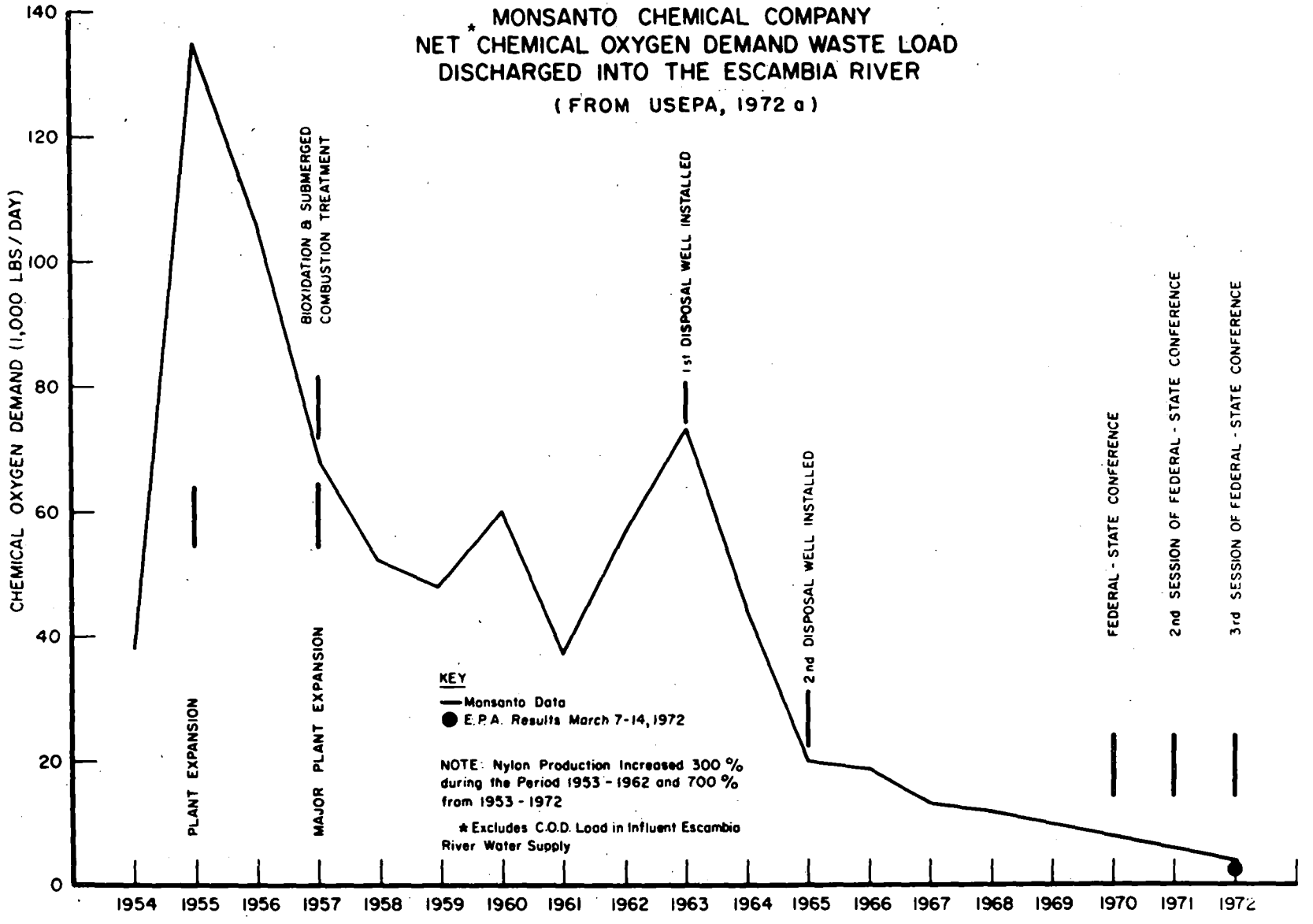


Figure 5-2. Monsanto Chemical Company net chemical oxygen demand waste load discharged into the Escambia River.

Table 5 - 2. Summary of data collected at Monsanto Chemical Co., American Cyanamid Co., and Air Products and Chemicals, Inc. by the U. S. Environmental Protection Agency and its predecessor agencies.

Date	Flow	BOD_5		TSS		Total-Nitrogen		Total-Phosphorus		References
	tcmd (1) (mgd)	kg/day (ppd)	% change	kg/day (ppd)	% change	kg/day (ppd)	% change	kg/day (ppd)	% change	
MONSANTO CHEMICAL CO.										
Sep. 1969	198.7 (52.5)	4580 (10100)	-	- -	-	1452 (3200)	-	191 (421)	-	USDI, 1970
Mar. 1972	127.2 (33.6)	526 (1160)	-88.5	603 (1330)	-	303 (668)	-79.1	27 (60)	-85.7	USEPA, 1972a
Feb. 1974	112.4 (29.7)	943 (2080)	-79.4	1926 (4246)	-	263 (580)	-81.9	20 (45)	-89.3	USEPA, compliance monitoring report
Jan. 1975	79.5 (21.0)	339 (748)	-92.6	-	-	90 (198)	-93.8	6.7 (14.7)	-96.5	USEPA, compliance monitoring report
AMERICAN CYANAMID CO.										
Sep. 1969	17.0 (4.5)	2020 (4450)	-	- -	-	2200 (4850)	-	1.0 (3.0)	-	USDI, 1970
Mar. 1972	20.4 (5.4)	2900 (6390)	+44.0	460 (1020)	-	1750 (3850)	-20.0	3.0 (6.0)	-	USEPA, 1972b
Feb. 1974	16.3 (4.3)	1520 (3350)	-25.0	366 (806)	-	1270 (2800)	-42.0	- -	-	USEPA compliance monitoring report
Jan. 1975	16.4 (4.33)	3280 (7240)	+62.0	329 (725)	-	1480 (3260)	-33.0	- -	-	USEPA, compliance monitoring report
AIR PRODUCTS AND CHEMICALS										
Sep. 1969	19.7 (5.2)	130 (290)	-	- -	-	2560 (5650)	-	145 (320)	-	USDI, 1970
Mar. 1972	6.8 (1.8)	84 (185)	-35.0	120 (260)	-	1450 (3190)	-43.0	18 (39)	-88.0	USEPA, 1972c
Jan. 1975	3.8 (1.0)	29 (64)	-78.0	26 (58)	-	554 (1220)	-78.0	7 (16)	-95.0	USEPA, compliance monitoring report

(1) thousand cubic meters per day

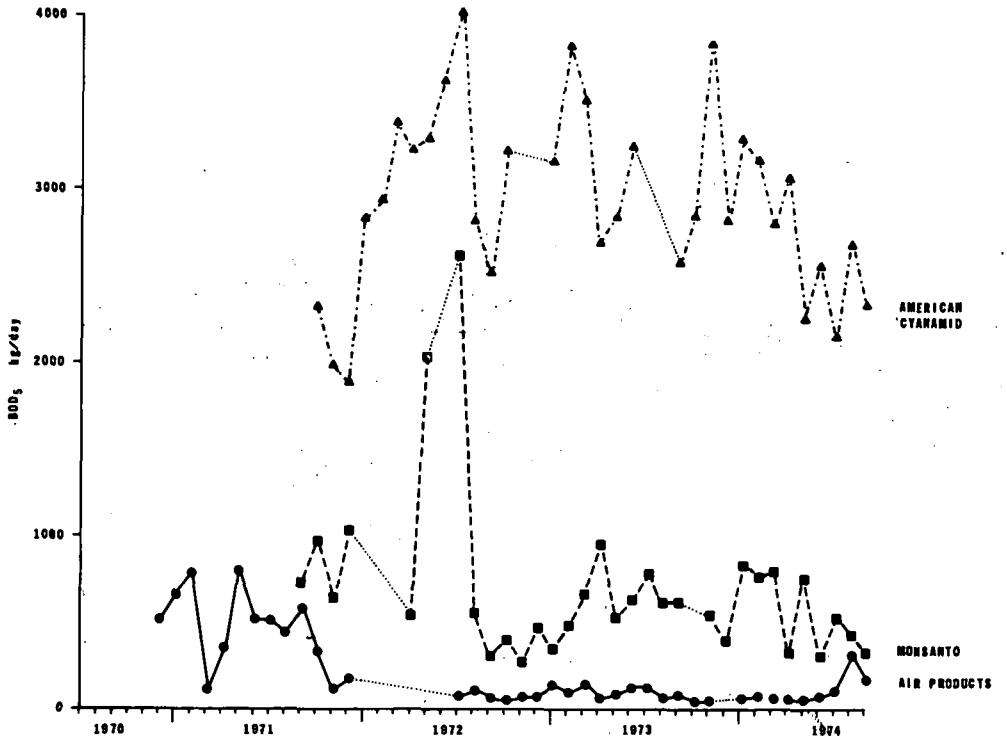


Figure 5-3. Average monthly BOD_5 effluent loads (based on company self-monitoring data).

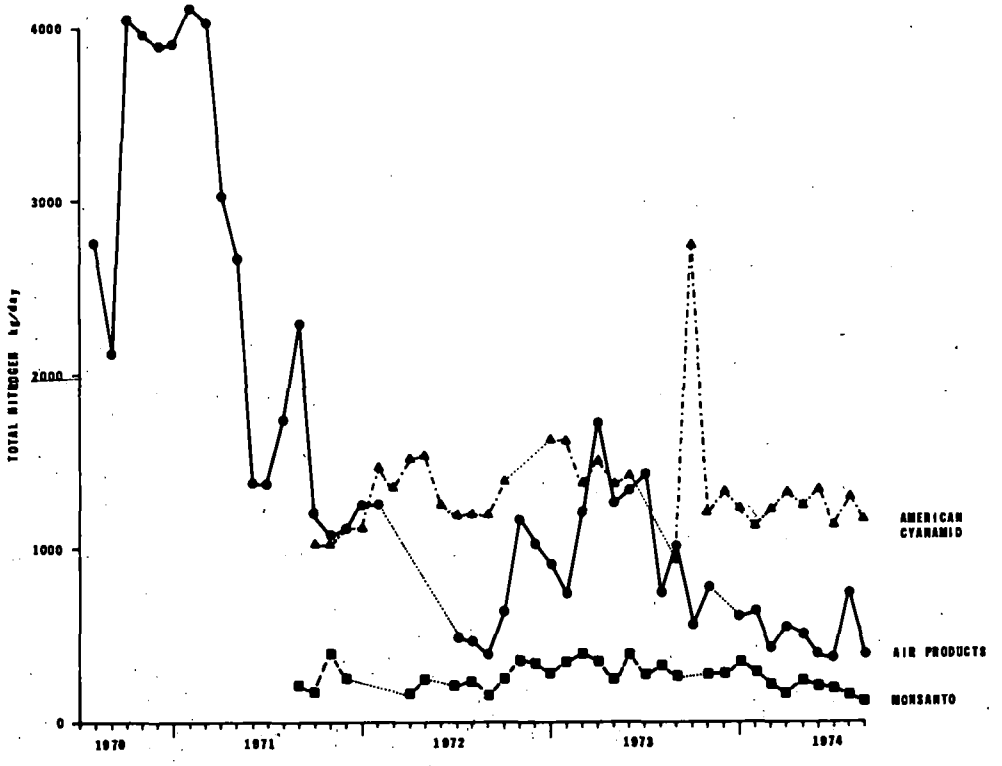


Figure 5-4. Average monthly total nitrogen effluent loads (based on company self-monitoring data).

American Cyanamid Company

The American Cyanamid Company, Santa Rosa Plant, has produced acrylic polymer from acrylonitrile and methyl-methacrylate monomers since 1958. The monomers are reacted, washed, stored, and, when needed, dissolved in sodium thiocyanate solvent. The dissolved polymer is passed through spinnerettes which produce continuous fibers. The solvent is separated from the fiber by countercurrent washing with water. Solvent recovery is built into the manufacturing process, and more than 99 percent of the solvent is recovered and reused. The fiber is then subjected to further mechanical processes of crimping, cutting, and bailing. Fiber production in September 1969 was about 103 MT/day (114 tons/day) (USEPA 1972b). Fiber production was about 107 MT/day (118 tons/day) in March 1972 and increased to 122 MT/day (135 tons/day) in 1974 and early 1975.

Treatment facilities at the plant consist of two 1.6 ha (4.0 acre) baffled lagoons. The influent to the lagoons is composed of process and primary treated sanitary wastewaters. Sanitary wastes receive preliminary treatment through a manual bar screen and two Spirahoff units. The effluent is discharged into Escambia Bay through a 1524 m (5000 ft) submerged outfall with three diffusers spaced at intervals of 183 m (600 ft). Under the terms of the American Cyanamid Company NPDES permit (No. FL0002593), their facility shall commence discharging into a deep well disposal system by May 31, 1975. This deep well will be an interim method of waste disposal. This company is required to perform treatability and pilot plant studies for surface treatment of the total plant waste by March 31, 1978.

Four studies of the American Cyanamid Plant were performed by USEPA and its predecessor agencies (Table 5-2). The BOD_5 discharge loading from the Santa Rosa Plant increased by 62 percent between the September 1969 and January 1975 surveys. The total nitrogen load discharged by the plant decreased by 33.0 percent between the same surveys.

Monthly average effluent data from 1971 through 1974 for BOD_5, total nitrogen, and total phosphorus and cyanide indicated the discharge varies considerably.

The monthly average BOD_5 waste loading from the plant was very erratic and there was a decrease in the discharge in late 1974 (Figure 5-3).

Total nitrogen discharges by the plant were relatively constant between October 1971 and September 1974 (Figure 5-4), with the exception of an extremely high mean monthly discharge in October 1973. The quantity of phosphorus discharged by this plant was extremely small (Figure 5-5). The quantity of cyanide discharged by the plant decreased drastically between late 1971 and early 1972 (Figure 5-6), and remained relatively low thereafter.

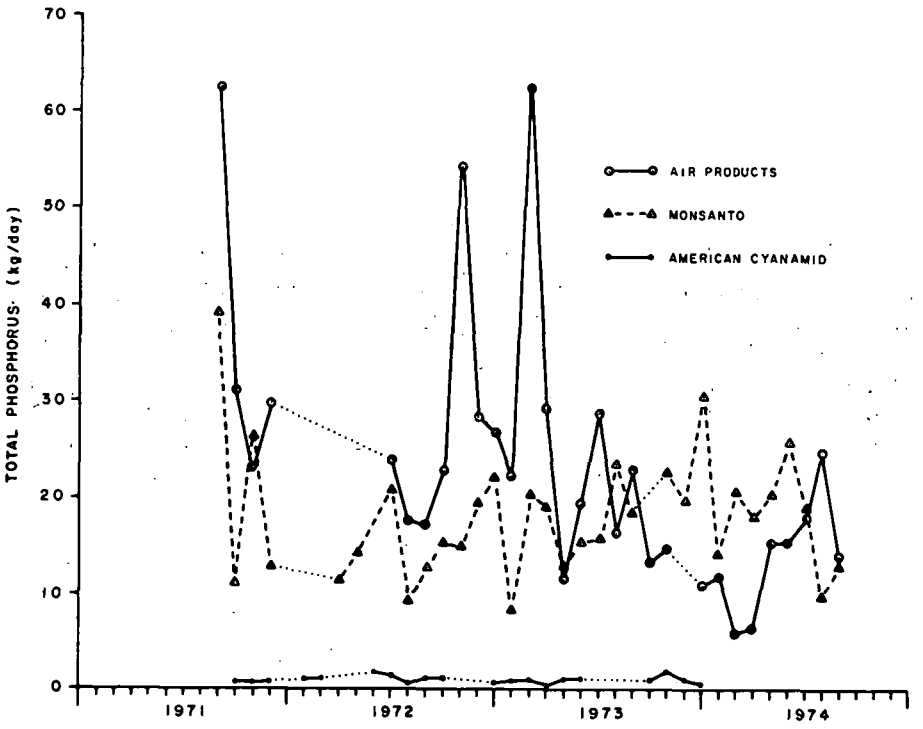


Figure 5-5. Average monthly total phosphorus effluent loads (from company self-monitoring data).

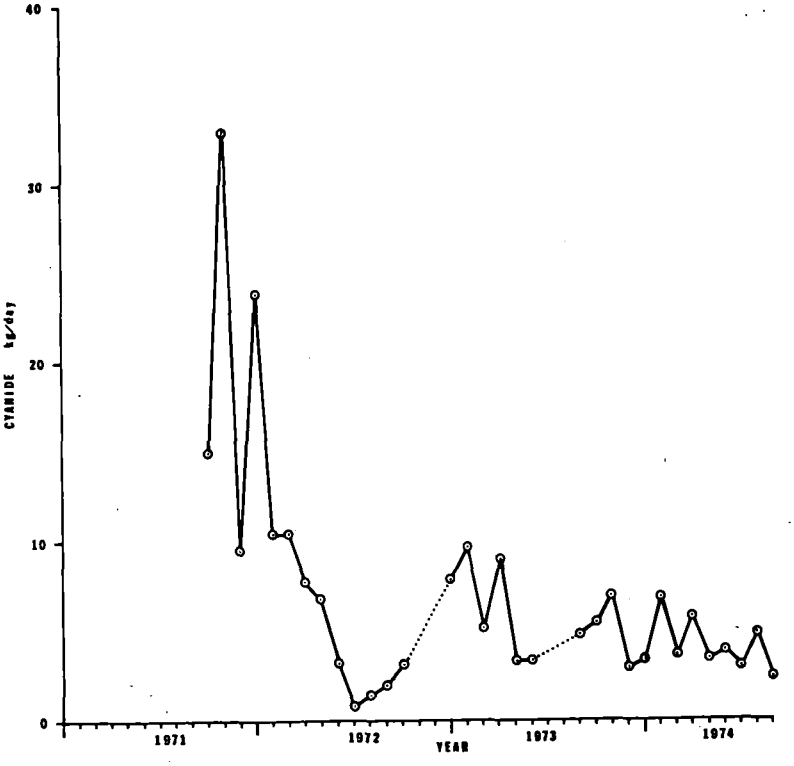


Figure 5-6. Average monthly cyanide effluent loading from American Cyanamid Co.

Air Products and Chemicals, Incorporated

The Escambia Plant was constructed in 1955, and it produces ammonium nitrate, ammonia, nitric acid, amines, urea, dinitrotoluene, and polyvinyl chloride. In 1970, methanol and mixed fertilizer (NPK) plants at this facility were closed.

The wastewater treatment system at the plant consists of a 3.2 ha (8.0 acre) anaerobic lagoon, followed by four aerobic lagoons with a total area of 29.4 ha (72.5 acres), and finally discharges into Escambia Bay. The plant has a serious problem with contaminated groundwater, which accounted for 50 percent of the total nitrogen in the plant effluent (USEPA, 1972c). The plant has reduced this problem by improved housekeeping and by intercepting contaminated groundwater before it enters the lagoon system.

Based on U.S. Environmental Protection Agency studies, BOD_5, total nitrogen, and total phosphorus have been reduced by 78, 78, and 95 percent, respectively, between September 1969 and January 1975 (See Table 5-2).

Company self-monitoring data again indicated the effluent loads from this plant were variable. Mean monthly BOD_5 effluent loads discharged in 1973 and 1974 were much lower than the 1971 effluent loading (Figure 5-3).

The mean monthly total nitrogen loads discharged were extremely high during the last half of 1970 and 1971 (Figure 5-4) and decreased steadily after April 1974.

Monthly average total phosphorus discharges by the plant were extremely erratic between June 1970 and September 1974 (Figure 5-5).

Gulf Power Corporation

The Gulf Power Corporation steam plant is located 5.3 km (3.3 mi) upstream of the mouth of the Escambia River. This fossil fuel electric generating plant produces 10,791 MWH of electricity (application for Corps of Engineers Discharge Permit - EPA, NPDES permit - dated July 13, 1971). The effluent consists of 1.09×10^6 m^3/day (288 mgd) of cooling water, 16.3×10^3 m^3/day (4.3 mgd) of ash sluice water, and 21.9×10^3 m^3/day (5.8 mgd) of cooling tower blowdown. Under the conditions of the NPDES permit (No. Fl0002275) issued to this plant, off-stream cooling facilities for the entire discharge are to be operational by February 26, 1976.

U.S. Naval Air Station, Pensacola

A primary mission of the Naval Air Station (NAS) at Pensacola is to overhaul and rework aircraft, including air frames and aircraft engines (USEPA, 1972d). The base population of approximately 16,755 people includes naval personnel, dependents, and civilians.

The wastewater treatment plant provides the equivalent of secondary treatment for all domestic and industrial wastes from the station (USEPA, 1972d). This system includes an old primary plant, which treated the domestic wastes prior to construction of the present 3.0 mgd combined treatment plant. The wastewater flow is about two-thirds domestic and one-third industrial. The Navy plans to increase the old primary portion of the wastewater treatment plant to 9.5 x 10^3 m^3/day (2.5 mgd). Before the existing waste treatment plant began operation, several waste streams (with and without treatment) discharged into Pensacola Bay from various locations around the station. At the present time, the effluent is discharged into Pensacola Bay through a submerged outfall line, 61 cm (24 in) in diameter and 732 m (2,400 ft) in length.

In March 1972, the USEPA (1972d) collected a single 24-hour composite sample at the polishing pond discharge (prior to chlorination) of this facility. The organic load discharged from this facility was 42 lbs/day of BOD_5, 988 lbs/day of COD, 382 lbs/day of organic carbon and 146 lbs/day of oil and grease. Metal analyses showed that the discharge into Pensacola Bay also contained 1.3 lbs/day of total chromium, 0.7 lbs/day of manganese, and 0.7 lbs/day of zinc. The daily discharges also contained 0.2 lbs of phenols and 0.3 lbs of cyanide. The metal, phenol, and cyanide loadings are relatively small and should not significantly contribute to the concentration of these substances in Pensacola Bay.

U.S. Naval Air Station, Whiting Field

The treatment facility at the Naval Air Station, Whiting Field, Milton, Florida, was constructed in the 1940's. Treatment consists of grit removal, primary clarification, standard rate trickling filter, secondary clarification, chlorination, and aerobic sludge digestion. The effluent is discharged into Clear Creek, a tributary of the Blackwater River.

Principal Municipal-Private Domestic Point Sources

City of Pensacola, Main Street Plant

The Main Street Wastewater Treatment Plant serves a majority of the population in the Pensacola metropolitan area. This activated sludge secondary treatment plant was designed for a sewage flow of 34.0 x 10^3 m^3/day (9.0 mgd), and presently serves a population of 55,000 and numerous industries (Table 5-3).

Treatment provided at the plant consists of screening, preaeration, grit removal, primary settling, activated sludge aeration, secondary settling, chlorination, anaerobic digestion, vacuum filtration of sludge, and sludge disposal in a landfill. The effluent is discharged through a 121 cm (48 in) diameter submerged outfall line which extends 853 m (2,800 ft) into Pensacola Bay. In addition to receiving domestic waste, the Main Street Treatment Plant receives between 7.6 x 10^3 and 11.3 x 10^3 m^3/day (2.0 and 3.0 mgd) of industrial waste (USEPA, 1972d).

In March 1972 a survey of the plant by the USEPA (1972d) was performed. Operating reports indicated that the plant was providing 80 to 90 percent treatment at that time. Based on one composite sample, 800 kg/day (1800 lbs/day) of BOD_5, 1300 kg/day (2900 lbs/day) of total suspended solids, 1100 kg/day (2400 lbs/day) of total nitrogen, and 290 kg/day (633 lbs/day) of total phosphorus were discharged.

The mean monthly BOD_5 and TSS waste loads discharged by the Main Street Wastewater Treatment Plant in 1973 and 1974, based on self-monitoring data, were extremely variable. The annual average BOD_5 loads discharged in 1973 and 1974 were 570 kg/day (1263 lbs/day) and 870 kg/day (1920 lbs/day), respectively; and the ranges of BOD_5 discharges were 157 to 1035 kg/day in 1973 and 547 to 1298 kg/day in 1974. Removal levels of BOD_5 were 92.9 percent in 1973 and 88.2 percent in 1974. In 1973 the mean annual suspended solids discharge was 940 kg/day (2080 lbs/day) and in 1974 the mean annual load discharged was 1120 kg/day (2460 lbs/day). Between February and September 1974, an average of 230 kg/day (510 lbs/day) of nitrate nitrogen and 160 kg/day (350 lbs/day) of total phosphorus was discharged. The mean flow from the plant during 1974 was 34.0 x 10^3 m^3/day (9 mgd). The plant reported exceptionally high flows for June through November 1974 due to high industrial discharges (letter from D. M. Heath, Department of Public Utilities, City of Pensacola, Florida, February 12, 1975).

To serve the future population of the Pensacola area, the City of Pensacola is planning to expand this plant to 75.6 x 10^3 m^3/day (20 mgd) and provide advanced waste treatment. Plans also include the extension of the outfall line in Pensacola Bay (letter from D.M. Heath).

City of Pensacola, Northeast Wastewater Treatment Plant

This wastewater treatment plant began operation in 1962, and serves a population of approximately 11,000. The design flow of the plant is 3.8 x 10^3 m^3/day (1.0 mgd). The waste undergoes screening, preaeration, grit removal, primary settling, biological treatment using trickling filters, chemical treatment, secondary settling, effluent chlorination, and disposal through a 550 m (1,804 ft) outfall line discharging into Escambia Bay just south of Devils Point in 1.4 m (4.5 ft) of water (NPDES permit application).

Table 5 - 3. Major industrial discharges to the Main Street wastewater treatment plant.

Industry	Pretreatment
Agrico Chemical Co.	Lime treatment - holding pond
Armstrong Cork Co.	Solids Removal - Neutralization
Ashland Chemical Co.	Holding Pond
Beasley Packing Co. of Florida, Inc.	----
Borden Co.	----
Escambia Treating Co.	Holding (Evaporation) Pond
Florida Sausage Co., Inc.	----
Gulf Coast Plating, Inc.	----
Pepsi-Cola Bottling Co. of Florida, Inc	----
Tenneco Chemicals, Inc.	Solids Removal - Neutralization

The effluent from the Northeast Wastewater Treatment Plant was sampled by the U.S. Department of Interior (1970) in September 1969, and 207 kg/day (457 lbs/day) of BOD_5, 765 kg/day (1,688 lbs/day) of total nitrogen, and 97 kg/day (213 lbs/day) of total phosphorus were measured. In the report on the above study the flow was estimated at 3.8×10^3 m^3/day (1.0 mgd) but the City of Pensacola claimed that the flow was about 1.9×10^3 m^3/day (0.5 mgd) during the study (USDI, 1970). Another survey was conducted by USEPA (1972d) in March 1972 and indicated the discharge contained 159 kg/day (351 lbs/day) of BOD_5, 60 kg/day (132 lbs/day) of total suspended solids (TSS), 87 kg/day (191 lbs/day) of total nitrogen, and 25 kg/day (56 lbs/day) of total phosphorus. The effluent flow of the plant was 1.9×10^3 m^3/day (0.5 mgd) during this study.

Based on self-monitoring data, the mean annual BOD_5 and TSS levels in the effluent were 82 kg/day (181 lbs/day) and 101 kg/day (223 lbs/day), respectively, in 1973; and 154 kg/day (340 lbs/day) and 161 kg/day (355 lbs/day), respectively, in 1974. The average degree of BOD_5 removal was 92.5 percent in 1973 and 84.2 percent in 1974

The Northeast Wastewater Treatment Plant is being enlarged to treat 1.85 mgd. A higher degree of treatment than secondary will be provided and by June 30, 1975 the plant will only be allowed to discharge 53 kg/day (116 lbs/day) of BOD_5 and TSS, 63 kg/day (139 lbs/day) of total Kjeldahl nitrogen, and 15 kg/day (32 lbs/day) of total phosphorus (NPDES permit). The NPDES permit for this plant also states that operation of this plant will be discontinued when the Main Street Sewage Treatment Plant can serve this area on or before June 30, 1977.

City of Milton Wastewater Treatment Plant

This 6.4×10^3 m^3/day (1.7 mgd) secondary wastewater treatment plant was placed in operation in 1955. Treatment units consist of grit removal, primary clarification, high-rate trickling filters, secondary clarification, chlorination and anaerobic sludge digestion. The plant effluent is discharged into the Blackwater River.

The USEPA (1972d) collected a 24 hour composite sample from this plant in March 1972, when the average flow through the plant was 3.8×10^3 m^3/day (0.99 mgd). Analysis of the samples indicated that the amount of BOD_5, TSS, total nitrogen, and total phosphorus loads discharged were 180, 98 103, and 35 kg/day (396, 215, 227, and 78 lbs/day), respectively.

The quantity of waste discharged by the plant for a portion of 1974 (January through June, and August) based on self-monitoring data indicates that the BOD_5 load discharged has increased considerably since 1972 and the TSS load discharged has remained the same. The mean effluent flow during this period was 4.9×10^3 m^3/day (1.3 mgd) which was 76 percent of design flow.

The mean BOD_5 discharge load was 299 kg/day (659 lbs/day) with a range of mean monthly values from 200 to 387 kg/day (441 to 854 lbs/day), and the mean monthly TSS effluent load was 99 kg/day (218 lbs/day) with a range from 46 kg/day (101 lbs/day) to 176 kg/day (387 lbs/day).

Other Significant Point Sources

The three industrial and twenty municipal-private domestic point sources not discussed in the previous sections are described in Appendices 5-2, 5-3, and 5-4.

Discussion

The Pensacola Bay system and its total drainage area receives a considerable quantity of waste from man-associated point sources (Table 5-4). The total amounts of waste that can be discharged, based on present NPDES permit limits (in effect during Janaury 1975) or estimated permit limits for sources where permits have not been issued, are 10,198 kg/day (22,480 lbs/day) of BOD_5, 11,796 kg/day (26,000 lbs/day) of TSS, 5,474 kg/day (12,070 lbs/day) of total nitrogen, and 1,368 kg/day (3,016 lbs/day) of total phosphorus.

Sixty percent, or 6120 kg/day (13,490 lbs/day), of the total quantity of BOD_5 discharged, entered the estuarine reaches of the system. The forty percent of the BOD_5 discharge that entered freshwater reaches, travels at least 50 km (31 mi) before arriving at the estuarine reaches and should be assimilated in the river. Escambia Bay received 34 percent of the total quantity of BOD_5 discharged by point sources to the system and Pensacola Bay received 17 percent.

The estuarine reaches of the Pensacola Bay system received 30 percent, 3,540 kg/day (7,800 lbs/day), of the total quantity of TSS discharged by point sources. The Conecuh River received 69 percent of the total TSS discharge by point sources, 8,193 kg/day (18,062 lbs/day), and this consisted mainly of the effluent from the Container Corporation of America paper mill which may discharge 4,490 kg/day (9,900 lbs/day).

Most (79 percent) of the total nitrogen received by the Pensacola Bay system is discharged into the estuarine reaches. Of this, 43 percent is discharged by point sources into Escambia Bay and 24 percent into Pensacola Bay.

Sixty-four percent of the total phosphorus discharged into the system is received by estuarine reaches. Pensacola Bay receives 44 percent of the total discharge, or 602 kg/day (1,330 lbs/day).

Most of the discharges to the freshwater reaches of the Pensacola Bay system occur at a distance of at least 50 km (31 mi) upstream of the estuarine reaches of the system. Based on

Table 5 - 4. Summary of industrial and domestic - municipal point sources of discharge into the Pensacola Bay system by drainage area.

Drainage Area	BOD_5		Total Suspended Solids		Total Nitrogen		Total Phosphorus	
	Load (kg/day)	Percent (%)	Load (kg/day)	Percent (%)	Load (kg/day)	Percent (%)	Load (kg/day)	Percent (%)
Conecuh River	3865	38	8193	69	1019	19	439	32
Escambia River	511	5	113	1	271	5	39	3
Blackwater River	312	2	312	3	243	4	104	8
Yellow River	170	2	170	1	132	2	57	4
Escambia Bay	3432	34	1039	9	2351	43	63	5
Pensacola Bay	1685	17	1685	14	1308	24	602	44
Santa Rosa Sound (west end)	223	2	284	2	150	3	64	5
Total kg/day	10198		11796		5474		1368	
(ppd)	(22480)		(26000)		(12070)		(3016)	

the low concentrations of pollutants at the upstream end of the estuarine reach, these discharges appear to be assimilated in the rivers before they enter the estuaries. Consequently, water quality problems in the bays appear to be due to discharges entering the estuarine areas directly.

NON-POINT SOURCES

Non-point sources of pollution into the Pensacola Bay system consist of: 1) urban storm water runoff; 2) agricultural runoff; 3) forest and swamp drainage and runoff; and 4) groundwater seepages into surface waters. The first three categories are slug type discharges that occur during rainstorms. Urban storm water runoff usually contains substantial quantities of suspended solids, oxygen demanding materials, nutrients, bacteria, oil, grease, and miscellaneous debris such as sticks and paper. The pollutant load in urban storm water runoff depends on the amount of the above materials present, the topography and type of ground cover in the drainage basin, the intensity and duration of the rain storm, and the period between rain storms. Agricultural land runoff pollutant loads depend on the type of soil, the type of agricultural activity, fertilizer types and application schedule, and rainfall patterns. Because of the ability of heavily vegetated forests, marshes, and swamps to hold runoff, the pollutant loads from this category are lower than the two categories previously discussed. However, intense rainfall may flush swamp waters containing low dissolved oxygen concentration, low pH, and some oxygen demanding potential into the bay system.

In the Water Quality Management Plan for Escambia and Santa Rosa Counties (Henningson, Durham and Richardson, 1975), unit values (per km^2) of average annual BOD_5 and nutrient loads for the three categories discussed above were developed from study area data and a literature review. These unit values are presented in Table 5-5.

Groundwater discharges into surface waters consist of material from septic tank drain field leachate, sanitary landfill leachate, and the pollutants described above that infiltrate into groundwaters. Pollutant discharges from groundwaters entering surface waters were not considered in this report. However, this contribution is significant and should be the subject of further studies.

The average annual loading due to storm water runoff from urban, agricultural, and forest-marsh-swamp areas was 3,111, 676, and 205 kg/day of BOD_5, total nitrogen and total phosphorus, respectively. The breakdown of these loadings by system components are shown in Table 5-6, which only includes non-point source discharges directly into estuarine areas and the Pond Creek drainage basin. The breakdown of land use and the pollutant discharges were obtained from Exhibit 6-2 of the Water Quality Management Plan (Henningson, Durham and Richardson, 1975). The total land area considered in this analysis was 828.5

km^2 (319.9 mi^2). The classification of this area for urban, forest-marsh-swamp, and agricultural use is 6.7, 74.3, and 19.0 precent respectively.

Pensacola Bay received the greatest quantity of BOD_5 and significant amounts of total nitrogen and phosphorus from non-point sources. Escambia Bay received the lowest quantities for each pollutant, because the bluff on the west shore of Escambia Bay prevents most urban storm water runoff from entering the bay. This runoff entered the bay system through Bayou Texar which received 14 percent of the BOD_5, 10 percent of the total nitrogen, and 11 percent of the total phosphorus discharge to the Pensacola Bay system.

In reality, the discharge from storm runoff would occur as individual slugs and not continuously as inferred in Table 5-6. The discharge loadings from stormwater runoff are comparable to the point source pollutant loadings discussed in the previous section, and, as is becoming evident in other sections of the country, control of these materials will have to be considered.

Table 5 - 5. Average annual quantities of storm water runoff expressed as unit values.

Parameter	Unit Values (kg/day/km^2)		
	Urban	Agricultural	Forest - Swamp
BOD_5	12.2	7.7	1.2
Total Nitrogen	1.8	3.7	0.2
Total Phosphorus	0.6	0.6	0.1

Table 5 - 6. Average non - point source pollutant discharges into the estuarine reaches of the Pensacola Bay system.

Basin	Area (km^2)	BOD_5 (kg/day)	Total Nitrogen (kg/day)	Total Phosphorus (kg/day)
Escambia Bay	126.9	433	92	29
Pensacola Bay	148.7	1,337	202	69
Blackwater River	316.2	884	280	70
East Bay	236.7	457	102	37
Total	828.5	3,111	676	205

6 - HYDRODYNAMICS

BATHYMETRY

The Pensacola Bay system is located in Escambia and Santa Rosa Counties in the extreme northwest portion of Florida. The Bay system contains four sub-systems - Pensacola Bay, Escambia Bay, East Bay, and Blackwater Bay (Figure 6-1).

The surface area and volume of the system were determined using Coast and Geodetic Survey Chart 1265 (17th Ed., Nov. 6, 1971). The areas of the bays were found using a planimeter. The volume of the bays were determined by dividing each bay into 0.8 km squares and determining the volume of each square using the mean chart depth for the particular square. The mean depth of each bay was obtained by dividing the volume of each bay by its area. Since the datum of the chart is mean low water, all dimensions presented in this section are with respect to mean low water.

The total area of the Pensacola Bay system (Table 6-1) is 372.9 km^2 (143.8 mi^2), and its total volume is 1,348.8 x 10^6 m^3 (47,640 million ft^3). With respect to both surface area and volume, the Pensacola Bay sub-system is the largest, with East, Escambia, and Blackwater Bays following in descending order.

FRESHWATER HYDROLOGY

Introduction

The freshwater discharge into an estuary affects the system in numerous ways. The relationship between river discharges and tides will dictate circulation patterns in the estuary, i.e., whether the type of circulation is two layer flow or homogeneous. The river discharge controls the salinity of the estuary which in turn determines the organisms that can live there. Large quantities of materials are transported into the estuary by river discharge. Some of these materials are nutrients, which provide energy for the system, and others like suspended solids disrupt energy flows by diminishing light penetration into the water. Since all of these factors are related to, or controlled by, river discharge, it is necessary to understand variations in river discharge in order to evaluate a system.

Methods

All surface water records used to describe river discharges into the Pensacola Bay system were obtained from the United States Geological Survey, (1934 through 1974), and from provisional data supplied by the United States Geological Survey, District Office, Tallahassee, Florida. Information about the rivers that discharge into the Pensacola Bay system, and the U.S. Geological Survey streamflow gages located on them, are presented in Table 6-2.

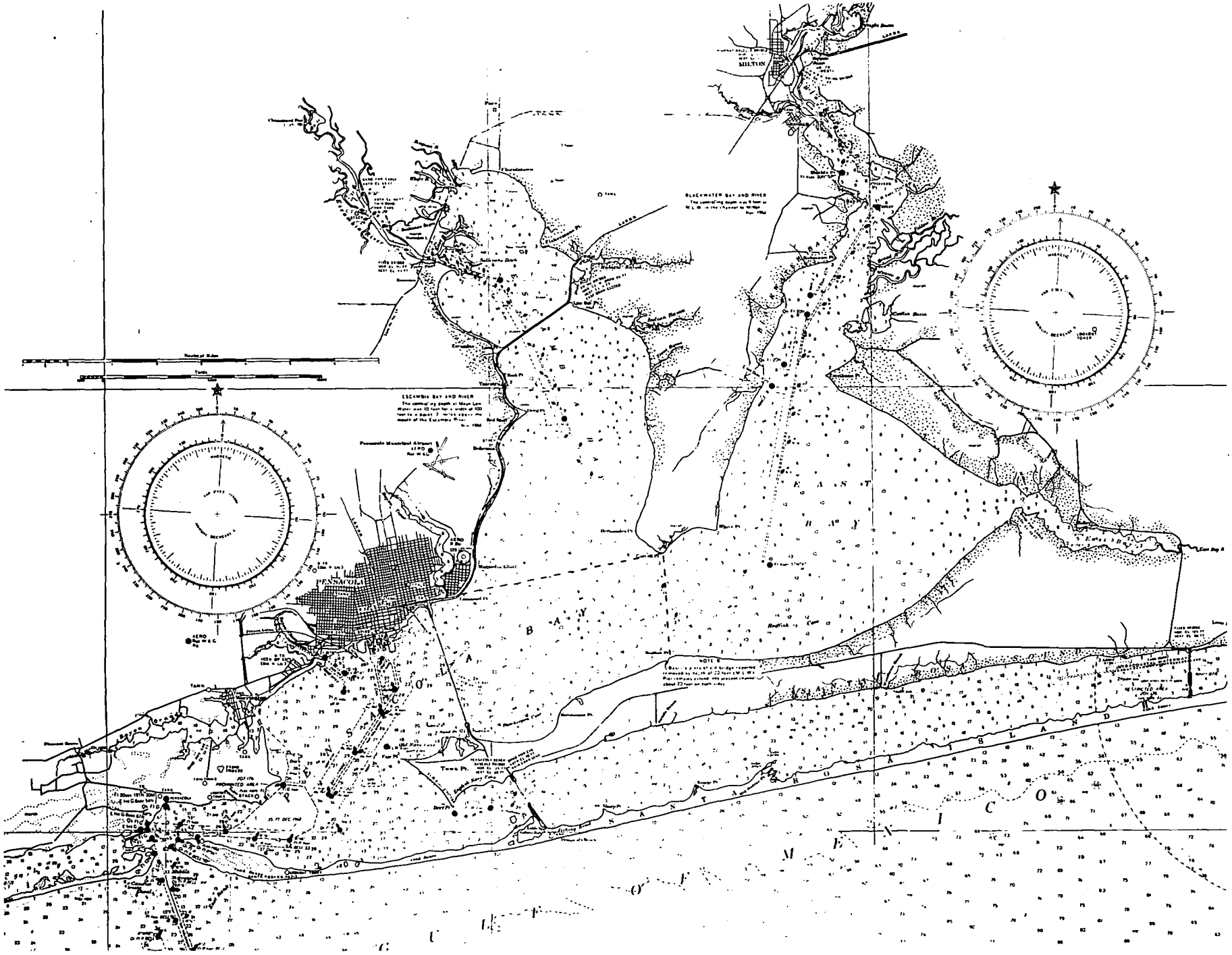


Figure 6-1. Map of the Pensacola Bay system.

Table 6 - 1. Summary of the bathymetry of the Pensacola Bay system. (All data with respect to mean low water - C & GS Chart 1205, 17th Ed., Nov. 6, 1971.)

Bay	Surface Area km²	Surface Area mi²	Volume mill. m³	Volume mill. ft³	Mean Depth m	Mean Depth ft
PENSACOLA BAY SUBSYSTEM						
Pensacola Bay	133.6	51.6	793.8	28040	5.9	19.5
Bayou Grande	3.8	1.5	10.3	364	2.7	9.0
Bayou Chico	1.1	0.4	2.0	71	1.8	6.0
Bayou Texar	1.5	0.6	2.8	99	1.9	6.1
subtotal	140.0	54.1	808.9	28570		
ESCAMBIA BAY SUBSYSTEM						
Escambia Bay	92.6	35.7	225.7	7972	2.4	8.0
Mulatto Bayou	0.9	0.3	1.4	49	1.5	4.9
subtotal	93.5	36.0	227.1	8021		
BLACKWATER BAY SUBSYSTEM						
Blackwater Bay	24.6	9.5	47.1	1664	1.9	6.8
Catfish Basin	0.9	0.3	1.1	39	1.2	3.9
subtotal	25.5	9.8	48.2	1702		
EAST BAY SUBSYSTEM						
East Bay	109.4	42.2	259.3	9158	2.4	7.9
East Bay Bayou	4.5	1.7	5.3	187	1.2	3.9
subtotal	113.9	43.9	264.6	9347		
Grand Total	372.9	143.8	1348.8	47640		

Table 6 - 2. Summary of information about major streamflow gaging stations in the Escambia, Blackwater and Yellow River drainage basins.

Drainage Basin	Gage no.	Location of Gage	Drainage area km² (mi²)	Mean flow m³/sec (cfs)	Flow/unit area m³/sec per km² (cfs mi⁻²)	7 day 10 year low flow m³/sec (cfs)	Period of record
YELLOW RIVER			3380 (1305)				
	3680	Yellow River at Milligan	1616 (624)	32 (1124)	0.02 (1.80)	5.7 (201)	July 1938 to 1974
	3690	Shoal River near Crestview	1228 (474)	30 (1051)	0.02 (2.22)	8.5 (331)	July 1938 to 1974
BLACKWATER RIVER			2227 (860)				
	3705	Big Coldwater River near Milton	614 (237)	14 (515)	0.02 (2.17)	6.1 (215)	Oct. 1938 to 1974
	3700	Blackwater River near Baker	531 (205)	9 (305)	0.02 (1.49)	1.3 (64)	Mar. 1950 to 1974
ESCAMBIA RIVER			10,963 (4233)				
	3755	Escambia River near Century	9886 (3817)	170 (6015)	0.02 (1.58)	23.0 (812)	Oct. 1934 to 1974
	3760	Pine Barren Creek near Barth	195 (75.3)	4 (141)	0.02 (1.87)	1.7 (60)	Oct. 1952 to 1974
POND CREEK							
	3707	Pond Creek near Milton	152 (58.7)	2 (72.9)	0.01 (1.24)	1.1 (38)	Jan. 1958 to 1974
Total Drainage Area			16,722 (6457)				

The estimated discharge for the Escambia River drainage basin was obtained by adding the flows for the Escambia River at Century and Pine Barren Creek near Barth to the average of the unit flows at Pine Barren Creek near Barth, and Pond Creek near Milton, multiplied by the ungaged drainage area of the Escambia River Basin as follows:

$$Q_{ESC} = Q_{CENT} + Q_{PBC} + \left(\frac{q_{PBC} + q_{PC}}{2} \right) \times 882.4$$

Where Q_{ESC} = Estimated Escambia River discharge - m^3/sec

Q_{CENT} = Escambia River at Century, Florida, discharge - m^3/sec

Q_{PBC} = Pine Barren Creek near Barth, Florida, discharge - m^3/sec

q_{PBC} = Pine Barren Creek near Barth, Florida - unit flow m^3/sec per km^2

q_{PC} = Pond Creek near Milton, Florida, unit flow m^3/sec per km^2

882.4 = Drainage area of Escambia River drainage basin downstream of streamflow gages - km^2

The estimated discharges for the Blackwater and Yellow River drainage basins were calculated by assuming that unit flows were the same throughout the drainage basins and by multiplying the total gaged flows by 1.95 for the Blackwater River, and 1.24 for the Yellow River. These values are the ratios of the total to gaged areas of the drainage basin.

To describe river discharge conditions during a particular study, a seven-day average flow referred to in the report as the "effective flow" was used. This flow is the average flow for the date of the study and the six preceeding days. A seven-day average flow was used because the estimated time of travel on the Escambia River from Century, Florida, to the mouth is about three days under mean annual river discharge conditions, and the estimated time of travel for Escambia River water through Escambia Bay is four days under mean annual river discharge conditions. If the study was longer than one day, the effective flow for the study was the average of the effective flows for each day.

Results

The Escambia River is the fifth largest river in Florida (Musgrove, et al., 1965). It starts near Union Springs, Alabama, as the Conecuh River and changes to the Escambia River near the Florida State Line. The drainage area is 10,963 km^2 (4233 mi^2) of which 10 percent is in Florida. The mean Escambia River discharge at Century, Florida was 170 m^3/sec (6,016 cfs) from 1934 to 1974, and using the method described in the previous section, the mean discharge of the Escambia River drainage basin for 1935 to 1974 was 189 m^3/sec (6,687 cfs). Mean annual flows in the Escambia River at Century, Florida, ranged from 82 to 293 m^3/sec in water years (October through September) 1960 through 1974 (Figure 6-2). The mean annual flow of 293 m^3/sec (10,350 cfs) in water year 1973 was the highest annual flow since 1960 and the maximum monthly mean of 890 m^3/sec (31,410 cfs) was also the highest since 1960. Water year 1974 was also a high flow year. Water years 1967, 1968, and 1969 had extremely low mean annual discharges. In fact, the lowest mean annual flow for the period of record, 82 m^3/sec (2895 cfs), occurred in water year 1968.

The mean monthly discharges, along with the minimum and maximum daily discharges for the Escambia River at Century, Florida, during water years 1970 through 1974, were variable as shown in Figure 6-3. This figure shows the pattern of high flows in March, and April and low flows in September, October, and November described by Musgrove, et al. Water year 1973 began in October 1972 with an extremely low mean monthly flow of 25 m^3/sec (868 cfs). From December through June, river discharges were extremely high with a maximum mean monthly value of 890 m^3/sec (31,410 cfs) in April 1973. River discharges decreased to a mean monthly value of 54 m^3/sec (1917 cfs) in October 1973. During water year 1974 high flows occurred in January, February, and April. Low flows occurred in July, and an unusually high mean monthly flow of 235 m^3/sec (8,305 cfs) was measured in September 1973. This high discharge was due to rains from Hurricane Carmen.

The mean annual discharges of the Escambia River at Century, Florida, for water years 1935 to 1974 ranged from 82 to 296 m^3/sec (Table 6-3). Water years 1967, 1968, and 1969 were extreme low flow years and only eight, none and three years, respectively, had lower mean annual flows. Water year 1972 was also an extremely low flow year and only nine years had lower mean annual flows. The mean annual discharge of 293 m^3/sec (10,350 cfs) in water year 1973 was only exceeded once during the period of record. The mean annual discharge for water year 1974 was 190 m^3/sec (6,708 cfs) and was exceeded by 12 years during the period of record.

The Escambia River flooded in April 1973 and a maximum daily flow of 2,097 m^3/sec (74,100 cfs) having a return period of seven years, was measured at Century, Florida. A maximum daily flood flow of 1,221 m^3/sec (43,100 cfs) occurred in September 1974,

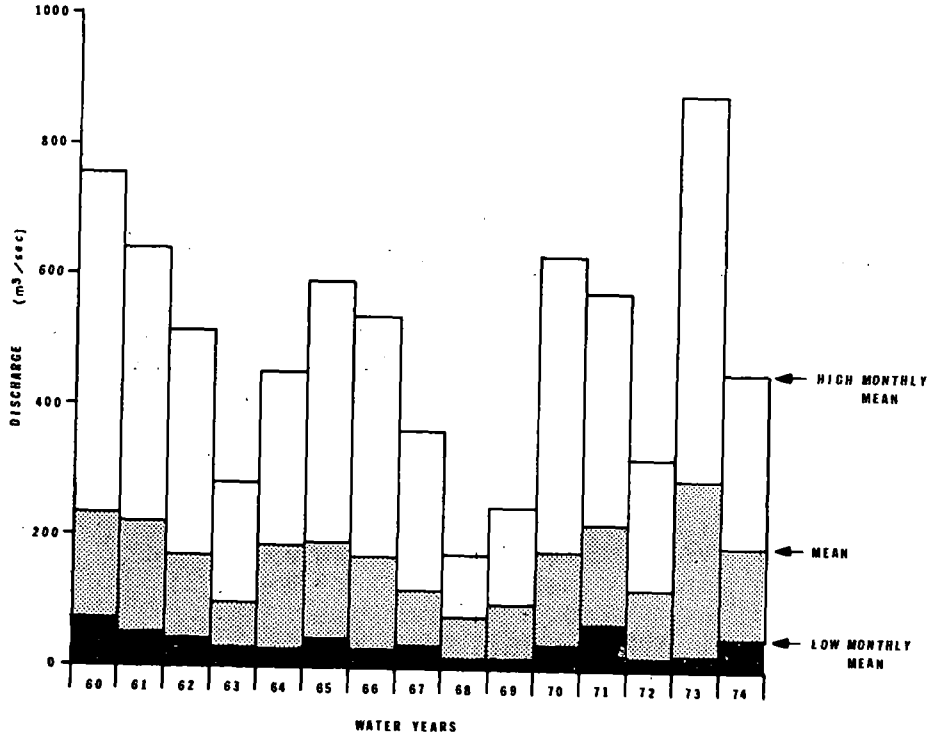


Figure 6-2. Mean, high monthly mean, and low monthly mean discharges for the Escambia River at Century, Florida for water years 1960 through 1974.

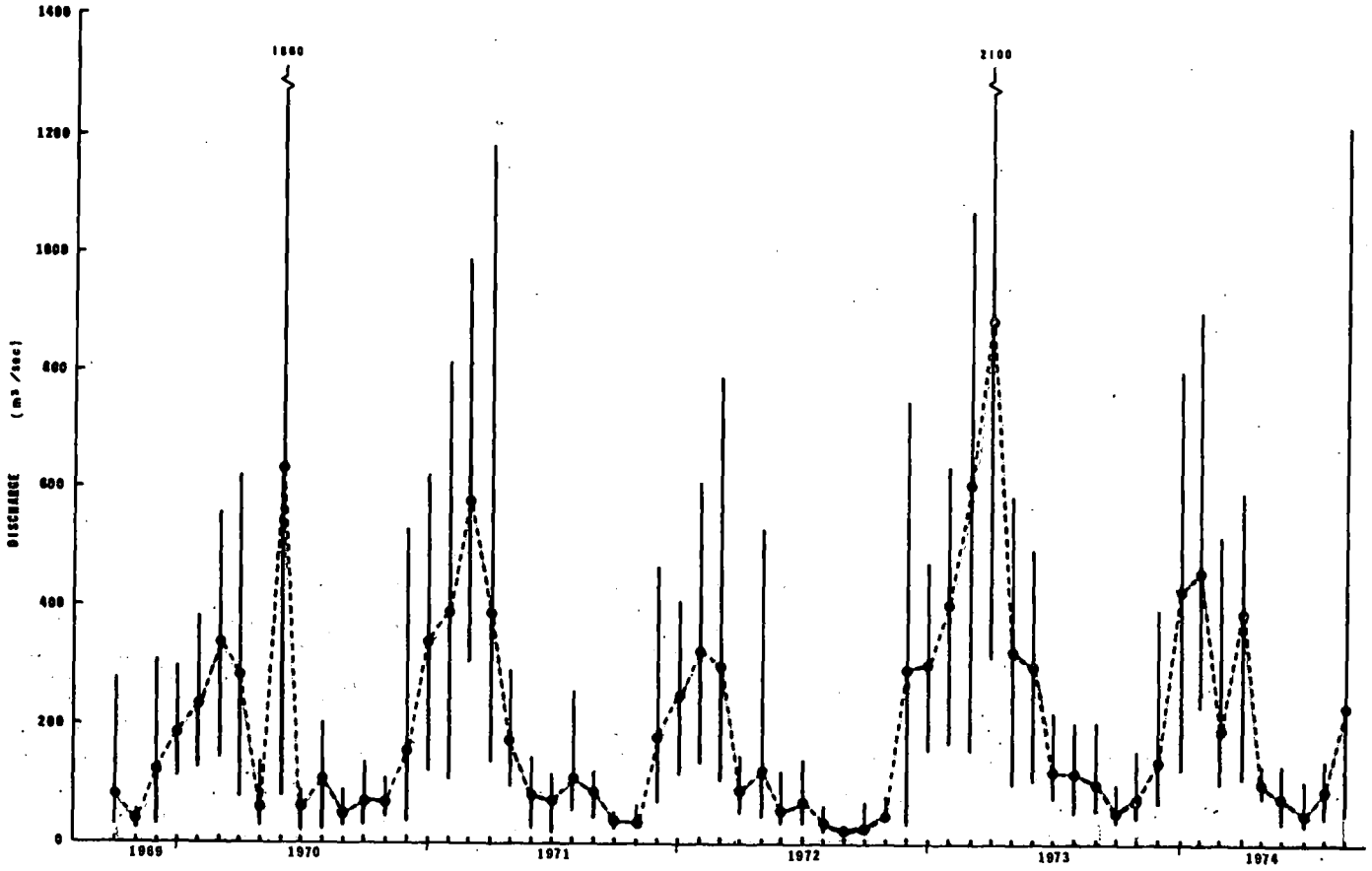


Figure 6-3. Mean monthly, maximum daily, and minimum daily discharge for the Escambia River at Century, Florida during water years 1970 through 1974.

Table 6 - 3. Mean annual discharge of the Escambia River at Century, Florida for water years 1935 through 1974.

Rank	Year	Mean Annual Flow m^3 /sec	Rank	Year	Mean Annual Flow m^3 /sec
1	1968	82	21	1940	173
2	1956	87	22	1962	174
3	1951	93	23	1938	181
4	1969	100	24	1942	183
5	1963	101	25	1970	183
6	1950	103	26	1964	187
7	1955	108	27	1939	189
8	1941	112	28	1974	190
9	1967	120	29	1965	191
10	1972	127	30	1936	198
11	1953	128	31	1943	203
12	1952	132	32	1971	210
13	1945	139	33	1948	212
14	1958	142	34	1961	224
15	1957	142	35	1960	239
16	1954	148	36	1947	243
17	1935	148	37	1949	278
18	1959	157	38	1946	284
19	1937	169	39	1973	293
20	1966	173	40	1944	296

having a return period of three years. The return periods are based on an analysis of annual maximum daily flows for the Escambia River at Century, Florida, 1929 - 1971, performed by Rumenik (letter dated April 17, 1973 from Roger P. Rumenik, U.S. Geological Survey, Tallahassee, Florida). The maximum discharge for the Escambia River was estimated to be 8,921 m^3/sec (315,000 cfs) in March 1929 by the U.S. Geological Survey based on information from local residents.

The seven-day, 10-year low flow, which is usually used to describe critical low flow conditions, was 23 m^3/sec (812 cfs) for the Escambia River at Century, Florida, during the period of record (Stone, 1974). The seven-day low flows for 1973 and 1974 were 17 m^3/sec (605 cfs) and 38 m^3/sec (1350 cfs), respectively. The seven-day low flow in water year 1973 had a recurrence interval of greater than 30 years. In water year 1974, the recurrence interval was about two years (Stone, 1974). Thus, extremely high and extremely low flows occurred in 1973.

The total annual gaged river discharge into the Pensacola Bay system from the three major river systems for the period of record was 259 m^3/sec (9,150 cfs) as shown in Table 6-4. The estimated total mean discharge from these river basins was 311 m^3/sec (11,000 cfs), and the total mean gaged discharge was 83 percent of the estimated total mean discharge. The estimated seven-day, 10-year low flow from the entire basin was 61 m^3/sec (2160 cfs).

FLOWS IN THE ESCAMBIA RIVER DELTA TRIBUTARIES

Introduction

Circulation in the northeastern section of upper Escambia Bay was found to be poor during past studies (USDI, 1970). A lack of freshwater discharge into this area, because it is farther from the Gulf than the mouth of the Escambia River, was considered the cause of this poor circulation. In the recommendations of the Escambia Bay Conference that established the Escambia Bay Recovery Study (USEPA, 1972e) it was suggested that the feasibility of diverting freshwater from the Escambia River into the northeast section of upper Escambia Bay be investigated. Escambia River delta tributaries, such as the Little White and

Table 6 - 4. Total flows into the Pensacola Bay system.

River Basin	Mean Annual Flow: Total Gaged m^3/sec (cfs)	Mean Annual Flow: Total Estimated m^3/sec (cfs)	7-day 10-year Low Flow m^3/sec (cfs)
Escambia	174 (6157)	189 (6690)	28 (1000)
Blackwater	23 (820)	44 (1570)	18 (620)
Yellow	62 (2175)	78 (2750)	15 (540)
Total	259 (9150)	311 (11000)	61 (2160)

Simpson Rivers, would have to be modified to accomplish the diversion.

Methods

Discharge estimates in the Escambia, Little White, and Simpson Rivers were performed on October 26, 1973, February 15, 1974, March 6, 1974, and April 16, 1974, during flood tides, and river discharge was considered to be the seaward flow. Current speed and direction in each river were measured using an Oceanographic Engineering Corporation (Hydroproducts) Model 451 Savonius rotor current meter and Model 452 current direction meter. The current meter was calibrated against a Marine Advisor's Model S-6a ducted current meter with internal calibration during each field study. Current speed and direction and salinity were measured at approximately third points of a lateral transect of the river during the October 26, 1973 study and at quarter points during the other studies. At each current measurement point, current and salinity measurements were made at a depth of 0.2 m (0.5 ft) and then every 0.6 m (2.0 ft). Four current speed and direction measurements were made at each depth and the averages were used in calculations. The cross-section area of each river was measured using a Raytheon DE-719 Survey Fathometer.

Discharge was calculated by drawing isopleths of constant current speed on a drawing of the cross-section area and then measuring the areas of constant current speed with a planimeter. The total discharge of each river was estimated by summing the products of cross-section area and current speed for all constant current speed areas.

Salinity was measured using a Beckman RS5-3 induction salinometer.

Results

Exploration of the tributaries in the Escambia River delta indicated that Saltzmans Bayou, Little White River, and Simpson River connect the Escambia Bay upstream of the U.S. Highway 90 Bridge with Escambia Bay (Figure 6-4). To determine the flow of these rivers relative to the Escambia River, flow was measured in the Escambia, Little White, and Simpson Rivers on four occasions at the locations shown on Figure 6-4. Flow was not measured in Saltzmans Bayou because of its relatively small cross-section area.

The measured total flow ranged from 80 to 87 percent of the estimated total flow for the entire Escambia River basin (Table 6-5). An average of 75 percent of the total measured flow entered Escambia Bay through the Escambia River, during the studies; and averages of 16.5 and 8.5 percent of the total measured flow entered the northeastern section of upper Escambia Bay through the Simpson and Little White Rivers, respectively.

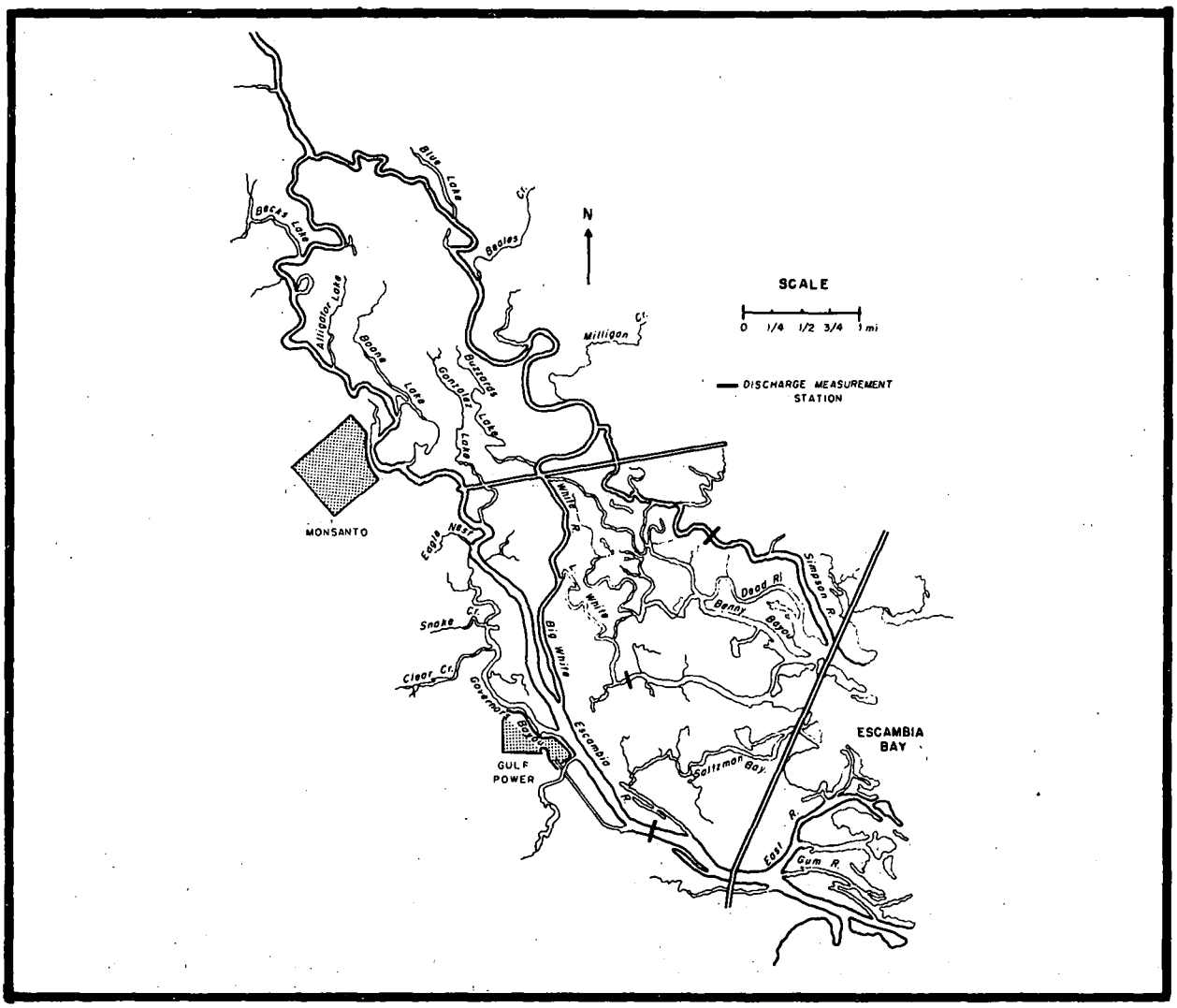


Figure 6-4. Map of the Escambia River delta showing location of discharge measurement stations.

Table 6 - 5. Estimates of flows in the Escambia River delta tributaries, 1973 - 1974.

Parameter	Units	Date			
		October	February	March	April
Measured total flow	m^3 /sec	48	477	155	410
Estimated total flow	m^3 /sec	55	600	191	497
Percent of estimated total flow	percent	87	80	81	82
ESCAMBIA RIVER					
Measured flow	m^3 /sec	33	364	119	320
Percent of measured total flow	percent	69	76	77	78
Center channel salinity - surface	ppt	--	0	0	0
Center channel salinity - bottom	ppt	--	0	0	0
SIMPSON RIVER					
Measured flow	m^3 /sec	8	78	28	60
Percent of measured total flow	percent	17	16	18	15
Center channel salinity - surface	ppt	4	0	0	0
Center channel salinity - bottom	ppt	23	0	0	0
LITTLE WHITE RIVER					
Measured flow	m^3 /sec	7	35	8	31
Percent of measured total flow	percent	14	7	5	7
Center channel salinity - surface	ppt	6	0	0	0
Center channel salinity - bottom	ppt	21	0	0	0
Change in tide level during study	meters	+0.23	+0.29	+0.20	+0.11
Average wind speed	km/hr	12	9	19	10

Consequently, about 25 percent of the total flow of the Escambia River basin flows directly into the northeastern section of upper Escambia Bay. However, most of this water does not alleviate circulation problems in the vicinity of Floridatown and the industrial discharges since it flows seaward in a southerly direction along the Escambia River Delta. Thus, there appears to be no justification for diverting additional water from the Escambia River into the northeastern section of upper Escambia Bay.

Although no flow measurements were made in Escambia River delta tributaries downstream of the U.S. Highway 90 bridge, it is believed that most of the discharge from the Escambia River drainage area enters the Escambia Bay through the dredged channel of the Escambia River. Other tributaries entering the bay in this area are East River, Sullivans Ditch, and Gum River, and all are relatively shallow, especially at their mouths.

TIDES

Introduction

Tidal energy is a major driving force of estuarine circulation or water transport. The tides of the Gulf of Mexico are relatively weak compared to those in the Atlantic Ocean; nevertheless, they are considerably more complex. Marmer (1954) in his excellent discussion of the tides in the Gulf of Mexico separates tides into three major types. The first type is semidiurnal where most of the time two tidal cycles of approximately equal range occur each day. The second type is mixed tides where either one or two tidal cycles with unequal ranges can occur during a day. The third type is diurnal, with one tidal cycle per day occurring most of the time.

At all locations in the Gulf of Mexico, tides are generally mixed or diurnal, and because tide producing forces are profoundly modified by hydrographic features, the type of tide found from location to location varies significantly. Marmer's (1954) explanation of the relatively large diurnal component in Gulf tides is that due to the bathymetry of its basin its free period of oscillation is about 24 hrs which approximates the period of diurnal tide producing forces, and thus, it responds better to the diurnal forces than to the semidiurnal forces. The section of the coast of the Gulf of Mexico near Pensacola has diurnal tides.

Methods

In 1973, two tide gages were installed in Escambia Bay by the Escambia Bay Recovery Study. One was attached to the Interstate 10 bridge, west of the barge channel, and the other to the U.S. Highway 90 bridge at the mouth of the Little White River. The Interstate 10 tide gage proved unreliable and only the data

collected by the U.S. Highway 90 tide gage will be discussed in this section.

A Stevens Type-A71 water level recorder was used to measure tide level. Recorder charts were changed monthly and the recorder was calibrated against a known datum on the U.S. Highway 90 bridge. Mean sea level (MSL) as referred to in this report is 0.0 elevation 1929 datum.

Results

Typical tides for the Pensacola Bay system (Figure 6-5a) include a bi-weekly cycle of variation in the number of tidal cycles and the tide range. Two tidal cycles occurred on January 13, 26, and 27, and the range of these tides was less than 0.24 m (0.80 ft). Approximately 7.5 days later the tidal range was 0.7 m (2.3 ft). Low range tides are known as equatorial tides and they occur when the moon is over the equator; and high range tides are known as tropic tides and they occur when the moon is above the northern or southern tropics.

Weather can have profound affects on the tides. Tides on January 20, 1974 were unusual, since both the high and low tides were considerably higher than the tide levels on the previous or following days (Figure 6-5a). This is typical of the effects of weather conditions. Another example of this was an extremely high tide of 0.76 m (2.5 ft) above MSL that occurred on September 8, 1974 (Figure 6-5b) due to Hurrican Carmen.

The mean tide level (MTL) on a given day usually does not coincide with mean sea level (MSL) (Figure 6-6a). The average MTL in January, February, March, July, and August was below MSL; in May it was slightly above MSL; and in April, June, and September it was equal to MSL. The lowest mean tide level, measured during February, was 0.55 m (1.80 ft) below MSL, which means that 205.1×10^6 m^3 (54.8 billion gallons) of water, or about eight days of average inflow from all rivers discharging into the bay, were displaced from the bay. The highest mean tide level in February was 0.24 m (0.79 ft) above MSL. It should also be noted that mean sea level is not constant. Provost (1973) indicates that MSL is rising at the rate of 0.3 m (1.0 ft) per 124 years at Pensacola.

Mean monthly tide ranges for January through September 1974 were relatively constant (Figure 6-6b). The mean tide range for this nine-month period was 0.45 m (1.49 ft). The maximum tide range was 0.98 m (3.2 ft) in September, and the minimum range was 0.06 m (0.20 ft) in January.

Discussion

The Pensacola Bay system is located on a section of coast which has the least amount of tidal energy available to drive circulation of almost any coastal location in the United States

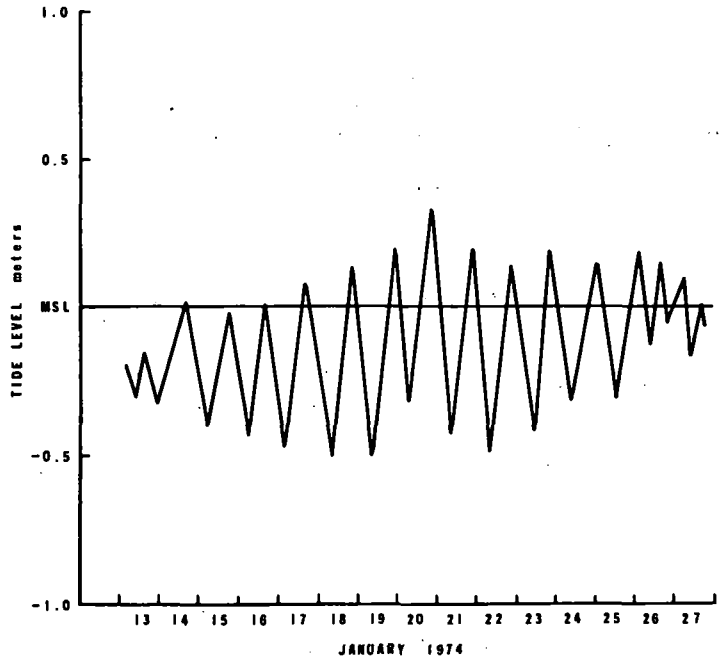


Figure 6-5a. Tides at U.S. 90 bridge during January 13-28, 1974.

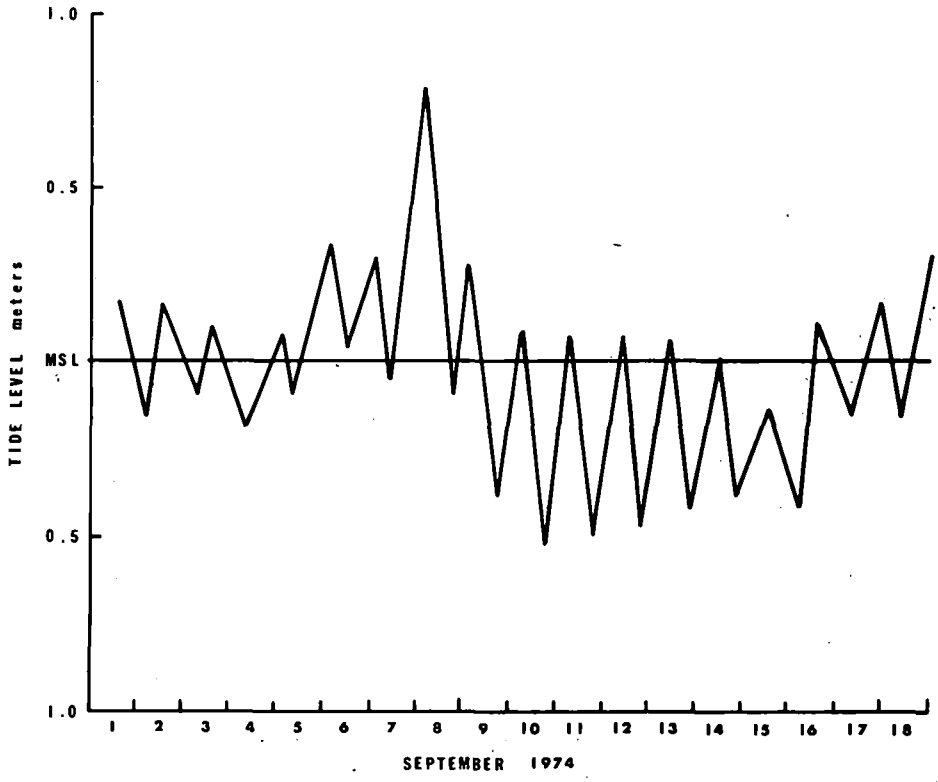


Figure 6-5b. Tides at U.S. 90 bridge during September 1-18, 1974.

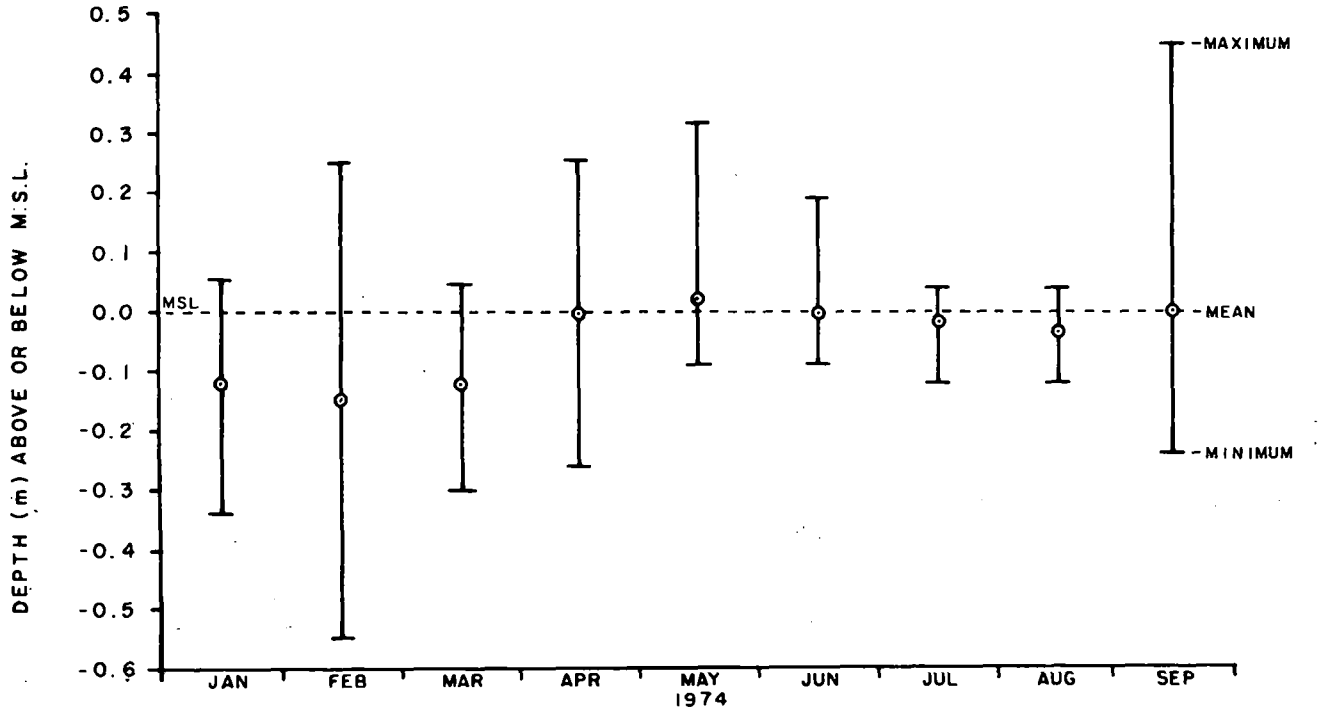


Figure 6-6a. Mean tide levels during January through September 1974 at U.S. 90 bridge.

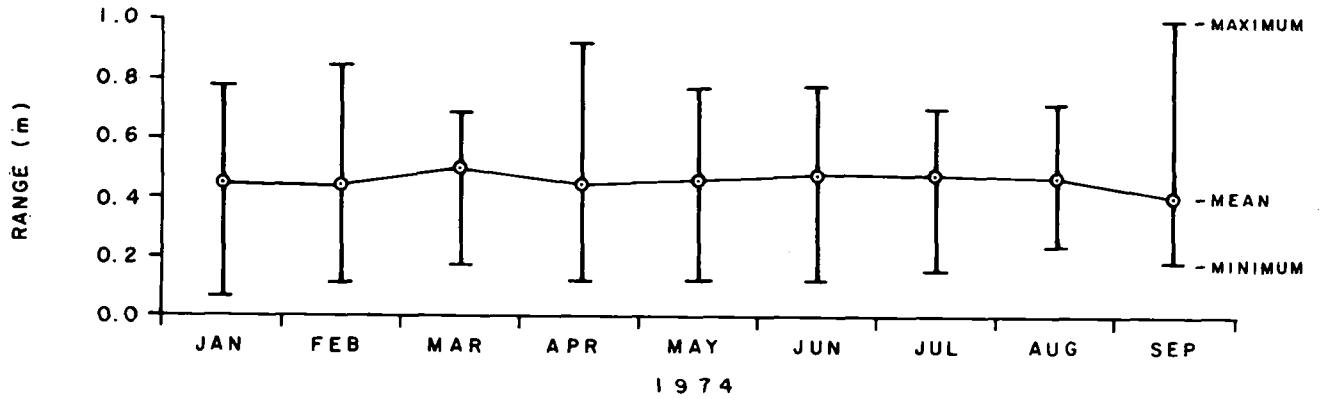


Figure 6-6b. Mean tide range during January through September 1974 at U.S. 90 bridge.

on the Atlantic Ocean or Gulf of Mexico. Two factors contribute to this: (1) The mean tidal range of 0.34 m (1.1 ft) at the Pensacola Bay entrance is minimal; and (2) tides are diurnal. Diurnal tides with a low tidal range also occur from Panama City, Florida to the west as far as Louisiana. Thus, at an Atlantic coast estuary, with the same tidal range, but where the tides are semidiurnal, twice the volume of water is transported into and out of the estuary each day. The matter is further compounded by the occurrence of equatorial tides, about every seven days, that have a tidal range near 0.15 m (0.5 ft) and last for about three days.

Tidal ranges of selected southeastern estuaries (U.S. Dept. of Commerce, 1975) are shown below:

Location	Tide Type	Tide Range	
		m	ft
Charleston Harbor	Semidiurnal	1.6	5.2
Savannah River	Semidiurnal	2.1	6.9
Saint Lucie Inlet	Semidiurnal	0.8	2.6
Tampa Bay	Mixed	0.6	2.0
Pensacola Bay	Diurnal	0.3	1.1

Of these estuaries, the tide range for Pensacola Bay is the lowest; consequently, tidal forces are relatively weak in Pensacola Bay compared to the other systems.

Marmer (1954) indicated that tidal ranges vary slowly over a period of 18.6 years due to changes in the inclination of the moon over the equator. Based on data presented by him for Pensacola from 1931 to 1949, a period of low mean annual tidal range is being approached, and the minimum point of the 18.6 year cycle will be 1977. The mean annual tidal range will not exceed the mean range until 1982.

Based on the above, the tidal contribution to the circulation of the Pensacola Bay system is relatively small compared to that expected in other southeast estuaries.

SALINITY

Introduction

In the Pensacola Bay system, as in most other estuaries, seawater and freshwater combine to form a mixture. The salt concentration or salinity of the mixture at any location, in the estuary depends on forces such as river discharge, density, meteorologic conditions, the earth's rotation, tides, and

bathymetry of the system. Salinity is the weight (in grams) of dissolved salts in one kg of water. Since salts are conservative substances, salinity can be used as a tracer to describe the effects of the above forces on the circulation of an estuary. A knowledge of salinity is also important from an ecological standpoint, because the salinity regime of a system will determine the organisms that can survive there.

Estuarine circulation was divided into four major types by Bowden (1967):

- Salt wedge,
- Two-layer flow with entrainment,
- Two-layer flow with vertical mixing, and
- Vertically homogeneous.

Salt wedge circulation occurs when river flow dominates circulation. A saltwater wedge sloping downwards in a riverward (toward the freshwater source) direction extends along the bottom into the estuary and there is practically no mixing between the salt and freshwater layers. The earth's rotation, as represented by the Coriolis Effect, causes the salt-freshwater interface to slope downwards to the right in the northern hemisphere when looking seaward.

When river flow is modified by tidal currents, estuarine circulation becomes two-layer flow with entrainment. Saltwater from the deeper layer is entrained into the freshwater layer and the deeper layer remains unchanged. In reality, a certain amount of mixing occurs between the layers and a transition zone with a steep salinity gradient, known as a halocline, is formed.

In shallow estuaries, river flow and tidal mixing dominate circulation and a pattern of two-layer flow with vertical mixing occurs. Freshwater moves seaward in the upper layer and saltwater moves riverward in the lower layer. This system is known as a partially mixed estuary. The maximum salinity gradient occurs near the level of no net motion. The volume of water transported by this type of circulation in the upper and lower layers may be many times the river discharge.

When the tidal currents are very strong relative to the river discharge, vertical mixing can be so strong that the salinity becomes homogeneous with depth. This is known as vertically homogeneous circulation. A horizontal salinity gradient still occurs in this type of estuary.

Methods

Salinity was measured in the field using a Beckman RS5-3 induction salinometer. The dates of the studies where salinity

was measured are presented in Table 8-1. Surface measurements were taken 0.3 m (1.0 ft) below the surface and bottom measurements were taken 0.3 m (1.0 ft) above the bottom. The mean sampling depth at each station is shown in Appendix 8-3 and 8-4, and the locations of the sampling stations are described in Appendix 8-2.

The Two-Layer Model, a method of determining the flushing rate of an estuary, has been described by Bowden (1967). It is assumed in the model that the exchange of water between the estuary and the sea is caused by advection and that horizontal diffusion is negligible. Accordingly, the rate of flow in the two layers can be calculated, with a knowledge of the mean salinity of the inflowing and outflowing layers and the river discharge. According to Bowden (1967), the depth at which the maximum salinity gradient is found is the level of no net motion. Above this depth is the outflowing layer, and below is the inflowing layer.

From the conditions for continuity of water and salt

$$Q_u - Q_l = R$$

$$Q_u S_u = Q_l S_l$$

Solving for the inflow and outflow

$$Q_u = R/(1 - S_u/S_l)$$

$$Q_l = R/(S_l/S_u - 1)$$

The flushing time of freshwater out of the estuary is

$$T = V/(Q_u \times 86{,}400) = V(1-S_u/S_l)/(R \times 86{,}400)$$

where

R = river discharge - m^3/sec

Q_u = volume transport of outflowing water - m^3/sec

Q_l = volume transport of inflowing water - m^3/sec

S_u = mean salinity of outflowing water - ppt

S_l = mean salinity of inflowing water - ppt

V = volume of water in the bay riverward of the salinity measurement point - m^3

T = flushing time - days

Using data from the James Estuary, Pritchard (1965) has developed another method of determining the values of S_u and S_l to be used in the Two-Layer Model. In this method, the level of no net motion is assumed to be the depth at which the salinity gradient begins to decrease appreciably but which is above the level of the maximum gradient. The mean salinity of the upper two-thirds of the layer above this level is S_u, and S_l is the mean salinity of the lower two-thirds of the layer below this level. Pritchard's method of determining S_u and S_l was used in this report.

Results and Discussion

Salinity Variation

Freshwater from Escambia River tended to stay on the western side of Escambia Bay as it moved seaward (Figure 6-7) during January through September 1974. The mean surface salinity values in the northeastern portion of the upper bay (Stations EEKV, and EGLY), were higher than those in the northwestern portion (Stations EIIL and EIKC) which are farther seaward, but close to the mouth of the river. Mean surface salinities were considerably higher on the eastern side of the bay than directly across the bay on the western side. Mean surface salinity data also indicated that freshwater entering East Bay from Blackwater Bay also flowed seaward on the western side of the Bay.

Intrusion of saltwater into the Escambia River is an inverse function of river discharge. A saltwater wedge was not present in the Escambia River, 14.2 km (8.8 mi) upstream of the mouth, (Station ERIO) during any of the 1974 studies. A saltwater wedge was observed, 7.4 km (4.6 mi) upstream of the mouth of the river, when the effective Escambia River discharge was less than 85

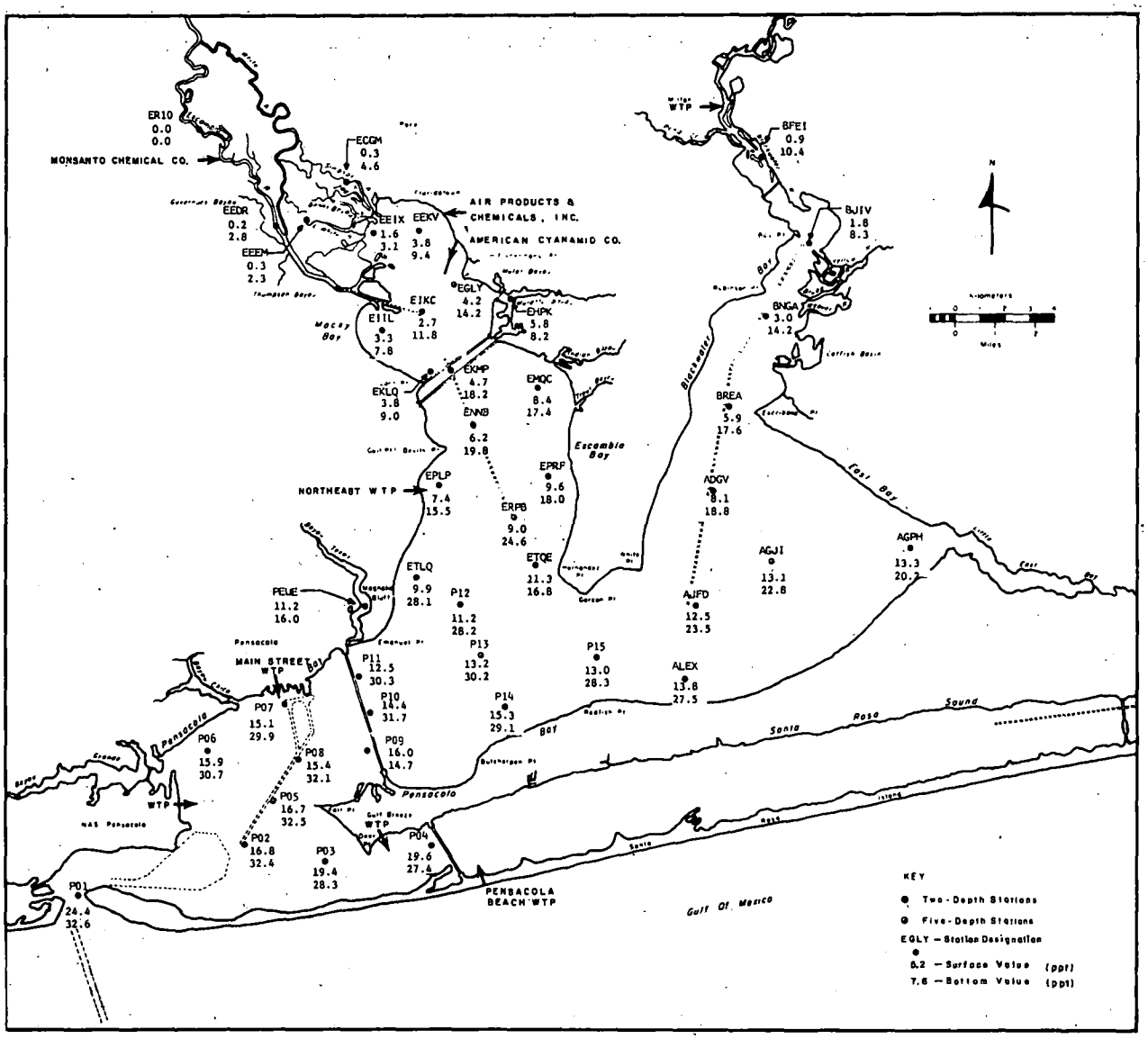


Figure 6-7. Mean surface and bottom salinities in the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

m^3/sec (3,012 cfs). At the U.S. Highway 90 bridge, 2.6 km (1.6 mi) upstream of the mouth of the river, a saltwater wedge was found in more than half of the studies when the estimated river discharge was less than 226 m^3/sec (7974 cfs).

Mean salinities in Pensacola Bay indicate that less saline water flows seaward along the northern side of the bay. The mean salinity of seawater entering the bay (as indicated by the mean bottom value at the inlet, Station P01) is 32.6 ppt. The mean bottom values throughout the bay in the deep areas are only slightly less than the salinity of incoming seawater, indicating water from the lower layer is entrained into the upper layer, but the reverse does not occur.

The movement of more freshwater seaward on the western side of Escambia and East Bays and on the northern side of Pensacola Bay appears due to the Coriolis Effect which is a function of the earth's rotation. However, vertical stratification throughout the system indicates that freshwater moves seaward and saltwater moves riverward throughout the entire bay.

Fluctuations in salinity at most stations were considerable during the studies in January through September 1974. The mean, maximum, minimum, and coefficient of variation at each station sampled is presented in Appendix 6-1.

Analysis of salinities in the Pensacola Bay system and river discharge indicated that the higher the river discharge into the system, the lower the salinity (Figure 6-8). In addition, bays with river inflows had lower mean salinities. Thus, mean salinities in East Bay were always higher than those in Escambia and Blackwater Bay. Pensacola Bay, being closest to the inlet, had mean salinities 6.8 ppt higher than East Bay on the average.

There was a significant correlation between mean Escambia Bay salinity and the inverse of the effective flow of the Escambia River ($r = 0.824$, $df = 11$, $p < 0.01$).

Daily fluctuation of surface and bottom salinity and tide level (measured in upper Escambia Bay at U.S. Highway 90 bridge) is presented in Figure 6-9 for selected stations sampled during the August 1973 water quality studies. During Study III, August 16, and 17, 1973, the variation in surface and bottom salinity was two and one ppt, respectively, in mid Escambia Bay (Station ENNB) when the tidal range was about 0.3 m (0.8 ft). During Study IV, on August 23 through 24, 1973 when the tide range was 0.7 m (2.0 ft), the surface salinity varied by eight ppt and the bottom salinity varied by one ppt. This indicates that tidal mixing has a considerable influence on surface salinity and that there was significant horizontal transport of surface water due to the tides. This also indicates that movement of bottom water is limited.

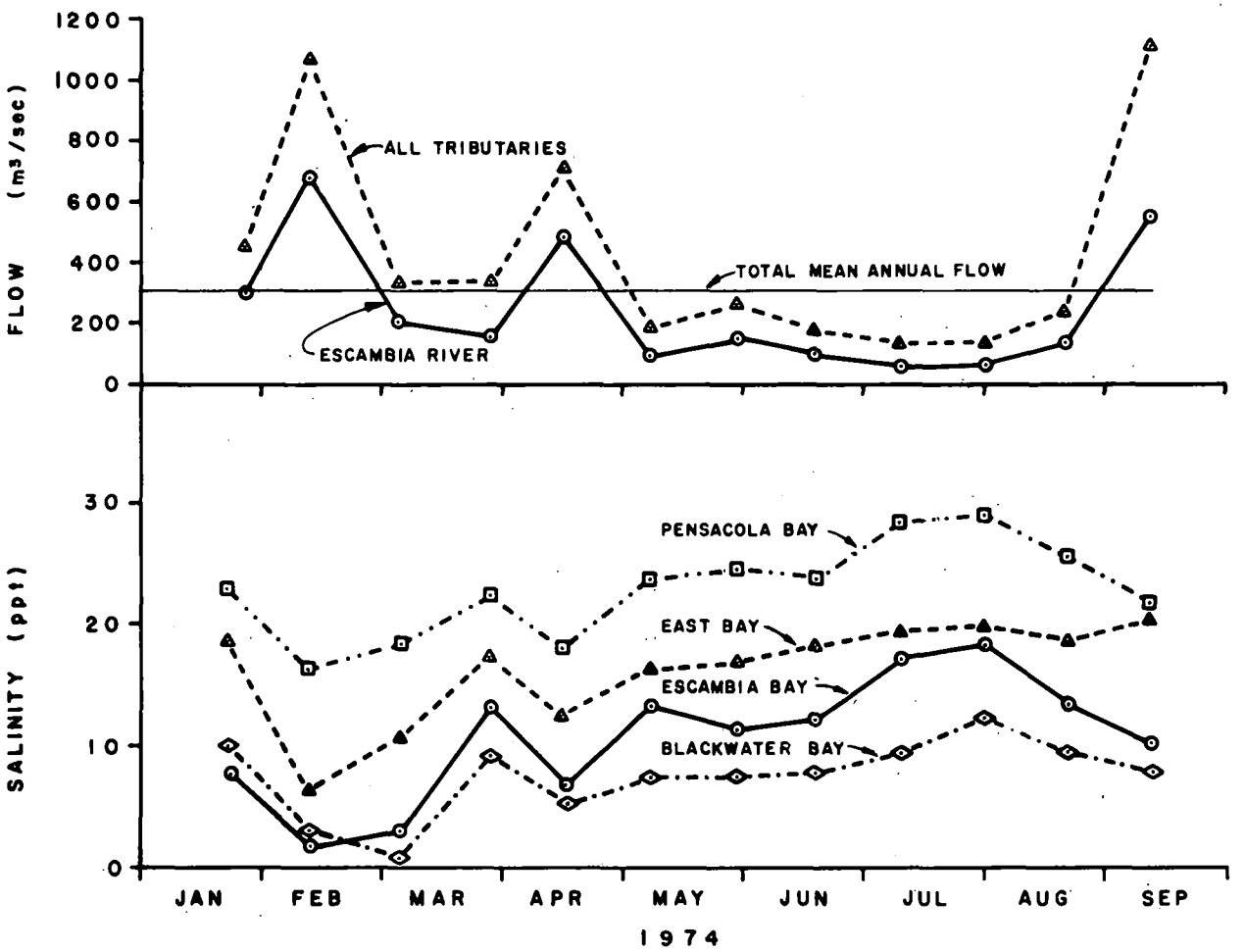


Figure 6-8. Mean salinities of the components of the Pensacola Bay system during January through September, 1974 and the total effective discharge of the Escambia River and all tributaries to the Pensacola Bay system (Pensacola Bay data from the University of West Florida).

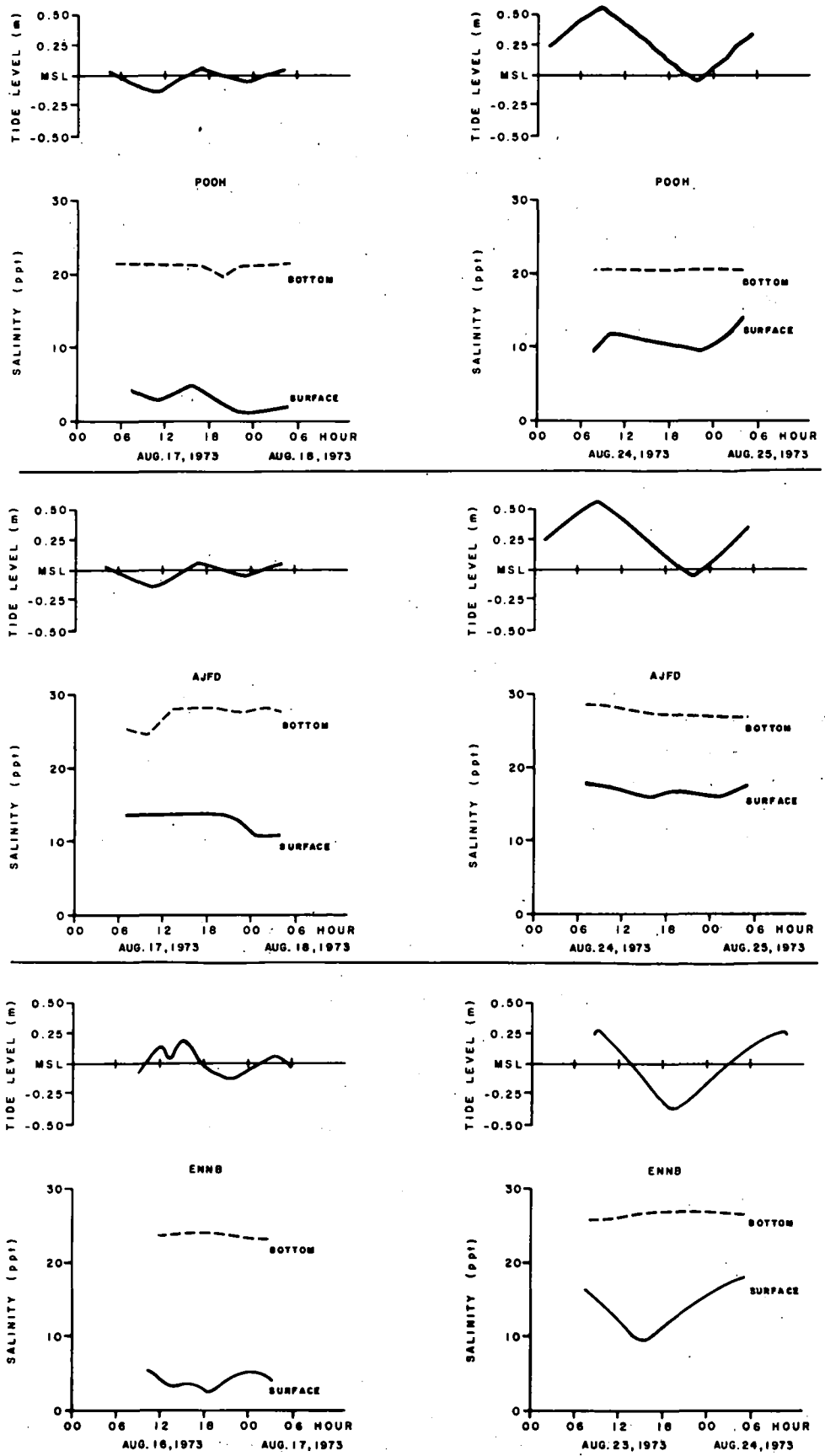


Figure 6-9. Salinity and tide variation at Stations ENNB, AJFD, and POOH during the August 1973 water quality studies.

In East Bay (Station AJFD) there was very little fluctuation in salinity due to variation in tide level (Figure 6-9), indicating that transport of water in East Bay was due to other factors than tide.

In Pensacola Bay (Station POOH - PO5), the surface water salinities indicated tide caused the transport of surface water (Figure 6-9). During Study III (August 17-18, 1973) surface salinity varied by three ppt and during Study IV (August 24-25, 1973) surface salinity varied by 4.5 ppt. The salinity variation followed tidal variation during both studies. Bottom salinity was relatively constant during both studies, indicating practically no movement of bottom water.

During Studies I and II in April 1973 the rivers discharging into the Pensacola Bay system were at flood stage and the water in the bays was essentially fresh.

Chloride concentrations in Escambia Bay were studied during September 23 to 25, 1969 (USDI, 1970). The chloride concentration was assumed to approximate chlorinity and the following equation was used to convert the data collected to salinity:

Salinity (ppt) = 1.80655 x Chloride (mg/l)/1000.

The mean salinity of Escambia Bay above the Interstate 10 bridge was 18.4 ppt. At mid Escambia Bay (Station E25-ENNB) the mean surface salinity was 17.0 ppt with a range of 13.9 to 19.5 ppt, and the mean bottom salinity was 28.1 ppt with a range of 30.9 to 22.4 ppt.

Unused submerged pilings under the L and N Railroad bridge were found to hinder circulation during the above study. The conference on Escambia Bay (USDI, 1970a) recommended that these excess pilings be removed, and this was accomplished shortly thereafter.

Salinities were measured in Choctawhatchee Bay during a survey performed on September 12, 1974. Surface salinities increased from 0.0 ppt in the lower Choctawhatchee River (Station ZO6X) to about 22 ppt near the inlet (Figure 6-10). Bottom salinities were near 20 ppt in the shallow eastern and western ends of the bay, and near 30 ppt in the deep central portion of the bay. The circulation type in the eastern portion of the bay (Station ZLQE) was two-layer flow with vertical mixing, and that in the central and western portions of the bay (Stations YK7U and YNKF) was of the two-layer flow with entrainment. Thus, circulation in Choctawhatchee Bay was similar to that in the Pensacola Bay system.

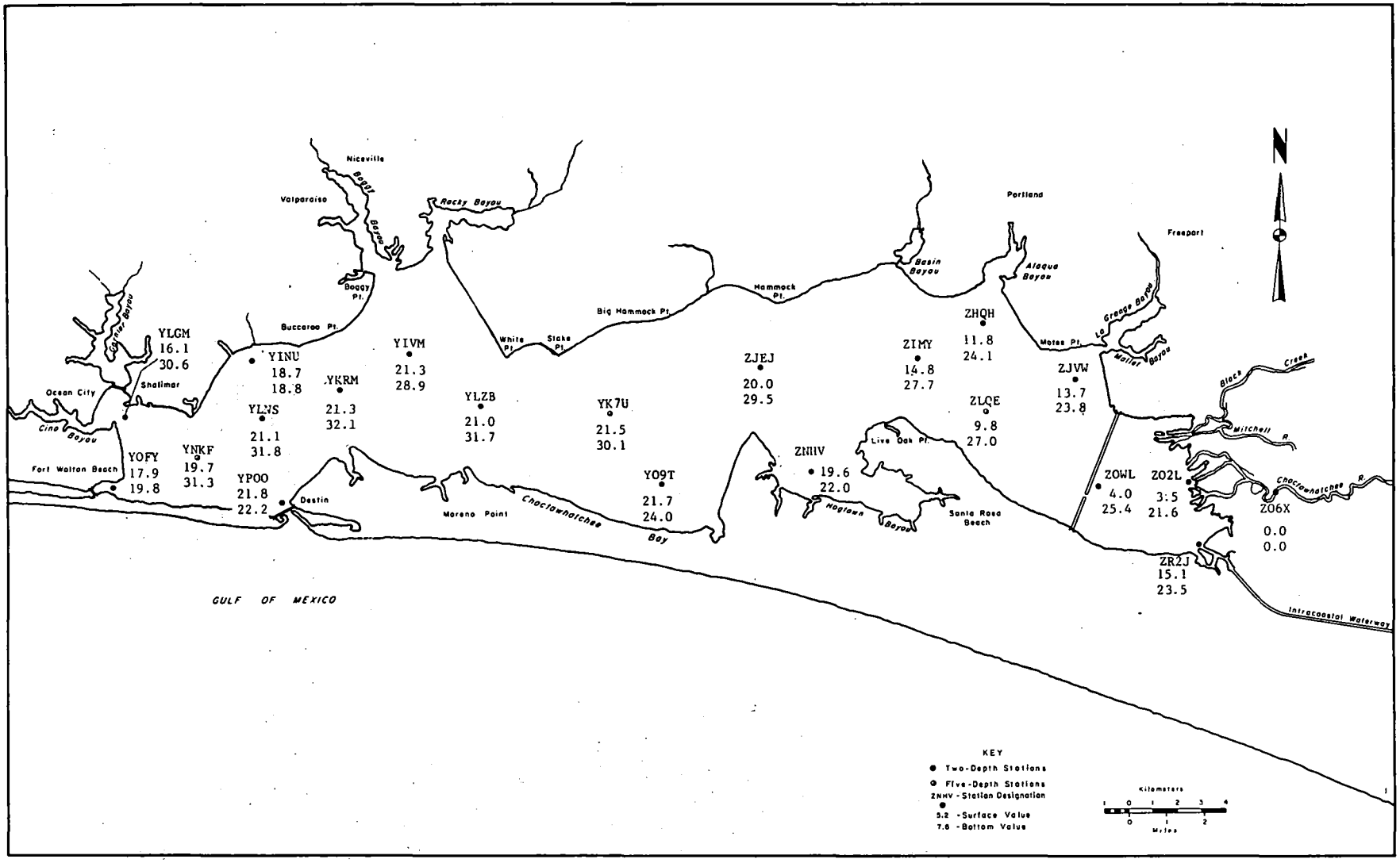


Figure 6-10. Salinities (ppt) in Choctawhatchee Bay on September 12, 1974.

Inflow and Outflow Based on Salinity

Evaluation of salinity-depth profiles for selected stations in Escambia, East, and Pensacola Bays, sampled in 1974, provided information on circulation in the Pensacola Bay system. Salinity profiles in mid Escambia Bay (Station ENNB) indicated that Escambia Bay has a stratified circulation pattern between partially mixed and two-layer flow with entrainment (Figure 6-11). During most studies there were three distinct layers, an upper layer of homogeneous salinity 1.0 to 1.3 m (3.0 to 4.0 ft) deep, a transition layer or halocline 0.7 to 1.6 m (2.0 to 5.0 ft) thick, and a lower layer of homogeneous salinity. The upper layer usually had salinities less than 10.0 ppt and the lower layer greater than 20.0 ppt.

In East Bay (Station AGJI), there was less vertical stratification than in Escambia Bay (Figure 6-11). During most of the studies three distinct layers were present, an upper layer of homogeneous salinity (9.0 from 19.0 ppt) extending to 1.6 to 2.3 m (5.0 to 7.0 ft), a halocline, and a thin lower layer. The salinity gradient of the halocline was steeper in East Bay than in Escambia Bay, indicating less transfer between layers.

Pensacola Bay (Station P05) - sampled by the University of West Florida) had two-layer flow with entrainment type circulation during most of the 1974 studies (Figure 6-11). On most of the sampling dates, a surface layer with a steep salinity gradient and a homogeneous deep layer were present. The salinity of the deep layer exceeded 30.0 ppt on all sampling dates. The steep surface salinity gradient indicated poor mixing in the surface layer. High salinity in the bottom layer indicated entrainment of saltwater from the deep layer to the surface layer was occurring, and that there was practically no transfer of surface water into the lower layer.

The salinity profiles (Figure 6-11) and the salinity-tide variation curves (Figure 6-9) both indicate a difference between the salinity of the upper and lower layers in the bay. It appears that as far as transport of pollutants in the bay is concerned the bay is vertically stratified or there are two separate layers in the bay with limited exchange between them. Due to this, the Pensacola Bay system must be regarded as a three-dimensional system when considering circulation.

Flushing of the Pensacola Bay system was significantly improved by increased river inflows and tidal mixing, based on an analysis using the Two-Layer Model (Table 6-6). The flushing time increased from 21.2 days during a high river inflow period (average for Studies I and II, April 1973) to 34.2 days during a low river inflow period (average for Studies III and IV, August 1973). Tidal mixing accelerated flushing of the bay system by 12.9 days during a high river inflow period and by 62.6 days during a low river inflow period. Mean river inflows to the Pensacola Bay system were 1227 m^3/sec or 294 percent of the mean

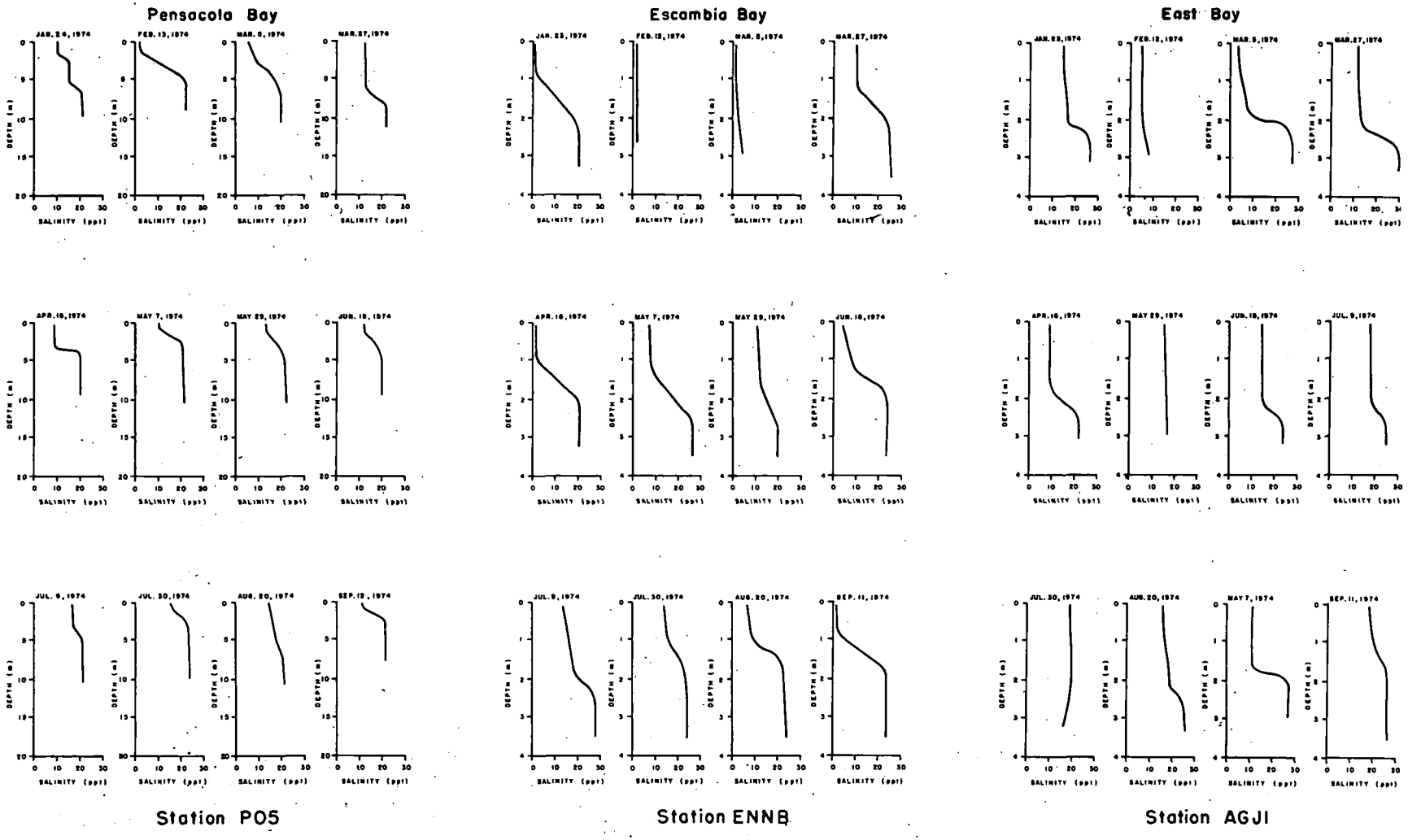


Figure 6-11. Salinity-depth profiles at Stations P05, ENNB, and AGJI during water quality studies performed in January through September, 1974.

annual inflow, during the high inflow period and 247 m^3/sec or 79 percent of the mean annual inflow during the low inflow period. Average tidal ranges were 0.4 m during both periods (Table 8-1). The increase in tidal range associated with cycling from equatorial to tropic tides caused a 12.7 day acceleration in flushing of the bay system during the high inflow period and a 41.7 day acceleration during the low inflow period (Table 6-7). During both flow periods, river discharge was higher during the studies with equatorial tides (low tidal ranges). Thus, the acceleration in flushing of the bay system can only be attributed to increased tidal mixing.

If we assume that tidal energy would cause about a 60-day acceleration in flushing time, as it did during the low flow period, the flushing time of Pensacola Bay system would be about 200 days for the seven-day, ten-year low flow of 61 m^3/sec.

Bottom salinities during both of the high inflow and both of the low inflow remained about the same even through river inflow and tidal conditions changed (Figure 6-12). This is an indication of weak bottom circulation.

The variables used in calculating flushing time are presented in Appendix 6-2.

WATER TEMPERATURE

Introduction

Fluctuations in water temperatures are an extremely important factor in determining the type of aquatic community that will inhabit a body of water. High water temperatures also reduce saturation values of dissolved gases in water, increase transfer rates of gas between air and water, and accelerate the metabolic rates of organisms in the system.

Methods

Temperatures were measured with a Beckman RS5-3 induction salinometer and thermometer. Surface measurements were taken 0.3 m (1.0 ft) below the surface and bottom measurements were taken 0.3 m (1.0 ft) above the bottom. The mean sampling depth at each station is presented in Appendix 8-4, and the locations of the sampling stations are described in Appendix 8-2.

Results and Discussion

Mean temperatures in Escambia, East, Blackwater, and Pensacola Bays during each 1974 water quality study were about the same. In all of the bays, minimum temperature occurred in February, and in all bays except Pensacola Bay the maximum mean temperature occurred in July. Mean temperatures in Escambia Bay and Pensacola Bay during each water quality study in 1974 are shown in Figure 6-13.

Table 6 - 6. Flushing characteristics of the Pensacola Bay system during high (Studies I and II) and low (Studies III and IV) river inflow periods in April and August 1973 respectively.

River Inflow	Escambia	East-Blackwater	Pensacola	Total
Flushing time (days)				
High	3.7	10.8	6.7	21.2
Low	8.6	16.2	9.4	34.2
Displacement time (days)				
High	3.7	20.8	9.6	34.1
Low	19.0	38.4	39.4	96.8
Reduction in flushing time due to tidal mixing (days)				
High	0.0	10.0	2.9	12.9
Low	10.4	22.2	30.0	62.6

Table 6 - 7. Reduction in flushing time (days) due to tidal mixing in the Pensacola Bay system during 1973.

	Studies			
Bay	I	II	III	IV
Escambia	0.0	0.0	5.1	15.7
East and Blackwater	5.6	14.2	17.1	27.3
Pensacola	0.8	4.9	19.5	40.4
Total system	6.4	19.1	41.7	83.4
Flow	High	High	Low	Low
Tides	Equatorial	Tropic	Equatorial	Tropic
Month	April	April	August	August

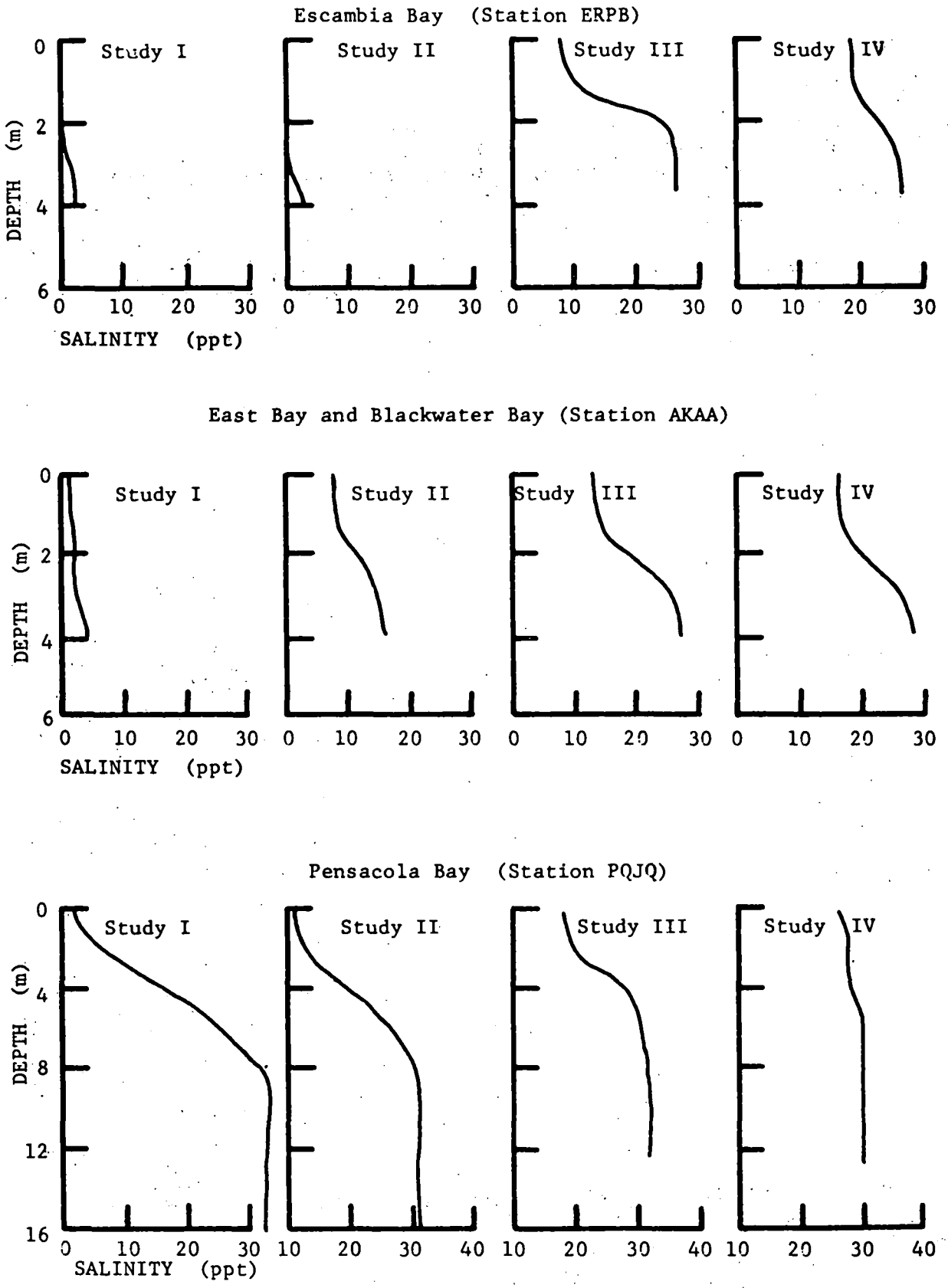


Figure 6-12. Mean salinity-depth profiles over a tidal cycle at stations near the center of the mouths of bays in the Pensacola Bay system during 1973.

Waters discharged into the Pensacola Bay system by tributary streams were cooler than waters in the bay during every 1974 study (Figure 6-14, Appendix 6-3). Mean temperatures in lower Escambia Bay, East Bay, and Pensacola Bay were slightly above 23°C and the mean surface and bottom temperatures were essentially the same. In Blackwater Bay and upper Escambia Bay, mean temperatures were lower than those in the remainder of the system due to mixing with cool river water.

The lowest water temperatures during the April and August 1973 water quality studies (Studies I through IV) were also found near the Escambia River delta and were due to cool river water entering the bay. The highest temperatures usually occurred in Pensacola Bay. Generally, there was not much diurnal water temperature fluctuation, but the variation that occurred was caused by solar heating in the afternoon. Water temperature data collected during intensive water quality studies performed in April and August 1973 are presented in Table 6-8. Surface and bottom temperatures at all sampling stations were essentially 20°C during the April studies. In August 1973 surface and bottom water temperatures were near 30°C. In lower Escambia, temperature ranges were about three and one °C on the surface and bottom, respectively, during the April studies, and less than one degree during the August studies.

An intensive water quality study was performed in Escambia Bay during September 23-25, 1969 (USDI, 1970). In lower Escambia Bay, (Station E27 - ERPB) the mean surface and bottom water temperatures were about 25°C. The surface water temperature range was 23.0 to 27.0°C, and the bottom water temperature range was 23.5 to 25.5°C.

The mean water temperature in Choctawhatchee Bay was 27.8°C, with a range of 25.5 to 29.4 during a water quality study performed there on September 12, 1974.

CIRCULATION IN ESCAMBIA BAY

Introduction

A circulation study was performed in Escambia Bay that traced Escambia River water as it moved throughout the bay under conditions approximating mean annual tidal range and river discharge.

Methods

The study began at 0800 on August 6, 1974, when 45 kg (100 lbs) of Rhodamine WT fluorescent dye were discharged uniformly throughout the cross section of Escambia River 19 km (12 mi) above its mouth, and it ended on August 10, 1974. The tide was beginning to ebb at the U.S. Highway 90 tide gage during the dye dump. The dye was sampled every three hours by two sampling crews at 30 of the 60 sampling stations established for the study

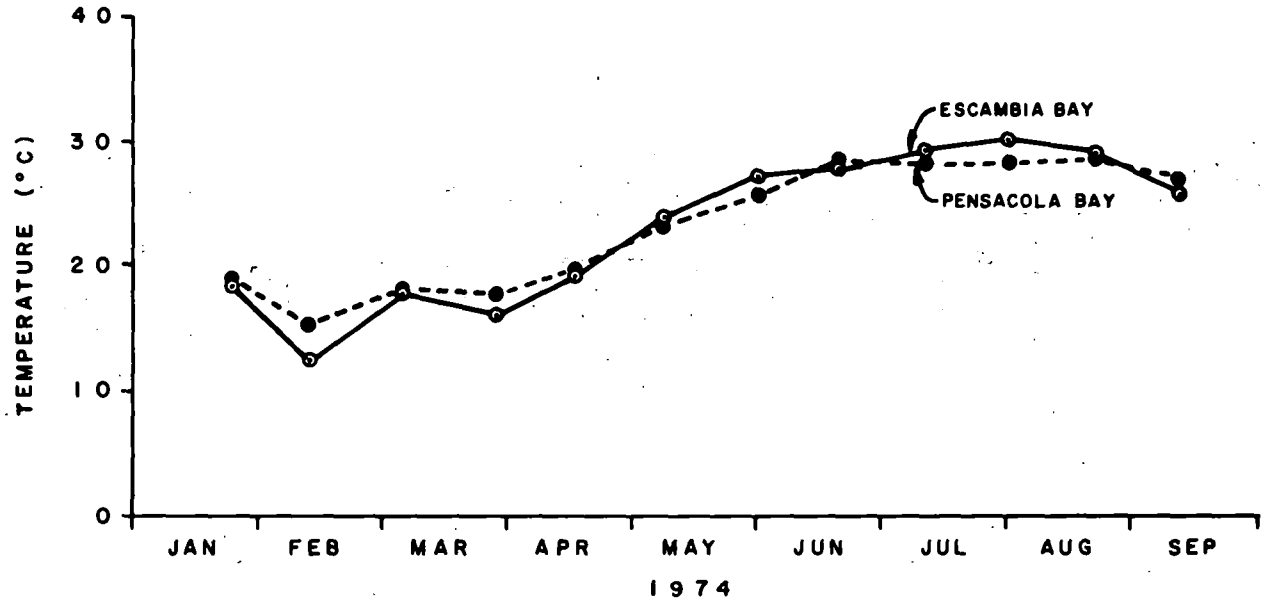


Figure 6-13. Mean temperature in Escambia Bay and Pensacola Bay for each study performed in 1974 (Pensacola Bay data from the University of West Florida).

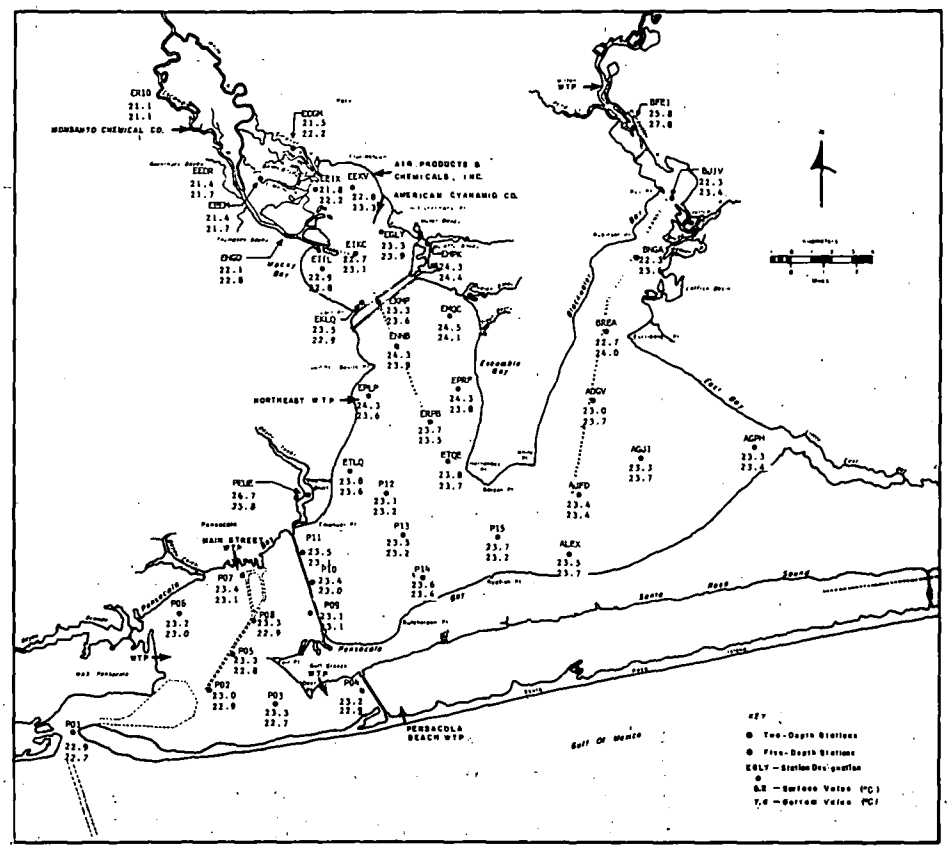


Figure 6-14. Mean surface and bottom temperatures for stations sampled during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Table 6 - 8. Water temperature data (°C) for 1973 intensive water quality studies.

Study Date	Mean	Maximum	Time	Date	Minimum	Time	Date
April 13 - 15, 1973 - Study I							
surface	17.2	19.3	1250	4/13/73	16.0	0700	4/13/73
bottom	16.4	17.1	2147	4/13/73	15.9	1541	4/13/73
April 19 - 21, 1973 - Study II							
surface	19.7	20.1	1906	4/19/73	19.4	0703	4/19/73
bottom	19.8	20.0	1905	4/19/73	19.5	1600	4/19/73
August 16 - 18, 1973 - Study III							
surface	28.8	29.2	1619	8/16/73	28.4	0320	8/17/73
bottom	29.9	30.2	1319	8/16/73	29.7	0816	8/16/73
August 23 - 25, 1973 - Study IV							
surface	28.0	29.2	1604	8/23/73	26.8	0740	8/23/73
bottom	29.0	29.4	1859	8/23/73	28.7	0746	8/23/73

(Figure 6-15). Bottom dye samples (0.3 m - 1.0 ft above the bottom) were collected with an incremented rod with a test tube attached to the bottom. The test tube could be opened and closed from the boat, to obtain a sample at any depth up to 2.1 m (7.0 ft). At depths greater than 2.1 m (7.0 ft) a Kemmerer sampler was used. The water samples were kept in the dark until analyzed.

The concentration of dye was measured at the EBRS laboratory using an Aminco Fluoro-Microphotometer Model 4-7102. Dye standards from 0.1 µg/l to 3,000 µg/l were prepared and the instrument was standardized every 12 hours. All dye measurements were made at 20.0°C ± 0.1°C.

Salinity and temperature measurements were taken with a Beckman RS5-3 induction salinometer in conjunction with each dye sample.

Environmental Conditions

The effective flow of the Escambia River was 190 m^3/sec (6,730 cfs), which is about mean annual flow, during this dye study. The tide range at the U.S. Highway 90 tide gaging station was 0.4 m (1.2 ft) on August 6, 1974 and 0.6 m (1.9 ft) on August 10, 1974 (Appendix 6-4). Prevailing winds were from the south during the study and wind velocities were relatively low, less than 12 km/hr.

There was considerable vertical salinity stratification in the bay during the study, but the horizontal salinity distribution remained relatively constant throughout the study. Salinities were 2.8 and 17.0 ppt at the surface and bottom, respectively, in upper Escambia Bay (Station D2) at 1023 on August 6; and 1.4 and 18.7 at the surface and bottom, respectively, at the same location at 1018 on August 9. In the lower bay (Station I3), surface and bottom salinities were 8.0 and 25.3 ppt, respectively, at 2210 on August 7; and 6.5 and 26.1 ppt, respectively, at 1618 on August 9. Water temperature in Escambia Bay ranged between 26 and 32°C during the study.

Results and Discussion

The time (average time of sampling run) that the first major dye peak arrived at the surface of each sampling station is shown in Figure 6-15. The isopleths indicate the location of this dye peak during odd-numbered runs. A dye peak was first measured in Macky Bay about 16 hr after the dye dump, indicating that a significant amount of water from the Escambia River enters Macky Bay. The dye reached the I-10 bridge after about 8 hr of travel in the bay and Devils Point after about 19 hr in the bay. South of the I-10 bridge, dye arrived near Indian Bayou on the East shore of the bay about 26 hr after entering the bay. The first major dye peak reached the mouth of the bay 55 hr (2.3 days) after the dye entered the bay.

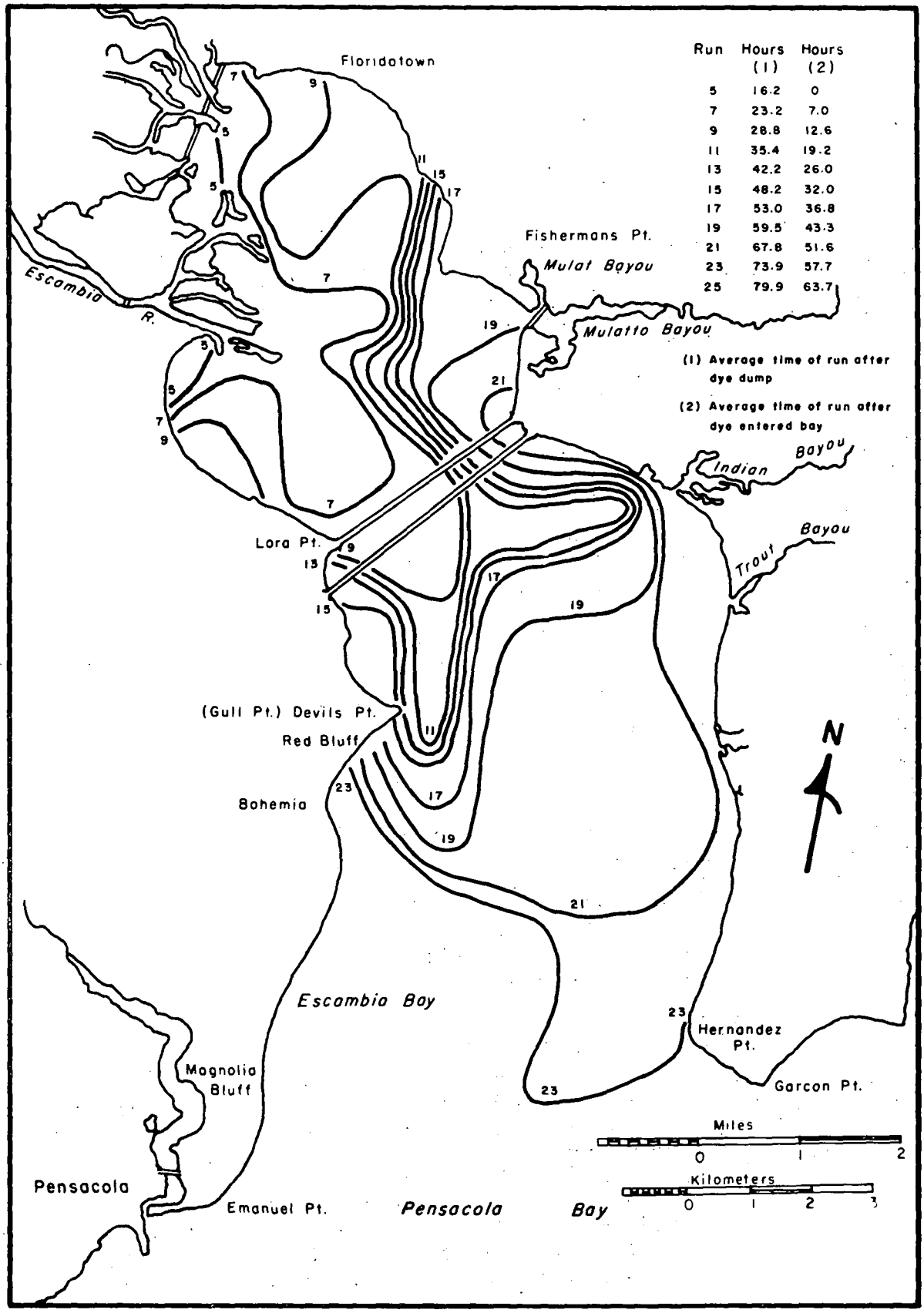


Figure 6-15. Isopeths of the run on which major surface dye peaks arrived at the given location. Sampling depth 0.3 m.

The major dye peak was first observed in northeast Escambia Bay at the mouth of the Little White River 16 hr after the dye dump. The dye peak moved through the northeast section of the bay in 13 hr. This period was just prior to and during an ebb tide. This dye peak moved more rapidly seaward along the Escambia River delta than along the eastern side of the northeast section of the bay.

The dye peak did not arrive at the northern inlet to Mulatto Bay until 40 hr after the peak entered the bay. Due to the movement of the dye peak in an easterly direction near Mulatto Bay, it appears that the waste discharges from Air Products and Chemicals, Incorporated and American Cyanamid Company were forced along the eastern shore of the bay.

Most of the fresh river water remained in the surface outflowing layer since the bay was vertically stratified. Bottom water was mixed into the upper layer, and some upper layer water was entrained into the lower layer. At the center of the upper bay (Station D2), the average dye concentration in the lower layer was 44 percent of that in the upper layer. In the center of the lower bay (Station H3), the average dye concentration in the lower layer was only 3.6 percent of that in the upper layer.

In summary, Escambia River water tended to flow down the western side of Escambia Bay as it moved seaward under conditions of average flow and tides. The mean time of travel for river water on the surface was 16 hr from the mouth of the Escambia River to Devils Point during an ebb tide. North of Devils Point Stations G1 to G5), the dye peaks on the western side were approximately eight times higher than those on the east side indicating most of the freshwater was transported across this transect down the western side of the bay. South of Devils Point, freshwater moved seaward on the eastern side of the bay more rapidly than on the western side. Since the dye peaks were about the same concentration on both sides, the quantity of freshwater moving down both sides of the bay south of Devils Point appeared to be equal. The major surface dye peak reached the mouth of the bay in about 2.3 days.

In addition, major dye peaks entered Escambia Bay from the Escambia, Little White, and Simpson Rivers at approximately the same time. The dye peak entering the bay from the Little White and Simpson Rivers moved rapidly through the northeastern portion of upper Escambia Bay during an ebbing tide. River water tended to flow seaward along the Escambia River delta, which borders the western side of the upper northeast bay. This has the effect of confining the waste discharges from Air Products and Chemicals Corporation and American Cyanamid Company near the eastern side of the upper bay. Discharge from the Escambia River mouth also tended to force water from the northeast section of the upper bay towards the eastern shore.

In the upper bay, approximately 44 percent of the dye in the upper layer was transported to the lower layer (assuming mid-depth separates the upper and lower layer). This means that a portion of waste discharged in this area would be transported to the lower layer and would remain in the bay longer than river water flushed directly from the bay.

DISTRIBUTION OF INDUSTRIAL DISCHARGES IN ESCAMBIA BAY

Introduction

A tracer was injected into the effluents of Air Products and Chemicals, Inc. and American Cyanamid Company at different times to determine the steady state distribution of these discharges in Escambia Bay. The results also described the efficiencies of the outfalls in distributing the discharges in the bay. In addition, the steady state distributions described the circulation of upper Escambia Bay.

Methods

The Air Products Dye Study was performed on August 26 through 30, 1974, and the American Cyanamid Dye Study was performed on September 17 through 24, 1974. The tracer used during the studies was Rhodamine WT fluorescent dye (20 percent solution). It was injected into each effluent by syphoning from a constant-head chamber and a pump was used to maintain the level in the chamber. The constant-head chamber and syphon were necessary to obtain a constant flow of dye into effluent. During the injection, the effluent stream of each industry was sampled every half-hour using Serco Automatic Samplers, and the concentration and mass of dye discharged was determined for each sample. Effluent flow data was provided by the industries. During the early stages of each study, samples were collected from the bay every two to three hours, and as the studies progressed, the time between sampling runs was increased (Appendix 6-5). The stations sampled during both dye studies and the locations of the discharges are shown on Figure 6-16. Two boats were used during the initial runs. Each boat started sampling near Transect 7 (line connecting stations starting with seven) and then one boat worked riverward and the other seaward. Surface dye samples were collected by dipping test tubes by hand. Mid-depth and bottom samples were collected using the dye sampler previously described. The dye samples were kept in the dark, to minimize photo decay, until they were analyzed at the EBRS laboratory.

The concentration of dye in the samples was measured using an Aminco Fluoro-Microphotomer Model 4-7102. Dye standards from 0.1 µg/l to 3,000 µg/l were prepared and the instrument was standardized every 12 hours. All dye measurements were made at 20.0°C ± 0.1°C.

The method of superposition used by Bailey, et al. (1966) in San Francisco Bay and Kilpatrick and Cummings (1972) in Port

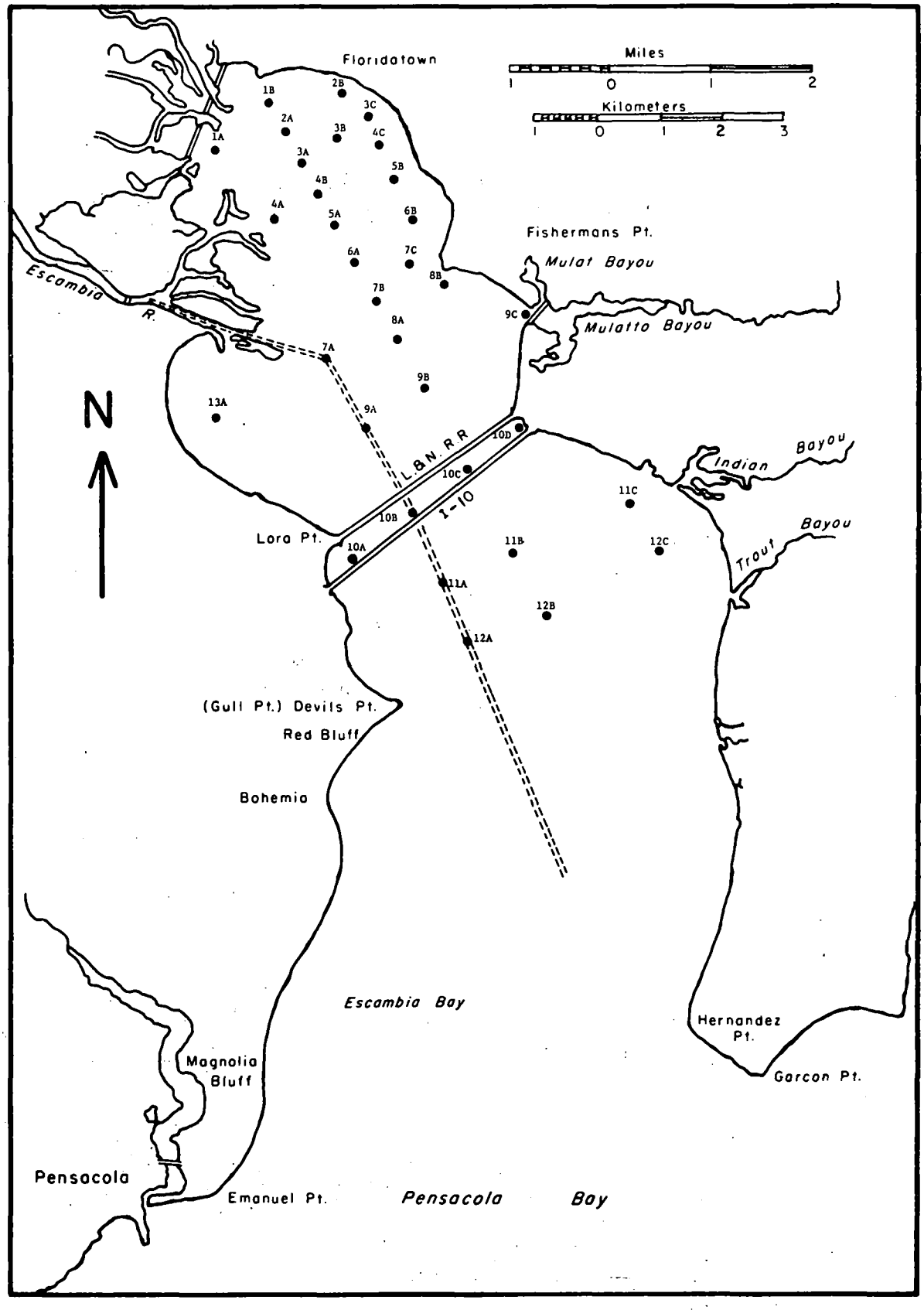


Figure 6-16. Locations of stations sampled during the Air Products and American Cyanamid dye studies.

Royal Sound was used to determine the steady state concentration in Escambia Bay due to discharges from the industries. In this method, a slug of dye is released and dye concentrations in the bay are determined. When using this method in a bay, the dye slug is released over at least one tidal cycle to approximately quasi steady state conditions. To find the steady state dye concentration at a location due to continuous discharge of the same magnitude as the one tidal cycle slug discharge, a number of identical dye concentration-time curves for that location are superimposed offsetting each curve by the time of the dye release. Each of the superimposed curves represents the contributions from previous and later discharges of the same magnitude and duration as the actual dye injection. The results of adding these curves is to reproduce the effects of a continuous discharge. The actual mathematical method used to determine the steady state concentration due to a continuous discharge is described by the following equation:

$$C_s = \frac{m}{M} \int_0^{\infty} C_t \, dt$$

where

C_s = Steady State concentration, in µg/l, resulting from a continuous release of source strength m

m = Amount of dye released per unit time in kg/day

M = Total mass of dye released in kg

C_t = Dye concentration at time t in µg/l

t = Time in days after the dye release

The integral portion of the equation is the area under the dye concentration history distribution with units of µg/l-days. The value of the integral was determined by numerical integration. The value of m divided by M is the reciprocal of the time of dye injection. This offsets the superposition process by the time of dye injection. Because of the voluminous amount of data collected during the dye study, a Fortran IV program for an IBM 370 computer was written to perform the numerical integration.

To standardize the distributions in Escambia Bay due to the Air Products and the American Cyanamid dye injections, the steady state concentrations in the bay caused by an effluent loading rate of 1,000 kg/day (2,205 lbs/day) are reported. The actual calculations were performed per the amount of dye injected and values were increased proportionally to obtain concentrations per 1,000 kg/day.

Environmental Conditions

The estimated effective freshwater discharge of the Escambia River during the Air Products Dye Study, August 26 through 30, 1974 was 77 m^3/sec (2,720 cfs), which is 41 percent of the average annual discharge of the river. During the American Cyanamid Dye Study, September 17 through 24, 1974, the estimated effective flow of the river was 188 m^3/sec (6640 cfs) which is approximately equal to the average annual flow.

The mean, maximum and minimum tidal ranges approximate the mean tide range of 0.46 m during the Air Products and American Cyanamid Dye Studies (Appendix 6-5).

During the Air Products Study, the wind was predominantly from the south and the wind velocities were between 9 and 17 km/hr most of the time (Table 6-9). The wind originated in the north most of the time during the American Cyanamid Study and again the predominant wind velocities were between 9 and 17 km/hr. All wind data were collected by the National Weather Service Office, at Pensacola Regional Airport.

Just before the beginning of the Air Products Dye Study at 0600 on August 26, 1974, 1.04 cm (0.41 in) of precipitation was measured at Pensacola Regional Airport. No additional precipitation occurred during this study, and there was no precipitation at the Pensacola Regional Airport during the American Cyanamid Dye Study.

At various times Escambia Bay was either a one or two layer system. Salinity, which should be directly proportionate to water density in a shallow bay, was used to determine if the bay was stratified (Figure 6-17a and 6-17b). Based on salinity profiles, upper Escambia Bay was a one-layer system at the time of the Air Products Dye Study (Figure 6-17a). Therefore, there was no barrier to prevent the dye tracer from mixing vertically in the upper bay.

Tracer Release

A total of 8.5 kg (18.7 lbs) of tracer was injected into the Air Products plant effluent from 0845 on August 26, 1974 to 0945 on August 27, 1974, a period of 1.04 days. However, due to accumulation in a swamp between the discharge point and Escambia Bay, dye entered the bay for a period of 1.96 days. As a result of this, the mean dye discharge rate was 4.3 kg/day. The average Air Products effluent flow was 5.75 x 10^3 m^3/day (1.52 mgd) and the flow range was between 4.47 and 6.81 x 10^3 m^3/day (1.18 to 1.80 mgd) during the dye release.

A total of 18.6 kg (41.0 lbs) of dye was discharged into the American Cyanamid plant effluent for a period of 1.28 days from 0945 on September 17, 1974 to 1600 on September 18, 1974. Thus, the average dye discharge rate at this plant was 14.5 kg/day.

Table 6 - 9. Summary of wind conditions during the Air Products and the American Cyanamid dye studies.

Velocity (km/hr)	(knots)	Air Products Study Percent of time	American Cyanamid Study Percent of time
Calm		8.3	4.7
1.8 - 7.4	(1 - 4)	16.7	7.8
9.3 - 16.7	(5 - 9)	52.1	65.6
18.5 - 25.9	(10 - 14)	22.9	21.9
27.8 - 44.4	(15 - 24)	0.0	0.0
Direction	**Degrees**	**Percent of time**	**Percent of time**
North	320 - 40	12.5	54.7
East	50 - 130	27.1	32.8
South	140 - 220	41.7	7.8
West	230 - 310	10.4	0.0
Calm		8.3	4.7

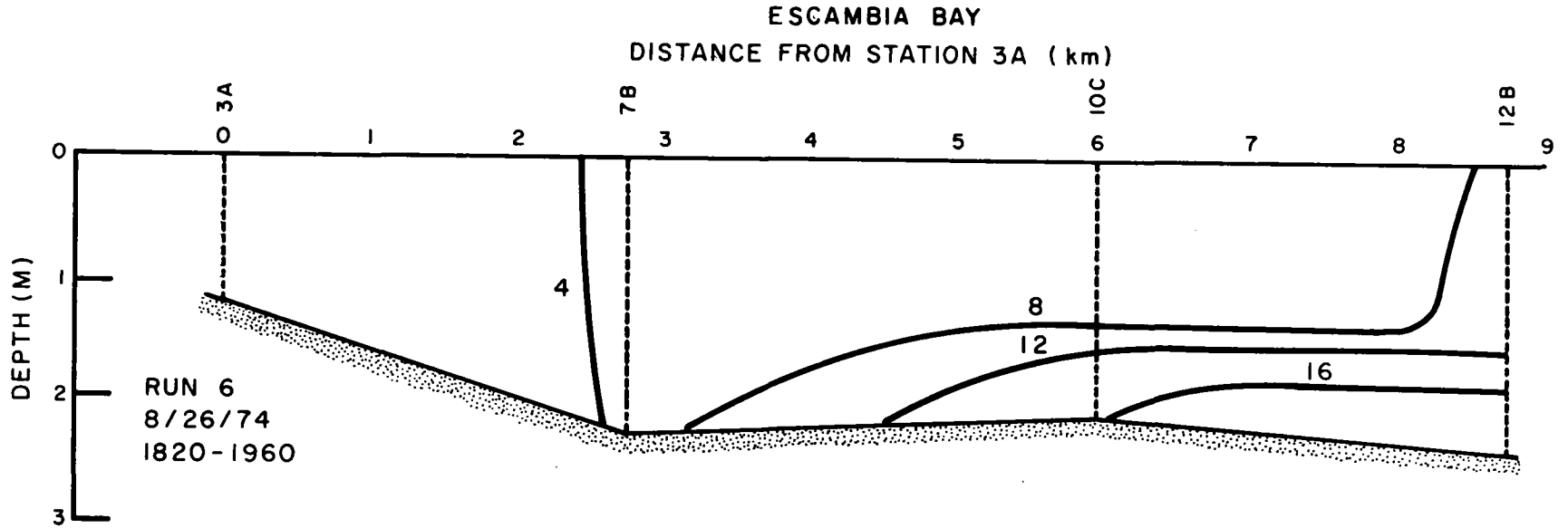


Figure 6-17a. Salinity profile during Air Products dye study at 1820 to 2000 hrs. on August 26, 1974.

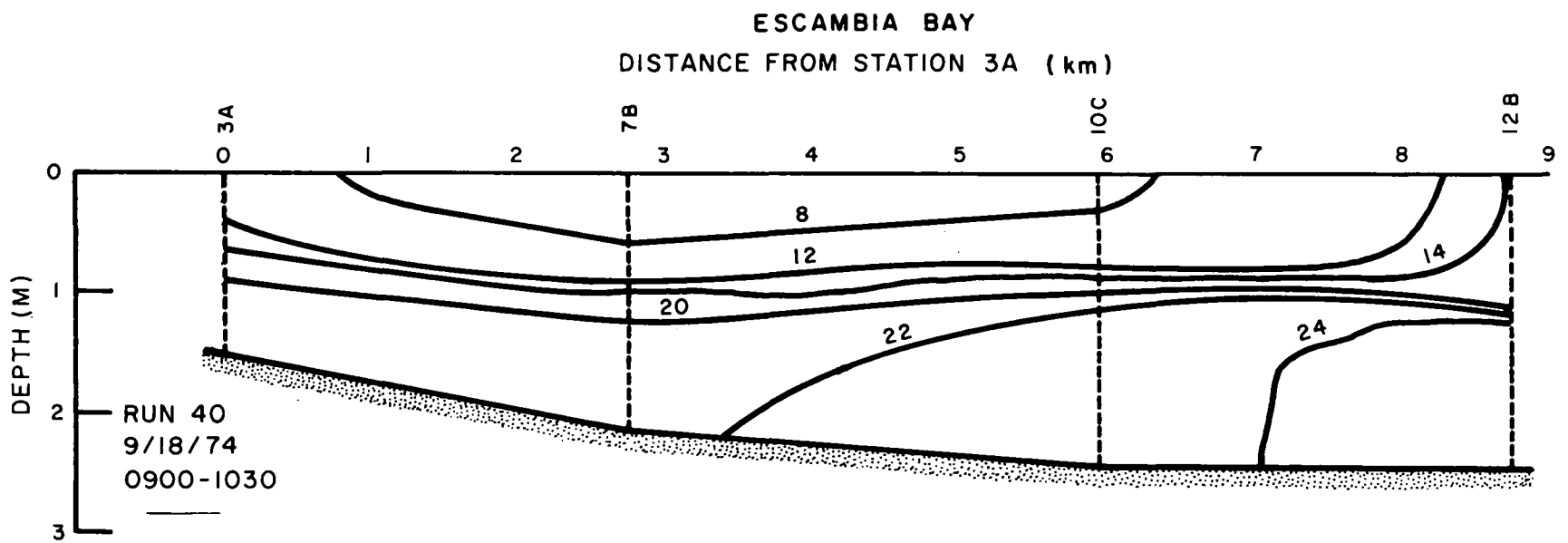


Figure 6-17b. Salinity profile during American Cyanamid dye study at 0900 to 1030 hrs. on September 18, 1974.

The average effluent flow was 17.60 x 10^3 m^3/day (4.65 mgd) with a range of 16.65 to 18.85 x 10^3 m^3/day (4.40 to 4.98 mgd).

The average concentration of dye in the discharge during the Air Products Dye Study was 655 µg/l and the range was 45 to 4050 µg/l (Appendix 6-6). The concentration in the effluent was less than 1400 µg/l 95 percent of the time. The concentrations in the American Cyanamid Plant effluent ranged from 1.55 to 3400 µg/l with an average of 599 µg/l and the concentration was less than 2000 µg/l, 97 percent of the time (Appendix 6-7).

The dye was not discharged at a constant rate because factors such as changes in viscosity of the dye with lower night temperatures, and retention and short circuiting in a swamp (Air Products plant) caused the concentration and mass in the effluent to fluctuate. This should not reduce the validity of the results, because other investigators using the method of superposition to analyze tracer study data from a physical model of San Francisco Bay showed varied injection rates did not affect the results (Bailey et al., 1966).

Background Concentration

The first two runs of both the Air Products and American Cyanamid Dye Studies were performed before the dye tracer was injected. The actual dye concentrations in the bay after the dye was injected were obtained by subtracting the background values from measured values. The dye concentrations during the background runs were:

Study	Background Concentration (µg/l)		
	Mean	Maximum	C.V.%
Air Products	0.12	0.20	13.88
American Cyanamid	0.14	0.33	25.63

Background concentrations of 0.20 and 0.33 µg/l were subtracted from field measurements to obtain actual concentrations during the Air Products and American Cyanamid Dye Studies, respectively. Since the maximum concentrations were used to represent background conditions, the steady state concentrations were due only to waste discharges because background effects have been removed with 99 percent confidence.

Steady State Tracer Distributions

During the Air Products Dye Study the tracer appeared to be uniformly distributed north and south of the outfall under steady state conditions at a depth of 0.3 m (1.0 ft) (Figure 6-18a). A concentration of 809 µg/l occurred near the discharge (Station 3A). The 100 µg/l isopleth extended from Basshole Cove to Fishermans Point, indicating the tracer moved north and south along the eastern shore of the bay. Dye isopleths were generally

parallel to the eastern shore of the bay, and they decreased as a function of distance from the eastern shore and in a seaward direction. Below Fishermans Point, dye isopleths were in an east-west direction decreasing seaward, and the dye moved seaward across the entire bay moving slightly farther down the eastern side of the bay than the western side. Concentrations at the mouths of Mulatto Bayou were higher than at offshore stations, again indicating the movement of the tracer along the east shore. Tracer concentrations were very low seaward of the Interstate 10 bridge.

The steady state tracer distribution, due to the Air Products plant discharge, at a depth of 0.9 m (3.0 ft) was similar to the distribution for 0.3 m (1.0 ft), as was expected, since there was very little salinity stratification (Figure 6-18b). However, higher concentrations were measured farther south along the eastern shore. A high concentration (35 µg/l) was measured at the south inlet of Mulatto Bayou, and at a depth of 0.9 m (3.0 ft) higher concentrations occurred west of the channel and south of the Interstate 10 bridge than occurred at 0.3 m (1.0 ft).

The steady state concentration distribution at 0.3 m (1.0 ft) above the bottom was similar to that at 0.9 m (3.0 ft). The concentration at the north inlet of Mulatto Bayou of 98 µg/l, was highest near the bottom.

Dye from Air Products plant discharge was visible along the shore for a distance of approximately 1.0 km (0.6 mi) north of the outfall during two periods on August 27, 1974 (Figure 6-19). The wind was from the East during these periods and the tide was ebbing. During both periods, the tracer remained very close to the shore and concentrations there were much higher than those in the bay. The tracer was found all along the shore as far north as Basshole Cove during 0630 through 0800. A concentration of 2744 µg/l occurred along the shore 1.1 km (0.7 mi) south of the outfall. The concentration 30 m (100 ft) from the outfall was 102,300 µg/l.

During 1130 and 1300, the dye was visible south of the outfall along the shore. The concentration 30 m (100 ft) from the outfall was 10,420 µg/l and this decreased to about 500 µg/l approximately 0.20 km (0.12 mi) to the north. About 1.1 km (0.7 mi) south of the outfall the concentration was 2230 µg/l. Dye was not found in the center of the bay during this period. These data indicated that the discharge from Air Products and Chemicals, Inc. plant has a tendency to remain very close to the shore, because of littoral currents which appeared to reverse direction. East winds and an ebbing tide did not transport the discharge away from the shore.

The highest dye concentrations in the bay during the American Cyanamid Dye Study at a depth of 0.3 m (greater than 50 µg/l) were to the north of the outfall (Figure 6-20a). The dye moved north and south along the eastern shore of Escambia Bay, but

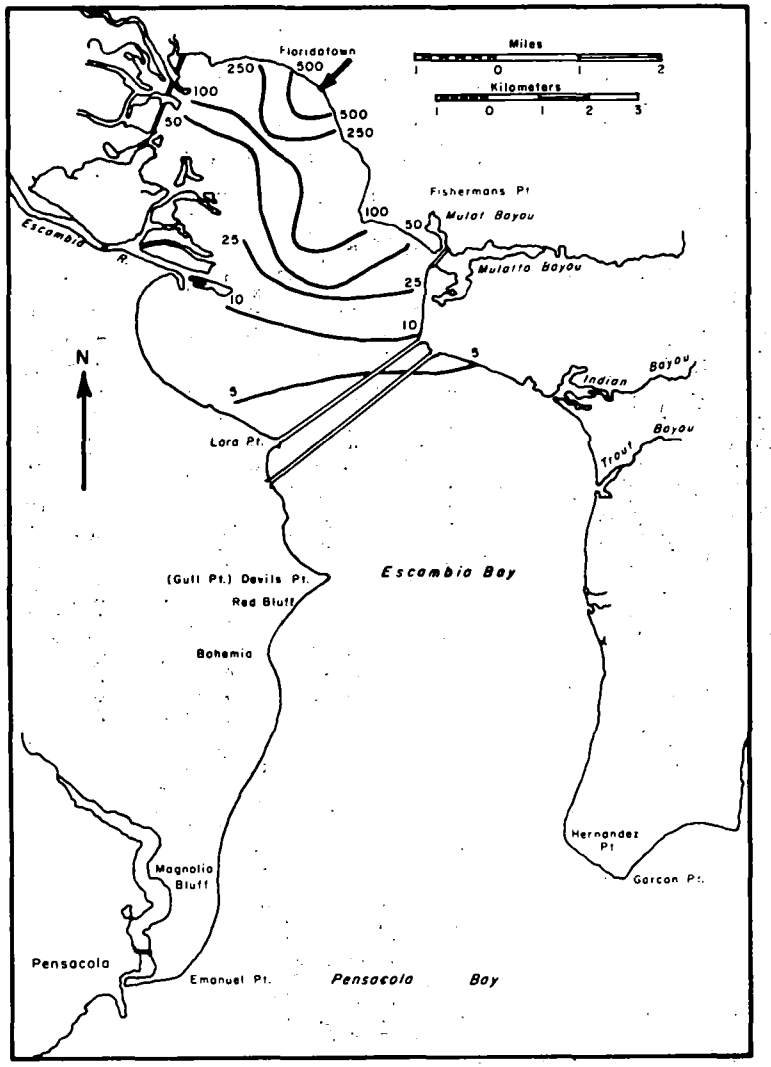


Figure 6-18a. Steady state concentrations (µg/l) at a depth of 0.3 m during the Air Products dye study for a discharge of 1,000 kg/day.

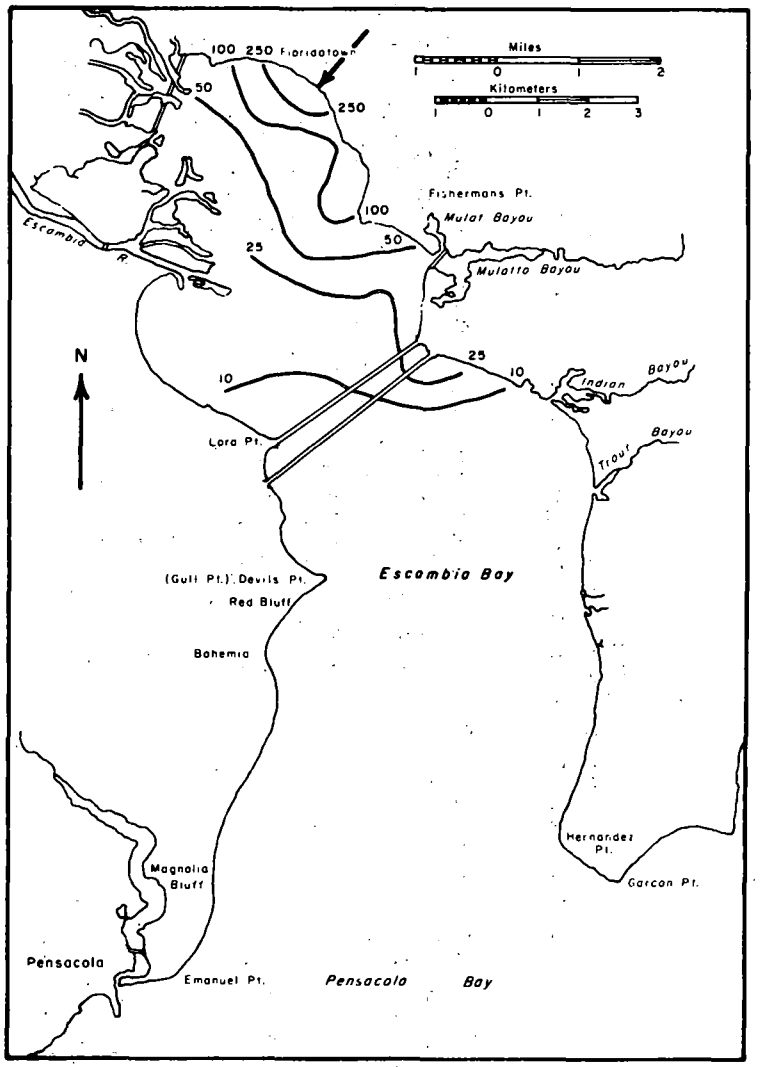


Figure 6-18b. Steady state concentrations (µg/l) at a depth of 0.9 m during the Air Products dye study for a discharge of 1,000 kg/day.

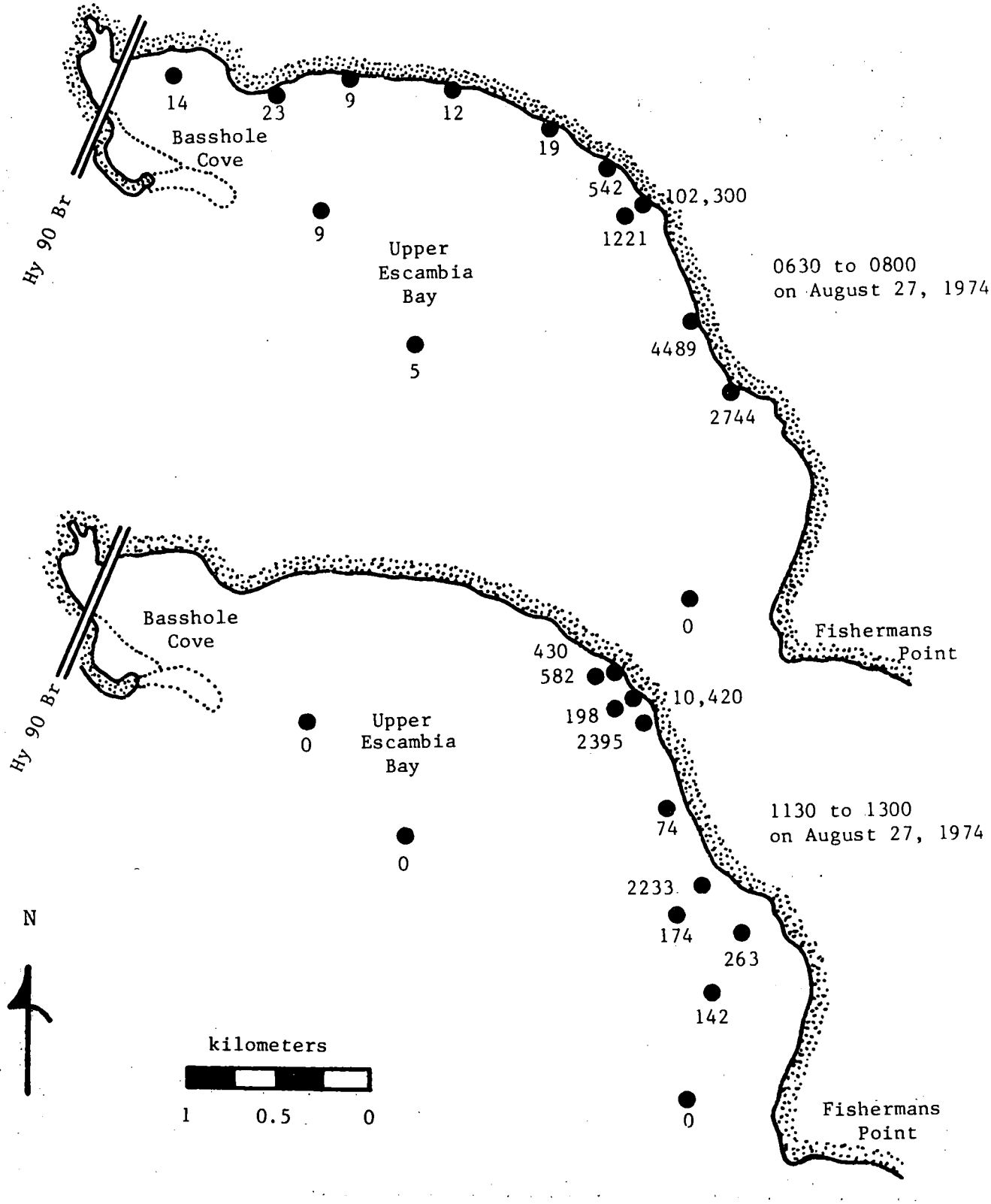


Figure 6-19. Instantaneous surface dye concentrations (µg/l) in Escambia Bay per 1,000 kg/day discharged by Air Products plant.

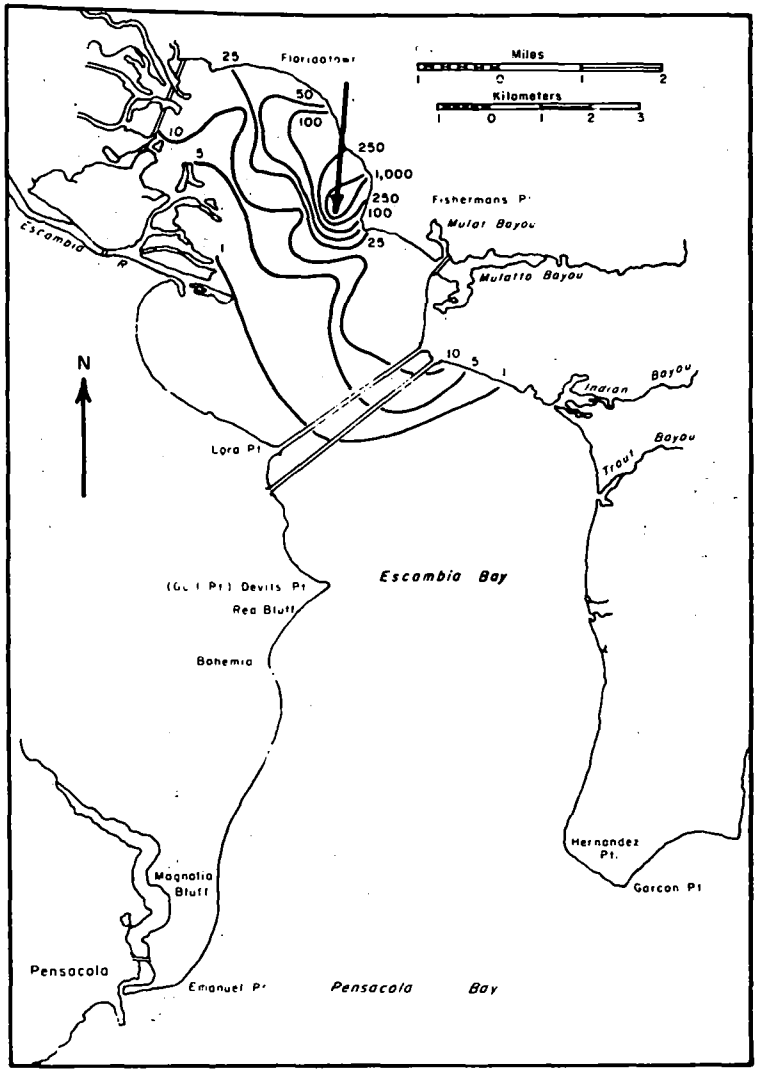


Figure 6-20a. Steady state concentrations (µg/l) at a depth of 0.3 m during the American Cyanamid dye study for a discharge of 1,000 kg/day.

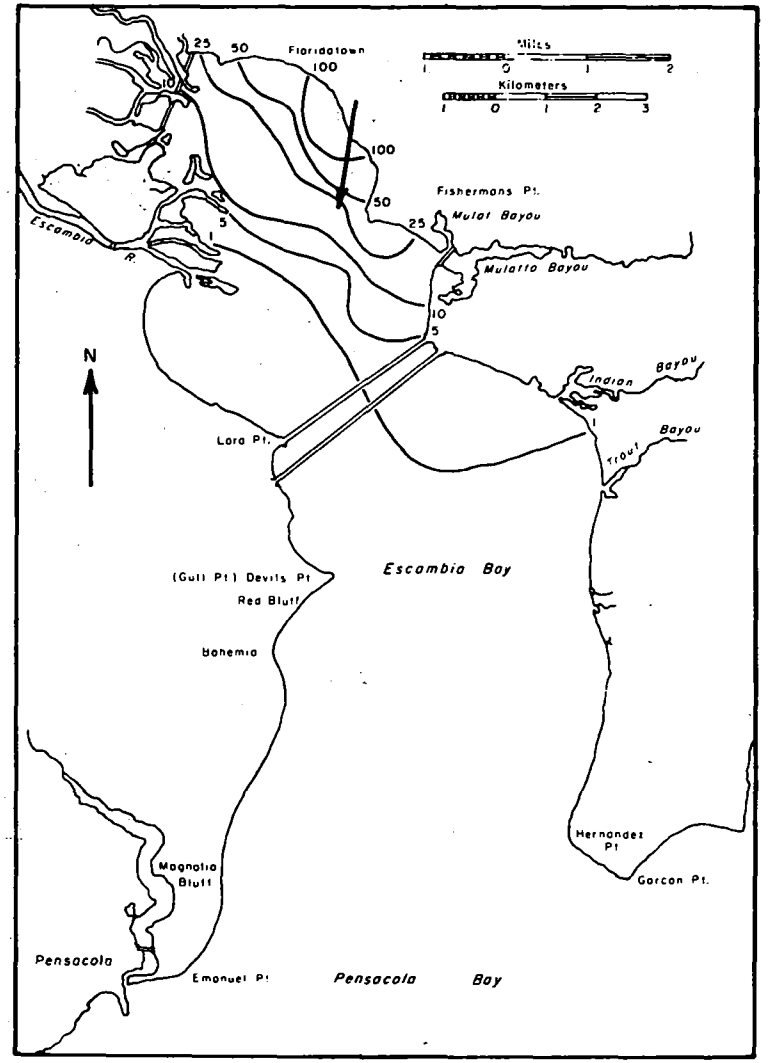


Figure 6-20b. Steady state concentrations (µg/l) at a depth of 1.2 m (4 ft.) during the American Cyanamid dye study for a discharge of 1,000 kg/day.

concentrated above Fishermans Point. No dye was measured to the west of the channel at a depth of 0.3 m during this study.

At a depth of 1.2 m, an extremely high concentration, 1208 µg/l, was measured near the outfall (Figure 6-20b) during the American Cyanamid Dye Study. The dye plume eminating from the outfall extended to the north, and with one exception relatively low concentrations, less than 10 µg/l, occurred to the south of the outfall. A halocline at a depth of slightly less than 1.2 m (4.0 ft) existed in the bay during the American Cyanamid Dye Study and it appears that a significant portion of the discharge was trapped below the halocline.

The Rhodamine WT dye used in these tracer studies can be considered a conservative (non-decaying) substance due to its low decay rate and the short duration of the studies. The dye has been found to follow first order decay. Hetling and O'Connel (1966) found a first order dye loss rate constant of 0.034 per day (base e) as an upper limit. Kilpatrick and Cummings (1972) used a dye loss rate constant of 0.03 per day (base e) to correct Rhodamine WT dye to a conservative substance. If a dye loss rate constant of 0.03 per day (base e) is used to calculate the steady state concentrations of a conservative substance in Escambia Bay from the results of these studies, the steady state dye concentrations described within should be multiplied by approximately 1.1. Therefore, the steady state concentrations of conservative substances would be slightly higher than those discussed here.

A mass balance was performed to approximate the quantities of dye in various areas of the bay under steady state conditions. This was accomplished by dividing the bay into segments with a sampling station at or near the center of each segment. The mass in each segment was determined by multiplying the mean low water volume of each segment by the steady state concentration.

The analysis indicated 56.1 percent of the discharge from Air Products plant and 76.6 percent of the discharge from American Cyanamid plant were in segments along the eastern shore (Figures 6-21a and 6-21b). Steady state concentrations were not determined along the shore of the bay; consequently, more dye was probably along the eastern shore of the bay than indicated here. Most of the discharges, 76.1 percent from Air Products plant and 90.4 percent from American Cyanamid plant, were in the segments north of Fishermans Point, and 3.9 percent of the discharge from Air Products plant and 1.6 percent of the discharge from American Cyanamid plant were in the segments at the inlets of Mulatto Bayou.

This study indicated that the methods Air Products and American Cyanamids Plants used to discharge effluents into Escambia Bay were insufficient, because their wastes tended to accumulate near the upper eastern shore of the bay instead of being rapidly removed from the bay. The study also indicated

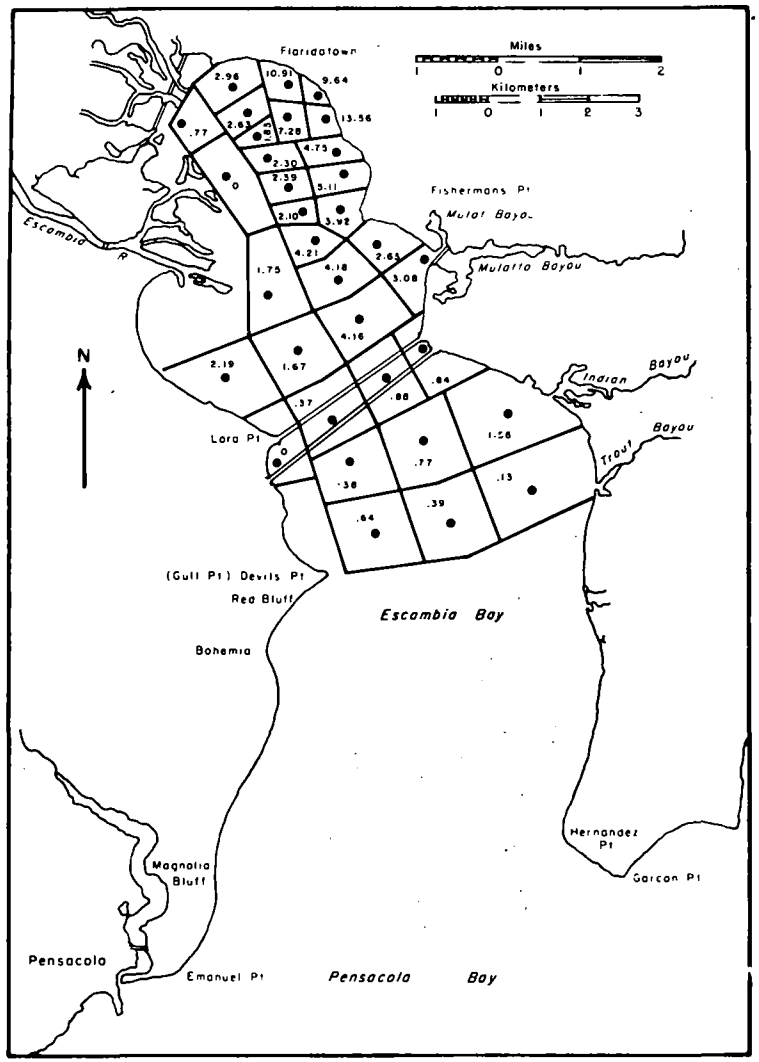


Figure 6-21a. Percent of steady state dye mass in segments of Escambia Bay during the Air Products dye study.

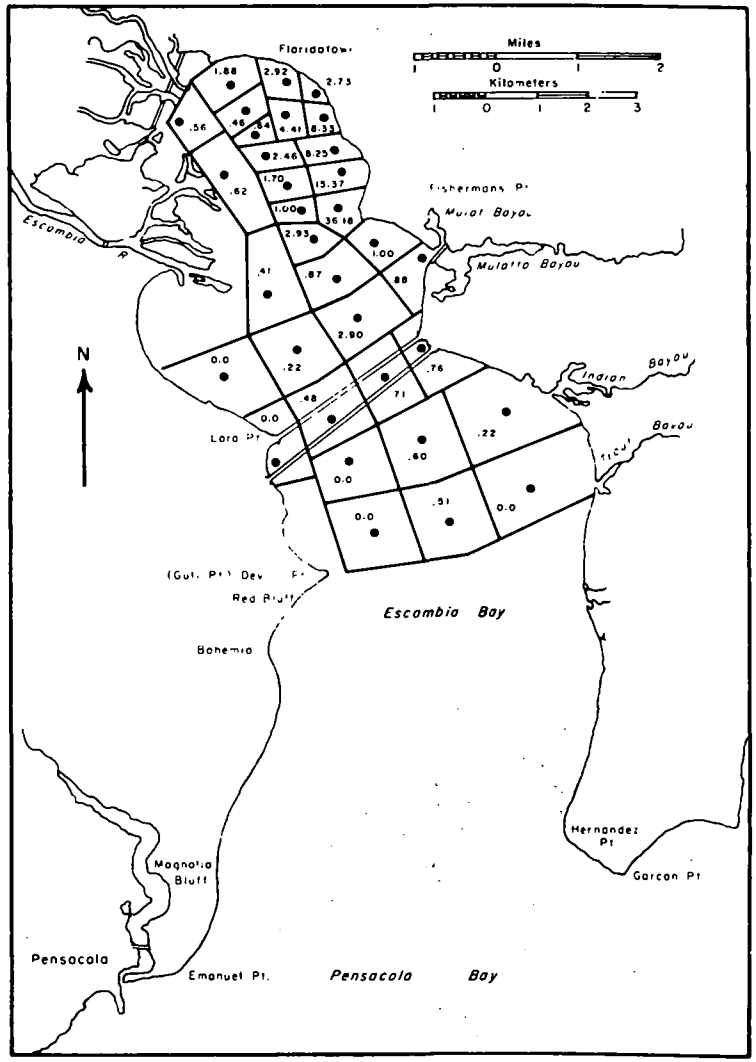


Figure 6-21b. Percent of steady state dye mass in segments of Escambia Bay during the American Cyanamid dye study.

that wastes from both industries entered Mulatto Bayou, the scene of numerous fish kills. To eliminate the buildup of wastes in upper northeast Escambia Bay, the effluents should discharge through submerged outfalls extending to the vicinity of the Escambia Bay dredged channel. In the case of the American Cyanamid plant, their present outfall would have to be extended about 1920 m (6,300 ft).

CIRCULATION IN PENSACOLA BAY SYSTEM

Circulation in the Pensacola Bay system is weak and not conducive to a high assimilative capacity. Based on all studies performed by the Escambia Bay Recovery Study and the University of West Florida, mean circulation over a tidal cycle in the upper layer of the Pensacola Bay system normally follows the pattern shown in Figure 6-22. Although current velocities in some areas are higher than in other areas, all currents are relatively weak. Mean current velocities over a tidal cycle in the lower layer are extremely weak. Due to weak circulation in the system, the elimination of wastewater discharges should be considered or the highest degree of wastewater treatment possible should be provided before discharge.

Furthermore, under certain conditions current reversals occur in the bay and inflow takes place in the upper layer and outflow occurs in the lower layer (Figure 6-23) (G. Ketchen, Florida State University, personal communication). As shown in the figure, a current reversal of the type described above occurred. This means that waste discharges to the bay are sometimes transported riverward and remain in the system for a longer period than the flushing time suggests. The cause of these current reversals is most likely wind, and this should be clearer when Ketchen's study is completed.

CIRCULATION IN MULATTO BAYOU

Introduction

Mulatto Bayou has been significantly altered by the construction of Interstate Highway 10 (I-10). In 1965, a channel connecting the southern portion of the bayou with Escambia Bay was blocked by I-10, and an alternate channel was dredged just north of and parallel to I-10. During this same period, approximately 8 x 10^2 m^3 (one million cubic yards) of sediment was removed from the bayou for I-10 fill causing deep borrow pits (approximately 12 m).

Mulatto Bayou has been the scene of numerous fish kills (see Chapter 10). A September 1969 study by the Federal Water Pollution Control Administration (USDI, 1970) indicated the fish kills were caused by degraded water quality resulting from waste discharges near the mouths of the bayou, residential finger canal dredging within the bayou, and dredging and filling for I-10 construction. The Florida Department of Transportation also

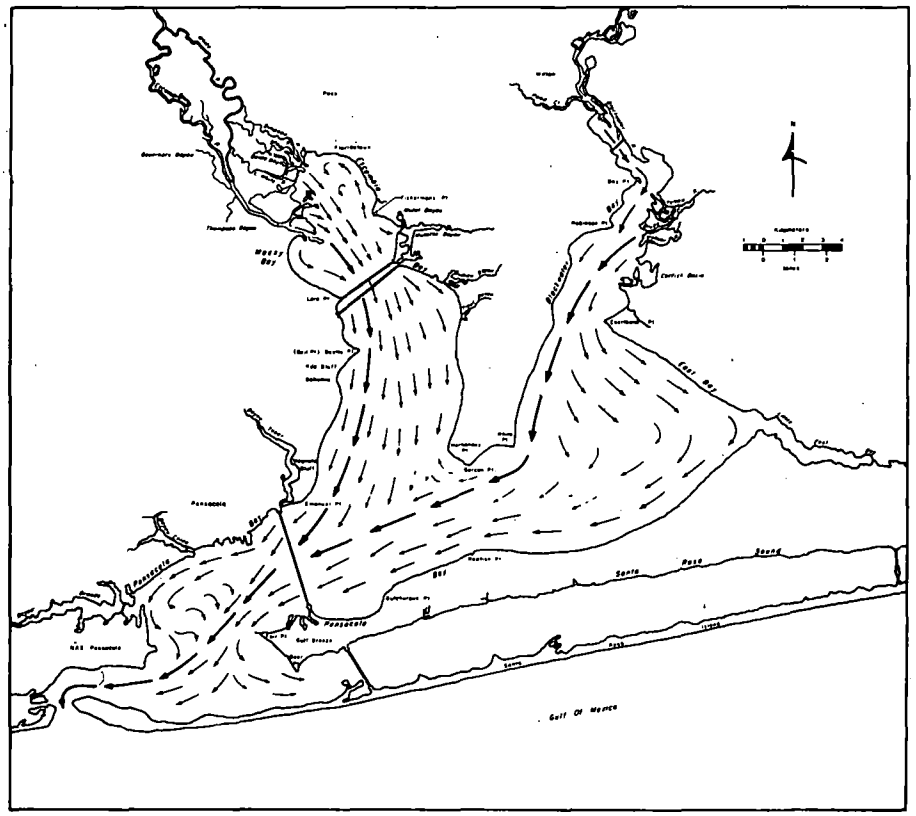


Figure 6-22. Mean water transport over a tidal cycle for the upper layer of the Pensacola Bay system.

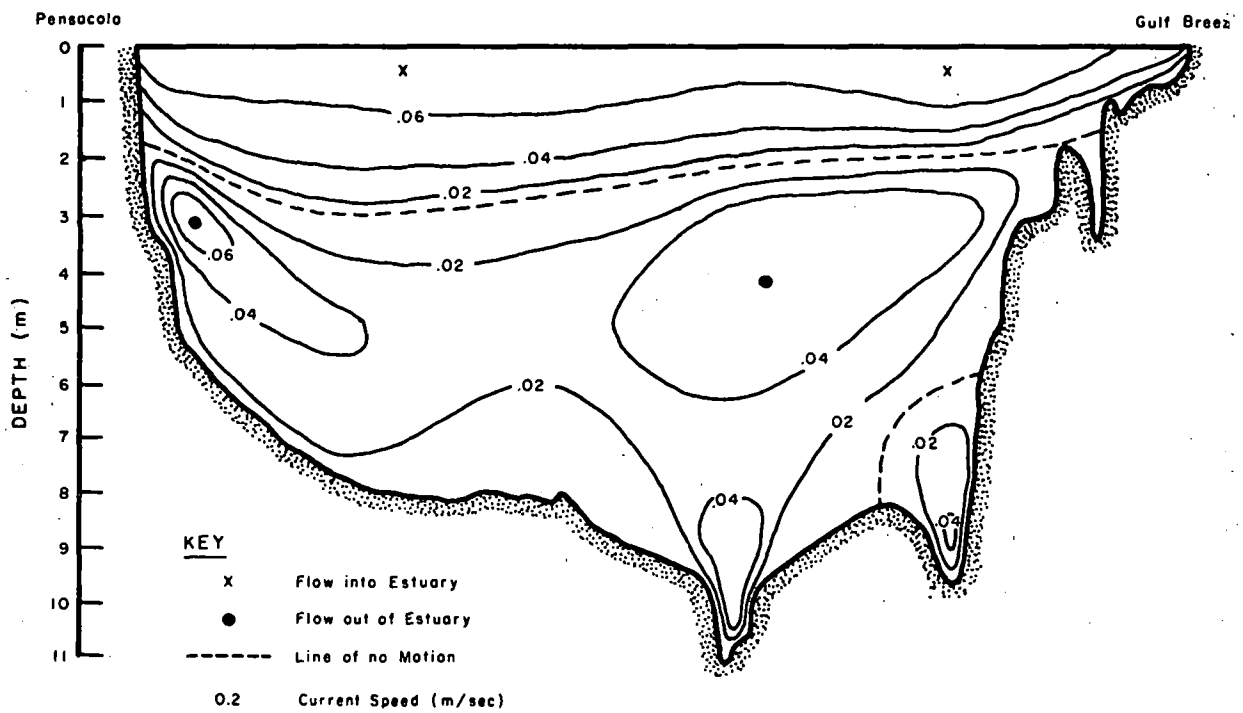


Figure 6-23. Current speed on June 12-13, 1974 in Pensacola Bay.

funded a study to evaluate conditions in Mulatto Bayou (Livingston et al., 1972). They concluded that dredging and filling strongly influenced circulation patterns of tidal currents and horizontal and vertical exchanges of water, and have contributed to a deterioration of water quality in the Mulatto Bayou area. They recommended that a weir to restrict tidal exchange between the north and south sections of the bayou be installed, and a canal connecting the dead-ends of the finger canals with the main channel of the bayou be constructed. To provide additional information on circulation in Mulatto Bayou, dye tracer studies were performed in June and July 1974.

Methods

Tracer studies using Rhodamine WT dye (20 percent solution) were performed in Mulatto Bayou on June 24 and 25, 1974 and July 1 and 2, 1974. During the June study 0.9 kg (1.9 lbs) of dye was discharged at the north and south inlets to Mulatto Bayou, and 1.3 kg (2.8 lbs) was discharged at each inlet during the July study. In both studies, the dye was uniformly distributed across the mouths of the inlets at the beginning of a flood current. The methods used to collect the samples during the June study were the same as those described previously (see this chapter; Circulation in Escambia Bay; Methods). During the July study all samples were collected at a depth of 0.9 m (3.0 ft) using a pump system. All dye concentrations were determined at the EBRS laboratory using equipment previously discussed (see this chapter; Circulation in Escambia Bay; Methods).

Environmental Conditions

Environmental conditions during the dye studies are described in Table 6-10.

Results and Discussion

Water movement into Mulatto Bayou through the north and south inlet on a flooding current was rapid during the tracer studies (Figure 6-24). The dye discharged at the south inlet was transported to the mouths of the finger canals and about 0.2 km into the northern area of the bayou during a flooding current. The dye discharged at the northern inlet was transported into most of the northern section of the bayou and Mulatto Bayou during a flooding current. The dye did not enter the finger canals or the eastern arm of the northern area of the bayou in detectable quantities during one flood current. Short circuiting of waters, which entered the bayou through the south inlet and exited through the north inlet during a flooding current was observed by Livingston et al., 1972, but did not occur during these studies.

A minor fish kill occurred in the southern area of the bayou during the July study. Wind eventually transported most of the dead fish that accumulated on the shoreline of the bayou into the

Table 6 - 10. Environmental conditions during tracer studies in Mulatto Bayou performed on June 24 - 25, 1974 and July 1 - 2, 1974. Weather data collected at Pensacola Airport (U.S. Dept. of Commerce, 1972 - 1974).

Tide range (m)	0.3	0.6
Prevailing wind direction	North	Southeast
Average wind speed (km/hr)	17.0	10.0
Precipitation (cm)	0.0	0.2
Minimum salinity (ppt)	8.3	15.0
Maximum salinity (ppt)	20.6	19.6
Minimum temperature (°C)	26.0	17.0
Maximum temperature (°C)	28.6	31.0

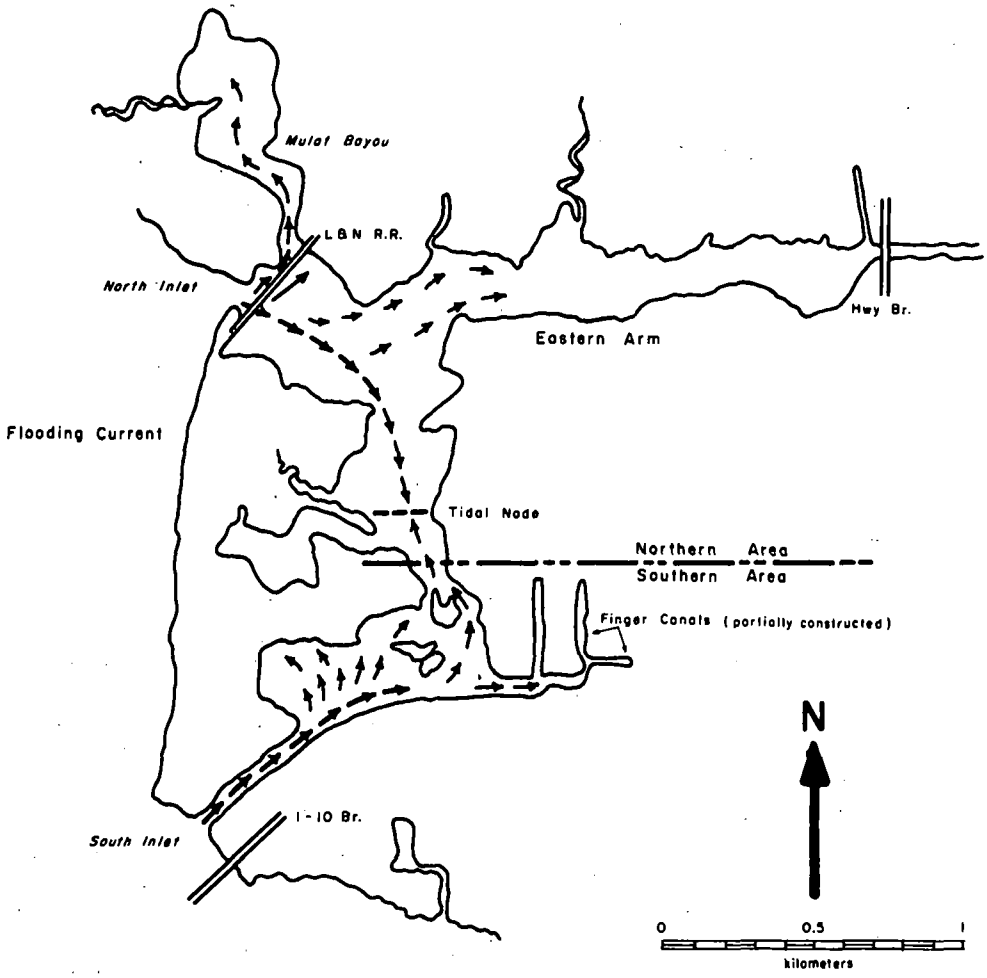


Figure 6-24. Circulation patterns in Mulatto Bayou derived from tracer dye studies performed during June and July, 1974.

two eastern finger canals. As the fish decomposed, a highly visible algae bloom developed in the canals and subsequent east winds transported the bloom into the main portion of the southern area. The partially constructed finger canals in Mulatto Bayou should be sealed off from the rest of the bayou to eliminate depressed dissolved oxygen concentrations that could be caused by a slug of organic material entering the bayou from this area.

7 - BAY SEDIMENTS

SEDIMENTATION

Introduction

The sand and mud sediments of the Pensacola Bay system are a result of watershed erosion since the Pleistocene Epoch. During the Pleistocene, the Citronelle deposits were reworked and intermixed with marine terraces (Marsh, 1966). These deposits are now eroding and therefore determine the minerology of the bay sediments.

Terrestrial geology of the Escambia Bay watershed includes principally unconsolidated sands, silts, and clays of the Coastal Plain Province, which were deposited before the shoreline of the continental mainland reached its present position (Walker and Carlisle, 1960). Horvath (1968) and Goldsmith (1966) reviewed the literature and reported this layer is underlaid by a veneer of Pleistocene terrace deposits overlaying Tertiary beds of sand, silt, and limestone. The Citronelle formation is the only formation that crops out in this area and consists of layers of sand, gravel, iron-cemented sandstone, fossil wood, and lenses of kaolinite (Marsh, 1966). Bluffs along the west bank of Escambia Bay have many such outcroppings.

Clay contributed by the Escambia River is mainly kaolinite, with smaller amounts of montmorillonite and some vermiculite, illite and gibbsite. The Escambia River is intermediate in clay minerology between the extremely kaolinitic Apalachicola River and the less kaolinitic Mobile River (Griffin, 1962). Escarosa I, Figure 184 (1973) effectively shows the influence of the kaolinitic flows into the northeastern Gulf and the increasing influence of the montmorillonite group westward and offshore. The Mississippi River discharges primarily montmorillonite clays.

Practically all clays entering Escambia Bay via the river are retained within the bay (Escarosa I, 1973). Much is deposited within the delta area with the remainder settling throughout the bay.

Much of the sand entering the estuary is dumped in the delta area; however, some enters the bay by littoral drift and is moved indiscriminately by wind and tidal current. Escambia Bay beach slopes and shoreline configurations are constantly changing due to these processes.

Horvath (1968) defined the sediment of the Pensacola Bay system, including Escambia Bay, based on 214 samples taken with a LaFonde Dietz sampler. Until then, only two other samples had been taken in the system by Griffin (1962). One sample from the nearshore beach area was taken by Hsu (1960), and Martens (1931) made a study of sand samples in the vicinity of Pensacola.

Jeffrey and Moskovits (1955) reported on silting in the Pensacola Bay system. At this Escambia Bay test site, silting was reported as moderate to heavy.

The bay to the immediate west of Pensacola Bay was studied by Parker (1968) who did a sedimentological study of Perdido Bay and the adjacent offshore area. He concluded the deeper water sediments are composed predominantly of silt and clay and the nearshore region of the bay to be quartz sand. Goldsmith (1966) did a sedimentological study of Choctawhatchee Bay which is east of Pensacola and found a quartz sand shelf around the margin of the bay, and the center of the bay contained a clay size sediment brought in by the river. The western portion of the bay lacked clay deposits and consisted of relict quartz sand.

The University of West Florida, under a Sea-Grant project, has sampled fifteen stations in Pensacola Bay and are currently analyzing the top 15 centimeters of each core.

The objective of the EBRS sediment study was to characterize sediments and their related distributions in the system. Relationships of sediment-benthic macroinvertebrates will also be discussed in another chapter. Previous reports (FWPCA, 1970; Hopkins, 1973) discuss sludge beds in various portions of the bay. The present study was designed to determine the extent of any unusual organic deposits.

Sampling Stations

Cores were collected at a total of 207 stations in the Pensacola Bay estuary during the present study (Figure 7-1 and Appendix 7-1). A group of 85 stations was located in Escambia Bay on east-west transects. The inshore station on each transect was 15 meters from shore, the next station was 100 meters from shore, and all others on the transect were 900 meters apart. Transects were 1000 meters apart in the north-south direction. Fifty-nine additional cores were taken on the above transects and transects within East and Blackwater Bays and Santa Rosa Sound, with location based on cross-sectional profiles of the bay bottom. Appendix 7-2 is a list of these stations and their habitat type.

A third group of 48 stations was sampled at discrete locations in East Bay, Pensacola Bay, and Blackwater Bay. In addition, six stations were sampled in Choctawhatchee Bay (Figure 7-2) and nine in the Panama City bay system (Figure 7-3).

Methods

Sediment cores were taken with a three-inch diameter piston-type corer to a depth of one meter. The top 15 cm were removed for physical and chemical analyses and transported in plastic containers on ice to the laboratory. When samples were not analyzed immediately, they were frozen. Of the 207 cores, 85

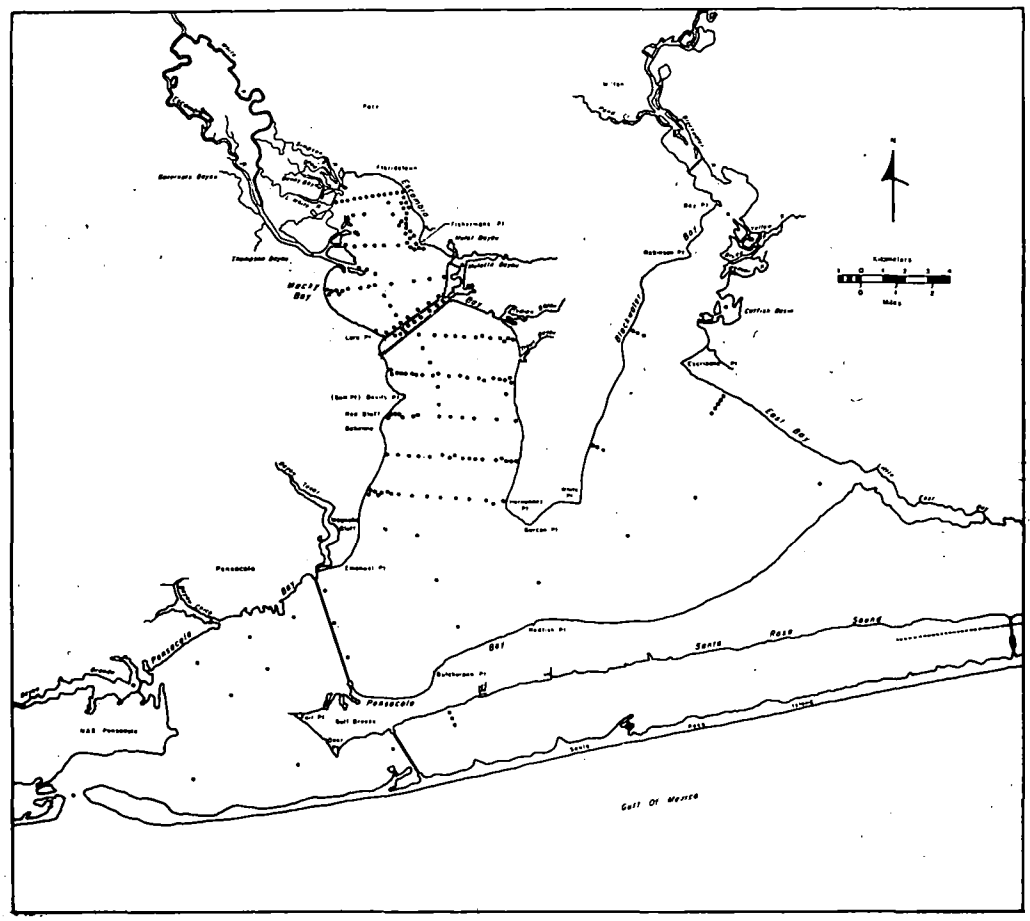


Figure 7-1. Sediment core sample locations in the Pensacola Bay system.

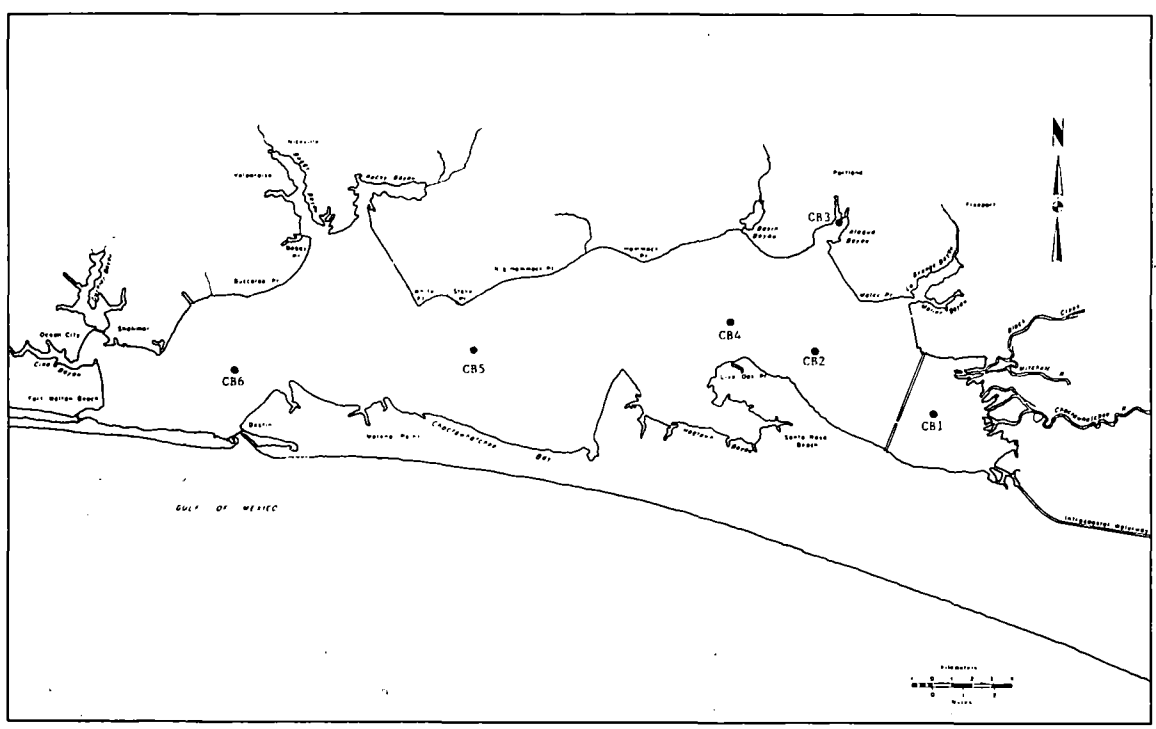


Figure 7-2. Sediment core sample locations in Choctawhatchee Bay, Florida, 1974.

Figure 7-3. Sediment core stations in Panama City bays.

were analyzed for physical parameters by Escambia Bay Recovery Study using methods described in EPA's Biological Field and Laboratory Methods, (EPA-670/4-73-001) and the remaining cores were analyzed by the Sedimentological Laboratory of the Geology Department, Florida State University. The Sedimentological Laboratory used a settling tube for the sand fractions and the pipette method (Carver, 1971) for separating the silt and clay fractions.

EBRS determined all chemical parameters except the metals and pesticides which were determined by Surveillance and Analysis Division, Athens, Georgia. Chemical analyses methods were conducted according to the EPA Chemistry Laboratory Manual, Bottom Sediments. Great Lakes Region, FWQA, 1969 with modifications for automated analyses.

Fifteen core samples were taken throughout Pensacola Bay by the University of West Florida using SCUBA and hand-held core tubes (Figure 7-1). EPA, Surveillance and Analysis Division, Region IV conducted the chemical analyses for metals and pesticides.

Depths of bottom contours were determined with a survey grade recording fathometer.

Results

Data from analyses of sediment core samples taken from the Pensacola Bay system, Panama City bays, and Choctawhatchee Bay are presented in Appendix 7-3. These data include physical and chemical parameters for each individual station.

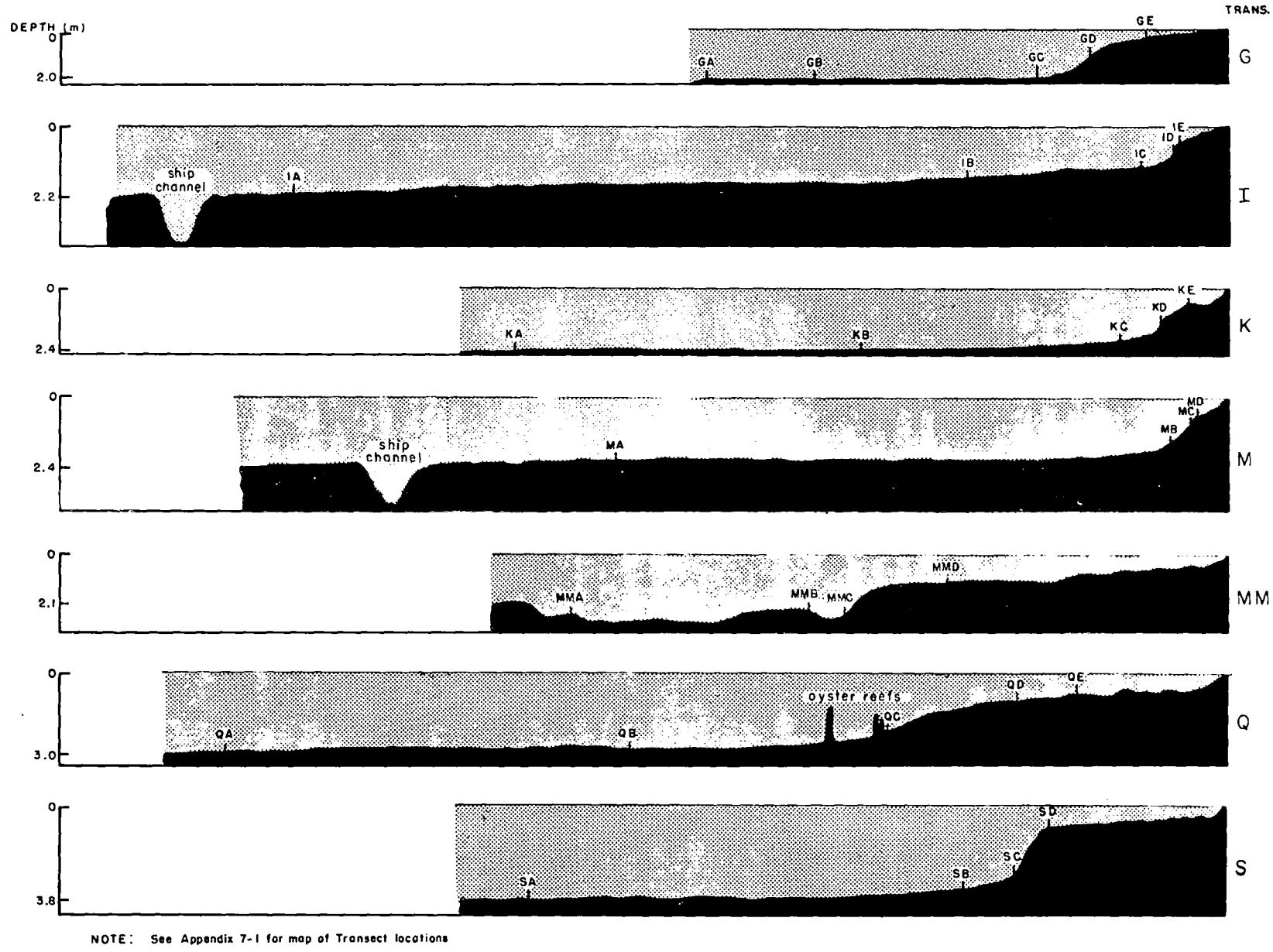
Bay Bottom Profiles

Profiles of bottom contours taken on seven benthos transects are shown in Figure 7-4. In general, these profiles show a broad, almost flat central basin of primarily mud gently sloping to a near-shore zone of steeper gradient (called a transition zone in this report) and then, next to shore, a sand shelf. The width of the shelf varies throughout the bay. This condition exists throughout the adjacent bays in the Pensacola Bay system. In the Benthic Macroinvertebrate section of this report the different communities are related to the three types of sediments, i.e., sand shelf, muddy plain and transition zone.

Sediment Particle Size Characterization

Sand-Silt-Clay

Like most bays in the northern Gulf of Mexico, the near-shore is predominantly sand in Escambia Bay. Figure 7-5 shows the relationship of depth to sediment type, with sand above the two m contour and particles becoming smaller with increasing depth.



NOTE: See Appendix 7-1 for map of Transect locations

Figure 7-4. Bottom profiles and station location along benthic transects in Escambia Bay.

Normally, sediment types are continuous and parallel to the shoreline throughout the bay with a more gradual change in sediment type on the eastern shore. However, there is discontinuity in this pattern in the lower portion of the bay where fine to very fine sand interrupts the normal deposits of sandy silt. The result is a saddle of sand across the muddy plain. This interruption is shown in Figure 7-5 and also on the figure for sand fraction grain sizes (Figure 7-6).

A possible explanation for this saddle effect is the offshore movement of sand at Devil Point originating from littoral sand drift. Water depth contours indicated a large bar extending eastward from this point. During revegetation studies in this area, plantings were covered with 7.6-12.7 cm (3.0-5.0 in) of sand in a two-month period. In water depths of 0.6-0.9 m (2.0-3.0 ft), there is extensive sand movement, and possibly this is occurring to some degree in deeper waters in this general area.

In East Bay and Blackwater Bay the same trend existed as in Escambia Bay, i.e., a gradient from coarse to fine particles toward midbay. In Pensacola Bay, sediment distribution was similar except in areas where dredging had occurred (Hopkins, unpublished data). There has been extensive dredging and filling throughout Pensacola Bay within the last 60 years, and much of the shoreline has been filled to provide port development and various real estate projects. Most of this fill material was dredged from the bay. Consequently, there are large portions of the bay that are deeper than normal near the shoreline.

Silt and clay fractions have been combined and are termed mud in this report. In Escambia Bay, about 50 percent of the bay is covered with sediments that have a composition of 80 percent or greater mud (Figure 7-5). This is not unusual as most bays along the northern Gulf Coast have broad muddy basins. Table 7-1 lists data from six bays in this area and indicates that all have similar mud and clay contents. Masch and Espey (1967) discuss muddy sediments, their resuspension and "fluid mud" phase, in relation to consolidated or semi-consolidated muds being resuspended by man's activity or natural activities. Their work in Galveston Bay was concerned with resuspended sediments from dredging and their effects on oyster reefs. Their consensus was that sediments with >80 percent mud or >50 percent clay could develop "fluid muds" which could travel considerable distances and affect many benthic communities. There are in Escambia Bay many oyster beds which could be similarly affected if the muddy central basin were altered, unless remedial measures were taken during the project. The present study defines the benthic community (Benthic Macroinvertebrates, Chapter 11) that now exists in this muddy plain.

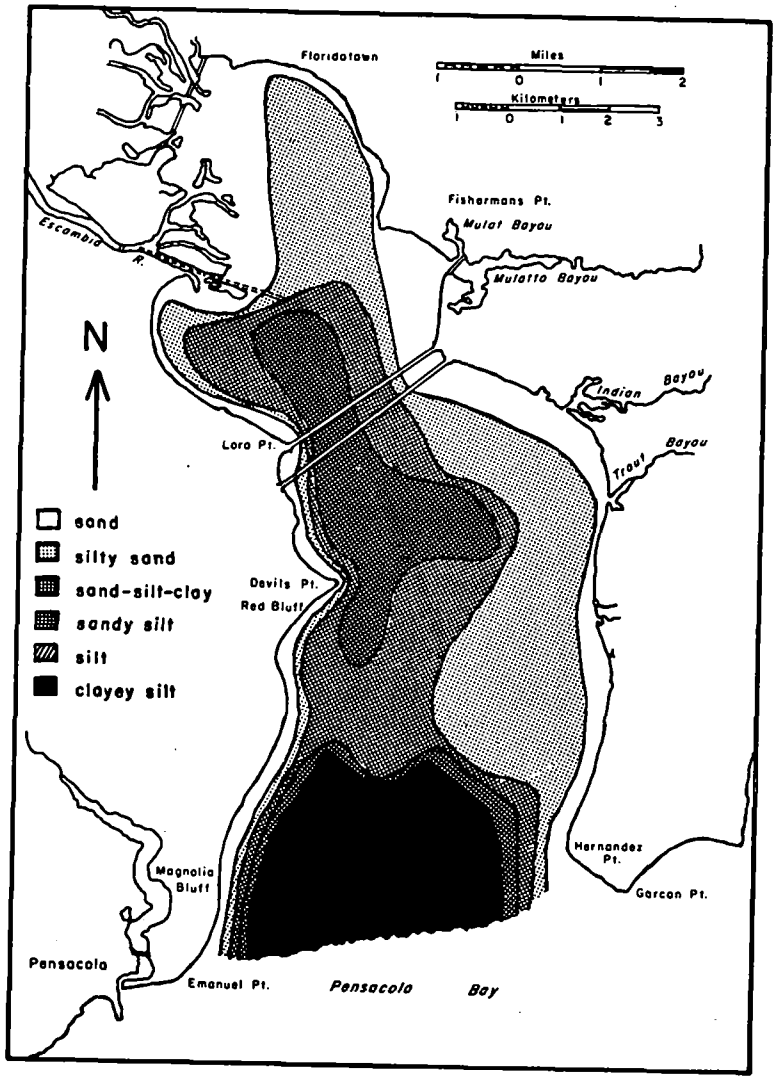


Figure 7-5. Classification of surface sediments (top 15 cm.) in Escambia Bay during 1973.

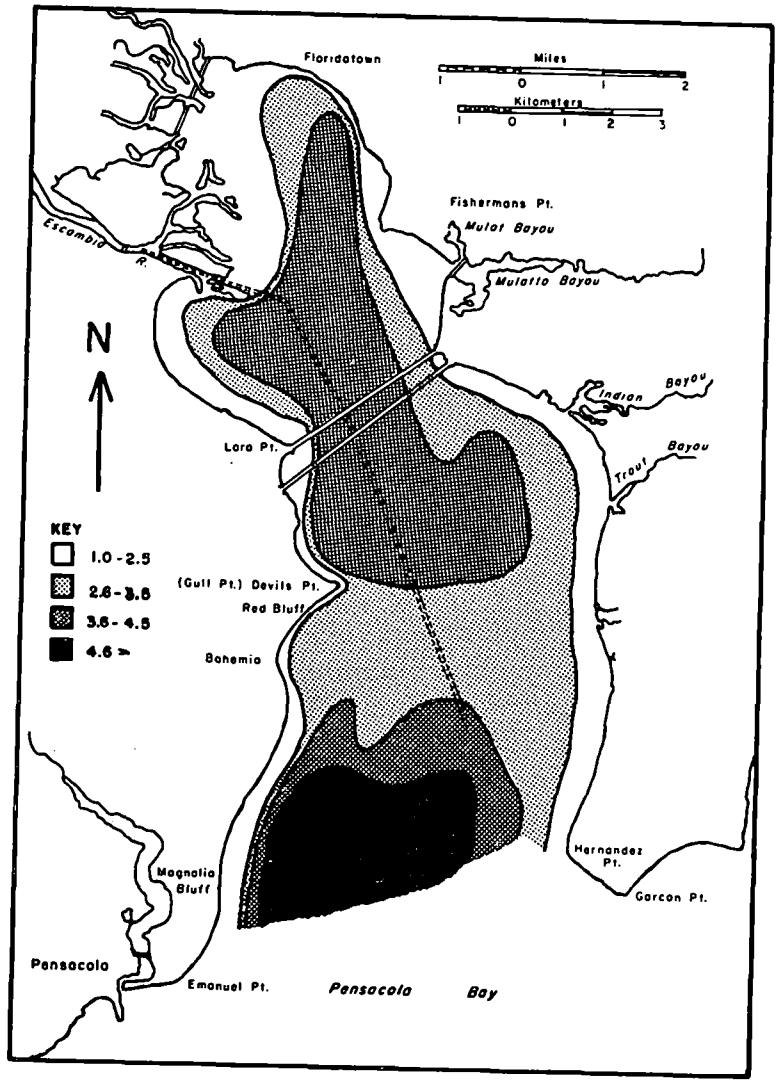


Figure 7-6. Grain size distribution of the sand fraction in Escambia Bay during 1973.

Table 7 - 1. Percent of mud in sediments (top 15 cm.) from central basins of six northwest Florida bays.*

Bay	Number of Stations	Mean Depth (m)	Percent Mud (%)	Percent Clay (%)
Escambia Bay	17.	3.3	91.36	50.63
East Bay	4.	4.2	88.34	64.69
Pensacola Bay	1. **	8.4	97.47	60.05
Choctawhatchee Bay	6.	5.2	98.00	73.93
Bays at Panama City	7.	6.3	91.43	62.19
Blackwater Bay	1.	2.6	94.78	70.30

* Data generated from samples that have either greater than 30% mud or greater than 50% clay.

**Station near a recent channel dredging project and probably this station dredged in the past year.

Triangle diagrams are a useful technique for comparing sediment characteristics by presenting an array of points based on percentages of sand, silt, and clay fractions from a given sample as shown at A, Figure 7-7. Mud, sand, and transition zone stations in Escambia Bay are shown at B, Figure 7-7. The sand shelf group was classified as sand only; however, the transition zone and mud plain stations were arrayed from sand to clayey silt. It is not unusual for the latter two groups to have a wide classification since station locations were selected by bottom profiles, depth, and slope of the bottom rather than by sediment grain sizes. Therefore, the term "mud plain" refers to a location rather than a muddy bottom; however, in most cases the mud plain does consist of mud. Ordinarily, these mud plain stations would not fall into a sand classification in northern Gulf of Mexico bay sediments. This study was in good agreement with Shepard and Moore's (1955, p. 15) work in the Central Texas bays. Arrays of sediment types from East Bay, Blackwater Bay, Choctawhatchee Bay, Panama City bays, and Santa Rosa Sound are shown at C through F, Figure 7-7.

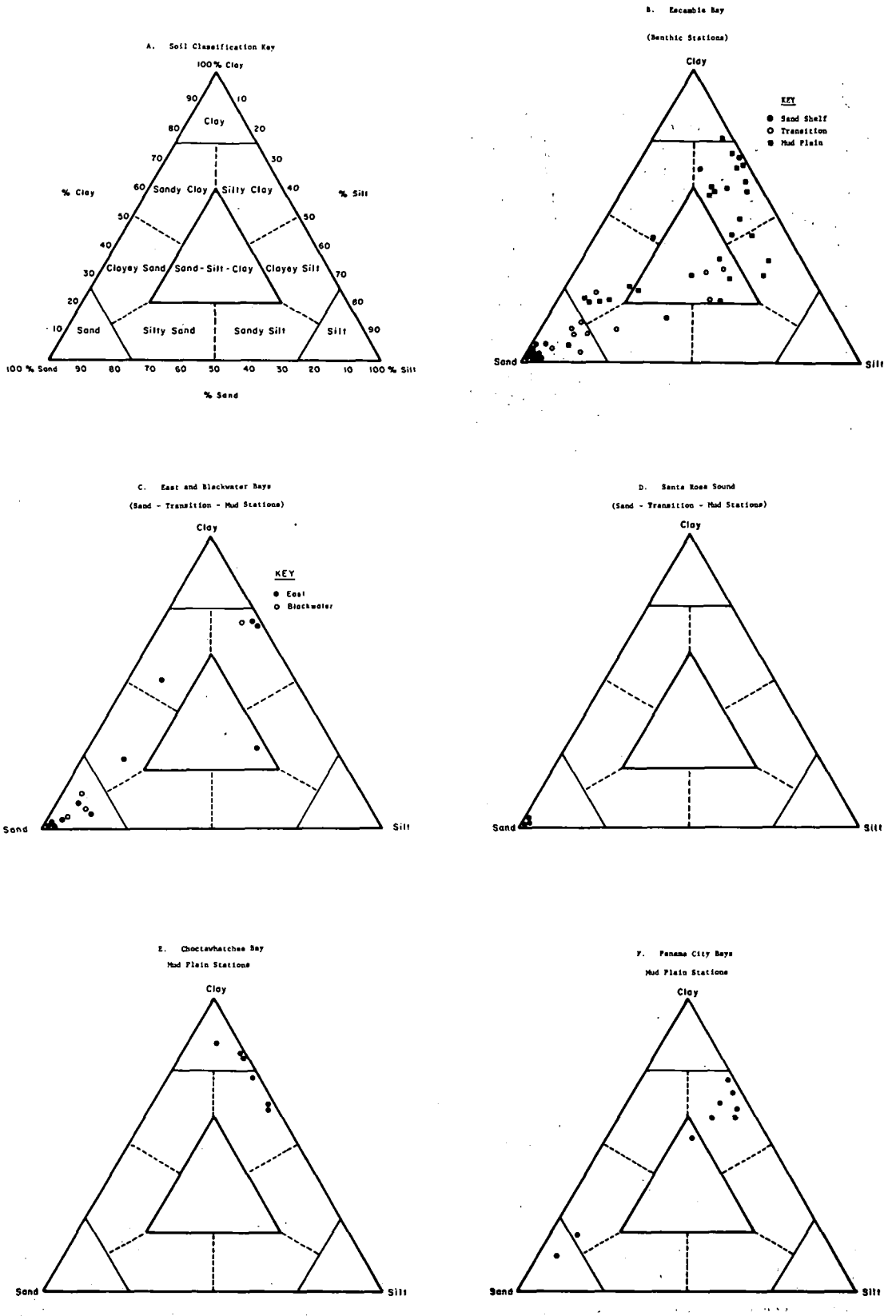


Figure 7-7. Sand-silt-clay sediment distributions in three northern Gulf Bay systems.

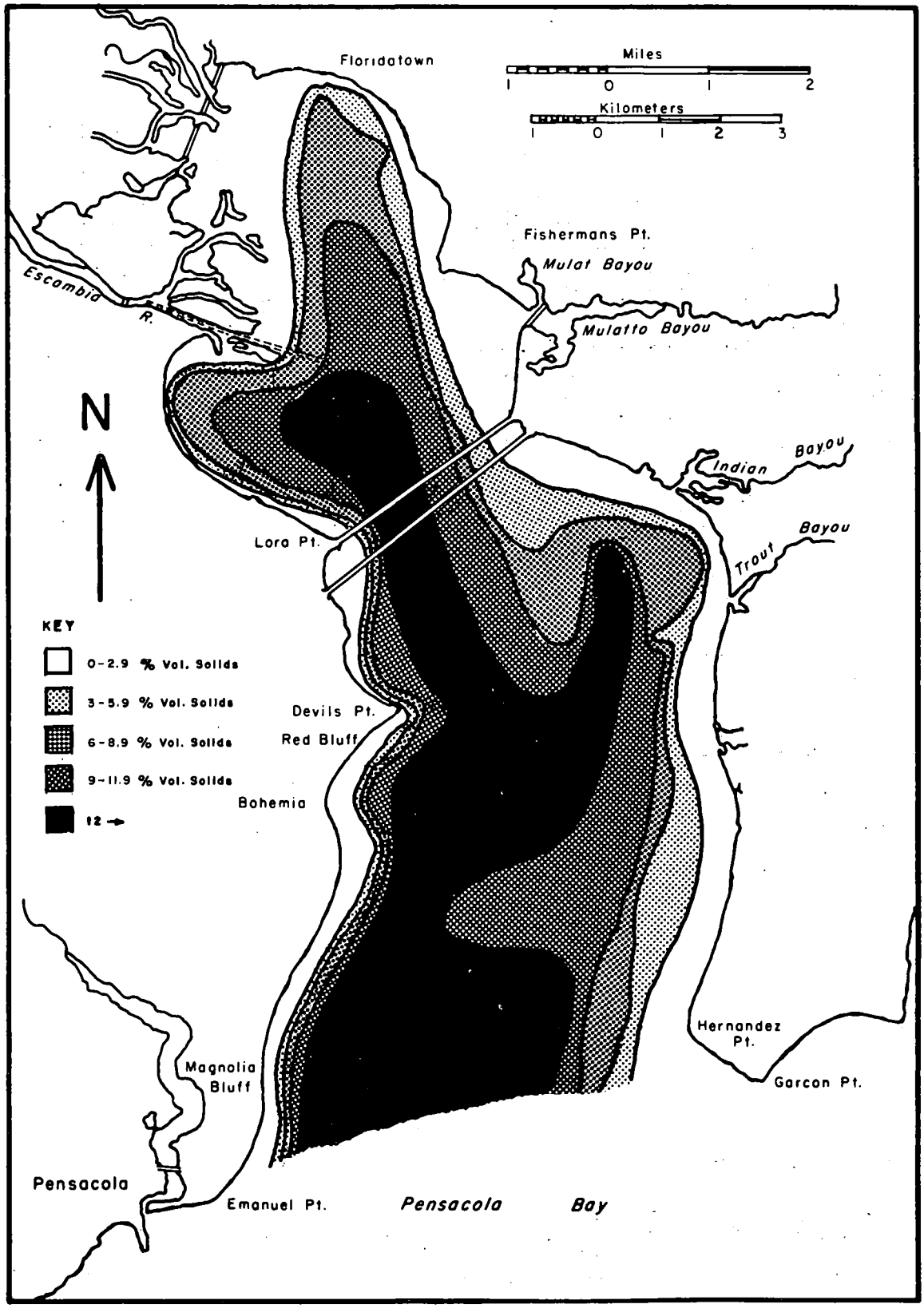


Figure 7-8. Distribution of surface sediment (top 15 cm.) volatile organics in Escambia Bay during 1973.

Sediment Chemistry

Volatile Organics

Volatile organics in Escambia Bay are directly correlated to the depth of the bay ($r = 0.7729$, $p<.01$) (Figure 7-8). South of Lora Point, in Escambia Bay, the western shore has a sharp gradient from low to high percent volatile organics progressing from nearshore to bayward. Along the western shore north of Lora Point and throughout the eastern shore there is a more gentle gradient from shore to deeper water. Volatile organics at the transition zone stations averaged 3.97 percent, whereas the mud plain and sand shelf stations averaged 7.38 and 0.59 percent, respectively. A comparison of upper bay and lower bay stations (using the L and N trestle as a divider) by analysis of variance indicated no difference in the volatile organics ($F = 2.827$, $p = 0.091$).

Additional samples were taken around the L and N trestle to determine if high organic sediments were collecting in this area. Six stations north of the trestle at intervals across the bay (Figure 7-1) and six stations on the south side revealed no unusually high organic concentrations.

A comparison of volatile organics in Escambia Bay sediments with other bays throughout the Pensacola Bay system and other northern Gulf of Mexico bays indicated no unusual concentrations in Escambia Bay sediments. EBRS stations in East Bay yielded concentrations similar to those in Escambia Bay for similar water depths. Also, the one EBRS deep water station in Pensacola Bay had a similar value as a comparable deep water station in Escambia Bay. The University of West Florida Sea Grant Study concentrations (Hopkins, unpublished data) for East Bay and Pensacola Bay showed Pensacola Bay had somewhat higher concentrations of volatile organics ($\bar{x} = 11.32$) than East Bay ($\bar{x} = 7.46$). There was a gradient of lower volatile organic concentrations from shallower waters in the upper portions of East and Escambia Bays to deeper waters in Pensacola Bay. However, volatile organics decreased from mid-Pensacola Bay toward the Gulf of Mexico inlet where the inlet station had a value of 0.14 percent.

Volatile organics concentrations from northeast Gulf bays were similar to those obtained in Escambia Bay (Table 7-2). Escambia Bay has a normal distribution of organic material throughout the surface sediments with the exception discussed below.

Regression analysis of organics vs. depth revealed certain stations falling outside the upper 95 percent confidence limit. These stations included three that were near the Northeast Sewage Treatment Plant, which discharges near the western shore at Bohemia. It was suspected that the STP effluent was causing these unusually higher concentrations. The area around the STP discharge that had higher than usual concentrations covered approximately 200 acres. Two stations located in the oyster bed

Table 7 - 2. Percent volatile organics in surface sediments in northeast Gulf of Mexico bays and sounds.

Area	Percent Volatile Organics	No. of stations	Source
Escambia Bay	0.07 - 26.00	160	EBRS
Mississippi River	0.50 - 9.40	4	Lindberg, R.S. (1973.
Mississippi Sound	0.10 - 23.90	38	EPA (unpublished data)
Mobile Bay	0.59 - 13.81	30	EPA
Mobile Bay	5.50 - 11.40	2	Lindberg, R.S. (1973.
Mobile Bay	10.20 - 19.30	2	Lindberg and Harriss (1973)
Perdido Bay	2.20 - 14.10	17	EPA (unpublished data)
Pensacola Bay	18.85 - 25.30	2	EBRS
Blackwater Bay	4.30 - 13.80	10	EPA (unpublished data), EBRS
East Bay (Pensacola)	0.30 - 27.71	48	EBRS - UWF
Choctawhatchee Bay	0.10 - 17.20	5	EPA (unpublished data)
Choctawhatchee Bay	8.42 - 24.52	6	EBRS
St. Andrews Bay	4.76 - 25.68	3	EBRS
North Bay, Panama City	13.44 - 16.05	3	EBRS
West Bay, Panama City	12.00 - 13.00	2	EBRS
East Bay, Panama City	4.92	1	EBRS

areas near the eastern shore also had high concentrations which were likely caused by physical trapping of organic particles within the oyster bed and the concurrent fecal droppings of the oysters. Another area of abnormally high volatile solids was the ship channel under the Interstate 10 bridge and L and N Railroad trestle. Microbial activity (discussed further under the Microbial Activity section) was also high at this site.

Biochemical Oxygen Demand (BOD_5)

Higher BOD_5 values were positively correlated with deeper waters of Escambia Bay, however, some of the highest concentrations were not necessarily related to the deepest areas. The area with BOD_5 values equal to or greater than 900 mg/g was the deeper portion of the upper half of the bay (Figure 7-9). The two stations in Escambia Bay with the highest concentrations were in the northeast sector near industrial discharges and river delta marshes. Material developing this demand are organic deposits resulting from both natural and man-produced introductions. Industries adjacent to the bay are presently discharging organics, and in years past they discharged even greater amounts. Dissolved organics from river water sources and industries are flocculated upon contact with saline water. Although no specific studies were designed to determine a zone of flocculation in Escambia Bay, the area of maximum BOD_5 deposits was the zone of maximum contact of fresh river water with saline waters. Although flocculation occurred throughout the water column, including shallow waters, there was resuspension by wave action

with ultimate deposition in the upper two-thirds of the bay as shown on Figure 7-9.

Average BOD_5 concentrations for sand shelf, transition zone, and mud plain stations were 306, 603, and 733 mg/g, respectively. Analysis of variance indicated sand concentrations were different from transition and mud concentrations, but the transition concentration was not significantly different from the mud concentrations. (mud and tran: $F = 1.134$, $df = 22$, $p>0.05$; mud and sand: $F = 20.848$, $df = 26$, $p<0.01$; tran and sand: $F = 12.378$, $df = 22$, $p<0.01$)

The eight BOD_5 samples taken in East Bay were less than 500 mg/g. Three stations in Blackwater Bay averaged 705 mg/g. Central portions of Choctawhatchee Bay (eight stations) had higher concentrations than all but one station in Escambia Bay. A centrally located station in Mulatto Bayou had a BOD_5 concentration of 1110 mg/g. Three other bayous off Pensacola Bay had equally high concentrations. Catfish Basin off Blackwater Bay had a low BOD_5 concentration, while in the four bayous listed above with high concentrations various organic wastes were not assimilated completely.

When compared to other bays, Escambia Bay BOD_5 concentrations were not unusually high.

Total Phosphorus

Spatial distribution of total phosphorus in Escambia Bay sediments followed the depth contours (Figure 7-10). Higher phosphorus concentrations were found south of the L and N Railroad trestle in waters generally deeper than 2.44 meters (8.0 feet). The four stations with highest concentrations (> 0.4 mg/g) were found near the trestle and Interstate 10 bridge.

At comparable water depths, concentrations in East Bay were lower than those in Escambia Bay. The one station sampled in Pensacola Bay had a concentration of 0.468 mg/g. The trend in Choctawhatchee Bay was for higher phosphorus concentrations in the upper bay (near the river) and lower concentrations near the Gulf inlet. Depths at these stations, like Escambia Bay, were shallow in the upper bay and deeper toward the Gulf. Phosphorus concentrations in Choctawhatchee Bay were similar to the higher concentrations in Escambia Bay (> 0.3 mg/g). A comparison of total phosphorus in mud sediments of Escambia Bay to other northwest Florida bays is presented in Table 7-3.

Phosphorus concentrations in the Panama City bay system did not have a good correlation ($r = 0.515$, $p<0.01$) with depth; higher concentrations were found near population centers and industrial complexes. Of the eight stations in this system, three concentrations were greater than 0.6 mg/g. The highest concentration in Escambia Bay was 0.54 mg/g near the L and N Railroad trestle.

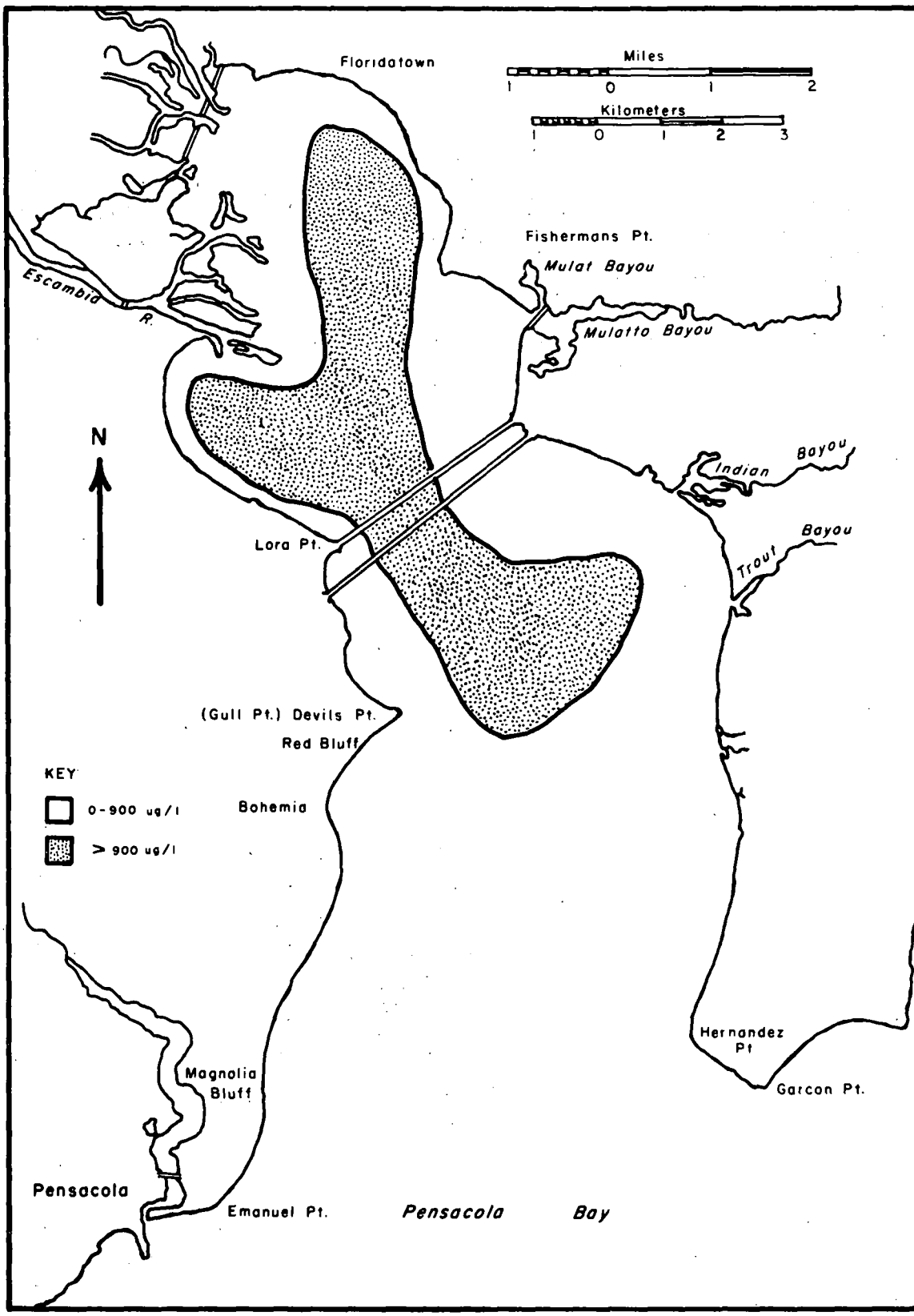


Figure 7-9. Biological oxygen demand (BOD_5) in surface sediments (top 15 cm.) in Escambia Bay during 1973-1974.

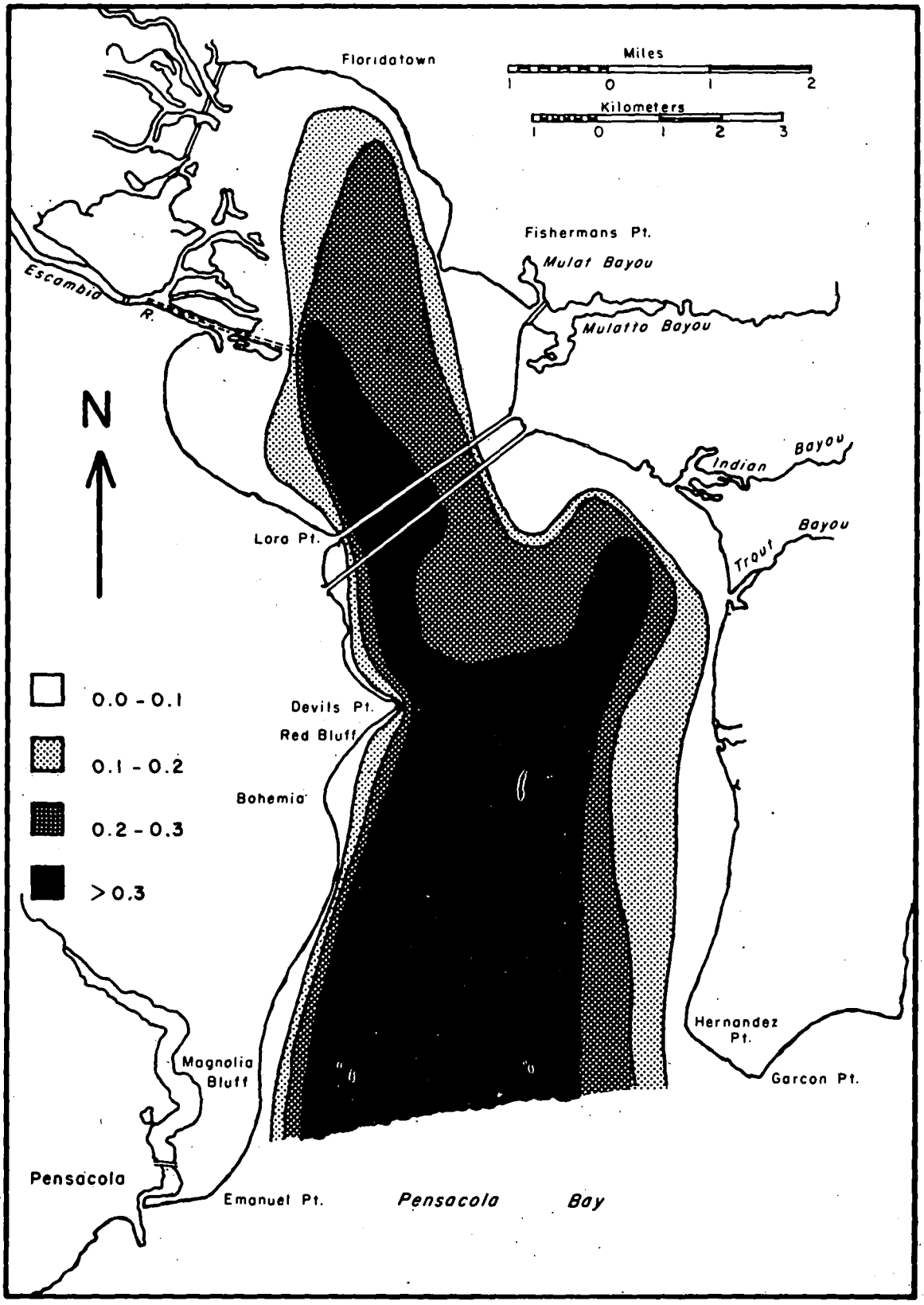


Figure 7-10. Phosphorus concentrations (mg/g) in surface sediments (top 15 cm.) in Escambia Bay during 1973-1974.

Table 7 - 3. Total phosphorus, organic nitrogen, and organic carbon in mud sediments from northwest Florida.

Location	Number of Samples	Mean Total Phosphorus (µg/g)	Mean Organic Nitrogen (mg/g)	Mean Organic Carbon (mg/g)
Escambia Bay	19	248.8	0.57	31.4
East Bay	5	195.6	0.59	33.7
Panama City bays	9	468.9	1.18	58.6
Choctawhatchee Bay	6	350.7	1.60	59.0
Pensacola Bay	1	468.0	0.71	35.4

Total phosphorus concentrations in the bayous of the Pensacola Bay system were lower than concentrations found in deeper water stations of the bays.

Phosphorus concentrations in Escambia Bay were higher than East Bay but lower than Pensacola Bay (deep water), Choctawhatchee Bay, and Panama City bays.

Organic Nitrogen

Organic nitrogen distribution was similar to total phosphorus in that both had concentrations that tended to correlate with the natural depth contours; highest concentrations were below the Interstate 10 bridge in deeper waters in Escambia Bay (Figure 7-11). East Bay had consistently lower concentrations than Escambia Bay. Choctawhatchee Bay stations had organic nitrogen values that were positively correlated with depth with one exception. The station nearest the river had a concentration of 1.3 mg/g, whereas the next deeper station was only 0.8 mg/g. Choctawhatchee Bay was very similar to Escambia Bay in organic nitrogen concentrations and their distribution. The Alaqua Bayou station off Choctawhatchee Bay had a high concentration that was associated with sawdust present on the bayou bottom. Organic carbon was also high at this station.

Bayou stations in the Pensacola Bay system had low concentrations of organic nitrogen compared to bay stations with sediments of similar physical characteristics.

Mid-bay stations in the Panama City bays had lower concentrations ($\bar{x}$ = 21.5 mg/g) than mud stations in central Escambia Bay.

Both Escambia Bay and Choctawhatchee Bay had relatively large river inflows and similar organic nitrogen concentrations. Conversely, East Bay and Panama City bays had lower organic nitrogen concentrations and less freshwater inflow. Escambia Bay sediment did not seem to have unnaturally high organic nitrogen concentrations.

Organic Carbon

The distribution of organic carbon in the Pensacola Bay system was similar to that of total phosphorus and organic nitrogen; that is, as muddy sediments increased, concentrations increased. Figure 7-12 showed highest concentrations were at midbay in deeper waters in 1973. These high concentrations were similar in both the upper bay and lower bay.

Figure 7-13 showed the relationship of organic carbon in Escambia Bay and East Bay in 1974. In both bays the lower concentrations were near-shore and higher concentrations in midbay.

There was no apparent significant change in organic carbon concentrations in the sediments in 1973 compared to 1974 (Figures 7-12 and 7-13). Table 7-3 compares organic carbon (chemical oxygen demand) within four bays and indicates Escambia Bay had the lowest concentrations. The average of the Panama City bays was high because one station was near a paper mill waste discharge. Escambia Bay sediments did not have any unusual concentrations of organic carbon.

Polychlorinated biphenyl (PCB)

Aroclor 1254 (a trade name for a PCB) was found throughout the sediments of the Pensacola Bay system (Figure 7-14). The range of values was 0.0 to 1500 µg/kg (ppb). The mean of 54 stations was 71.4 µg/kg, including ten stations where Aroclor 1254 was not detected. Station C-15 located in the Escambia Bay barge channel had the highest value at 1500 µg/kg. Escambia Bay transects G and O, each with three stations representing sand, transition, and mud had the following PCB concentrations in µg/kg:

Sand stations		Transition stations		Mud stations	
GC	9.8	GB	45.0	GA	70.0
OC	20.0	OB	43.0	OA	86.0

Analysis of these data indicated a trend to higher PCB's in finer particles. This trend is prevalent throughout the entire bay system.

During February 1974, two cores taken near Air Products' and American Cyanamid's discharges had concentrations of 245 and 250

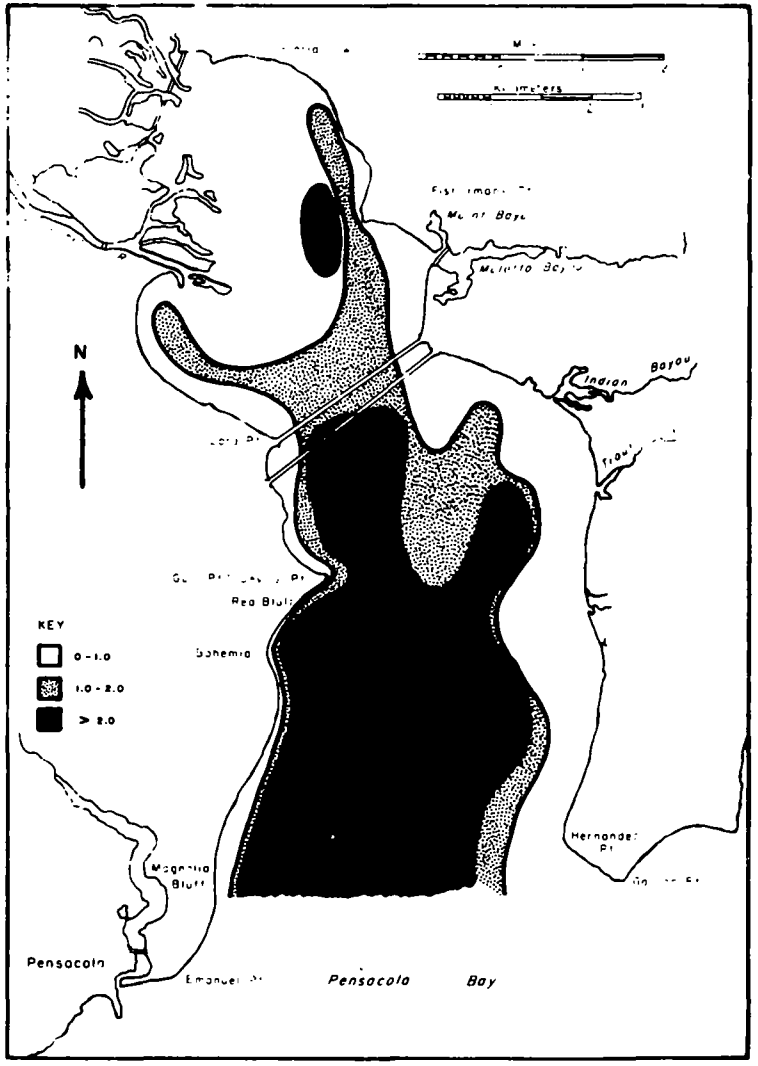


Figure 7-11. Total organic nitrogen (mg/g) in surface sediments (top 15 cm.) in Escambia Bay during 1973-1974.

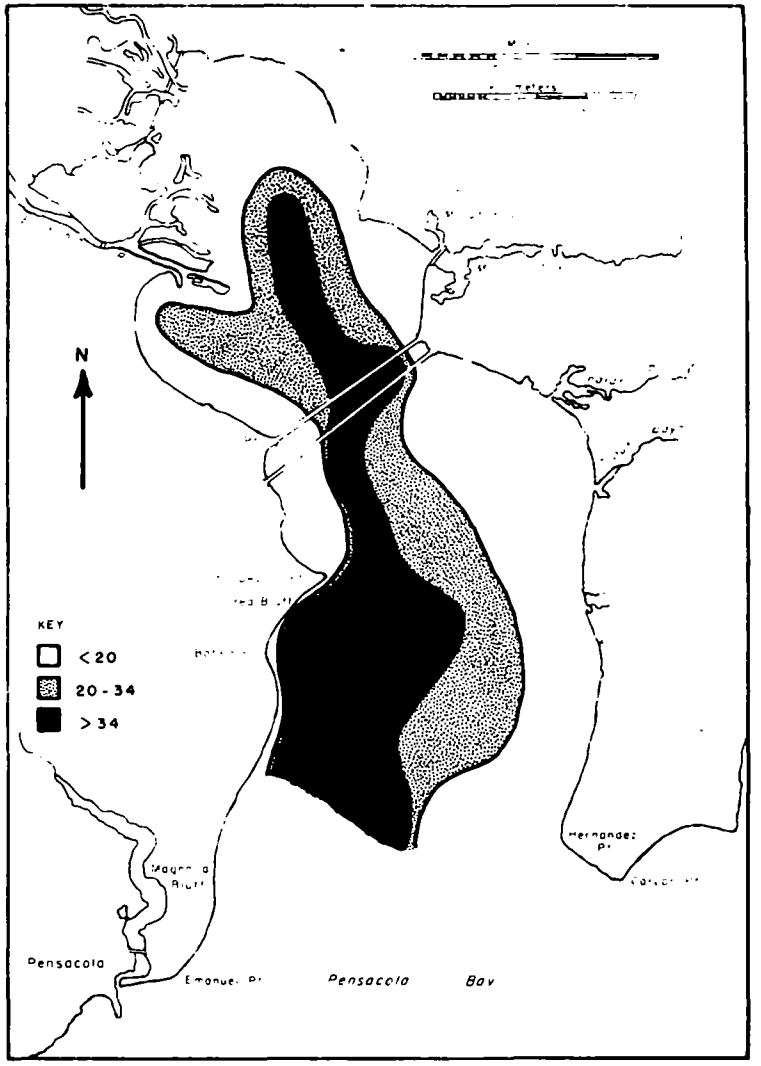


Figure 7-12. Organic carbon (mg/g) distribution in surface sediments (top 15 cm.) in Escambia Bay during 1973.

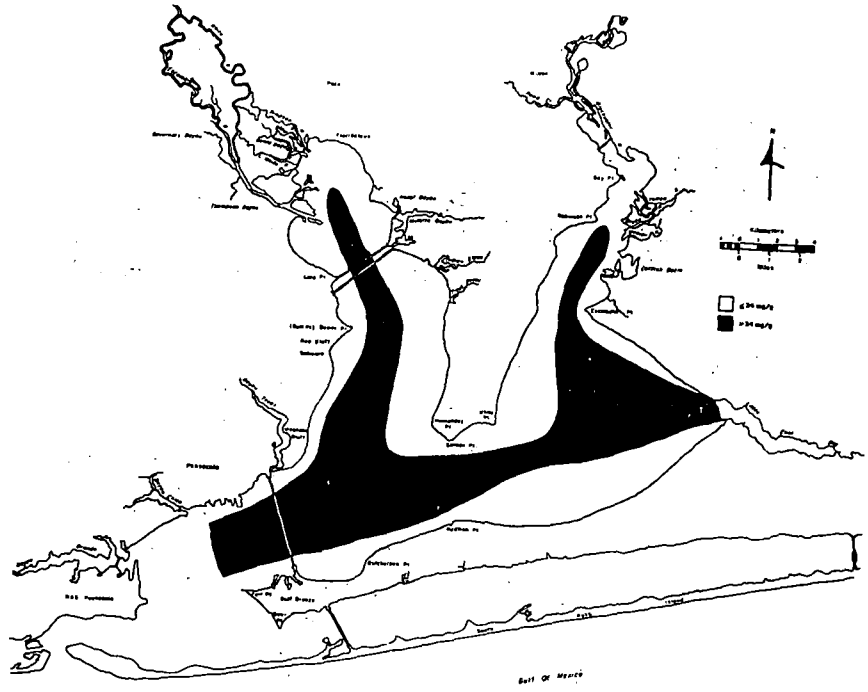


Figure 7-13. Organic carbon (mg/g) distribution in surface sediments (top 15 cm.) in the Pensacola Bay system during 1974.

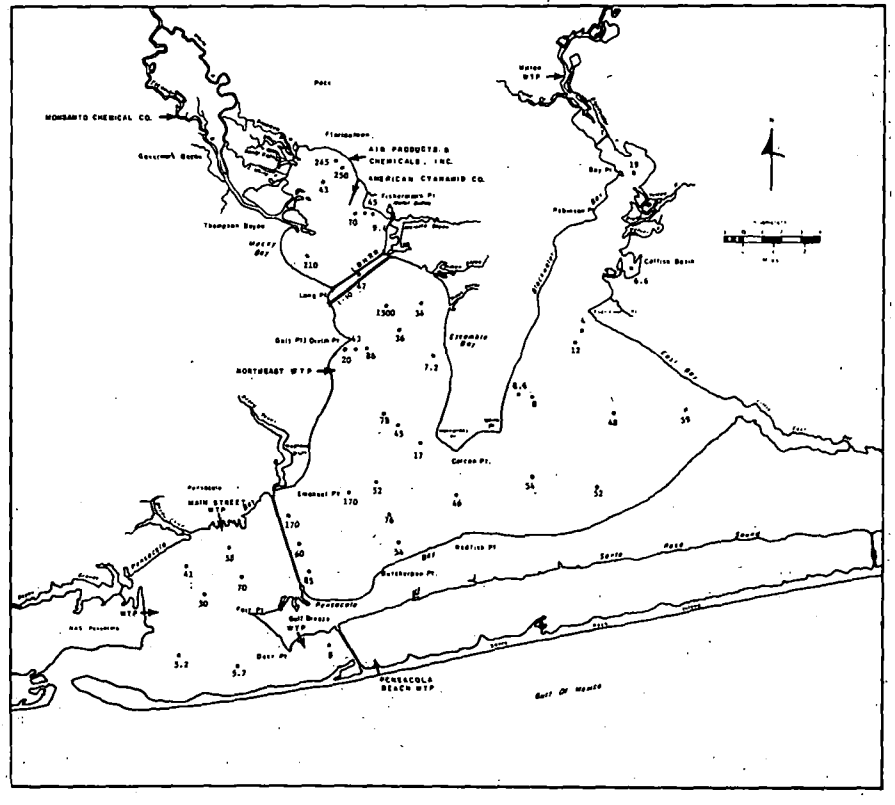


Figure 7-14. Polychlorinated biphenyls (Aroclor 1254, µg/kg) distribution in surface sediments (top 15 cm.) in the Pensacola Bay system during 1974.

µg/kg of PCB. Since these are relatively high concentrations compared to most of the bay, ten additional stations on a transect between these discharges were sampled by coring. The range of these concentrations was <80 to 340 µg/kg (ppb). (Analyses performed by the EPA, NERC, Gulf Breeze Research Lab). Organic scans with gas chromotography and electron capture detector in 1972 did not reveal any PCB's in either of these industrial discharges. During this study there was no sampling of these discharges.

Station B-11C (a channel station) had a concentration of 78 µg/kg while B-11, which was adjacent to the channel but on the mud plain, had a concentration of 45 µg/kg. The channel acts as a trap for fine sediments which in turn are attractants of PCB molecules. Since PCB can be incorporated with clay and silt particles and also organisms can accumulate the material, eventually PCB will accumulate in deep water sediments. Any material deposited on the sediment will be reworked deeper into the sediment by organisms, and therefore, be available for uptake by benthic infauna.

An industrial leak of Aroclor 1254 was discovered and stopped in 1969 upriver of Station A-10. This station is influenced greatly by freshwater flow from the river and has a low salinity (annual average one foot above bottom is 7.8 ppt). There is an accumulation of upland vegetative debris at this station. This station had a relatively high concentration of Aroclor 1254 (210 µg/kg).

PCB's in sediments of Escambia Bay have been analyzed at intervals since 1969 (Nimmo, et al, 1975). Their discussion of sediment data from 1969 to 1971 shows a consistent decline of PCB. Samples for Aroclor 1254 taken in 1972 at eleven sediment surface stations ranged from <100 to 5700 µg/kg (EPA, Gulf Breeze Laboratory).

It appears that PCB is diminishing from the sediments at a rate of about 90 percent per year.

Pesticides

Sediments were analyzed for twenty-one pesticides listed in Appendix 7-4. Five pesticides were detected during the present study.

DDE, a derivative of DDT, was found in sediments during this study in Blackwater, East, and Pensacola Bays, but not in Escambia Bay. Concentrations ranged from non-detected to 1.9 µg/kg. In Choctawhatchee Bay, the range was from non-detected to 17.0 µg/kg. DDD was found at one station in Choctawhatchee Bay (2.5 µg/kg). DDT ranged from 1.2 to 2.8 µg/kg at three stations in Choctawhatchee Bay.

Dieldrin was found only in Escambia Bay at concentrations of 0.12 to 0.43 µg/kg at four of the 13 stations.

Mirex was found at the station nearest the Choctawhatchee River mouth in Choctawhatchee Bay at a concentration of 0.95 µg/kg.

Dieldrin is highly toxic to estuarine organisms and its presence in Escambia Bay sediments creates a definite threat to the bay ecosystem. This pesticide probably entered the estuary through lawn fertilization and ant control measures. It is presently not used to any great extent and in the future will likely not be available for public use.

Lead

The sandy shelf area along the margin of all bays in the Pensacola Bay system had lower concentrations of lead (<10 µg/g) than did deeper mid-portions of the bays. Muddy portions of the system had concentrations from 10 to 38 µg/g except Bayou Texar and Bayou Chico, which had values of 54 and 64 µg/g, respectively. Comparing muddy stations in the upper and lower portions (above and below the L and N Railroad trestle) of Escambia Bay, there were higher concentrations below the trestle by a factor of two. Concentrations in East Bay were about the same as the lower portion of Escambia Bay. Deep water stations in Pensacola Bay had higher values than deep water stations in Escambia Bay except those stations toward the Gulf inlet. Five stations along the northern margin of Pensacola Bay and in the bayous along the north shore had concentrations that were the highest for the entire bay system. These stations were influenced by the City of Pensacola's wastewater discharges. Lead concentrations in Choctawhatchee Bay were the same as in the lower portion of Escambia Bay. Lead concentrations did not seem excessive in Escambia Bay compared to Pensacola Bay and two relatively unaltered bays. Further comparison (Table 7-4) with other sediments indicated Escambia Bay had less lead concentrations than Mississippi coastal areas, Chesapeake Bay, Galveston Bay, and Mobile Bay.

Zinc

Zinc concentrations were lower in the shallower sand stations compared to deeper muddy stations in the entire Pensacola Bay system. Upper Escambia Bay had lower concentrations than the lower bay within mud stations. There was no significant difference in lower Escambia Bay and East Bay within mud stations ($t = 0.44$, $df = 1$, $p>0.05$). Bayou Texar had a high concentration (150 µg/g) compared to the highest value of 85 µg/g in Escambia Bay. Bayou Chico had a concentration of 1200 µg/g in its mud, which was quite high compared to other bay systems in the northern Gulf of Mexico (Table 7-5). Escambia Bay values were lower than those from Pensacola Bay, industralized areas of the Mississippi coast, Galveston Bay and Mobile Bay. It had values

Table 7 - 4. Lead concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	18.5	<2.0	43.0	20	EBRS
Pensacola Bay	39.8	<5.0	64.0	18	UWF - EPA, Region IV
East Bay	16.2	2.0	31.0	11	EBRS
Escatawpa River Estuary	18.1	2.4	44.0	18	EPA, Region IV
Pascagoula River Estuary	25.3	<4.0	44.0	4	EPA, Region IV
Bayou Casotte	30.8	4.7	49.0	3	EPA, Region IV
Mississippi Sound	15.2	8.8	23.0	4	EPA, Region IV
Turkey Creek, Miss.	<4.0	-	-	1	EPA, Region IV
Gulfport Seaway & Bayou Bernard	20.3	<4.0	38.0	4	EPA, Region IV
Bioloxi Backbay	22.5	4.4	34.0	4	EPA, Region IV
Chesapeake Bay	42.6	17.0	60.0	5	Sommer and Pyzik, 1974
Galveston Bay	26.8	9.0	46.0	5	Holland and Maciolek, 1973
Blackwater Bay	13.0	2.0	29.0	7	EBRS - EPA, Region IV
Choctawhatchee Bay	26.1	3.0	34.0	8	EBRS - EPA, Region IV
Panama City Bays	23.2	12.0	42.0	9	EBRS
Mobile Bay, Ala.	28.4	6.0	86.0	29	EPA, Region IV

Table 7 - 5. Zinc concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	43.2	1.0	98.0	20	EBRS
Pensacola Bay	140.3	1.0	1200.0	18	UWF - EPA, Region IV
East Bay	28.8			12	EBRS
Escatawpa River Estuary	71.4	0.8	230.0	18	EPA, Region IV
Pascagoula River Estuary	51.2	2.2	121.0	4	EPA, Region IV
Bayou Casotte	90.5	14.6	151.0	3	EPA, Region IV
Mississippi Sound	31.0	19.8	467.0	4	EPA, Region IV
Turkey Creek, Miss.	4.7	-	-	1	EPA, Region IV
Gulfport Seaway & Bayou Bernard	34.8	4.8	65.4	4	EPA, Region IV
Bioloxi Backbay	36.8	9.5	53.0	4	EPA, Region IV
Chesapeake Bay	no data				
Galveston Bay	66.2	32.0	122.0	5	Holland and Maciolek, 1973
Blackwater Bay	19.7	4.0	53.0	7	EBRS - EPA, Region IV
Choctawhatchee Bay	45.8	1.0	59.0	8	EBRS - EPA, Region IV
Panama City Bays	37.9	15.0	88.0	9	EBRS
Mobile Bay, Ala.	90.3	10.0	292.0	30	EPA, Region IV

Table 7 - 6. Chromium concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	39.7	4.0	110.0	20	EBRS
Pensacola Bay	55.7	12.0	78.0	18	UWF - EPA, Region IV
East Bay	38.4	4.0	54.0	12	EBRS
Escatawpa River Estuary	21.0	1.6	89.0	18	EPA, Region IV
Pascagoula River Estuary	20.3	<4.0	43.6	4	EPA, Region IV
Bayou Casotte	206.5	7.1	134.0	3	EPA, Region IV
Mississippi Sound	16.8	7.2	30.8	4	EPA, Region IV
Turkey Creek, Miss.	<4.0	-	-	1	EPA, Region IV
Gulfport Seaway & Bayou Bernard	14.6	5.1	34.5	4	EPA, Region IV
Bioloxi Backbay	17.0			4	EPA, Region IV
Chesapeake Bay	118.8	78.0	134.0	5	Sommer and Pyzik, 1974
Galveston Bay	40.4	14.0	89.0	5	Holland and Maciolek, 1973
Blackwater Bay	13.1	5.0	42.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	71.2	44.0	84.0	6	EBRS - EPA, Region IV
Panama City Bays	55.1	16.0	75.0	9	EBRS

Table 7 - 7. Cadmium concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	<1.0			20	EBRS
Pensacola Bay	1.0	<1.0	2.0	12	UWF - EPA, Region IV
East Bay	<1.0			10	EBRS
Escatawpa River Estuary	0.9	<0.4	4.8	18	EPA, Region IV
Pascagoula River Estuary	<2.0			4	EPA, Region IV
Bayou Casotte	<2.0			3	EPA, Region IV
Mississippi Sound	<2.0			4	EPA, Region IV
Turkey Creek, Miss.	<2.0			1	EPA, Region IV
Gulfport Seaway & Bayou Bernard	<2.0			4	EPA, Region IV
Bioloxi Backbay	<2.0			4	EPA, Region IV
Blackwater Bay	<1.0			5	EBRS - EPA, Region IV
Choctawhatchee Bay	1.0			6	EBRS - EPA, Region IV
Panama City Bays	<1.0			9	EBRS
Mobile Bay	1.2	0.6	1.9	9	EPA, Region IV after J.M.Lawrence (personal comm.)

about the same as Choctawhatchee Bay and Panama City bays and did not seem to have any unusual concentrations.

Chromium

Stations that were predominantly sand had lower chromium concentrations than did those in deeper waters that were principally mud. Within Escambia Bay the muddy stations in the upper bay had lower concentrations than the lower bay. Concentrations in muddy stations in East Bay were about the same as those in lower Escambia Bay. Concentrations in Bayou Texar, Bayou Chico, and Bayou Grande were similar to the muddy stations in Escambia Bay. Choctawhatchee Bay concentrations were about the same as those in Escambia Bay. Chromium concentrations in Escambia Bay did not seem excessive compared to other bays (Table 7-6).

Cadmium

The range of cadmium in the Pensacola Bay system was from <0.97 to 2.0 µg/g. Four of nineteen stations in Escambia Bay had cadmium concentrations ≥1.0 µg/g. Concentrations in East Bay were less than those in Escambia Bay. Bayou Grande and Bayou Chico had concentrations greater than 1.0 µg/g. Most stations in Choctawhatchee Bay had concentrations of 1.0 µg/g. Therefore, cadmium concentrations in sediments of Escambia Bay were lower than those in the relatively unpolluted sediments of Choctawhatchee Bay (Table 7-7).

Copper

Sandy stations had lower concentrations of copper than muddy stations within the Pensacola Bay system. Muddy stations in upper Escambia Bay had lower concentrations than muddy stations in the lower bay. East Bay copper concentrations were lower than either the upper or lower bay portions of Escambia Bay. Concentrations in Choctawhatchee Bay were about the same as lower Escambia Bay. Mulatto Bayou and Bayou Texar had concentrations of 10 µg/g, while Bayou Chico had 120 µg/g. Bayou Chico has a long history of receiving heavy metals discharged by industries.

Compared to East Bay (4.4 µg/g), the Escambia Bay system (8.7 µg/g) was somewhat contaminated with copper. Escambia Bay had greater concentrations than six areas (35 stations) in Mississippi (Table 7-8). It also had higher values than Blackwater Bay. If only deep water Escambia Bay stations were considered, the mean was 11.8 µg/g (n = 13) and deep water stations in Panama City bays (11.6 µg/g) and Choctawhatchee Bay (11.3 µg/g) were similar. Bayou Casotte, Mississippi, a heavily industralized area, had a mean of 11.7 µg/g. Conversely, Pensacola Bay (19.3 µg/g), Chesapeake Bay (35.2 µg/g), and Galveston Bay (28.0 µg/g) had higher values than Escambia Bay (Table 7-8).

Table 7 - 8. Copper concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	8.7	1.0	43.0	20	EBRS
Pensacola Bay	19.3	1.0	120.0	18	UWF - EPA, Region IV
East Bay	4.4	1.0	8.5	10	EBRS
Escatawpa River Estuary	5.9	0.6	16.0	18	EPA, Region IV
Pascagoula River Estuary	5.7	1.0	12.1	4	EPA, Region IV
Bayou Casotte	11.7	1.2	20.5	3	EPA, Region IV
Mississippi Sound	3.7	1.6	6.6	4	EPA, Region IV
Turkey Creek, Miss.	<1.0	-	-	1	EPA, Region IV
Gulfport Seaway & Bayou Bernard	4.5	<1.0	11.1	4	EPA, Region IV
Bioloxi Backbay	4.3	<1.0	6.0	4	EPA, Region IV
Chesapeake Bay	35.2	27.0	54.0	5	Sommer and Pyzic, 1974
Galveston Bay	28.0	5.1	80.0	5	Holland and Maciolek, 1973
Blackwater Bay	2.5	<1.0	7.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	11.3	10.0	15.0	6	EBRS - EPA, Region IV
Panama City Bays	11.6	3.0	42.0	9	EBRS

Table 7 - 9. Manganese concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	188.8	5.0	540.0	20	EBRS
Pensacola Bay	318.5	3.6	521.0	18	UWF - EPA, Region IV
East Bay	188.2	2.7	410.0	10	EBRS
Galveston Bay	412.6	212.0	727.0	5	Holland and Maciolek, 1973
Blackwater Bay	105.6	8.0	263.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	654.2	117.0	1480.0	6	EBRS - EPA, Region IV
Panama City Bays	129.8	50.0	270.0	9	EBRS

Table 7 - 10. Nickel concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	8.8	2.0	19.0	20	EBRS
Pensacola Bay	15.7	<2.0	28.5	18	UWF - EPA, Region IV
East Bay	8.7	<2.0	15.0	10	EBRS
Escatawpa River Estuary	6.5	<1.6	15.0	18	EPA, Region IV
Pascagoula River Estuary	8.0	<2.0	17.4	4	EPA, Region IV
Bayou Casotte	8.6	<2.0	12.3	3	EPA, Region IV
Mississippi Sound	7.0	2.4	12.1	4	EPA, Region IV
Turkey Creek, Miss.	<2.0	-	-	1	EPA, Region IV
Gulfport Seaway & Bayou Bernard	4.5	<2.0	9.4	4	EPA, Region IV
Bioloxi Backbay	6.6	<2.0	13.0	4	EPA, Region IV
Chesapeake Bay	44.8	33.0	57.0	5	Sommer and Pyzic, 1974
Galveston Bay	27.8	11.0	57.0	5	Holland and Maciolek, 1973
Blackwater Bay	2.8	1.0	4.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	15.6	7.8	20.0	6	EBRS - EPA, Region IV
Panama City Bays	11.1	<4.0	17.0	9	EBRS

Table 7 - 11. Aluminum concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	10078	300	21000	20	EBRS
Pensacola Bay	14565	64	26000	18	UWF - EPA, Region IV
East Bay	10554	360	20000	10	EBRS
Blackwater Bay	4684	1120	15000	5	EBRS - EPA, Region IV
Choctawhatchee Bay	21050	16600	28000	6	EBRS - EPA, Region IV
Panama City Bays	13433	4800	18800	9	EBRS

Concentrations around the discharges of American Cyanamid and Air Products were higher than other stations in the upper bay. Copper was apparently accumulating in an area near the discharges.

Manganese

Sandy stations had lower values of manganese, whereas higher concentrations were found at muddy stations. Within muddy stations, concentrations in upper bay stations were much lower (by 4.6 times) than lower bay stations. Bayou stations tended to be lower than open bay stations. Concentrations in East Bay were about the same as those in Escambia Bay (Table 7-9). Panama City bays and Blackwater Bay had lower values than Escambia Bay. Pensacola Bay, Galveston Bay, and Choctawhatchee Bay had higher values than Escambia Bay (Table 7-9). Manganese concentrations in Escambia Bay did not seem to be unusual when compared to other bays in northwest Florida.

Nickel

Nickel concentrations were lower in the sandy stations compared to muddy stations within the Pensacola Bay system. Muddy stations above the L and N trestle in Escambia Bay had lower concentrations than those in mud below the trestle. Escambia Bay concentrations were about the same as those in East Bay and the Mississippi coast (Table 7-10). Pensacola Bay system bayous and the Pensacola Bay northern shore stations were similar to Escambia Bay. Mid-Pensacola Bay stations had higher concentrations than any area of the total system. Chesapeake Bay and Galveston Bay had higher means than Escambia Bay (Table 7-10). Choctawhatchee Bay and Panama City Bays had somewhat higher concentrations, but these two were only sampled in muddy sediments. Escambia Bay muddy stations were similar to these two bays. There appeared to be no unusual concentration of nickel in Escambia Bay as compared to East Bay and other northern Gulf bays and sounds.

Aluminum

Aluminum makes up a large portion of the clay particle lattice and consequently is distributed in relation to the mud deposits in the bay. Thus, the sandy near-shore areas had low concentrations of aluminum while the deeper parts of the bay had higher concentrations. Less clay accumulated in the upper portion of Escambia Bay. Consequently, aluminum concentations were greater in the lower bay. East Bay had about the same concentrations as the lower Escambia Bay. There were no unusual concentrations of aluminum in Escambia Bay (Table 7-11).

Iron

The iron distribution in Escambia Bay was similar to the aluminum distribution and the above discussion on aluminum holds true for iron. Choctawhatchee Bay values (48,000 µg/g) were higher than any bay sampled (Table 7-12).

Cobalt

Cobalt concentrations in sandy stations were lower than muddy stations throughout Escambia Bay. The upper bay had lower concentrations than the lower bay. East Bay mud station concentrations ($\bar{x}$ = 6.8) were significantly lower ($t = 2.58$, $df=15$) than Escambia lower bay stations ($\bar{x}$ = 15). Choctawhatchee Bay concentrations ($\bar{x}$ = 12) were also significantly lower ($t = 6.67$, $df = 13$) than Escambia lower bay stations. Accumulations of cobalt in the lower portion of Escambia Bay within the deeper water sediments were higher than adjacent Bays. Chesapeake Bay values were higher than Escambia Bay values (Table 7-13).

Vanadium

Vanadium concentrations were lower in the sandy shallow stations and higher in the deeper muddy stations within Escambia Bay. Concentrations were twice as great in the lower bay mud stations than the upper bay mud stations. Lower bay concentrations at muddy stations were not significantly ($t = 1.6$, $df=15$) greater than concentrations in muddy East Bay stations; however, the mean for lower Escambia Bay was 73.6 µg/g compared to 37.4 µg/g for East Bay. There was a greater accumulation of vanadium in lower Escambia Bay compared to East Bay and Pensacola Bay (Table 7-14).

Titanium

Titanium is a common metal found in dark colored sand, silt, and clay particles originating from the upland watershed. These particles are apparently distributed evenly throughout the bay; therefore, the distribution of titanium in Escambia Bay was uniform with no relationship to water depth or sediment type.

Most samples had concentrations greater than 40 µg/g. Mud station concentrations were similar in East Bay and Escambia Bay. Pensacola Bay concentrations were lower than Escambia Bay, but the Pensacola Bay bayou stations were the same as Escambia Bay stations. Table 7-15 compares concentrations within several northwest Florida bays.

Channel Sediments

In general, channel sediments within Escambia Bay were quite different from sediments in the central bay mud plain. Maintenance dredging of the Escambia River and Bay channel was last performed in 1970 to 3.05 m (10 ft) below MLW. Although the

Table 7 - 12. Iron concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	29298	850	54000	20	EBRS
Pensacola Bay	32740	230	53000	18	UWF - EPA, Region IV
East Bay	23836	625	43000	10	EBRS
Galveston Bay	8220	5200	12700	5	Holland and Maciolek, 1973
Blackwater Bay	11520	2300	37000	5	EBRS - EPA, Region IV
Choctawhatchee Bay	47967	31400	60000	6	EBRS - EPA, Region IV
Panama City Bays	20522	6800	27000	9	EBRS

Table 7 - 13. Cobalt concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	12.2	5.0	32.0	20	EBRS
Pensacola Bay	9.8	4.9	15.0	18	UWF - EPA, Region IV
East Bay	8.6	<5.0	13.0	10	EBRS
Chesapeake Bay	146.6	16.0	260.0	5	Somer and Pyzik, 1974
Blackwater Bay	4.8	2.0	10.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	12.0	7.0	14.0	6	EBRS - EPA, Region IV
Panama City Bays	4.9	2.0	6.2	9	EBRS

Table 7 - 14. Vanadium concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	73.6	19.0	215.0	20	EBRS
Pensacola Bay	47.3	<10.0	80.0	18	UWF - EPA, Region IV
East Bay	37.4	<10.0	71.0	10	EBRS
Chesapeake Bay	108.2	78.0	135.0	5	Somer and Pyzik, 1974
Blackwater Bay	23.4	8.0	55.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	99.5	57.0	151.0	6	EBRS - EPA, Region IV
Panama City Bays	34.6	16.0	50.0	9	EBRS

Table 7 - 15. Titanium concentrations in surface sediments of selected bays.

System	Concentration (ppm) Mean	Min.	Max.	Number of Observations	Source
Escambia Bay	70.2	12.0	<80.0	20	EBRS
Pensacola Bay	33.0	12.0	30.0	18	UWF - EPA, Region IV
East Bay	55.0	12.0	<80.0	10	EBRS
Blackwater Bay	47.6	24.0	80.0	5	EBRS - EPA, Region IV
Choctawhatchee Bay	40.2	24.0	54.0	6	EBRS - EPA, Region IV
Panama City Bays	64.0	38.0	100.0	9	EBRS

channel depth is to be maintained at a minimum depth of 2.7 meters (9.0 ft) MLW, existing depth exceeds 2.7 m. Periodic maintenance work is required due to sediment deposition in the lower river and bay. An irregular bottom profile has been created, due mostly to dredging. High river flows cause periodic scouring to occur in the river, and fine sediment material which has accumulated is resuspended and moved down river to the bay, leaving only the coarser sands deposited in the river. There were, however, pockets of finer sediments scattered throughout lower reaches of the river.

Four stations sampled in mid-channel from Highway 90 bridge south to the mouth of the river contained less than 0.68 percent mud. Mean phi grain size for the sand fraction was 1.28, which is classed medium sand.

The channel in the bay was deeper than the surrounding bay bottom and, consequently, it acted as a sediment sink for mud fractions. Channel sediments only 0.3 km (0.5 mi) below the river mouth were 45 percent mud. Table 7-16 lists data on channel sediments and Figure 7-15 shows station locations. All except Stations B-11 and B-11C were sampled shortly after the high flow in Spring 1973. The mud fraction of the channel sediments increased toward the lower bay.

While volatile organics were negligible in the lower river sediments, they greatly increased 0.3 km (0.5 mi) seaward of the mouth of the river. From this point south for 5.5 km (3.4 mi),

Table 7 - 16. Ship channel sediments, Escambia Bay, Florida, from Highway 90 bridge to channel entrance.

Station	Date	Depth (m)	Percent Mud (%)	Percent Clay (%)	Percent Vol. Solids (%)	Total Phosphorus (mg/l)	Tot. Org. Nitrogen (mg/l)
ER-24	4/73	5.2	0.08	0.07	0.7	0.02	0.06
ER-20A	4/73	4.7	0.10	0.06	-	-	-
ER-20	4/73	4.1	0.68	0.0	-	-	-
ER-19	4/73	3.8	0.25	0.11	-	-	-
Ch 18	4/73	3.6	45.34	8.58	10.0	0.40	2.17
Ch 16	5/73	4.3	74.57	26.06	9.1	0.27	2.08
Ch 15	5/73	4.6	72.28	16.59	13.0	0.41	2.70
Ch 14	5/73	4.7	60.50	15.67	12.8	0.38	2.65
I10-LN	5/73	4.7	87.65	26.08	12.7	0.40	2.62
A 12	2/74	2.6	96.79	75.90	19.0	0.42	0.63
I-10	5/73	5.2	89.91	22.79	12.3	0.43	2.41
Ch 12	5/73	4.1	93.25	39.60	14.2	0.28	1.47
Ch 10	5/73	4.1	88.86	35.78	10.9	0.24	1.54
Ch 7	5/73	4.4	94.08	18.77	12.1	0.37	2.41
E11-C	2/74	-	96.69	72.65	25.31	0.47	0.98
B11	2/74	3.7	-	-	12.7	0.32	0.45

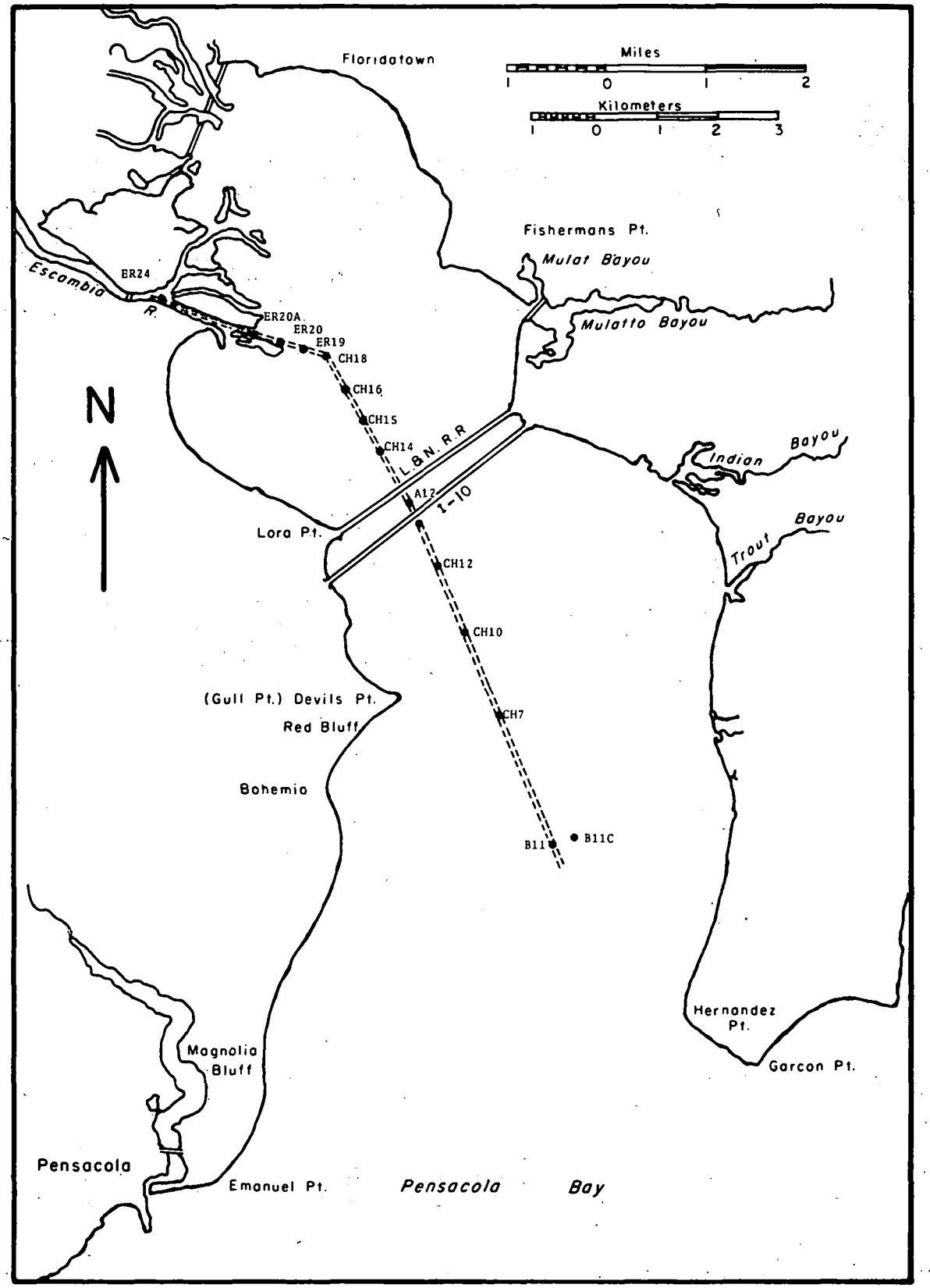


Figure 7-15. Ship channel sediment station locations in Escambia Bay.

volatile organics were nearly constant and averaged 11.9 percent. Station B-11C, 8.7 km (5.4 mi) down bay from the river mouth had 25.3 percent volatile organics, the highest value recorded in the channel.

Nutrient values in the river at Highway 90 were low; total phosphorus was 0.02 mg/g and organic nitrogen 0.06 mg/g. Total phosphorus averaged 0.37 mg/g in the bay channel. This compares closely with mud sediments elsewhere in the bay. Organic nitrogen at channel stations was considerably higher than in sediments outside the channel. Bay channel organic nitrogen averaged 2.1 mg/g in Spring 1973. Below is a comparison of the sediments at the southern end of the channel 8.7 km (5.4 mi) below the river. They were sampled concurrently inside and outside the channel.

	T-Phosphorus mg/g	Organic Nitrogen mg/g
In Channel	0.48	0.98
Outside Channel	0.32	0.45

The channel sediments between Interstate 10 and the L and N Railroad trestle contained the highest organic nitrogen values recorded in Escambia Bay. Data for this station is below:

Station	Date	Total Phosphorus mg/g	Organic Nitrogen mg/g	Volatile Organics (%)
A-12	5/4/73	0.40	2.6	12.7
A-12	5/3/74	0.43	4.5	8.5
A-12	6/5/74	0.24	2.1	7.0
A-12	8/5/74	0.42	5.1	8.4

Aroclor 1254, a PCB, was detected at a higher level in the channel than immediately outside. These data are presented on Figure 7-14. DDE, dieldrin, and other pesticides were not detected at stations sampled.

Heavy metals data on channel sediments are presented in Tables 7-4 through 7-15. Concentrations at a lower bay station both inside and outside the channel in February 1974 are given in Table 7-17.

The channel accumulated mud sediments containing high nutrients, volatile organics, PCB's, and heavy metals. These

Table 7 - 17. Heavy metal concentrations near and in the channel at two adjacent stations in Escambia Bay, 1974.

Station	Cu µg/l	Mn µg/l	Al µg/l	Fe µg/l	Ni µg/l	Cd µg/l
B - 11C (in channel)	16.0	540.	19000.	54000.	16.	1.
B - 11 (out of channel)	8.0	330.	15000.	44000.	12.	1.

Station	Co µg/l	Cr µg/l	Vi µg/l	Ti µg/l	Pb µg/l	Zn µg/l
B - 11c (in channel)	23.0	67.	110.	<80.	38.	85.
B - 11 (out of channel)	14.0	47.	99.	<80.	27.	62.

sediments may be periodically resuspended by high river flow and deep draft vessels. Redistribution of these sediments through dredging or other activity could jeopardize oyster beds or other organisms less tolerant than the mud plain community. Care must be exercised if these sediments are removed and deposited in the estuarine system.

SEDIMENT NUTRIENT RELEASE

Introduction

The objective of this experiment was to assess the contribution of Escambia Bay sediments to nutrient levels in the overlaying water. Release of nutrients from sediments is influenced by such factors as the metabolic activity of sediment bacteria (Lee, 1970; Martin, 1970), dissolved oxygen in the water above the sediment, and water currents which affect exchange processes by transporting leached material away from the release site and allowing concentration-dependent exchange reactions to proceed. Another important physical factor is resuspension of sediments, which exposes sub-bottom sediments to the water and increases release of nutrients (Lee, 1970). All of these factors are discussed further in this section.

To accomplish the objective of this experiment, the rates of sediment nutrient release were determined for several representative locations in Escambia Bay, and these rates were used to approximate the total nutrient release in the bay.

Methods

Sediment samples were taken with plexiglass corers at six stations in Escambia Bay (Figure 7-16). The square-shaped corers, with inner dimensions 23 cm by 23 cm, were designed to collect the samples in the field and to serve as reactors for the laboratory tests. The design of the corer is shown in Figure 7-17. The cores were taken by project SCUBA divers. The diver took the corer down to the desired location and submerged it into the sediment to a prespecified depth of 15 cm. A top and bottom were then placed on the corer to hold the sediment and water in place, and the apparatus was returned to the boat.

The corers, with sediment and bay water intact, were returned to the laboratory and placed in an incubator at 20°C. The bay water was removed and replaced with artificial sea water of the same salinity. The artificial sea water was kept circulating constantly by a pump to insure good mixing and to simulate natural currents over the sediments. Aerobic conditions were maintained in the water throughout the study.

The first three cores were collected on June 5, 1974, incubated for 45 days, and terminated on July 22, 1974. The second group of three cores was collected on July 25, 1974, incubated for 67 days, and terminated on October 2, 1974.

Samples of the water were taken periodically from the reactor chambers to be analyzed for five parameters: Total kjeldahl nitrogen (TKN), ammonia (NH_3), nitrate-nitrite (NO_3-NO_2), total phosphate (T-PO_4), total organic carbon (TOC). Dissolved oxygen was read by inserting a D.O. probe in the D.O. bottle (Figure 7-17). The concentrations in mg/l were obtained for each nutrient for each day analyzed, and were converted to total mg in the chambers (Appendix 7-5). The total mg was plotted against day number for total nitrogen (Figure 7-18). Also, for total nitrogen, a rate of release was calculated in terms of mg/m^2/day by using the maximum amount of release, the number of days it took to achieve the maximum, and the surface area of sediment in the chamber (Table 7-18).

Total nitrogen is defined as (TKN+NO_3+NO_2).

The TOC data were extremely erratic and were not considered in evaluating the results of this experiment.

Results and Discussion

Phosphorus release from sediments in this study was negligible. The maximum total release was about one mg (Table 7-18). Various investigators have shown that phosphorus is released very slowly if at all under aerobic conditions (Mortimer, 1941; Lee, 1970). Aerobic conditions were maintained at all times so the negligible release of phosphorus was to be expected. Values of dissolved oxygen are listed in Appendix 7-5.

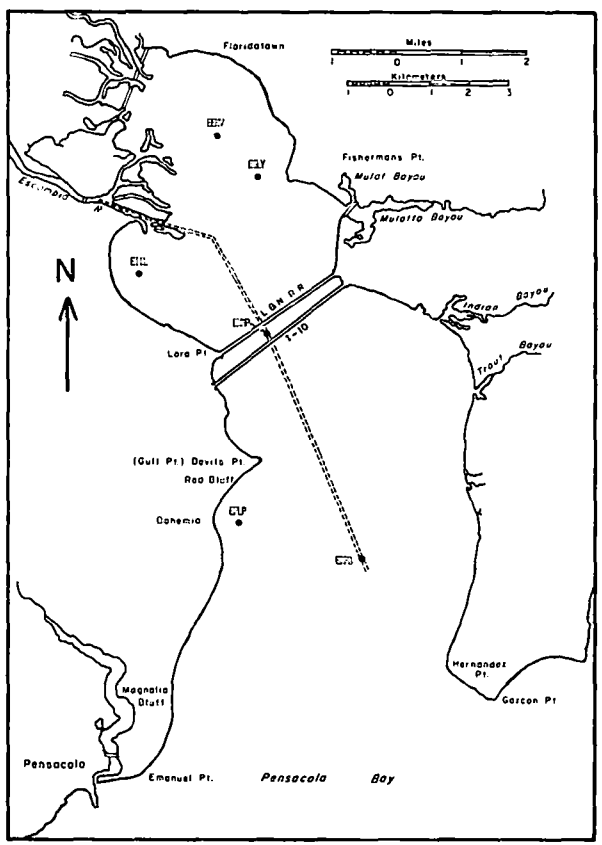


Figure 7-16. Nutrient release study station locations in Escambia Bay.

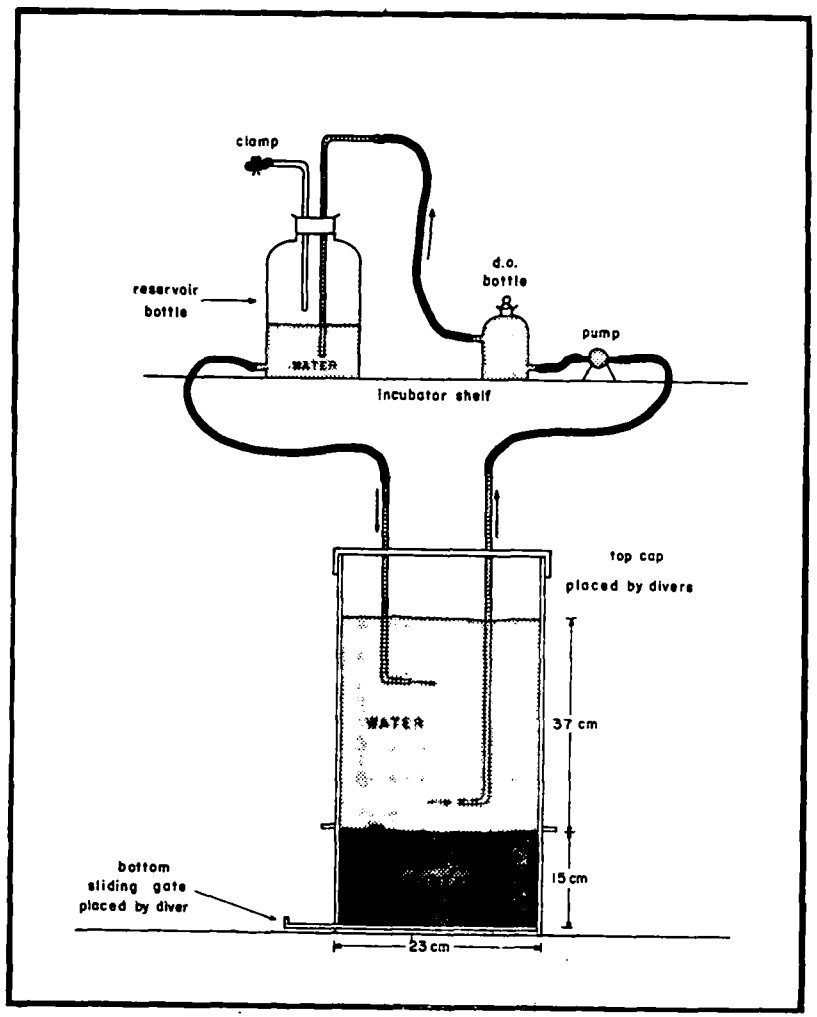


Figure 7-17. Sediment nutrient release study apparatus.

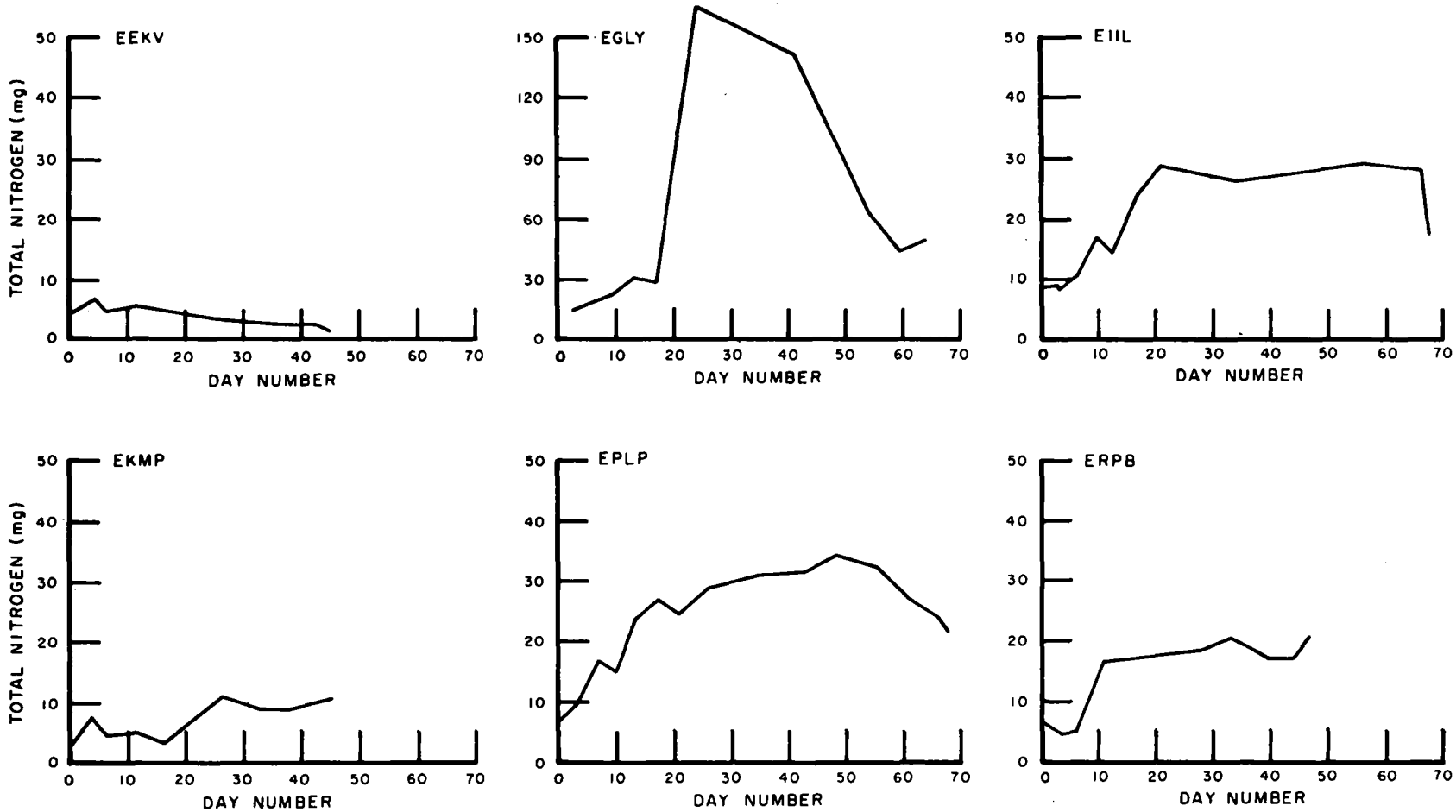


Figure 7-18. Plots of total milligrams of total nitrogen against day number for each station (total nitrogen = TKN + NO_3NO_2)

Table 7 - 18. Maximum amount (mg) and rates of release (mg/m^2/day) found in the nutrient release study.

Station	Total Phosphorus		Nitrate-Nitrite		TKN		Total Nitrogen	
	Released	Rate	Released	Rate	Released	Rate	Released	Rate
EEKV	0.43	0.195	1.47	0.11	0.80	0.26	2.27	0.37
EGLY	0.57	0.330	0.	0.	159.24	126.60	159.24	126.60
EIIL	0.74	0.235	13.07	3.84	17.24	8.02	30.31	11.86
EKMP	0.27	0.136	1.70	0.72	7.35	5.39	9.05	6.11
EPLP	1.08	0.624	10.61	10.66	25.52	10.58	36.13	21.25
ERPB	0.22	0.110	10.64	6.55	10.58	6.30	21.22	12.86
average	0.55	0.272	6.25	3.65	12.30	6.11	19.80	10.49

Since nitrogen forms are interchangeable with one another in an aquatic environment, it was not possible to assess the release of each individual form. Only total nitrogen is discussed in this section.

In order to assess the contribution of sediment nitrogen release in Escambia Bay, total release in the bay was calculated. The total release was calculated in two ways: First, the average rate (in $kg/m^2/day$) of release of total nitrogen was multiplied by the number of m^2 on the bay bottom to obtain a total release in the bay. Second, the amounts of release by type of sediment were obtained and these amounts were summed up to get a total release in the bay. The first of these calculations is shown below:

Total Area of Bay Bottom (m^2)	Avg. Rate of Release ($kg/m^2/day$)	Total Release kg/day (Area x Rate)
9256.2×10^4	10.5×10^{-6}	972

In order to calculate release of nitrogen from each sediment type, the following breakdown of Escambia Bay sediments was made:

Station	Sediment Type
EEKV	B = Silty-Sand
EGLY	A = Sand
EIIL	C = Sand-Silt-Clay
EKMP	D = Sandy-Silt
EPLP	C = Sand-Silt-Clay
ERBP	B = Silty-Sand
----	E = Silt
----	F = Clayey Silt

These sediment types were taken from the Escambia Bay sediment classifications as described in the Sedimentation Section of this report. A complication in this calculation was that none of the samples was collected in type E or F. However, since types D, E, and F are predominantly silt, these three were lumped together as an approximation. Station EKMP was taken to be representative of all three.

Data from Station EGLY were not used in the above calculation. This station was located near industrial outfalls, and the nitrogen release was so great that it was not representative of other sediments of the same type.

The results of the calculation are listed below:

Station and Type	Area in Bay (m^2)	Avg. Rate of Release $kg/m^2/day$	Total Release kg/day (Area X Rate)
EEKV-ERPB (A-B)	4679×10^4	6.6×10^{-6}	309
EIIL-EPLP (C)	2238×10^4	16.6×10^{-6}	372
EKMP (D-E-F)	2339×10^4	6.1×10^{-6}	143
		Total =	824

The two totals of 972 and 824 kg/day compare favorably with each other considering the limitations of the techniques used to obtain these figures. These values compare with 2622 kg/day that the industries are permitted to discharge into Escambia River and upper Escambia Bay. (The nitrogen release calculated here occurred under aerobic conditions. Anaerobic conditions would cause a much greater release.)

Type C (sand-silt-clay) released the most nitrogen. This was especially obvious since it had the least area. Types A-B (sand) and D-E-F (silt) released about the same amount per unit area. The only obvious explanation for the larger release from type C is that station EPLP was causing a disporportionate effect. Station EPLP was close to the Northeast Sewage Treatment Plant outfall, which could have been affecting the sediment in the same way as Station EGLY was affected by the industries. It appears that nitrogen release was not correlated in any way with sediment type, and some other factor was the primary influence.

A comparison of nitrogen release data with sediment microbial activity data was made to see if any useful correlation existed (Table 7-19). Nothing in this comparison indicated any correlation at all.

A comparison of the concentration of nitrogen in the sediment with rates and total amounts of nitrogen released showed that nitrogen release increased as nitrogen content of the sediment increased (Figure 7-19 and Table 7-20). Data from Station EGLY was not plotted because it was so abnormally high, as explained earlier in this section. The influence of waste outfalls on sediment nitrogen concentrations and on nitrogen release was seen at Stations EGLY and EPLP in Table 7-20. Station EGLY was near the industry outfalls and EPLP was near the Northeast Sewage Treatment Plant outfall.

In summary, considerable amounts of nitrogen and very little phosphorus were released from Escambia Bay sediments under the conditions of this study. Two factors were observed to increase potential for sediment nitrogen release. These were high concentration of nitrogen in the sediment, and location in the close vicinity of waste outfalls which discharge large amounts of nitrogen.

Table 7 - 19. Comparison of sediment nitrogen release data with microbial activity data.

Station	Total Nitrogen		Microbial Activity (*)
	amount Released (mg)**	Rate of Release ($mg/m^2/day$)	
EEKV	2.3	0.4	264.3
EIIL	30.3	11.9	455.6
EGLY	159.2	126.6	238.4
EKMP	9.1	6.1	1147.0
ERPB	21.2	12.9	0.0
EPLP	36.1	21.2	230.5

* (µg - TPF reduced per gram of sediment)
** Total Nitrogen = TKN + NO3-NO2.

Table 7 - 20. Comparison of percent organic and nitrogen content of sediment with rates of release of total nitrogen*.

Station	Percent Organic (%)	Rate of Release ($mg/m^2/day$)	Total Release (mg)	Concentration of TKN in sediment (µg/g)
EEKV	0.34	0.37	2.27	82
EIIL	3.49	11.86	30.31	5450
EGLY	5.83	126.60	159.24	6450
EKMP	7.42	6.11	9.05	3350
ERPB	6.29	12.86	21.22	2250
EPLP	7.49	21.25	36.13	6800

* Total Nitrogen = TKN + NO3-NO2

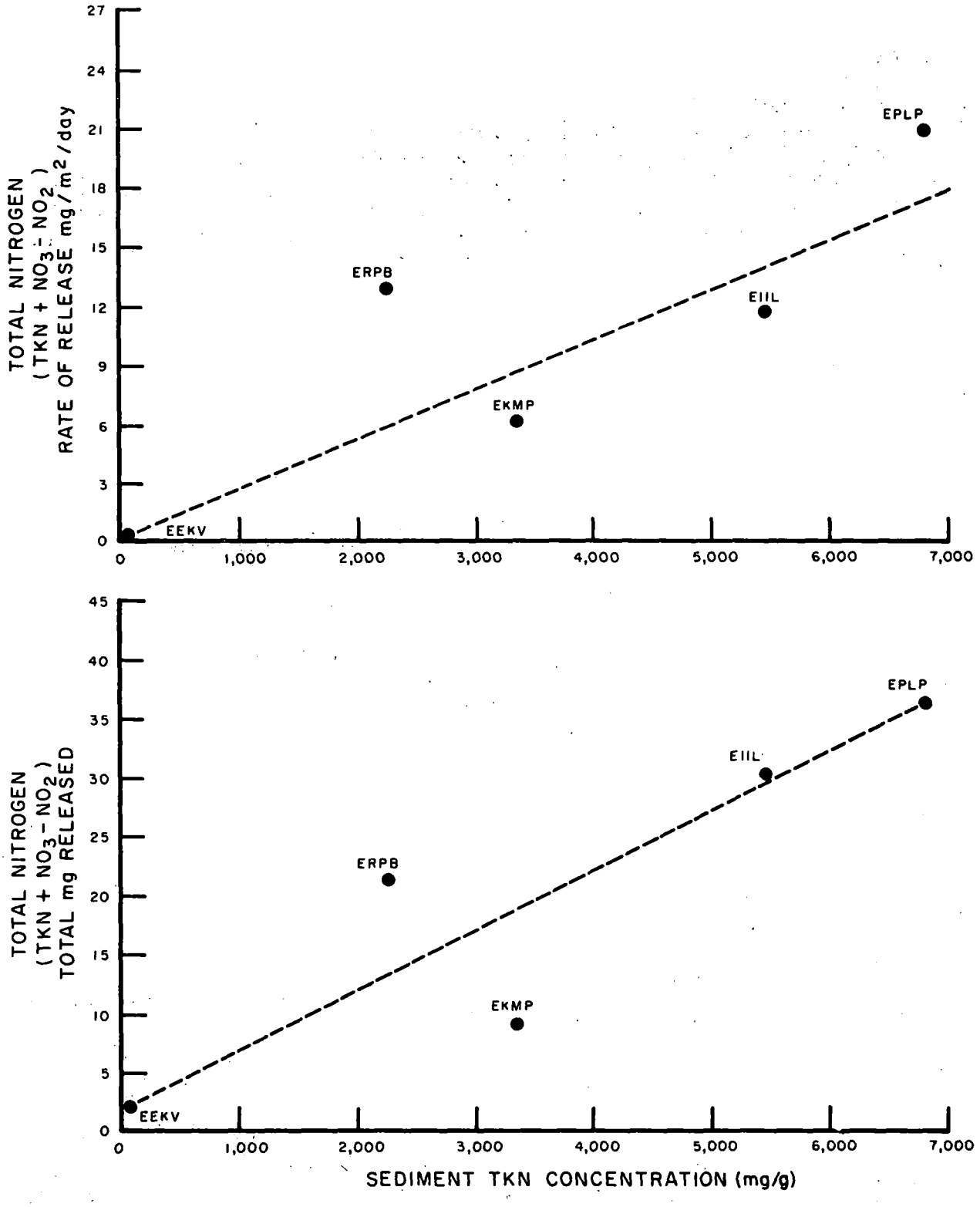


Figure 7-19. Plots of rates of release and total milligrams released of total nitrogen against sediment TKN concentrations.

It should be pointed out that resuspension of sediments could increase the amount of nutrient release. There was little or no suspension of sediments in the water during this study. The sediments remained undisturbed throughout. Suspension of sediments undoubtedly causes greater nutrient release than was measured in this study. It is important to note also that even though aerobic conditions were maintained in the chambers, there are times when bottom water in Escambia Bay becomes anaerobic. This would cause much greater release of both nitrogen and phosphorus than was measured in this study. The reasons for greater anaerobic release are discussed by Lee (1970).

MICROBIAL ACTIVITY

Introduction

The sediments in a bay can be considered a reservoir of nutrients which are constantly being released or cycled to the overlaying water column as one of the sources of nutrients contributing to the enrichment of a bay ecosystem. Micro-organisms at the base of the food chain are responsible for initiating the conversion of sediment to biomass and thus into a form that can be utilized by higher organisms.

Any method of measuring microbial activity in sediments has certain limitations. In-situ techniques have not been well perfected and are frequently plagued with technical difficulties. Often the change being measured in a given parameter is so slight that the accuracy of field instrumentation is questionable. Other problems with maintaining accuracy of instrumentation in field measurements are humidity and temperature changes throughout the day. Natural conditions are altered when sediment samples are collected and brought into the laboratory. Experimental conditions in the laboratory will very likely have an influence on the results. Data obtained from laboratory controlled experiments may be difficult to relate to field situations.

Considering all of the above factors and the expense of equipment for measuring radioactive compounds used in other possible techniques, the dehydrogenase procedure was chosen as most feasible for this project.

The objectives of this study were: (1) to measure the microbial activity of sediments as a comparative parameter for the various sediments of the bay system; and (2) to provide some information on the microbiological turnover of nutrients or the mineralization of sediments in the bay.

Methods

Sample Collection

Sediment samples were collected for this study at the tri-weekly water quality stations (Figure 7-20). Most of the samples were collected with a corer constructed of Lexan tubing attached to a tubular metal corer handle. The Lexan coring tube was 7.0 cm x 117.6 cm.

The corer was lowered over the side of the boat allowing it to fill with water, raised to a vertical position, and then lowered to the sediment surface. Downward pressure was applied to force the corer into the sediment approximately 0.6 m (2.0 ft). Average core length ranged between 0.5 m - 0.76 m (20-30 in). The filled corer was gently raised into the boat and held in a verticle position until the handle was removed. A plunger was used to push the core through the coring tube until the top surface of the core came to 1.5 cm (0.59 in), from the end of the coring tube. With the core held in this position, a combination Eh and pH probe was inserted into the surface of the sediment core. After the Eh and pH measurements were completed, the corer was inverted into a one quart plastic freezer container. Fifteen cm (5.9 in) of the sediment core was extruded from the surface end of the corer into the plastic container.

Sediments which were mostly sand could not be retained in the corer. These stations were sampled with a Peterson Dredge. The contents of the dredge were gently placed in a tub with the sediment surface disturbed as little as possible. The Eh and pH readings were taken as described in the following paragraph, and a sample of approximately equal diameter and depth to the core sample was scooped into the plastic container using a spatula. The containers of sediment were placed in an insulated ice chest as near to ambient water temperature as could be maintained until returned to the laboratory for analysis.

Field Measurements

Field determinations of Eh and pH were made with a Corning Model 610A pH-Mv Meter. The Eh measurements were taken with a Beckman platinum electrode in combination with a Fisher Calomel electrode. A Fisher brand glass electrode in combination with the same Fisher Calomel electrode used in Eh measurements was employed to determine the pH on each sediment sample.

The pH meter was calibrated to pH 4.0 and pH 7.0 standard buffer. After a pH reading was taken, the meter was then reset for Eh at a calibration mark previously determined in Zobell's redox buffer (Zobell, 1946). The electrodes were placed in the sediment and allowed to equilibrate for ten minutes. An Eh reading was then recorded.

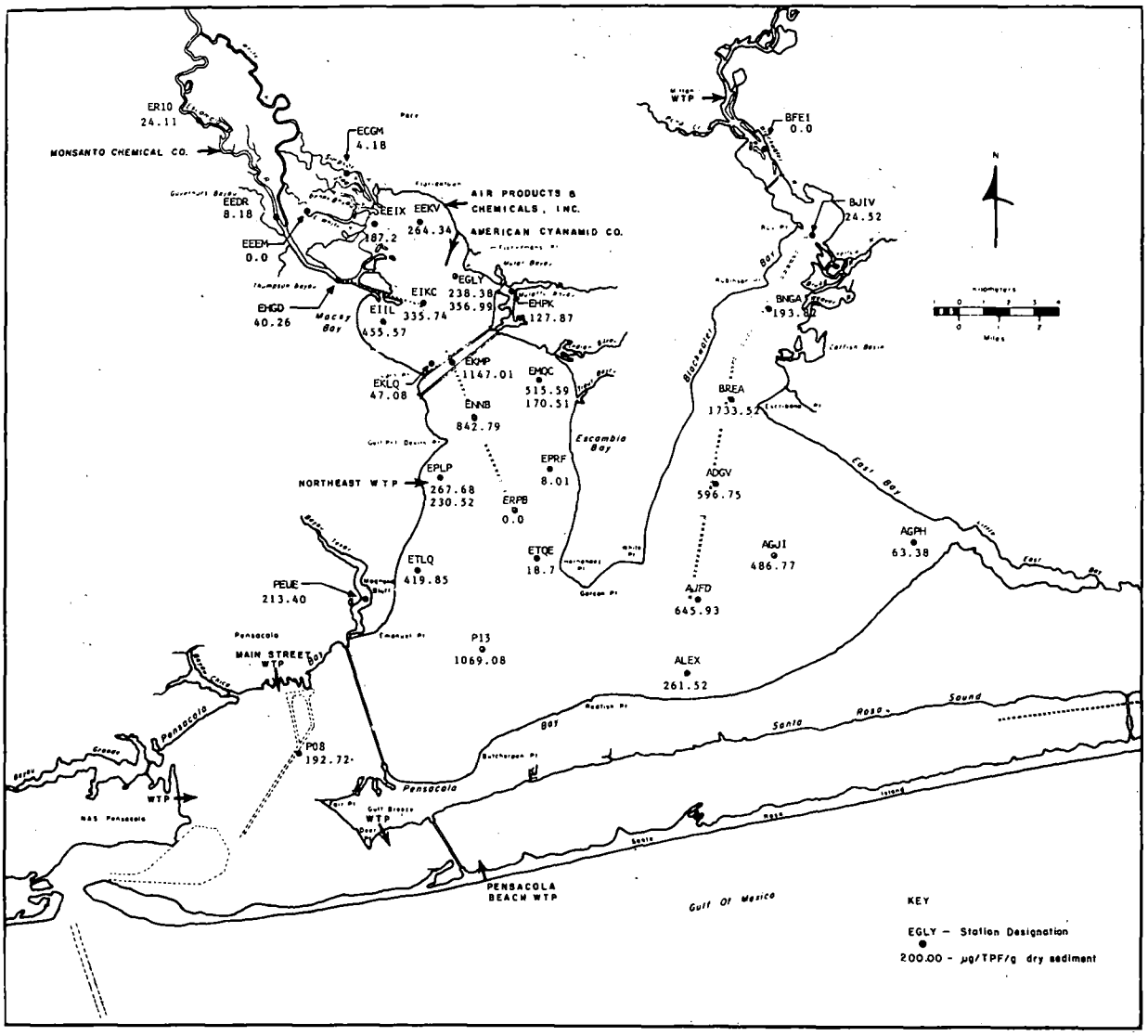


Figure 7-20. Microbial activity (by TPF reduced per gram of dry sediment) in the Pensacola Bay system during 1974.

Water depth, salinity, temperature, and transparency were measured and recorded at each station. A bottom water sample, 0.3 m (1.0 ft) above the sediment, was collected for dissolved oxygen determination on return to the laboratory.

Laboratory Analyses

To determine percent organic matter in the sediment, approximately 100 g wet weight of the mixed sample was placed in a tared crucible and oven dried at 105°C for 24 hours. The dried sample was cooled in a dessicator, weighed, and then ashed in a 550°C muffle furnace for 24 hours. This ashed sample was then removed, cooled, and saturated with distilled water. The re-wet sample was placed back in a 105°C oven. After 24 hours in the oven, the sample was cooled in a dessicator and weighed to determine the re-wet ash weight. A percent organic content was calculated from the dry weight and re-wet ash weight.

Chemical oxygen demand of the sediment was determined according to the procedures outlined in Standard Methods, (American Public Health Association, 1971). Total phosphorus and total Kjeldahl nitrogen were analyzed by the standard automated EPA procedure (USEPA, 1971).

Dehydrogenase Procedure

Microbial activity was determined by measuring the dehydrogenase activity of the sediment population according to the method of Cook, (personal communication from D. W. Cook, Microbiology Section, Gulf Coast Research Laboratory, Ocean Springs, Mississippi). This procedure is similar to one used by Lenhard, et al. (1965); Bucksteeg (1966); and Pamatmat and Bhagwat (1973), which employs the reduction of triphenyl tetrazolium chloride (TTC), a colorless dye in its oxidized state. Triphenyl formazan (TPF), the reduced form of the dye, is red. In solution the concentration of TPF can be determined spectrophotometrically. The TTC was incorporated into the assay procedure as a substitute hydrogen acceptor (or electron acceptor) to replace oxygen in aerobic systems and organic compounds which would become more reduced in anaerobic systems. This required an oxygen free atmosphere, which was accomplished by incubating the reaction mixture in an evacuated dessicator throughout the 24 hour incubation period.

On their return to the laboratory, each sample was thoroughly mixed with a teflon coated spatula. A one-gram quantity of the stirred sediment sample was weighed into each of five tared 50 ml tapered centrifuge tubes on a top loading balance. Dehydrogenase assays were performed in triplicate on each sediment sample. A fourth tube was used as a reagent blank with TTC withheld. The fifth tube was autoclaved and used as a sterile blank to determine any non-microbial reduction of TTC.

Reagents used for the assay were: (1) 0.05 M Tris buffer (pH 8.4), 0.5 ml; (2) 1.0% TTC, 0.5 ml; (3) 50 µg $CaCo_3$; and 1.0 g of mixed wet sediment. The TTC was added to the sterilized blank after it was removed from the autoclave and allowed to cool. An additional 0.5 ml of Tris buffer was substituted for the 1.0% TTC solution in the TTC blank. The reagents were thoroughly mixed on a Vortex Jr. Mixer, and placed in a dessicator. The dessicator was then evacuated and the tubes incubated at 25°C for 24 hours.

The dehydrogenase reduction of TTC was terminated by addition of 10 ml of methanol to each tube. The methanol also served as a solvent for the reduced TPF. The sediment and methanol were thoroughly mixed and then centrifuged for 5 minutes to separate the sediment from the TPF-methanol solution. The procedure was repeated three additional times and the final volume of TPF-methanol brought to 50 ml with methanol. The concentrations of TPF were determined spectrophotometrically at 485 nm by comparing the absorbance of the extracted TPF to a standard curve derived from known concentrations of TPF. Microbial activity of the sediment as measured by the dehydrogenase assay procedure was expressed as µg TPF/g dry sediment.

Results

In general, all the tributary stations (ER10, EEDR, EHBD, EEEM, EQGM, BFEI, and BJIV), were low in microbial activity (Table 7-21). These stations were also high in sand content and were low in percent organic matter. Two Escambia Bay stations, ETQE and EPRF, located in the proximity of the eastern shore, also had very low microbial activity. The sediment from these stations, like the sediment from the tributary stations, was high in sand content and low in organic matter. One major exception to this was Station ERPB which had zero microbial activity yet it ranked third of all stations in organic matter content. The zero reading for Station ERPB was due to the extremely high activity of the sterile blank which canceled out the activity observed in the triplicate reaction tubes. One possible explanation for the high activity observed in the sterile blank for sample ERPB would be chemical reduction due to large concentrations of reduced compounds in the sediment as shown by "Effenberger (1966, cited by Pamatmat and Bhagwat, 1973)". Pamatmat and Bhagwat (1973), however, did not observe this in their work. The +300 mv Eh of sample ERPB was no indication of a highly reduced sediment and would reinforce their observations.

Examination of the data showed stations higher in organic matter content and chemical oxygen demand generally had higher microbial activity. By statistical analysis, a significant correlation was shown for chemical oxygen demand and sediment microbial activity ($r = 0.7$, $df = 38$, $p < 0.01$). Percent organic matter and sediment microbial activity showed less correlation than chemical oxygen demand but still a significant correlation ($r = 0.42$, $df = 38$, $p < 0.01$). Other parameters tested which had significant correlations with sediment microbial activity were

Table 7 - 21. Summary of sediment microbial activity.

Date	Station	Depth (m)	Trans. (m)	Bottom Salinity (ppt)	Sed. Temp. (°C)	Bottom D.O. (mg/l)	Sed. pH (std un)	Sed. Eh	T-PO4 (µg/g)	TKN-N (µg/g)	COD (µg/g)	Percent Organics (%)	(TPP) Microbial Activity (µg/g)	(TPP) Sterile Blank (µg/g)
07/18/74	ER-10	1.8	0.8	0.0	27.0	6.2	6.7	+300.	13.0	26.	208.	0.54	24.11	0.00
07/18/74	EEDR	4.0	0.8	5.7	29.0	4.6	7.4	+140.	24.0	34.	3120.	0.61	8.18	34.03
07/18/74	EHGD	5.8	0.9	14.5	30.5	8.2	8.4	+14.	46.0	118.	5200.	0.67	40.26	26.08
07/15/74	EEIX	1.2	0.6	14.3	32.0	7.1	7.2	+70.	96.0	385.	24800.	1.61	187.24	89.69
07/15/74	EEEM	2.3	0.6	10.0	30.0	5.1	7.2	+90.	14.0	10.	624.	0.22	0.00	55.07
07/15/74	EQGM	3.4	0.8	15.5	30.0	2.4	7.2	-40.	70.4	182.	3328.	0.63	4.18	
07/22/74	EEKV	1.5	0.5	15.1	31.0	6.4	7.9	+95.	66.5	240.	16640.	1.32	264.34	25.28
07/22/74	EGLY	2.4	0.8	19.2	32.0	6.4	8.4	-80.	205.0	1100.	63440.	5.48	238.38	52.04
07/25/74	EGLY	2.4	0.8	19.2	30.0	6.4	8.4	-80.	300.0	1550.	92560.	4.66	356.99	49.33
07/22/74	EIKC	1.8	0.8	17.7	31.0	7.4	6.5	+130.	220.0	950.	93600.	6.63	335.74	276.38
08/05/74	EIIL	2.0		16.9	27.0	5.1	4.5	-130.	131.0	5300.	53590.	2.93	455.57	82.69
08/05/74	EKLQ	2.1		17.1	28.0	2.4	3.6	-5.	36.8	1980.	8700.	1.69	47.08	31.64
08/05/74	EKMP	2.6		18.4	29.0	6.9	5.1	-5.	420.0	5400.	118270.	8.38	1147.01	32.50
08/05/74	EHPK	1.5		13.4	29.0	5.6	6.1	+20.	146.0	6200.	78540.	5.26	127.87	42.29
08/08/74	EMQC	2.4	1.4	18.4	29.0	2.0			370.0	5950.	84080.	13.87	515.59	0.00
08/12/74	EMQC	2.6	0.9	23.2	31.0	2.2	7.1	-200.	310.0	6000.	90550.	6.35	170.51	96.13
08/12/74	ENNB	2.6	1.2	24.9	31.0	7.3	3.8	-150.	510.0	7200.	109960.	25.22	842.79	201.92
08/12/74	EPLP	2.3		17.9	31.0	6.5	6.5	-145.	190.0	2600.	87640.	11.27	230.52	199.77
07/25/74	EPLP	2.1	0.8	25.5	30.0	10.0	7.5	+280.	295.0	2100.	62400.	27.84	267.68	113.03
08/15/74	ETQE	2.4	1.2	28.2	29.0	4.6	8.9	+170.	18.0	1860.	4810.	3.60	18.70	18.57
08/15/74	EPRP	2.7	1.4	26.1	29.0	6.6	8.0	+190.	290.0	4900.	20330.	1.32	8.01	78.04
08/15/74	EBPB	3.7	1.4	29.2	29.0	2.3	7.8	+300.	380.0	5800.	86860.	21.38	0.00	611.16
08/15/74	ETLQ	4.6	1.4	30.2	29.0	1.3	7.9	+275.	530.0	6300.	96100.	13.01	419.85	489.73
10/09/74	PEUE	2.4	0.5	22.5	25.0	8.2	7.3	-60.	240.0	6000.	116420.	9.56	213.40	322.81
09/30/74	BPEI	3.5		20.0	26.0	0.6		+160.	22.4	1960.	7590.	0.58	0.00	15.00
09/30/74	BJIV	2.1	1.4	24.2	26.0	7.0		-160.	18.4	1940.	13320.	1.09	24.52	24.89
09/30/74	BNGA	3.0	1.5	25.3	26.0	2.4		-160.	39.0	4900.	23100.	2.15	193.82	119.02
10/02/74	BREA	3.0	1.5	19.7	24.0	7.6	8.0	-270.	350.0	7550.	145990.	10.49	1733.52	339.83
10/02/74	ADGV	2.7	1.4	19.8	25.0	6.5	6.3	-120.	250.0	5950.	111800.	7.56	596.75	431.97
10/02/74	AGPH	1.8	1.5	19.7	24.0	7.4	6.4	-180.	32.0	4700.	16630.	1.02	63.38	66.60
10/07/74	AGJI	3.4	2.4	28.4	25.5	6.4	7.4	+40.	230.0	6400.	110880.	13.66	486.77	174.46
10/07/74	AJFD	3.4	2.4	25.7	26.0	8.8	7.0	+30.	178.0	5400.	68380.	6.07	645.93	82.46
10/07/74	ALEX	4.3	2.1	28.5	25.0	7.3	7.4	-140.	540.0	6150.	110880.	11.78	261.52	295.86
10/09/74	P-08	10.4	2.1	31.6	25.0	7.2	6.4	-80.	310.0	6300.	112730.	9.31	192.72	771.96
10/09/74	P-13	5.5	1.8	30.1	25.0	6.4	7.2	+10.	350.0	7850.	109030.	16.60	1069.08	360.44

total phosphorus ($r = 0.56$, $df = 38$, $p < 0.01$), and total Kjeldahl nitrogen ($r = 0.54$, $df = 38$, $p < 0.01$).

Two stations in Escambia Bay were subject to the influence of industrial or domestic effluent entering the bay. One of these stations was EGLY near the American Cyanamid outfall. Effluent from Air Products holding ponds also flows through a swamp into the bay within 2.2 km (1.2 nautical miles) of Station EGLY. Microbial activity at Station EGLY was observed to be 356.99 µg TPF/g of dry sediment. This value is very close to the average of 332.91 µg TPF/g of dry sediment found from all stations in Escambia Bay, Blackwater Bay, East Bay, and Pensacola Bay. The other station, EPLP, was located in the vicinity of the outfall where effluent from the Northeast Sewage Treatment Plant empties into the bay. The microbial activity observed at Station EPLP was 267.68 µg TPF/g of dry sediment which was less than the average found for all stations, but greater than the average of 239.71 µg TPF/g dry sediment for Escambia Bay stations.

Discussion

Microbial activity as determined in this study by production of triphenylformazan (reduced TTC), varied considerably from station to station throughout the bay. Statistical analysis did show a significant correlation between microbial activity to chemical oxygen demand and some correlation to percent organic matter. This was not always the case, however, as some of the stations low in organic matter or chemical oxygen demand gave average or above average values for measured dehydrogenase activity. In general, the stations low in activity were low in organic matter and high in sand content.

Pamatmat and Bhagwat (1973) stated that the presence of toxic substances may be suspected in subsurface sediments which are high in organic matter, but low in dehydrogenase activity. Station ERPB in this study had high organic matter content and zero activity. As pointed out in the previous section, this was caused by a high reading in the sterile blank which canceled out the observed activity. Stations EKMP and ENNB had similar physical characteristics to Station ERPB. They were located at the channel, had similar depths, and had high organic matter content. Stations EKMP and ENNB had sediment microbial activities of 1147.01 and 942.79 µg TPF/g of dry sediment, respectively. Examination of the heavy metal and PCB content of the sediment from these stations revealed that Station ERPB is lower in heavy metal content than EKMP and ENNB for all metals but two. Cadmium, titanium, and PCB content were about equal for all three stations. Station ENNB was slightly lower in each case. The low activities at Station ERPB did not seem to be a result of toxic substances in the sediment.

Stations EGLY and EPLP, which were adjacent to industrial and domestic waste outfalls, respectively, did not reveal a sediment high in microbial activity stimulated by enrichment from the

outfalls nor did they reveal inhibited microbial activity due to presence of toxic substances in the sediment.

Examination of the data showed, in most instances, increased microbial activity at all stations which had an organic matter content of one percent or greater. Any increase in organic matter content of the sediment over one percent was not necessarily accompanied by a corresponding increase in microbial activity. This indicated that a one percent organic matter content will support a maximum microbial population to a steady state of growth. Any fluctuations in microbial activity are organismic responses subject to numerous stimuli. Variations in microbial activity can be attributed to: (1) variations in microbial species or metabolic types of organisms; (2) differences in the growth phase of a major portion of the population; (3) differences in the type of organic matter, and thus its recalcitrance to microbial conversion; (4) availability of other nutrients; and (5) conditions favorable for growth.

Nutrient cycling and mineralization could not be specifically determined. By inference, the measured microbial activity can be related to nutrient cycling and mineralization. The greater the sediment microbial activity, the greater the quantity of material converted to energy, biomass, and released metabolic products. A major portion of the nutrients converted to biomass would return to the sediments after the death of the organisms.

Microbial activity of sediment in Escambia Bay did not markedly differ from that observed in Blackwater Bay or East Bay. Escambia Bay sediments appeared to be normal, based on microbial activity, since East Bay and Blackwater Bay were used as controls.

8 - WATER QUALITY

INTRODUCTION

The Pensacola Bay system is an extremely valuable resource to the residents of the area, the state, and the nation. Its principal values are derived from recreation and commercial fisheries. The continued value of this resource depends on maintaining a healthy aquatic ecosystem which is dependent on the quality of the waters of the system. Consequently, it is imperative to determine the quality of the water in the bay to properly evaluate the system.

The water quality of the Pensacola Bay system, with emphasis on Escambia Bay, was monitored to determine seasonal, tidal, and spatial variations. The purposes of the water quality studies were to:

- describe water quality conditions in Escambia Bay and the Pensacola Bay system and to compare them to other Gulf of Mexico estuaries.
- determine if changes in water quality have occurred between 1969 and the present.
- determine what the effects of wastes discharged into the bays have on the system.

Interpretation of water quality data will provide information for the development of water resource recommendations.

METHODS

Water Quality Studies

Water quality studies were initiated in the Pensacola Bay system between April 1973 and September 1974. In April and August 1973, diel (24-hour) water quality studies were performed in the Pensacola Bay system when periods of high and low river discharge, repsectively, normally occur. During each period, separate studies were performed during equatorial and tropic tidal conditions. Water quality studies were also performed in Escambia Bay on October 4, and December 5, 1973. The University of West Florida (UWF) conducted water quality studies every two weeks in Escambia and East Bays during 1973. The EBRS and the UWF performed water quality studies in the Pensacola Bay system every three weeks from January to September 1974. The sampling dates and times are depicted along with tide level on Appendix 8-1. The locations, STORET station numbers, and parameters sampled for all sampling stations are presented in Appendix 8-2.

In this report, samples referred to as surface were collected 0.3 m (1.0 ft) below the surface, and those referred to as bottom

were collected 0.3 m (1.0 ft) above the bottom. The mean sampling depths for all stations occupied during EBRS are presented in Appendix 8-3 for diel studies performed in 1973, and in Appendix 8-4 for January through September 1974 studies.

Analytical Methods

The analytical, sample collection, and preservation methods used during this study are presented in Appendix 8-5.

ENVIRONMENTAL CONDITIONS

Environmental conditions, such as river discharge, tides, wind, and precipitation, must be known when evaluating water quality because they are the cause of significant variation. A summary of environmental conditions is presented in Table 8-1 for the water quality studies performed by the Escambia Bay Recovery Study. Tide stage and wind vectors for each study are presented in Appendix 8-1.

WATER QUALITY STANDARDS

Florida has enacted Water Quality Standards to protect the surface waters of the state. The Pensacola Bay system has been designated as either Class II or Class III waters. The criteria for Class II waters are designed to permit harvesting of shellfish safe for human consumption. The criteria for Class III waters are to provide satisfactory water quality for propagation and maintenance of fish and wildlife populations, and for recreational activities, including water contact sports. Class III waters include upper Escambia Bay and tributaries above the L and N Railroad bridge, Pensacola Bay west of a line from Emanuel Point to the south end of Highway 98 bridge at Gulf Breeze, and Blackwater Bay inclusive of the river north of a line from Robinson Point on the west to the mouth of Broad River on the east. All the remaining areas of Escambia Bay, Pensacola Bay, East Bay, Little East Bay, and Blackwater Bay are Class II waters (Figure 8-1). The criteria for the Florida Water Quality Standards are discussed in Florida Administrative Code (1973). Appropriate sections from Chapter 17-3, Pollution of Waters are presented in Appendix 8-6.

There are no compulsory Federal water quality standards for specific states or bodies of water. However, the State of Florida Water Quality Standards are subject to review and approval by the United States Environmental Protection Agency pursuant to Section 303 of the Federal Water Pollution Control Act Amendments of 1972.

The National Technical Advisory Committee, a joint committee consisting of members from the National Academy of Science and the National Academy of Engineering, compiled a report, recommending water quality standards, at the request of the Secretary of Interior. Their report, published as Water Quality

Table 8 - 1. Environmental conditions during water quality studies.

Study Date	Study	Estimated total flow				Tide			Wind		Precipitation
		Escambia River m^3/sec (cfs)	Yellow River m^3/sec (cfs)	Blackwater River m^3/sec (cfs)	Total m^3/sec (cfs)	Range m (f)	Mean Level m (f)	Current m (f)	Mean Speed km/hr (mph)	Prevailing Direction	cm (in)
9/23-25/69		132 (4657)	- -	- -	- -	0.7 (2.3)			8.1 (5.0)	N-NE	0.
4/13-15/73	I	1398 (49,400)	211 (7470)	88 (3092)	1697 (59,920)	0.1 (0.4)	0.0 (0.0)	-	15.5 (9.5)	Variable	0. (0.)
4/19-21/73	II	600 (21180)	108 (3818)	49 (1718)	757 (26730)	0.6 (2.1)	0.3 (0.9)	- -	21.9 (13.6)	SE	0 (0)
8/16-18/73	III	173 (6119)	72 (2546)	41 (1443)	286 (10100)	0.2 (0.5)	-0.1 (-0.2)	- -	4.8 (3.0)	E	2.97 (1.17)
8/23-25/73	IV	122 (4295)	53 (1888)	33 (1158)	208 (7340)	0.6 (2.0)	0.0 (-0.1)	- -	9.3 (5.8)	NE-NW	0 (0)
10/4/73		109 (3840)	- -	- -	- -	0.4 (1.4)	0.0 (0.0)	E	9.5 (5.9)	N	
12/5/73		88 (3120)	- -	- -	- -	0.2 (0.7)	0.1 (0.3)	F	13.8 (8.5)	NE	0.41 (0.16)
1/23/74		333 (11760)	81 (2860)	41 (1443)	455 (16070)	0.5 (1.6)	-0.2 (-0.8)	LWS	10.9 (6.8)	SW	0 (0)
2/12/74		737 (26040)	205 (7243)	128 (4534)	1070 (37780)	0.5 (1.5)	-0.2 (-0.6)	F	9.7 (6.0)	SE	0 (0)
3/5/74		226 (7974)	73 (2590)	39 (1374)	338 (11940)	0.6 (1.8)	-0.1 (-0.2)	F	16.7 (10.4)	S	0.03 (0.01)
3/27/74		203 (7180)	90 (3161)	53 (1855)	346 (12220)	0.6 (2.0)	-0.1 (-0.4)	F	14.3 (8.9)	E	3.78 (1.49)
4/16/74		506 (17865)	120 (4247)	70 (2479)	696 (24580)	0.3 (1.0)	-0.1 (-0.3)	F	8.5 (5.3)	N	0 (0)
5/7/74		85 (3012)	42 (1483)	27 (953)	183 (6460)	0.6 (1.8)	0. (0.)	HWS	10.1 (6.3)	NE	0 (0)
5/29/74		178 (6294)	48 (1708)	39 (1377)	265 (9360)	0.2 (0.6)	0. (-0.1)	HWS	12.2 (7.6)	SW	0 (0)
6/18/74		126 (4433)	33 (1165)	23 (812)	182 (6426)	0.6 (2.1)	-0.1 (-0.3)	HWS	9.5 (5.9)	SE	0 (0)
7/9/74		71 (2505)	32 (1130)	23 (812)	126 (4449)	0.3 (1.0)	0. (-0.1)	F	12.6 (7.8)	Variable	0 (0)
7/30/74		69 (2442)	38 (1342)	23 (812)	130 (4590)	0.5 (1.7)	0.1 (0.2)	E	13.7 (8.5)	SE	2.72 (1.07)
8/20/74		147 (5178)	56 (1977)	31 (1095)	234 (8263)	0.2 (0.7)	0.1 (0.2)	LWS	8.5 (5.3)	Variable	0 (0)
9/11/74		784 (27700)	167 (5897)	164 (5790)	1115 (39370)	0.5 (1.7)	-0.2 (-0.6)	E	10.0 (6.2)	SE	0 (0)

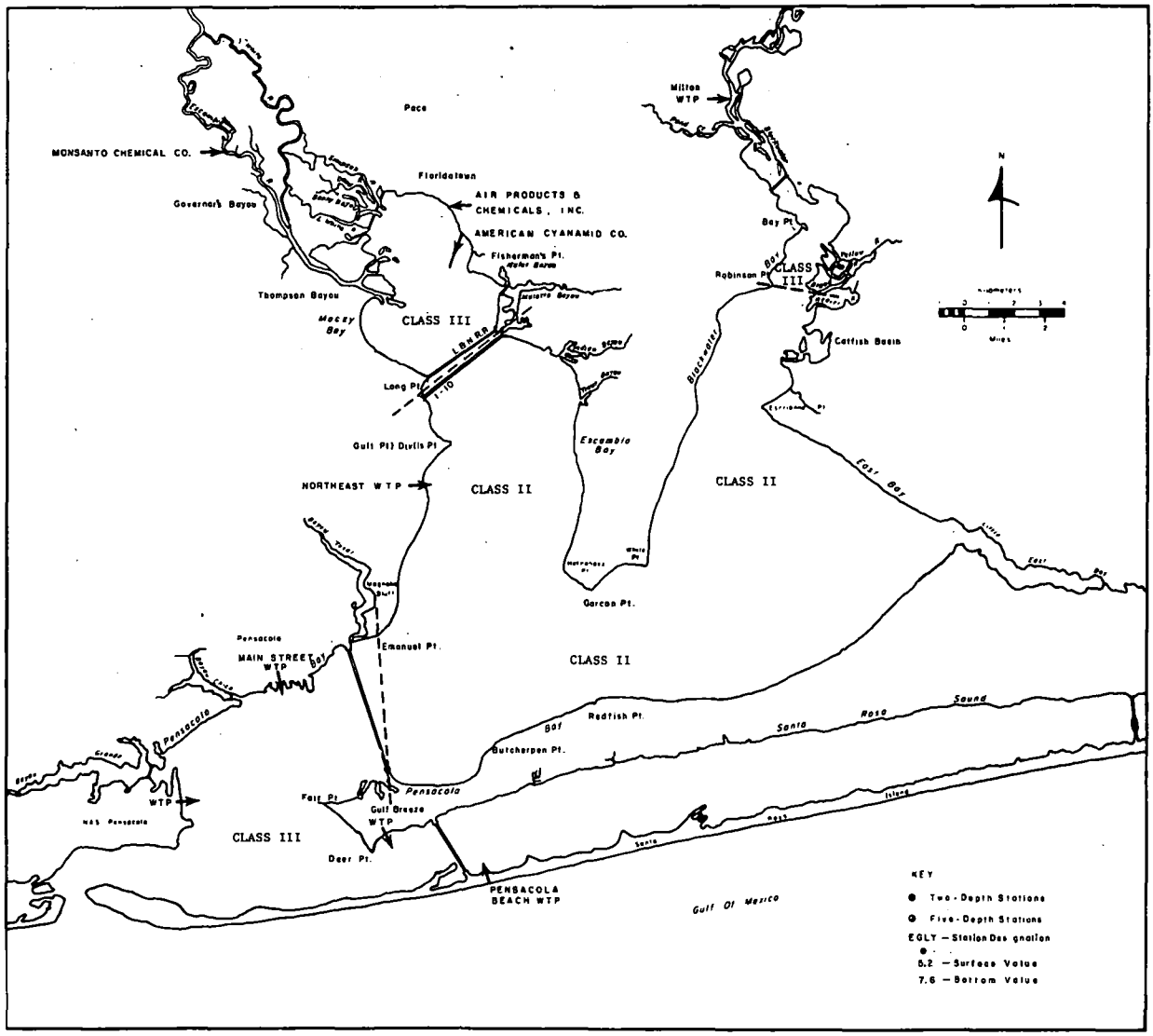


Figure 8-1. Classification of the Pensacola Bay system under the Florida Water Quality Standards.

Criteria (1972), suggests criteria for the following water uses: (1) Recreation and Aesthetics; (2) Public Water Supplies; (3) Freshwater Aquatic Life and Wildlife; (4) Marine Aquatic Life and Wildlife; (5) Agricultural Uses of Water; and (6) Industrial Water Supplies.

PRINCIPAL NUTRIENTS

Carbon

Introduction

The total organic carbon (TOC) measurement was used to assess the concentrations of organic material in the Pensacola Bay system. Carbon is a major component of microbial biomass and an oxygen demand is exerted by aerobic microorganisms as they consume carbon. Consequently, total organic carbon occurs in the biomass of plant and animal organisms, and as natural decomposition products. Waste discharges also add TOC to the Pensacola Bay system. An excessive concentration of TOC, greater than 2.0 mg/l (see Principal Nutrient Index section), can be an indicator of over enrichment which can depress dissolved oxygen levels by causing excessive populations of microorganisms.

Results and Discussion

Mean TOC concentrations in all components of the Pensacola Bay system were greater than the 2.0 mg/l calculated standard during all surveys performed in 1974 with the exception of the surveys performed on June 18 and July 30, 1974 (Table 8-2). Consequently, sufficient carbon was usually available in the Pensacola Bay system to theoretically cause the dissolved oxygen concentrations in the waters to be depressed below the concentrations specified in the Florida Water Quality Standard (Appendix 8-6).

Mean TOC concentrations during the 1974 water quality surveys were distributed uniformly throughout Escambia Bay (Figure 8-2). Mean concentrations throughout the bay were generally lower than those in the river. There were no obvious increases in TOC concentrations near waste discharges during this period.

Throughout East and Blackwater Bays the mean TOC concentrations were essentially the same during January through September 1974. In Pensacola Bay, TOC concentrations generally decreased in a seaward direction with the lowest mean concentrations occurring at Station P04, at the western end of Santa Rosa Sound.

A statistical analysis of TOC data collected during the 1974 surveys indicated that the mean TOC concentration in Escambia Bay was statistically higher than mean concentrations in Pensacola and East Bays (Table 8-3).

Table 8 - 2. Mean total organic carbon concentrations in the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Date	Effective Flow (1) (m^3/sec)	Escambia (mg/l)	East (mg/l)	Blackwater (mg/l)	Pensacola (mg/l)
1/23/74	455	4.8	3.9	4.6	3.3
2/12/74	1070	7.2	6.0	10.2	4.9
3/05/74	338	4.6	4.3	2.9	5.8
3/27/74	346	3.2	2.5	3.0	4.7
4/16/74	696	5.2	3.4	4.4	3.6
5/07/74	183	4.5	3.1	3.9	2.2
5/29/74	265	3.8	3.8	3.5	2.6
6/18/74	182	4.0	2.4	1.9	-
7/09/74	126	6.1	5.0	4.1	3.6
7/30/74	130	3.2	1.3	3.7	2.7
8/20/74	234	4.6	4.8	4.9	3.2
9/11/74	1115	8.2	6.9	12.8	3.3

(1) Total effective flow into the Pensacola Bay system.

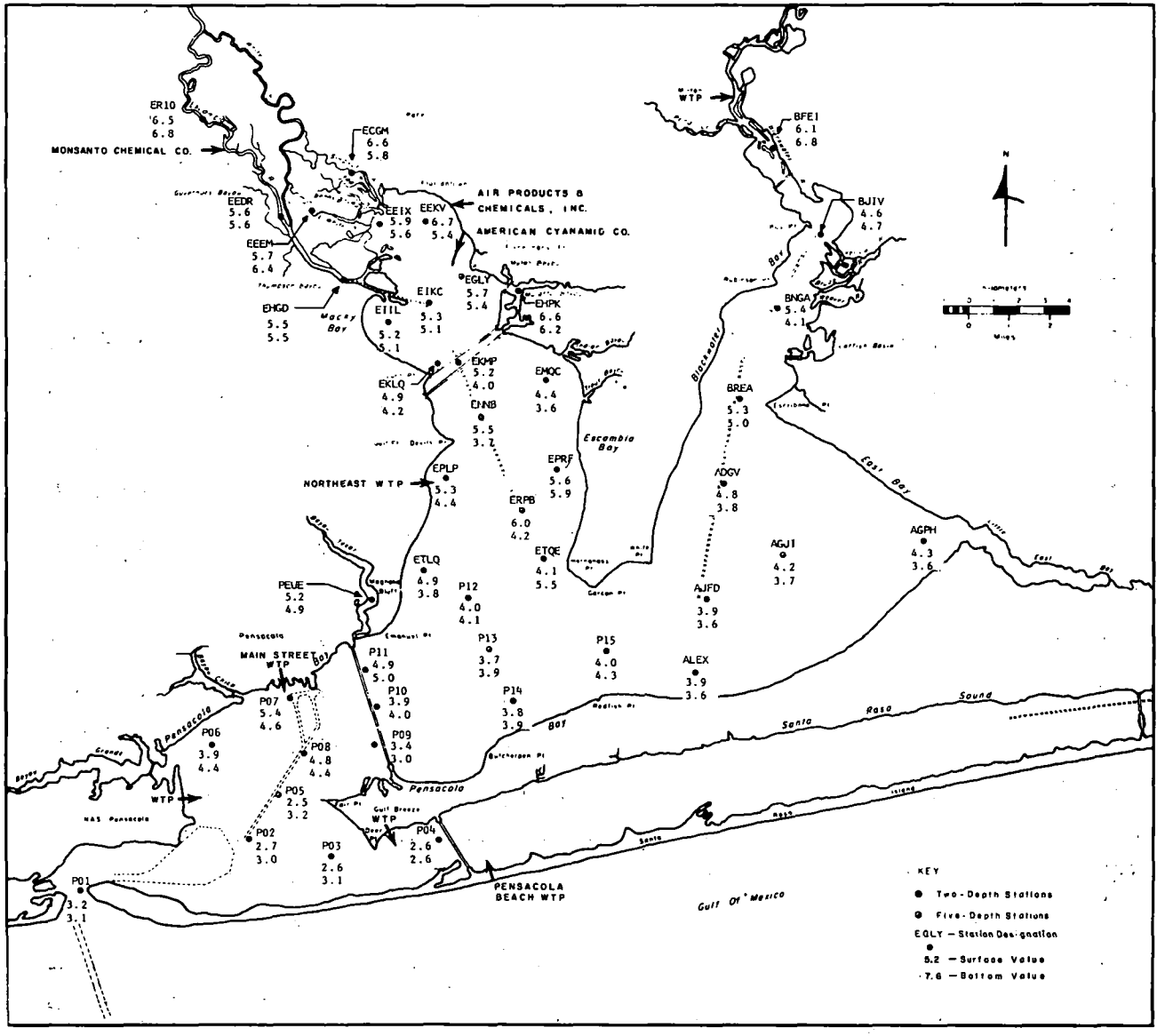


Figure 8-2. Mean total organic carbon (mg/l-C) in the Pensacola Bay system during January through September, 1974. (Pensacola Bay data from the University of West Florida).

Table 8 - 3. Statistical comparison of mean total organic carbon concentrations in Escambia Bay with those in other components of the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Bay	Mean TOC concentration (mg/l)	Calculated t	Degrees of freedom
Escambia	5.15	-	-
East	3.94	6.41 (1)	36
Blackwater	5.25	0.29 (2)	38
Pensacola	3.74	6.88 (1)	60

(1) The hypothesis that the mean TOC concentration in the given bay was less than that in Escambia Bay can be accepted with greater than 99 percent confidence.

(2) The hypothesis that the mean TOC concentrations in Escambia and Blackwater Bays are equal can not be rejected.

During the water quality survey performed in Choctawhatchee Bay on September 12, 1974, the surface and bottom values of TOC generally decreased in a seaward direction as shown in Figure 8-3). A comparison of the mean TOC concentration in Choctawhatchee Bay on this date with the mean concentration in the Pensacola Bay system during the period March through August 1974 indicated all bays had about the same mean concentrations as shown below:

BAY	TOC
Choctawhatchee	3.4
Escambia	4.4
Pensacola	3.7
East	3.4
Blackwater	3.6

The river discharge into the Choctawhatchee and Pensacola Bay systems were 71 and 75 percent of mean annual flow for the comparison periods. Again, the mean concentrations in all bays were above the 2.0 mg/l calculated standard.

Mean TOC concentrations in the components of the Pensacola Bay system were slightly lower during the 1973 low flow diel (24-hour) water quality surveys than during the high flow surveys (Table 8-4). Mean concentrations in all components of the system

Table 8 - 4. Mean total organic carbon concentrations in components of the Pensacola Bay system during 1973 diel water quality surveys.

Survey	Tide	Depth	Escambia Bay (mg/l)	East Bay (mg/l)	Pensacola Bay (mg/l)
I	Equatorial	A	8.0	8.0	7.6
		E	11.2	11.1	10.7
II	Tropic	A	7.8	8.0	7.9
		E	10.1	10.3	11.7
III	Equatorial	A	7.3	6.6	7.0
		E	6.1	5.2	4.1
IV	Tropic	A	5.6	4.4	4.2
		E	5.5	3.6	2.9

were about the same. All mean concentrations during all four surveys were greater than the 2.0 mg/l calculated standard.

There were no obvious patterns in the mean surface and bottom TOC data in Escambia Bay during September 1969 (USDI, 1970) as shown in Figure 8-4. A comparison was made of mean TOC concentrations during the 1969 water quality survey with those during the 1973 and 1974 water quality studies (Table 8-5). The stations considered were E1, E3, E7, E9, E10, E13, E18, and E20 during 1969; and EEIX, EEKV, EIIL, EKLQ, EIKC, EKMP, and EGLY in 1973 and 1974. All the above stations are located in upper Escambia Bay. The mean TOC concentration was 45 percent greater during August 1973 than during September 1969. During all the 1974 surveys considered, the mean TOC concentrations were lower than the 1969 mean, and the greatest decrease, 24 percent, occurred between September 1969 and June 1974.

Most TOC concentrations measured during surveys performed by the Escambia Bay Recovery Study and the University of West Florida were greater than the 2.0 mg/l standard calculated by the method used in Water Quality Criteria (1972). Little variation in TOC concentrations occurred throughout the components of the

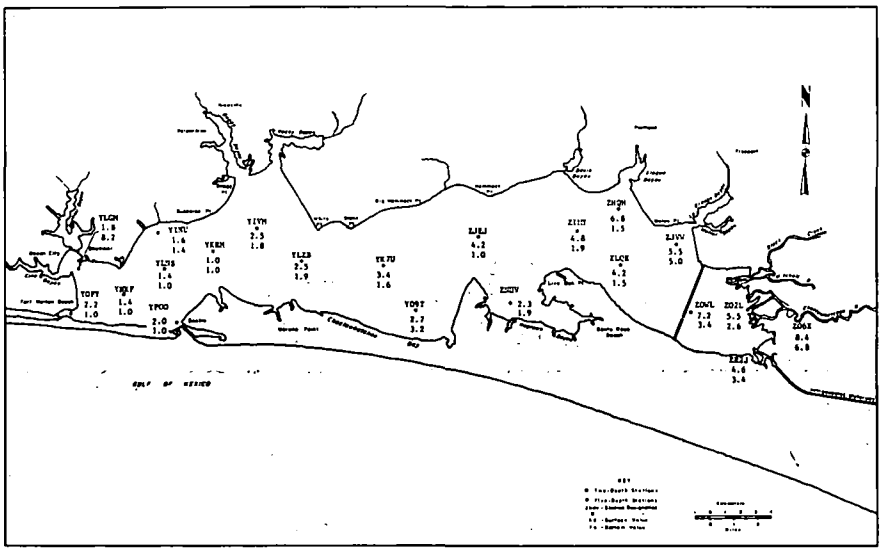


Figure 8-3. Total organic carbon (mg/l-C) in Choctawhatchee Bay on September 12, 1974.

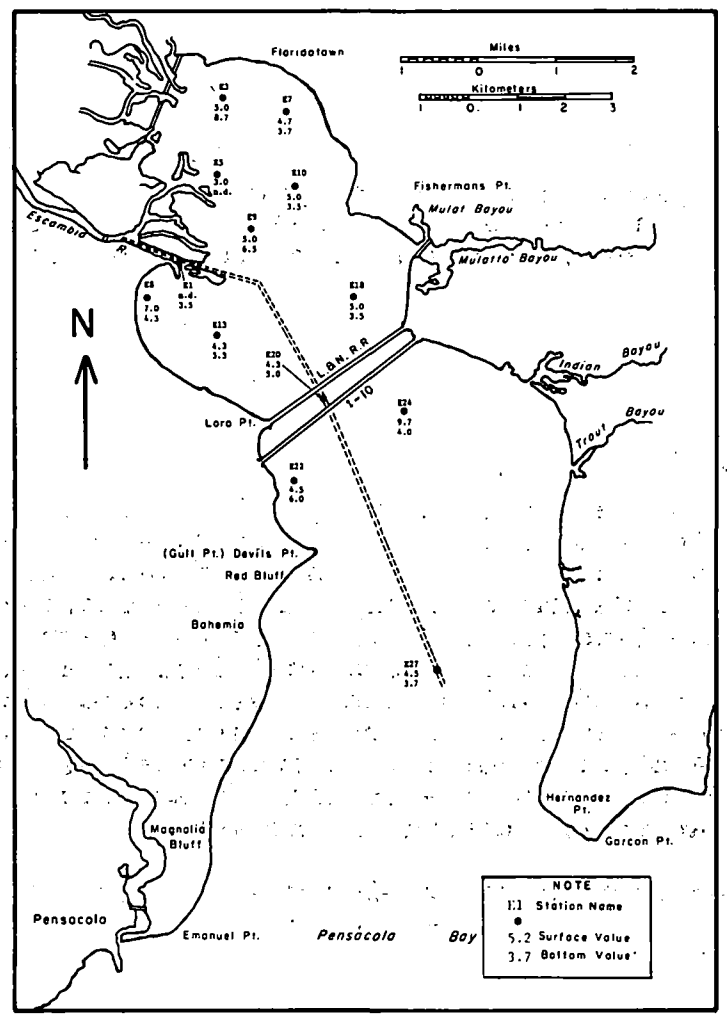


Figure 8-4. Mean total organic carbon (mg/l-C) in Escambia Bay during September 23 to September 25, 1969.

Table 8 - 5. Comparison of mean total organic carbon concentrations in upper Escambia Bay between September, 1969 water quality surveys and the surveys in 1973 and 1974.

Date	Total Organic Carbon		
	Mean total organic carbon concentration (mg/l)	Change in mean from 1969 (%)	Percent of 1969 flow (%)
September 23-25, 1969	4.9	-	-
August 23-25, 1973	7.1	+ 45.	92.
May 5, 1974	4.5	- 8.	86.
June 18, 1974	3.7	- 24.	95.
August 20, 1974	4.8	- 2.	111.
Summer 1974*	4.3	- 12.	89.

* Mean for studies performed during May through August 1974.

Pensacola Bay system, and distinct patterns of TOC concentrations due to waste discharges were not observed. A summary of TOC data by stations for January through September 1974 is presented in Appendix 8-7.

Nitrogen

Introduction

Nitrogen is present in most aquatic environments due to such processes as dieoff of organisms and release of nutrients from their biomass into the waters, sediment nutrient release (discussed in the Sediment Nutrient Release section), inflow from tributaries, and land runoff. When wastes which contain large amounts of nitrogen are introduced into an aquatic system, an imbalance is created which can cause eutrophication if the necessary concentrations of other nutrients such as phosphorus are present. Another problem with industrial nitrogenous wastes is that some of them are toxic to aquatic organisms and so present a threat to the health of the system.

Significant quantities of nitrogen can also enter an aquatic system from the atmosphere due to both precipitation and "dry fallout". This problem was not evaluated during this study.

A criterion for assessing the extent of nitrogen imbalance in an aquatic system is the nitrogen to phosphorus (N-P) ratio. This ratio, which on a weight basis is about 7.25:1, relates total nitrogen to total phosphorus (Water Quality Criteria, 1972; Redfield, et al., 1963). It holds true generally for the open oceans, but in coastal and restricted waters such as estuaries, the ratio is usually considerably different. This is because productivity is usually so much greater in estuaries, and inputs of nitrogen are so variable.

Water Quality Criteria recommends that a total nitrogen concentration of 0.360 mg/l in a marine ecosystem is excessive. This value is based on stoichiometric calculations which show that 0.360 mg/l total nitrogen together with 0.05 mg/l total phosphorus would produce enough organic matter to exhaust the oxygen content of the water at the warmest time of the year with poor circulation. The assumption made in these stoichiometric calculations is that 212 moles of oxygen are consumed in oxidizing each mole of phosphorus, and 4.0 moles of oxygen are consumed in oxidizing each mole of nitrogen (Redfield, et al., 1963). These calculations assume that all nitrogen and all phosphorus will eventually be biologically utilized. However, these values are the only reference standard available to assess nitrogen and phosphorus concentrations in an estuary. Even though they were used in this report, their limitations should be kept in mind.

Florida Department of Environmental Regulation criteria do not give specific limits for nitrogen.

Results and Discussion

All but two of the mean concentrations of total nitrogen in Escambia Bay during 1974 studies exceeded the reference standard of 0.360 mg/l (Water Quality Criteria, 1972) (Table 8-6). These two occurred during the June 18, 1974 and July 30, 1974 surveys. Total nitrogen concentrations in East, Blackwater, and Pensacola Bays were generally less than the 0.360 mg/l standard. On the basis of this standard, there was enough nitrogen in Escambia Bay during virtually all of the 1974 study period to theoretically deplete dissolved oxygen concentrations below the Florida Water Quality Standard specification of 4.0 mg/l.

The mean total nitrogen to total phosphorus ratios for the components of the Pensacola Bay system during the study period January through September 1974 are listed below:

Bay	Ratio
Escambia	14.6:1
Pensacola	10.5:1
East	18.5:1
Blackwater	14.6:1

These ratios are all considerably higher than the 7.25:1 ratio in the open ocean. According to these data, more than half of the time the limiting nutrient for phytoplankton in the Pensacola Bay system appears to be phosphorus, since nitrogen is usually available in sufficient amounts for biological utilization, and little soluble phosphorus was found in the Pensacola Bay system during the study period. Phosphate is utilized by microorganisms in the soluble form (USEPA, 1971).

Mean nitrate-nitrite concentrations in the Pensacola Bay system during January - September, 1974 decreased in a seaward direction from Escambia River to lower Pensacola Bay (Figure 8-5). Nitrate-nitrite was the only nitrogen parameter that showed this upper to lower bay pattern.

There were some localized elevations in nitrogen concentrations near waste outfalls in the Pensacola Bay system during the study period. These occurred in northeast Escambia Bay (Stations EEDR and EGLY) near the Main Street outfall (Station PO7) and near Bayou Texar (Station P11) (Figures 8-5 through 8-7). Organic nitrogen, ammonia, and nitrate-nitrite concentrations were affected.

A comparison of mean concentrations in components of the Pensacola Bay system during January through September 1974 showed that Pensacola, East, and Blackwater Bays had virtually identical nitrogen concentrations with the exception of one value. This exception was nitrate-nitrite in Blackwater Bay (Table 8-7), and this undoubtedly reflects tributary influence. Using a 't'-test, concentrations of all types of nitrogen were significantly higher in Escambia Bay than in Pensacola Bay with 99 percent confidence, as shown below:

NO_3-NO_2-N		NH_3-N		Org. N.		Total N.	
t	df	t	df	t	df	t	df
3.6	22	2.8	24	6.3	27	6.9	22

The major portion of nitrogen in the Pensacola Bay system in 1974 was organic nitrogen. The other nitrogen forms were relatively insignificant compared with organic nitrogen.

Table 8 - 6. Mean nitrogen concentrations in the components of the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Date	Flow (m^3 /sec)	Escambia Bay Total Nitrogen (mg/l)	Escambia Bay Nitrate-Nitrite (mg/l)	Escambia Bay Ammonia (mg/l)	Escambia Bay Organic Nitrogen (mg/l)	East Bay Total Nitrogen (mg/l)	East Bay Nitrate-Nitrite (mg/l)	East Bay Ammonia (mg/l)	East Bay Organic Nitrogen (mg/l)
1/23/74	455	0.549	0.085	0.112	0.352	0.407	0.028	0.055	0.324
2/12/74	1070	0.547	0.095	0.076	0.376	0.360	0.053	0.056	0.251
3/05/74	338	0.444	0.127	0.042	0.275	0.284	0.055	0.038	0.191
3/27/74	346	0.399	0.070	0.062	0.267	0.278	0.025	0.036	0.217
4/16/74	696	0.440	0.093	0.086	0.261	0.315	0.030	0.080	0.205
5/07/74	183	0.551	0.058	0.030	0.463	0.617	0.011	0.036	0.570
5/29/74	265	0.420	0.038	0.023	0.359	0.244	0.010	0.010	0.224
6/18/74	182	0.167	0.034	0.047	0.086	0.104	0.010	0.027	0.067
7/09/74	126	0.366	0.020	0.023	0.323	0.243	0.010	0.015	0.218
7/30/74	130	0.347	0.016	0.024	0.307	0.193	0.010	0.010	0.163
8/20/74	234	0.395	0.048	0.075	0.272	0.207	0.012	0.060	0.135
9/11/74	1115	0.517	0.056	0.198	0.263	0.305	0.021	0.117	0.167

Date	Flow (m^3 /sec)	Blackwater Bay Total Nitrogen (mg/l)	Blackwater Bay Nitrate-Nitrite (mg/l)	Blackwater Bay Ammonia (mg/l)	Blackwater Bay Organic Nitrogen (mg/l)	Pensacola Bay Total Nitrogen (mg/l)	Pensacola Bay Nitrate-Nitrite (mg/l)	Pensacola Bay Ammonia (mg/l)	Pensacola Bay Organic Nitrogen (mg/l)
1/23/74	455	0.398	0.056	0.077	0.265	0.345	0.020	0.041	0.284
2/12/74	1070	0.371	0.050	0.069	0.252	0.237	0.065	0.067	0.105
3/05/74	338	0.229	0.091	0.015	0.123	0.221	0.046	0.022	0.153
3/27/74	346	0.342	0.040	0.052	0.250	0.596	0.042	0.073	0.481
4/16/74	696	0.274	0.067	0.077	0.130	0.276	0.035	0.111	0.130
5/07/74	183	0.391	0.034	0.014	0.343	0.254	0.010	0.022	0.222
5/29/74	265	0.229	0.034	0.014	0.181	0.495	0.012	0.026	0.457
6/18/74	182	0.117	0.038	0.033	0.046	-	0.011	-	0.133
7/09/74	126	0.261	0.029	0.021	0.211	0.120	0.018	0.010	0.092
7/30/74	130	0.237	0.038	0.021	0.178	0.167	0.013	0.027	0.127
8/20/74	234	0.361	0.056	0.079	0.226	0.179	0.010	0.016	0.153
9/11/74	1115	0.301	0.036	0.095	0.170	0.280	0.020	0.092	0.168

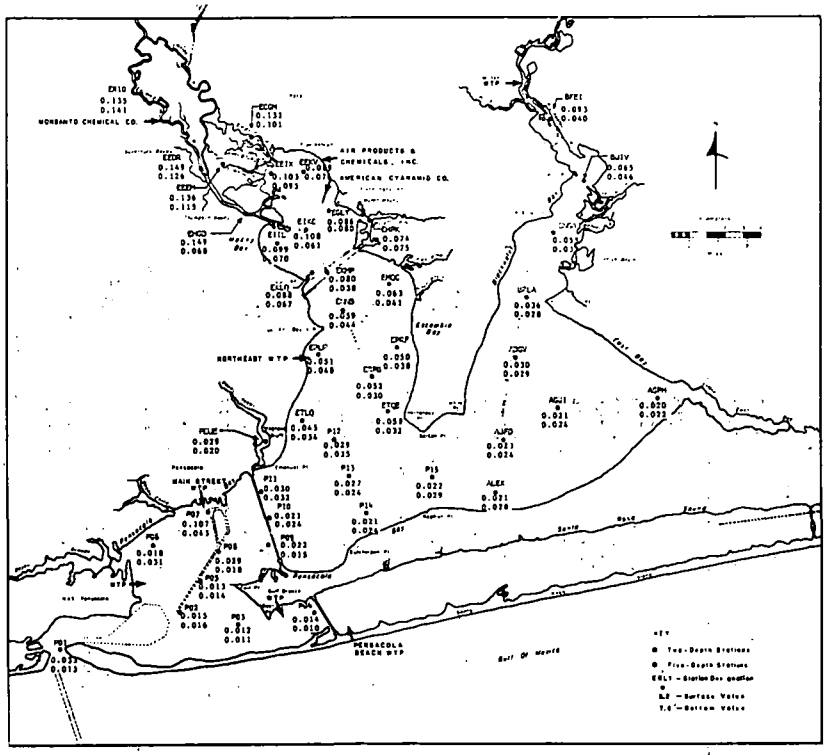


Figure 8-5. Mean nitrate-nitrite nitrogen (mg/l-N) in the Pensacola Bay system during January through September, 1974. (Pensacola Bay data from the University of West Florida).

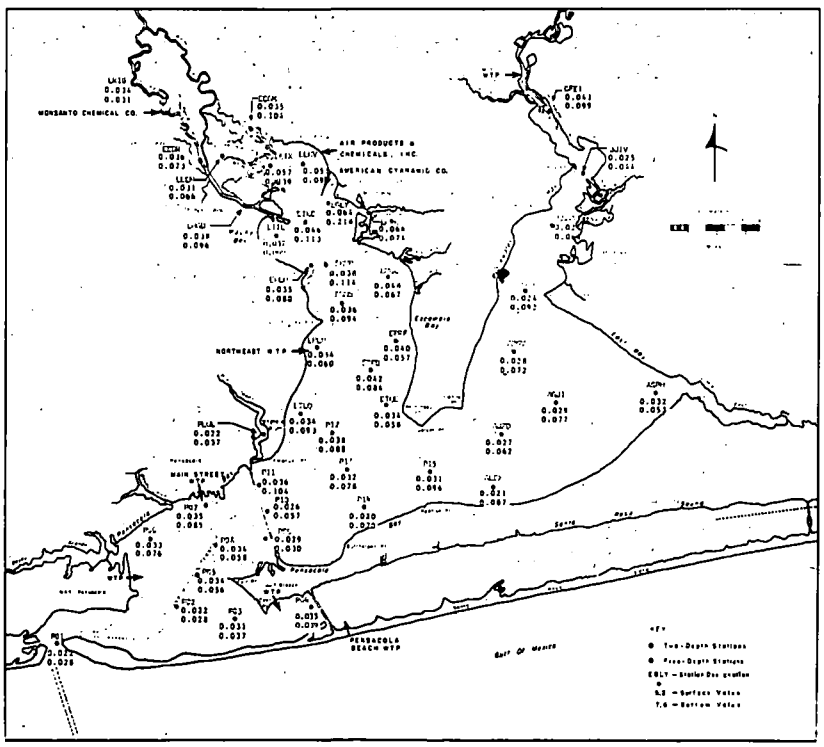


Figure 8-6. Mean ammonia (mg/l-N) in the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

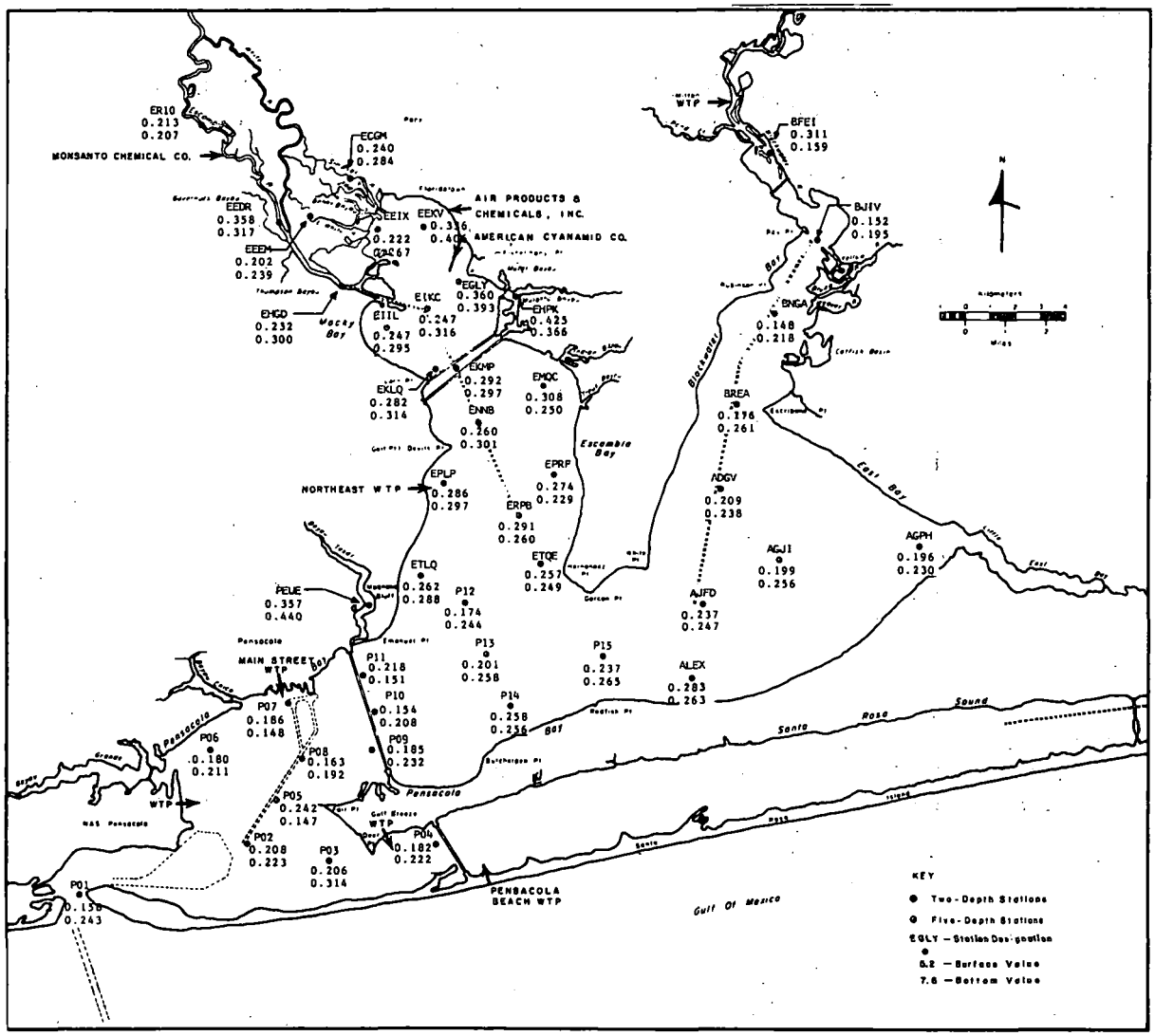


Figure 8-7. Mean organic nitrogen (mg/l-N) in the Pensacola Bay system during January to September, 1974 (Pensacola Bay data from the University of West Florida).

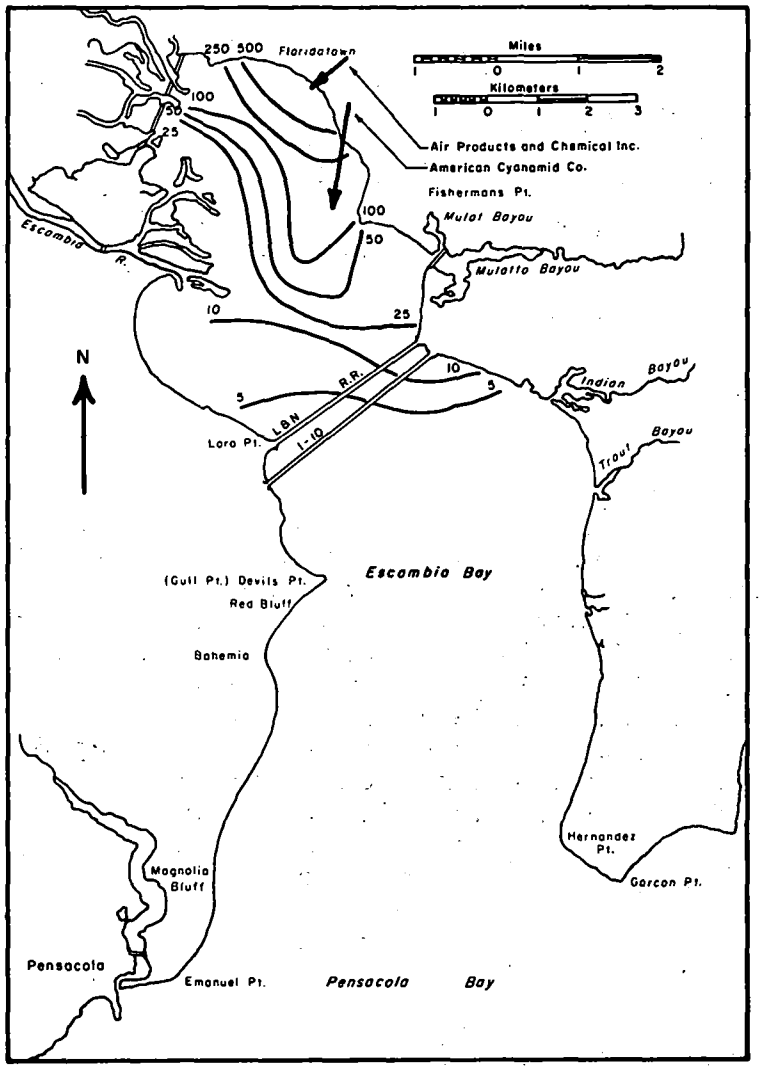


Figure 8-8. Predicted steady state total nitrogen concentrations in µg/l per 953 kg/day (2100 ppd) and 1314 kg/day (2897 ppd) discharged by American Cyanamid Co. and Air Products and Chemicals, Inc., respectively.

Table 8 - 7. Mean nitrogen concentrations in components of the Pensacola Bay system during January to September, 1974 (Pensacola Bay data from the University of West Florida).

Bay	nitrate-nitrite (mg/l)	ammonia (mg/l)	organic nitrogen (mg/l)	total nitrogen (mg/l)
Escambia	0.062	0.066	0.300	0.428
Pensacola	0.025	0.045	0.209	0.279
East	0.023	0.045	0.228	0.296
Blackwater	0.047	0.047	0.198	0.292

The models for the distribution of wastes from Air Products and Chemicals and American Cyanamid plants (See Chapter 6) were used to determine the relationship between actual and predicted concentrations. Predicted total nitrogen concentrations in µg/l per 953 kg/day (2100 lb/day) and 1314 kg/day (2897 lb/day) discharged by Air Products and American Cyanamid plants, respectively, (interim NPDES limits) are presented in Figure 8-8. The wastes remain relatively concentrated in the upper northeast portion of the bay. The highest concentrations occur near Air Products and Chemicals Plant discharge as was expected since wastes from American Cyanamid plant also concentrate in this area. Significant quantities of the nitrogen, 47 and 14 µg/l, reach the north and south inlets of Mulatto Bayou, respectively. The nitrogen isopleths indicate that portions of the wastewater move seaward along the eastern shore of Escambia Bay and are well diluted when they reach the mouth of Indian Bayou. The concentrations predicted here do not represent critical conditions because of high river discharges during the American Cyanamid Dye Study.

The relationship between the predicted surface steady state total nitrogen concentrations due to discharges from Air Products and Chemicals, Inc., and American Cyanamid Co., (Interim NPDES limits) and actual average values measured in the bay during August, and September, 1974 are shown in Table 8-8. The discharge accounted for a significant percent of the total nitrogen in upper Escambia Bay, and 8, 23 and 29 percent of the total nitrogen concentrations near the mouth of the Little White River (Station EEIX), the center of the upper portion of the bay (Station EEKV), and Fishermans Point (Station EGLY), respectively, appeared to be due to the waste discharges. Three percent of the concentrations at both the channel, near Marker "18" (Station EIKC), and in Macky Bay (Station EIIL) appeared due

to these waste discharges. At the channel near the Interstate 10 bridge, one percent of the total nitrogen concentration appeared due to these waste discharges.

A comparison of nitrogen data from Choctawhatchee Bay sampled on September 12, 1974 and the pooled average of Pensacola Bay nitrogen data from March through August 1974 showed that Choctawhatchee Bay had low nitrogen concentrations and Escambia Bay had the highest concentrations for all nitrogen species, (see listing below and Figures 8-9 through 8-12).

Bay	NH_3-N	NO_3-NO_2-N	Org. N.	Total N.
	mg/l			
Choctawhatchee	0.016	0.050	0.19	0.256
Escambia	0.046	0.056	0.29	0.392
East	0.035	0.019	0.22	0.274
Blackwater	0.036	0.048	0.19	0.274
Pensacola	0.034	0.022	0.22	0.276

The mean total nitrogen concentration in Choctawhatchee Bay was significantly less than in Escambia Bay, but was about the same in the rest of the Pensacola Bay system. Choctawhatchee Bay

Table 8 - 8. Predicted percent of actual surface total nitrogen concentrations due to Air Products and Chemical Inc. and American Cyanamid Co.

Station	Surface Total Nitrogen concentration (µg/l)		
	Mean actual August - September, 1974	Predicted based on Interim NPDES Limits	Percent of Actual
EEIX	233	18	8
EEKV	325	74	23
EGLY	344	100	29
EIKC	353	12	3
EIIL	299	9	3
EKMP	318	2	1

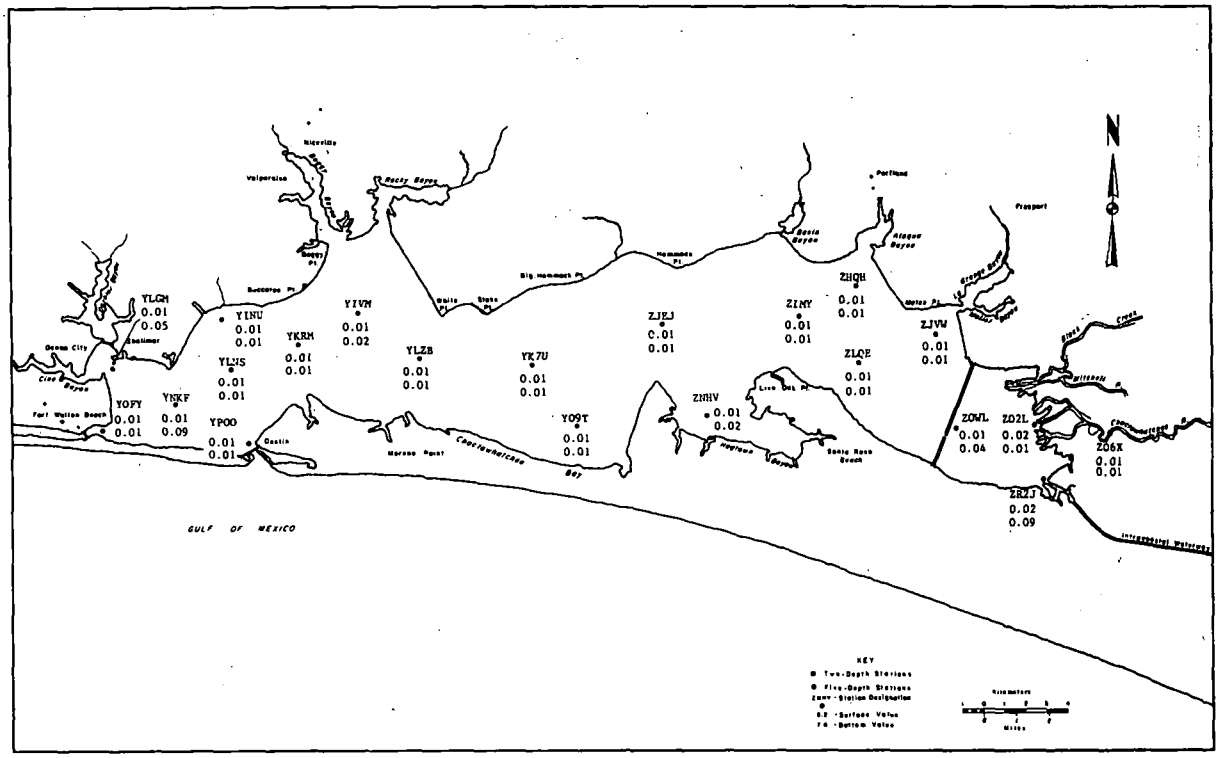


Figure 8-9. Ammonia (mg/l-N) in Choctawhatchee Bay on September 12, 1974.

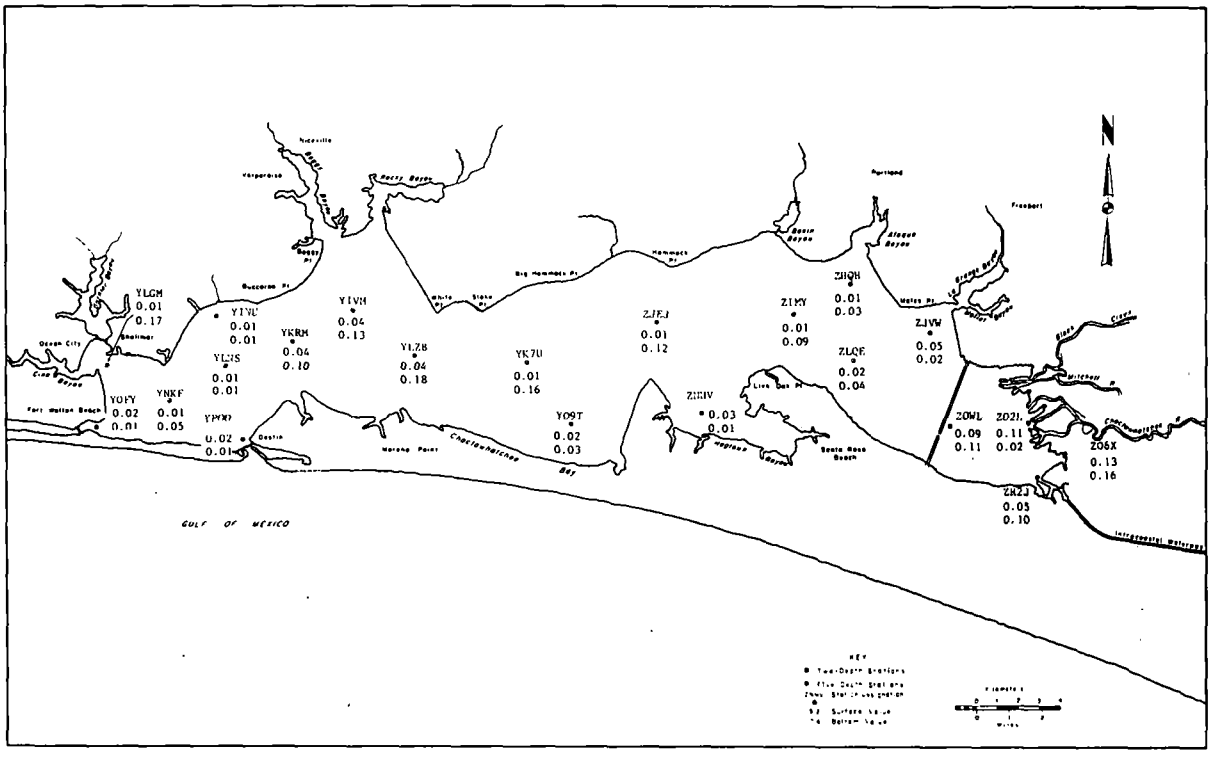


Figure 8-10. Nitrate-nitrite (mg/l-N) in Choctawhatchee Bay on September 12, 1974.

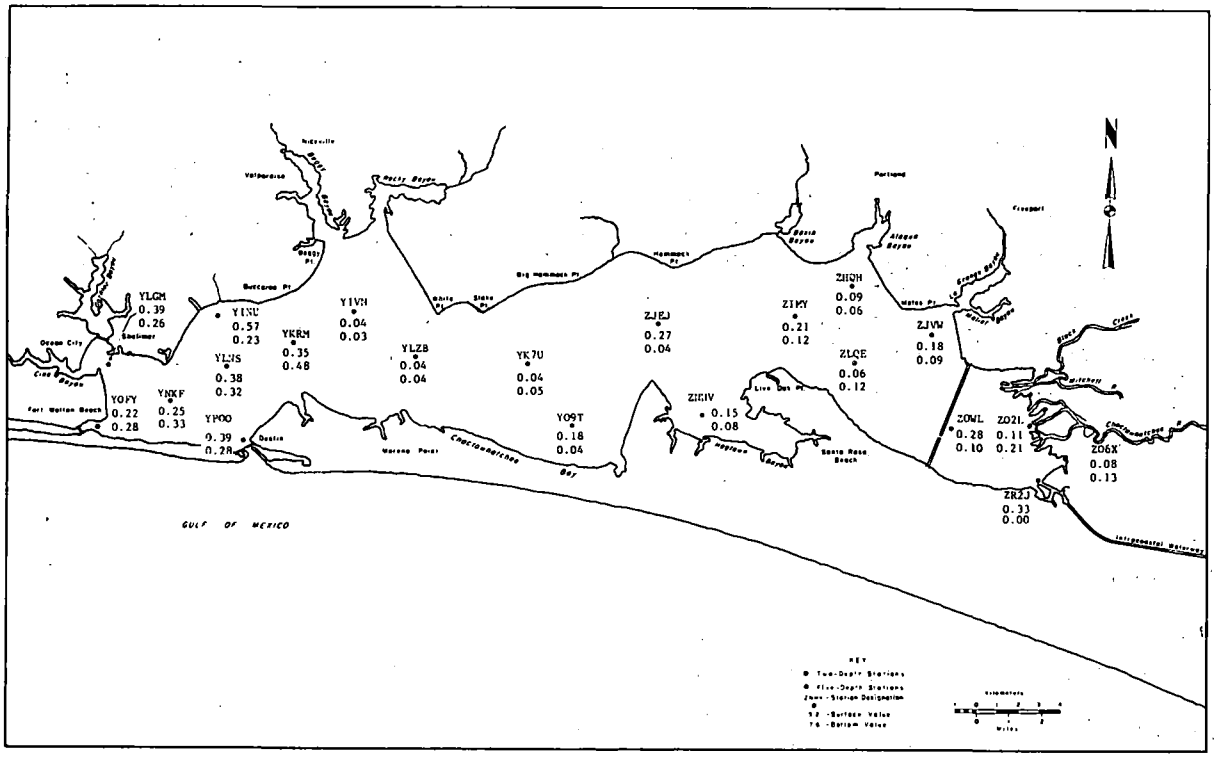


Figure 8-11. Organic Nitrogen (mg/l-N) in Choctawhatchee Bay on September 12, 1974.

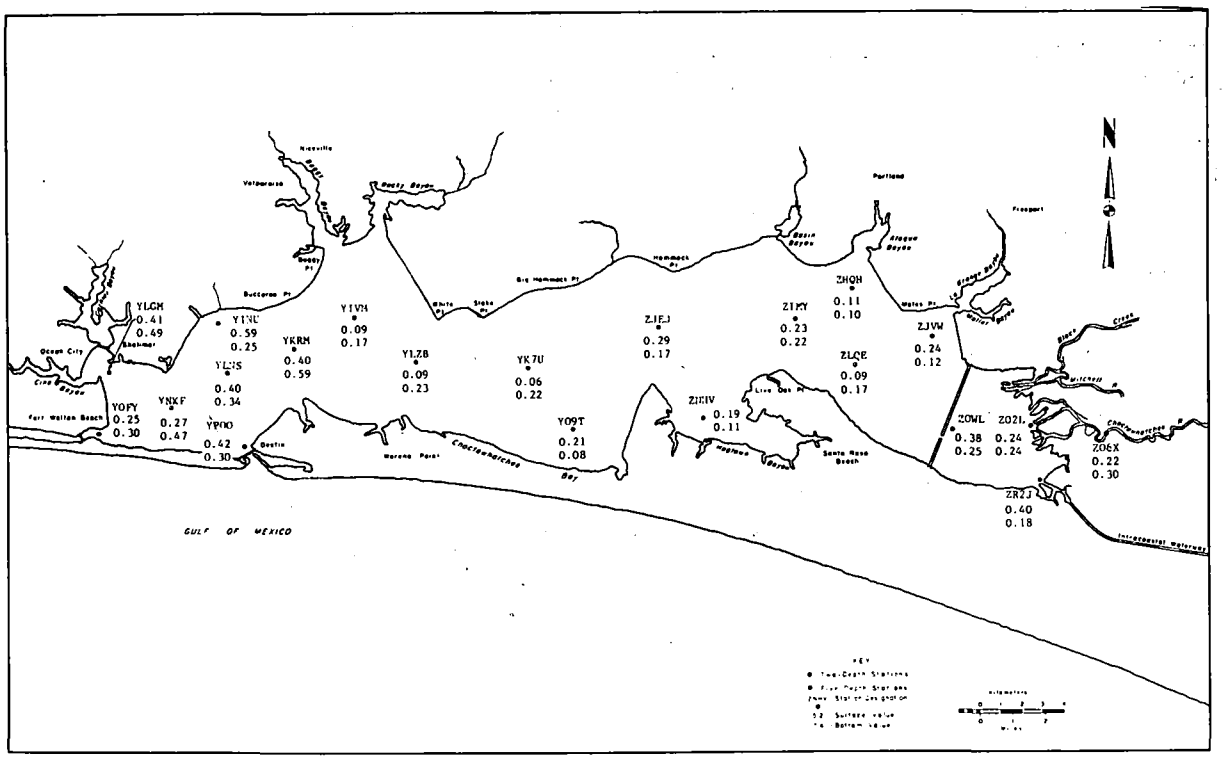


Figure 8-12. Total nitrogen (mg/l-N) in Choctawhatchee Bay on September 12, 1974.

had a mean total nitrogen concentration of 0.256 mg/l, which was well below the maximum of 0.360 mg/l recommended in Water Quality Criteria (1972).

Total nitrogen concentrations in Escambia and East Bays during the August 1973 low flow diel (24-hour) water quality surveys were noticeably higher than concentrations during the April high flow surveys. This probably reflects higher biological productivity in summer, rather than flow conditions. Mean total nitrogen concentrations in Pensacola Bay remained essentially the same in April and August. All mean total nitrogen concentrations during the August low flow surveys, and most concentrations during the high flow surveys, exceeded the 0.360 mg/l standard (Table 8-9).

During the September 1969 survey (USDI, 1970), concentrations of ammonia and nitrate-nitrite in Escambia Bay were the major portion of the total nitrogen (Table 8-10 and Figures 8-13 through 8-15). At Station E7, near Air Products and American Cyanamid Plant outfalls, there were elevated surface and bottom mean ammonia and nitrate-nitrite concentrations. Upper Escambia Bay data from the 1969 water quality survey were compared to the corresponding data from 1973 and 1974 studies (Table 8-10). The stations considered were E1, E3, E7, E9, E10, E13, E18 and E20 during 1969; and EEIX, EEKV, EEIL, EKLQ, EIKC, EKMP, and EGLY during 1973 and 1974. The data in Table 8-10 show that all nitrogen parameters have decreased since 1969 except for organic nitrogen, which remained about the same (The 1974 values used for comparison were the May-August means). Mean total nitrogen concentrations for the stations considered in Summer, 1974 were just about one-half of what they were in September 1969. Ammonia and nitrate-nitrite decreased by even larger percentages. Based on these limited data, water quality in Escambia Bay as it relates to nitrogen has improved considerably in five years, even though total nitrogen in 1974 still exceeded the 0.360 mg/l standard recommended by Water Quality Criteria. A summary of the 1974 nitrogen data by station is presented in Appendices 8-8 through 8-11.

Phosphorus

Introduction

Phosphorus is important in considering water quality due to its role in aquatic productivity. In excessive amounts it is associated with algal blooms which are the cause of much water quality degradation. Phosphorus compounds in the aquatic environment almost always occur in the oxidized state. Three forms occur most frequently: orthophosphate (H_2PO_4, HPO_4, and PO_4), polyphosphate (P_2O_7, P_3O_9, P_3O_{10}), and organic phosphorus. Organic phosphorus, which also occurs almost exclusively in the oxidized state, is combined with organic molecules in the cell biomass of plants and animals. Phosphorus is usually in an

Table 8 - 9. Mean Nitrogen concentrations in components of the Pensacola Bay system during 1973 diel water quality surveys.

Date	Tide		Escambia Bay Ammonia (mg/l)	Escambia Bay Nitrate-Nitrite (mg/l)	East Bay Ammonia (mg/l)	East Bay Nitrate-Nitrite (mg/l)	Pensacola Bay Ammonia (mg/l)	Pensacola Bay Nitrate-Nitrite (mg/l)
April	Equatorial	A	0.064	0.074	0.044	0.064	0.058	0.058
		E	0.059	0.069	0.054	0.064	0.095	0.037
April	Tropic	A	0.057	0.122	0.028	0.035	0.039	0.047
		E	0.061	0.117	0.045	0.030	0.042	0.021
August	Equatorial	A	0.035	0.092	0.010	0.010	0.011	0.010
		E	0.138	0.057	0.128	0.010	0.151	0.012
August	Tropic	A	0.019	0.047	0.010	0.010	0.010	0.010
		E	0.120	0.030	0.150	0.022	0.060	0.014

Date	Tide		Escambia Bay Organic Nitrogen (mg/l)	Escambia Bay Total Nitrogen (mg/l)	East Bay Organic Nitrogen (mg/l)	East Bay Total Nitrogen (mg/l)	Pensacola Bay Organic Nitrogen (mg/l)	Pensacola Bay Total Nitrogen (mg/l)
April	Equatorial	A	0.237	0.375	0.195	0.303	0.253	0.369
		E	0.168	0.296	0.191	0.309	0.268	0.409
April	Tropic	A	0.363	0.542	0.174	0.237	0.395	0.481
		E	0.395	0.573	0.257	0.332	0.455	0.518
August	Equatorial	A	0.512	0.639	0.414	0.434	0.470	0.491
		E	0.477	0.672	0.457	0.595	0.287	0.450
August	Tropic	A	0.483	0.549	0.488	0.508	0.382	0.402
		E	0.480	0.630	0.513	0.685	0.307	0.381

Table 8 - 10. Comparison of mean nitrogen concentrations in upper Escambia Bay between the September, 1969 water quality survey and the studies in 1973 and 1974.

Date	Nitrate - Nitrite: Mean nitrate-nitrite concentration (mg/l)	Change in mean from 1969 (%)	Percent of 1969 flow (%)	Organic Nitrogen: Mean organic nitrogen concentration (mg/l)	Change in mean from 1969 (%)	Percent of 1969 flow (%)
September 23-25, 1969	0.140	-	-	0.280	-	-
August 23-25, 1973	0.083	- 41.	92.	0.480	+ 71	92.
May 5, 1974	0.099	- 29.	86.	0.460	+ 64.	86.
June 18, 1974	0.082	- 43.	95.	0.080	- 71.	95.
August 20, 1974	0.073	- 50.	111.	0.190	- 32.	111.
Summer 1974*	0.047	- 66.	89.	0.270	- 4.	89.

Date	Ammonia: Mean ammonia concentration (mg/l)	Change in mean from 1969 (%)	Percent of 1969 flow (%)	Total Nitrogen: Mean total nitrogen concentration (mg/l)	Change in mean from 1969 (%)	Percent of 1969 flow (%)
September 23-25, 1969	0.290	-	-	0.710	-	-
August 23-25, 1973	0.110	- 62.	92.	0.670	- 6.	92.
May 5, 1974	0.047	- 84.	86	0.606	- 14.	86.
June 18, 1974	0.066	- 77.	95.	0.228	- 68.	95.
August 20, 1974	0.080	- 72.	111.	0.343	- 52.	111.
Summer 1974*	0.064	- 78	89.	0.392	- 45.	89.

* Mean for studies performed during May through August 1974.

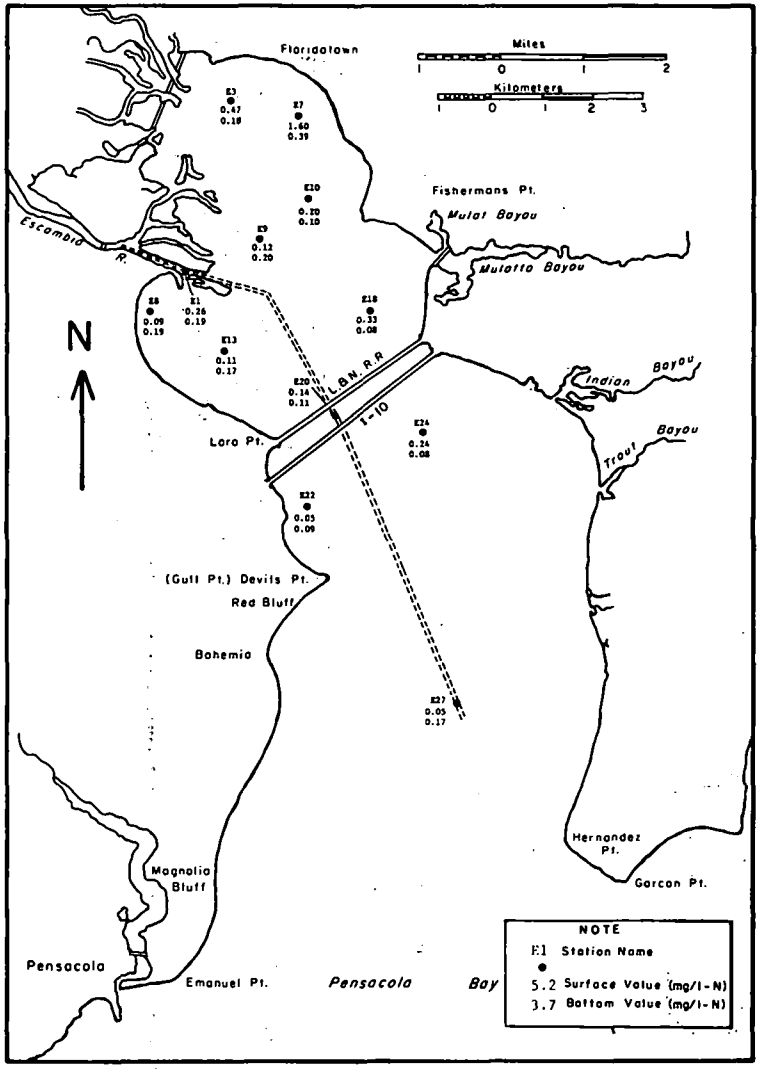


Figure 8-13. Mean ammonia in Escambia Bay during September 23 to September 25, 1969.

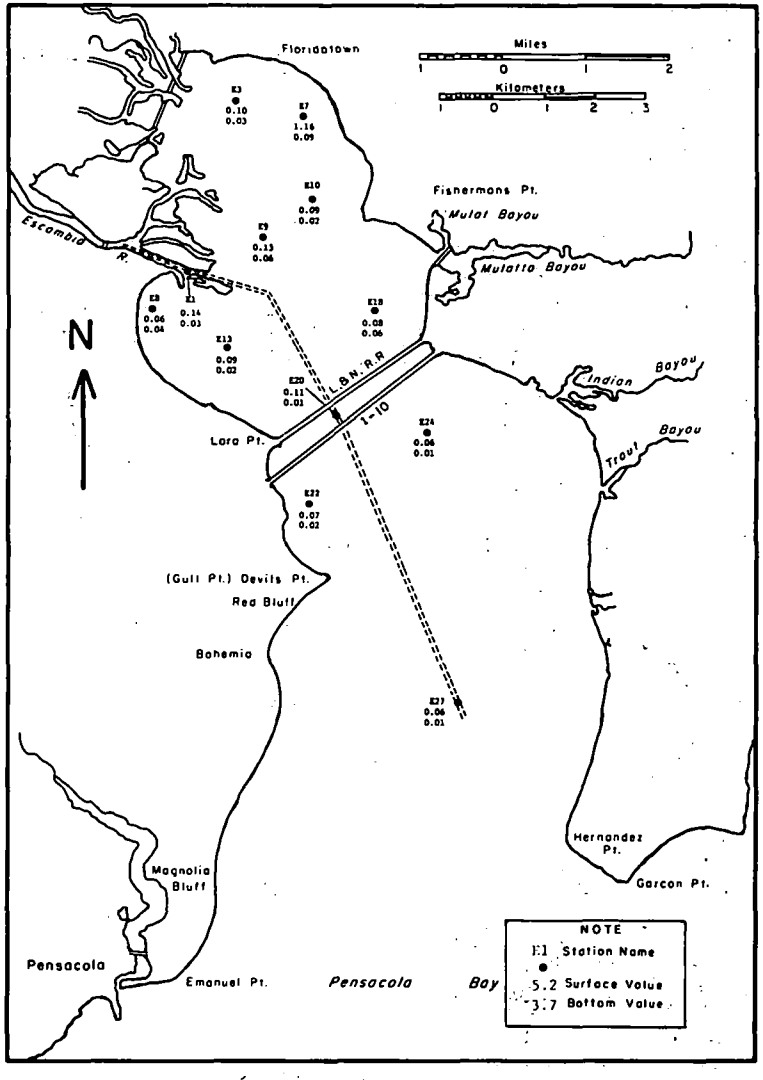


Figure 8-14. Mean nitrate-nitrite (mg/l-N) in Escambia Bay during September 23 to September 25, 1969.

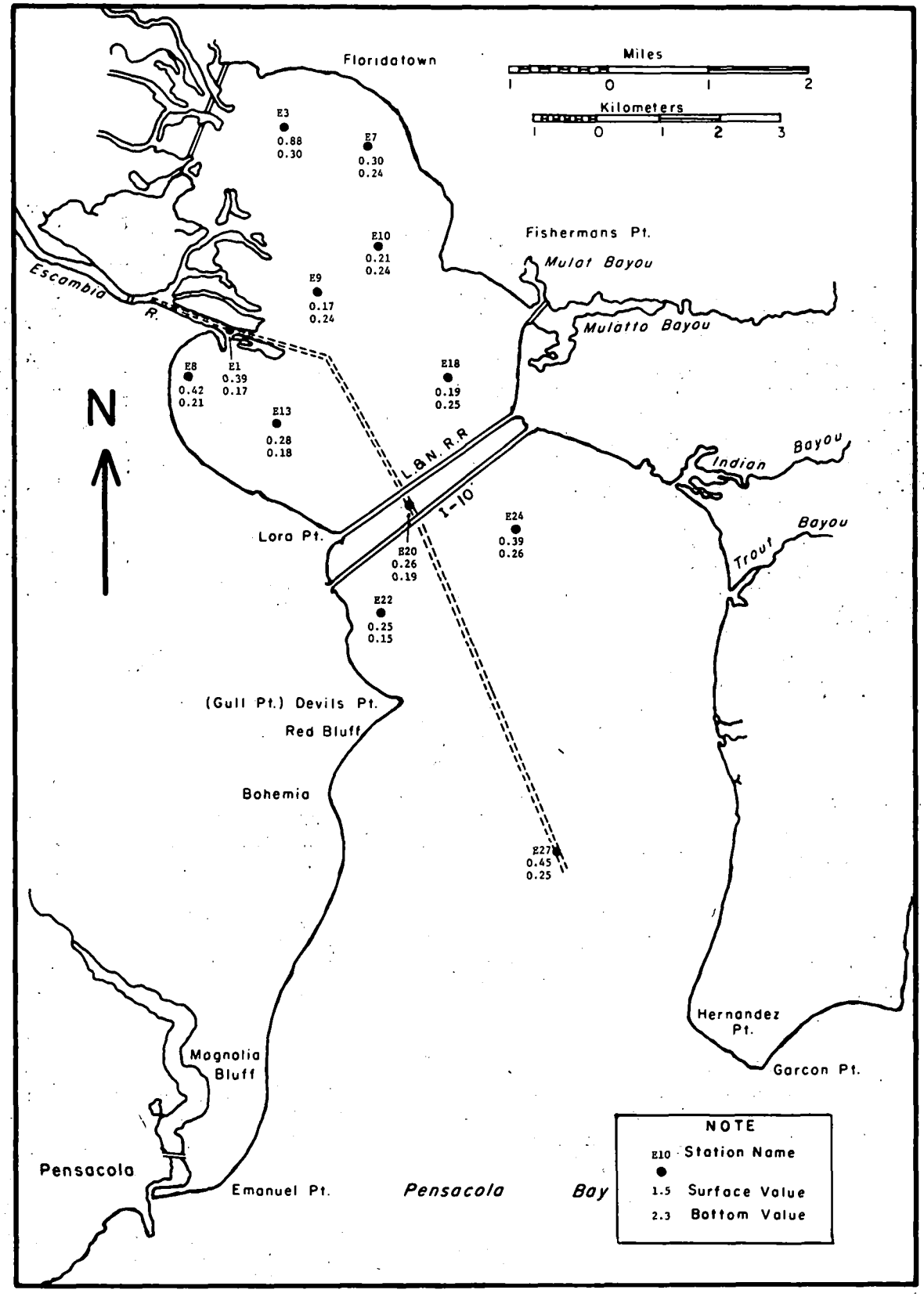


Figure 8-15. Mean organic nitrogen (mg/l-N) in Escambia Bay during September 23 to September 25, 1969.

insoluble form in an estuarine environment where there is a significant amount of biological productivity. This is due to three factors: much soluble phosphate is taken up into cell mass and so is kept out of solution; phosphate is readily adsorbed onto insoluble residues in the water; and the pH is in the range (slightly basic) in which phosphate combines with multivalent cations to form insoluble precipitates.

Phosphorus in significant quantities can enter the aquatic environment from the atmosphere as a result of precipitation or "dry fallout". This problem was not evaluated during the study.

Florida Department of Environmental Regulation (FDER) criteria do not give specific limits for phosphorus in estuaries. The recommendation in Water Quality Criteria (1972) is that 0.05 mg/l total phosphorus should be considered the upper limit for a marine ecosystem. This reference standard is discussed further in the nitrogen section.

A criterion for assessing phosphorus concentrations is the nitrogen to phosphorus ratio, which relates total phosphorus to total nitrogen. It is discussed in detail in the nitrogen section.

Results and Discussion

Mean dissolved orthophosphorus concentrations were negligible throughout the Pensacola Bay system during the 1974 study period (Figure 8-16). Mean orthophosphorus concentrations in Escambia Bay generally decreased in a seaward direction (Figure 8-17). Mean total phosphorus concentrations in Escambia Bay decreased in a seaward direction on the eastern side of the bay, and remained relatively constant on the western side (Figure 8-18).

Phosphorus concentrations in the Pensacola Bay system during January - September 1974 varied relatively little among bays (Table 8-11). All of the total phosphorus concentrations except during the April 16 and July 9, 1974 surveys were well within the 0.05 mg/l recommended WQC standard (Table 8-12).

A comparison of September 12, 1974 Choctawhatchee Bay total phosphorus data with Pensacola Bay system total phosphorus data from March - August 1974 showed little variation among bays. Orthophosphorus concentrations were identical for all bays. The data are listed below:

Bay	Total Phosphorus	Ortho-Phosphorus
	mg/l-P	
Choctawhatchee	0.030	0.013
Escambia	0.028	0.016
Pensacola	0.030	-----
East	0.018	0.012
Blackwater	0.021	0.013

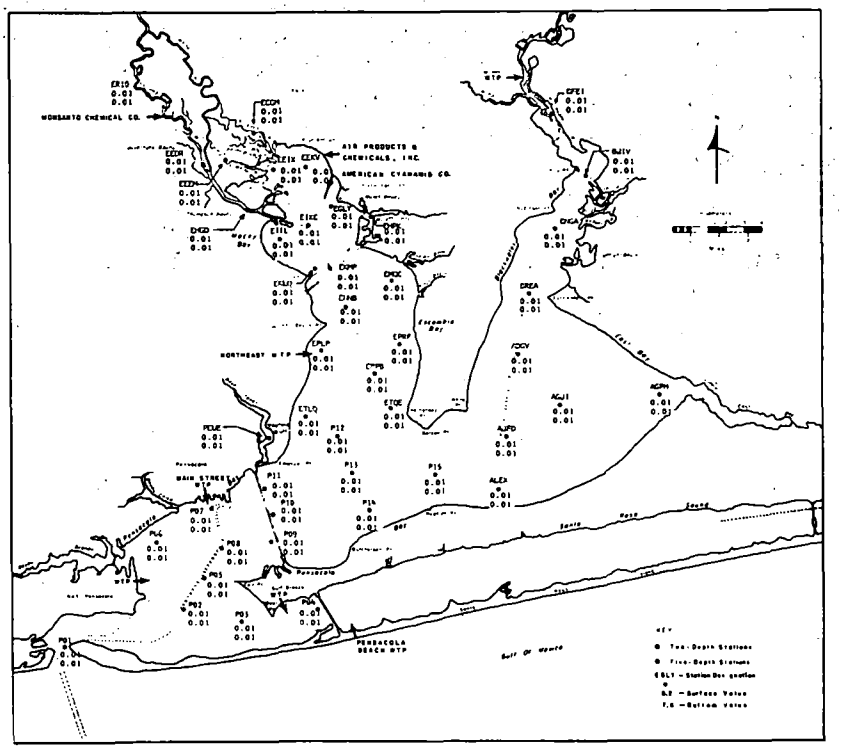


Figure 8-16. Mean dissolved orthophosphorus (mg/l-P) in the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

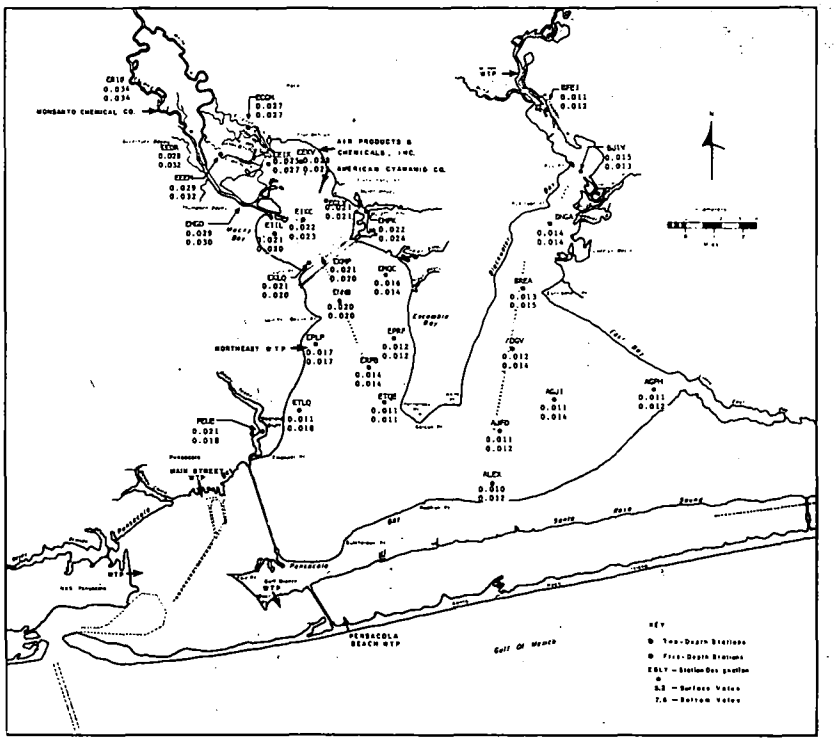


Figure 8-17. Mean orthophosphorus (mg/l-P) in the Pensacola Bay system during January through September, 1974.

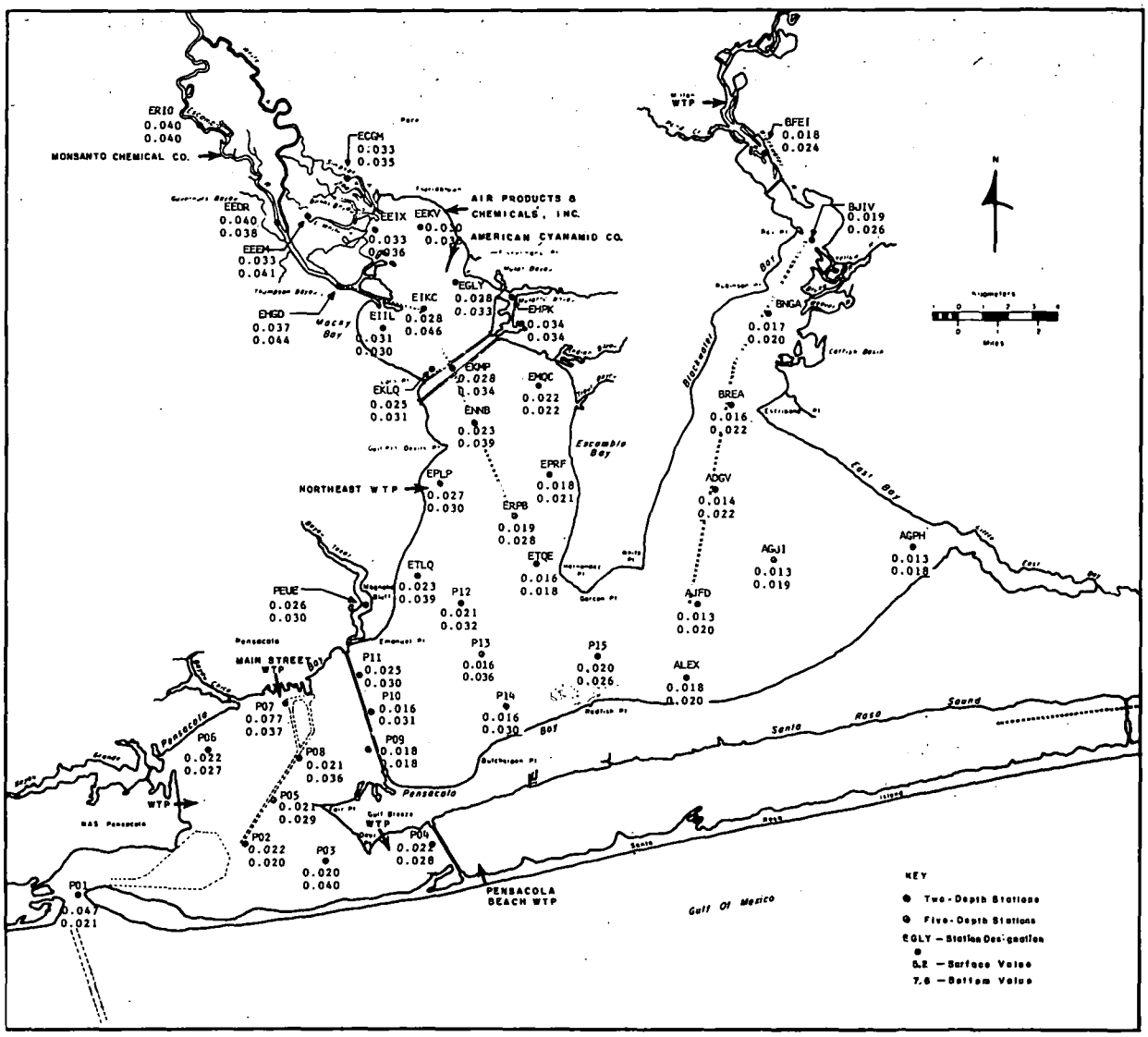


Figure 8-18. Mean total phosphorus (mg/l-P) in the Pensacola Bay system during January through September, 1974. (Pensacola Bay data from the University of West Florida).

Table 8 - 11. Mean total and orthophosphorus concentrations in the components of the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Bay	Total Phosphorus (mg/l)	Ortho-Phosphorus (mg/l)
Escambia Bay	0.028	0.018
Pensacola Bay	0.026	-
East Bay	0.016	0.011
Blackwater Bay	0.020	0.014

Table 8 - 12. Mean total phosphorus (T-P) and orthophosphorus (O-P) concentrations in the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Date	Effective Flow* (m^3/sec)	Escambia		East		Blackwater		Pensacola	
		O-P (mg/l)	T-P (mg/l)	O-P (mg/l)	T-P (mg/l)	O-P (mg/l)	T-P (mg/l)	O-P (mg/l)	T-P (mg/l)
1/23/74	455	0.014	0.020	0.011	0.011	0.011	0.012	-	0.020
2/12/74	1070	0.037	0.028	0.011	0.012	0.024	0.024	-	0.015
3/05/74	338	0.019	0.035	0.018	0.023	0.016	0.025	-	0.010
3/27/74	346	0.011	0.018	0.011	0.016	0.011	0.020	-	0.035
4/16/74	696	0.019	0.026	0.012	0.022	0.010	0.022	-	0.054
5/07/74	183	0.017	0.020	0.011	0.015	0.016	0.018	-	0.020
5/29/74	265	0.013	0.027	0.010	0.014	0.010	0.025	-	0.023
6/18/74	182	0.018	0.022	0.012	0.015	0.012	0.015	-	0.030
7/09/74	126	0.017	0.030	0.010	0.013	0.012	0.018	-	0.058
7/30/74	130	0.019	0.038	0.012	0.026	0.014	0.027	-	0.023
8/20/74	234	0.014	0.032	0.010	0.015	0.012	0.019	-	0.017
9/11/74	1115	0.024	0.044	0.010	0.013	0.018	0.022	-	0.023

* Total effective flow into the Pensacola Bay system.

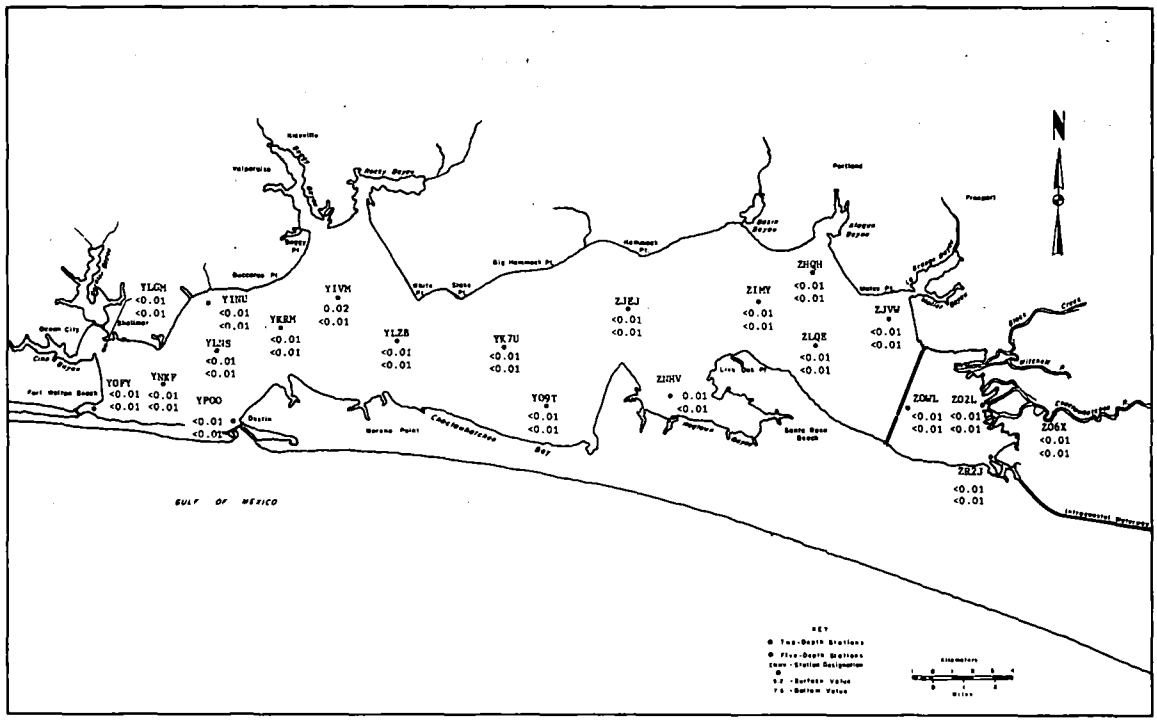


Figure 8-19. Dissolved orthophosphorus (mg/l-P) in Choctawhatchee Bay on September 12, 1974.

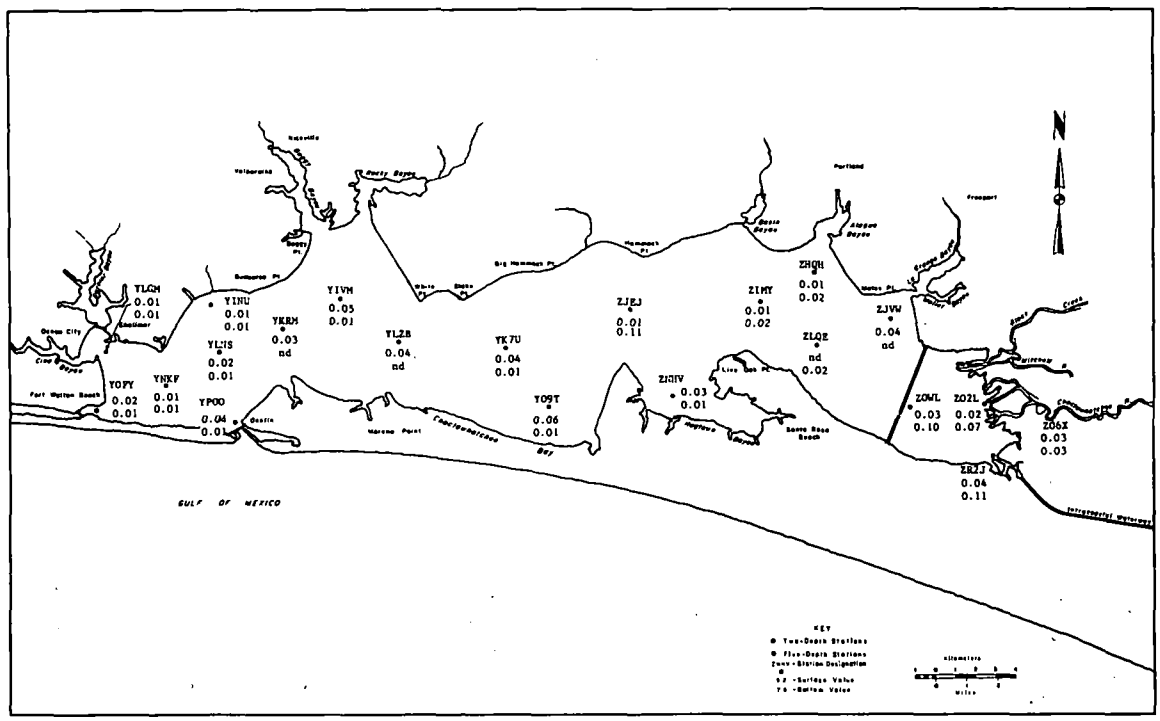


Figure 8-20. Total phosphorus (mg/l-P) in Choctawhatchee Bay on September 12, 1974.

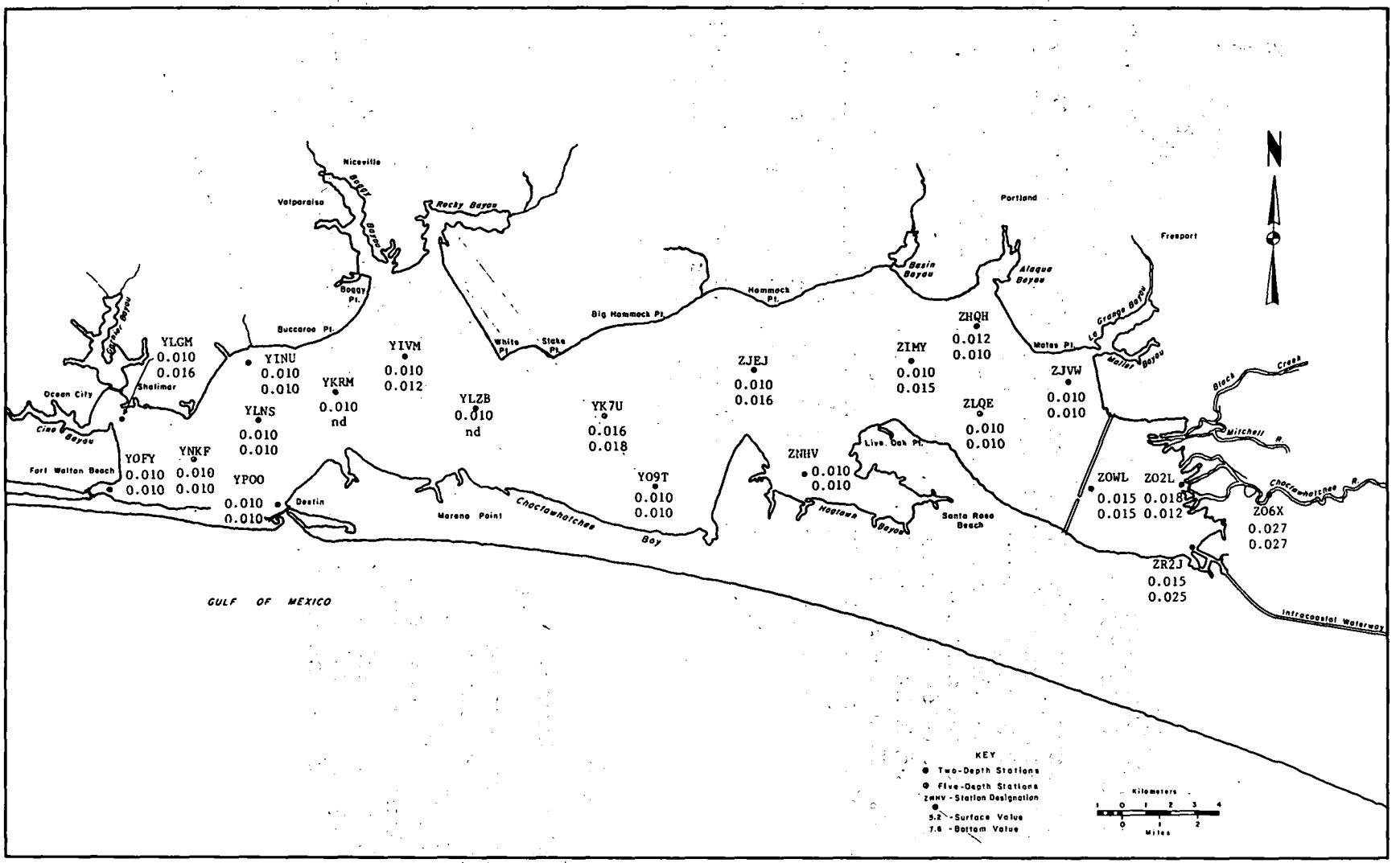


Figure 8-21. Orthophosphorus (mg/l-P) in Choctawhatchee Bay on September 12, 1974.

Dissolved orthophosphorus concentrations were negligible (Figure 8-19). Phosphorus concentrations in Choctawhatchee Bay generally were greater on the eastern, freshwater end (Figures 8-20 and 8-21). This again reflects the influence of freshwater sources. All concentrations were well below the 0.05 mg/l recommended WQC standard.

Mean total and orthophosphorus concentrations in the Pensacola Bay system were higher during the 1973 high flow diel surveys than during the low flow surveys (Table 8-13). Mean total phosphorus concentrations in Escambia Bay during Survey II exceeded the 0.05 mg/l standard.

Mean phosphorus data from the 1969 water quality study (USDI, 1970), showed elevated concentrations near industrial discharges in northeast Escambia Bay (Figures 8-22 and 8-23). Phosphorus concentrations in upper Escambia Bay from the 1969 survey were compared to the corresponding data from 1973 and 1974. The stations considered were E1, E3, E7, E9, E10, E13, E18, and E20 in 1969; and EEIX, EEKV, EIIL, EKLQ, EIKC, EKMP, and EGLY in 1973 and 1974. Mean concentrations for various periods are listed in Table 8-14. The concentrations of orthophosphorus dropped by 50 percent between 1969 and 1974 while total phosphorus concentrations decreased by 75 percent. These decreases brought phosphorus concentrations under the 0.05 mg/l standard in 1974.

The indication of these limited data is that phosphorus concentrations in Escambia Bay have decreased since 1969. A summary of the phosphorus data by stations is given for January through September 1974 in Appendices 8-12 through 8-14.

Principal Nutrient Index

Introduction

To evaluate water quality in an estuary like Escambia Bay, a massive data base for numerous parameters is required to describe natural and induced variation in the system, and to understand conditions in the bay relative to other bays. Evaluation can be simplified by combining water quality parameters in such a manner that a standardized distance from a control or an index can be calculated. Harkins (1974) suggested the use of a nonparametric classification procedure to compute an index.

Table 8 - 13. Mean total and orthophosphorus concentrations in components of the Pensacola Bay system during the 1973 diel water quality surveys.

Survey	Tide	Depth	Total Phosphorus (mg/l) Escambia Bay	East Bay	Pensacola Bay
I	Equatorial	A	0.050	0.017	0.024
		B	0.048	0.017	0.015
II	Tropic	A	0.061	0.035	0.039
		B	0.063	0.036	0.025
III	Equatorial	A	0.031	0.014	0.019
		B	0.038	0.030	0.027
IV	Tropic	A	0.017	0.012	0.016
		B	0.035	0.033	0.020

Survey	Tide	Depth	Ortho Phosphorus (mg/l) Escambia Bay	East Bay	Pensacola Bay
April	Equatorial	A	0.042	0.020	0.032
		B	0.042	0.024	0.015
I	Tropic	A	0.042	0.021	0.021
		B	0.043	0.030	0.012
III	Equatorial	A	0.013	0.008	0.010
		B	0.018	0.015	0.019
IV	Tropic	A	0.011	0.013	0.010
		B	0.021	0.016	0.012

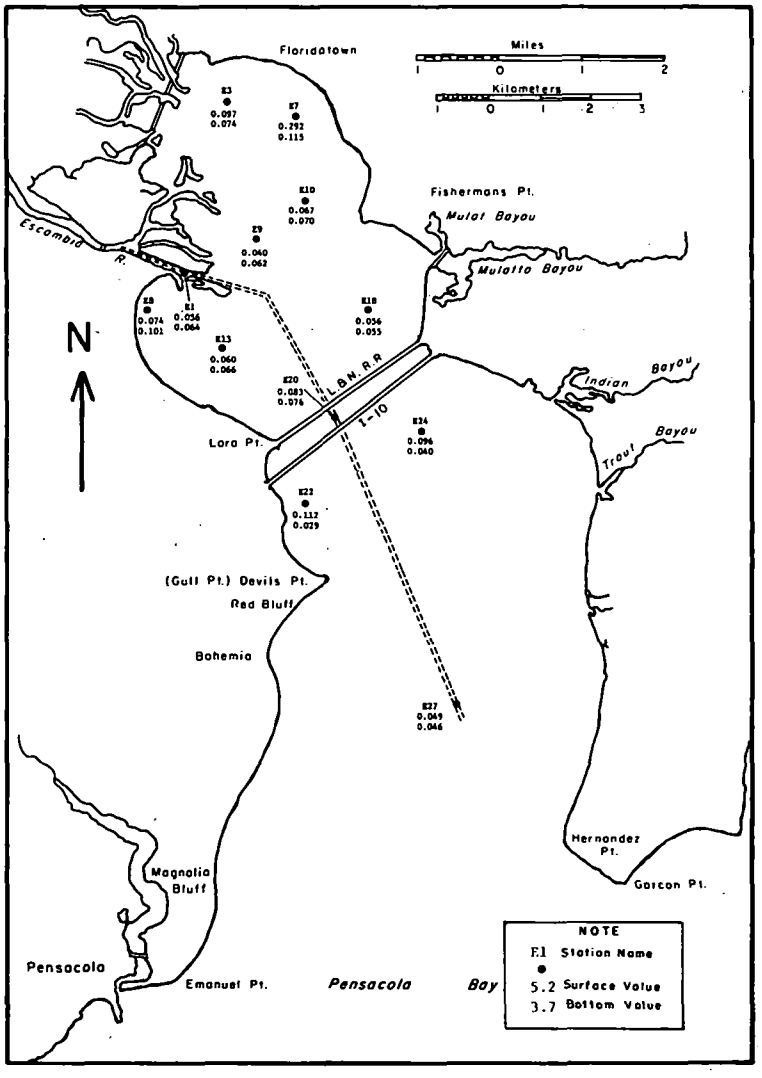


Figure 8-22. Mean total phosphorus (mg/l-P) in Escambia Bay during September 23 to September 25, 1969.

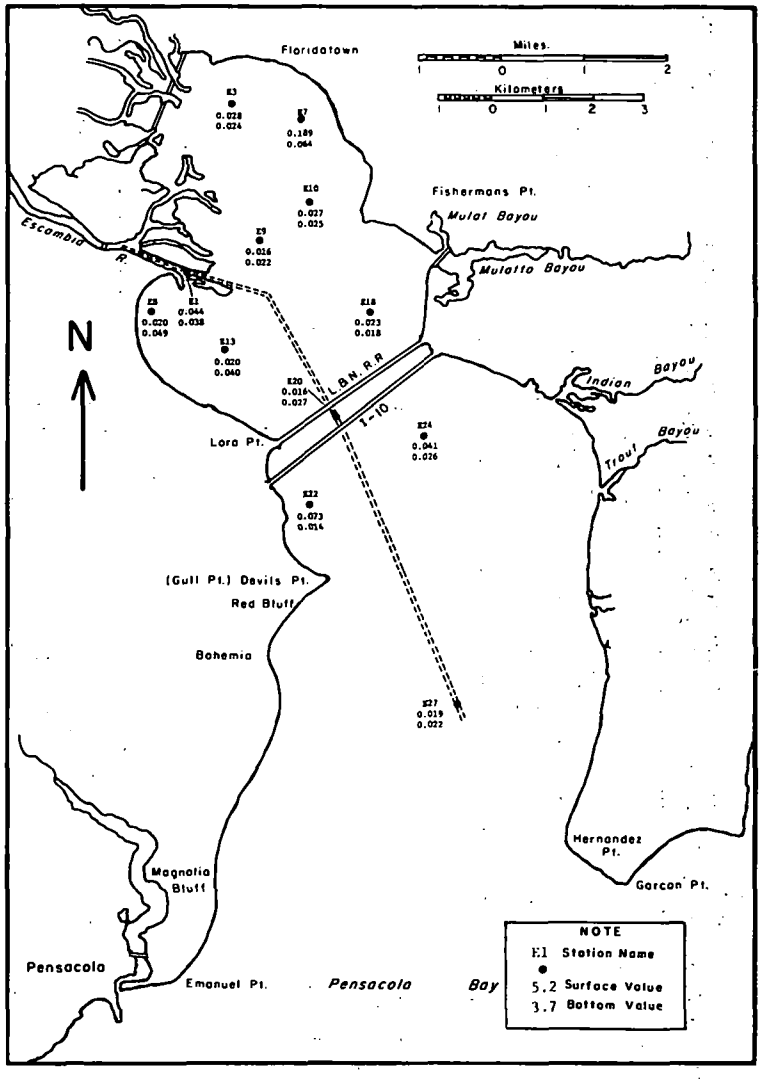


Figure 8-23. Mean orthophosphorus (mg/l-P) in Escambia Bay during September 23 to September 25, 1969.

Table 8 - 14. Comparison of mean total and orthophosphorus concentrations in upper Escambia Bay between September, 1969 water quality surveys and the surveys in 1973 and 1974.

Date	Total Phosphorus: Mean total phosphorus concentration (mg/l)	Total Phosphorus: Change in mean from 1969 (%)	Total Phosphorus: Percent of 1969 flow (%)
September 23-25, 1969	0.08	-	-
August 23-25, 1973	0.03	- 63.	92.
May 5, 1974	0.02	- 75.	86.
June 18, 1974	0.02	- 75.	95.
August 20, 1974	0.03	- 63.	111.
Summer 1974	0.02	- 75.	89.

Date	Ortho Phosphorus: Mean ortho phosphorus concentration (mg/l)	Ortho Phosphorus: Change in mean from 1969 (%)	Ortho Phosphorus: Percent of 1969 flow (%)
September 23-25, 1969	0.04	-	-
August 23-25, 1973	0.02	- 50.	92.
May 5, 1974	0.02	- 50.	86.
June 18, 1974	0.02	- 50.	95.
August 20, 1974	0.01	- 75.	111.
Summer 1974*	0.02	- 50.	89.

* Mean for studies performed during May through August 1974.

Using Harkin's method, the Principal Nutrient Index (PNI) was calculated from Escambia Bay Recovery Study data, University of West Florida Sea Grant data, and data from other Gulf Coast estuaries. Total organic carbon, total nitrogen, and total phosphorus were used as parameters in the PNI because high levels of these substances are an indication of possible enrichment. Because the total concentration of each nutrient was used, dissolved and particulate components of each parameter are included in the index.

The index is advantageous because it simplifies evaluating carbon, nitrogen, and phosphorus concentrations by combining them into one value that can be compared to a water quality standard (see Methods) and used as a water resources management tool. High values of the index indicate high concentrations of one or all of the parameters. Even though only one of the parameters has high concentrations, unacceptable water quality may still exist. Use of the index does not eliminate the need to evaluate the individual parameters in detailed water quality studies.

Method

The first step in the calculation of PNI was to assign a control value to each parameter. A control value of zero for each parameter was used in this analysis. The next step was to assign a rank by ascending order to each value by parameter, including the control value. Tied ranks within a given parameter were split by assigning each replicate value the mean rank of that group. The rank variance for each parameter was obtained using the following equation:

$$\text{Variance}(R_i) = \frac{1}{12n}\left((n^3 - n) - \sum_{j=i}^{k} (t_j^3 - t_j)\right) \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where

$i = 1, 2 \ldots\ldots, p$

$j = 1, 2 \ldots\ldots, k$

where

n = the number of observations, including controls,

p = the number of parameters used,

k = the number of groups of ties,

t_j = the number of observations in the jth group of ties.

$$PNI = \sum_{i=1}^{p} (R_i - R_c)^2 \ / \ \text{Variance}(R_i)) \quad \ldots\ldots\ldots\ldots\ldots\ldots (2)$$

where

R_i = the rank of the observation

R_c = the rank of the control

All other notation is the same as above. The minimum value of PNI possible is zero and the maximum value is p times 12 which was 36 for this analysis.

The values of PNI calculated using the method described above are initial values. Their data base is presented in Appendix 8-15.

The method used to calculate the initial PNI values limits the use of PNI as a water quality index because, for a given sample, the PNI value will change when the data base is altered. This problem can be eliminated by developing a multiple regression model of the initial PNI values. Since the data base used in calculating the initial PNI values consisted of 3574 sets of data from various Gulf Coast estuaries and rivers with varying water qualities, the multiple regression model can be used to calculate an index value for any set of data. The equation for the model is:

$$PNI = 20.601 + 3.995\ (\text{Ln } P) + 6.062\ (\text{Ln } C) + 3.451\ (\text{Ln } N) \quad \ldots\ldots 3$$

with the limits

If PNI < 0.0 then PNI = 0.0
If PNI > 36.0 then PNI = 36.0

where PNI = Principal Nutrient Index value
P = total phosphorus concentration - mg/l as P
C = total organic carbon concentration - mg/l as C
N = total nitrogen concentration - mg/l as N

The multiple correlation coefficient for the model was 0.88, indicating it provided a good fit of the data. The standard partial regression coefficients were 0.49, 0.45, and 0.38 for total phosphorus, total nitrogen, and total organic carbon, respectively, indicating each parameter has about the same influence on PNI. In addition, for the data base described in Appendix 8-15, the cumulative frequency distributions for the initial PNI values and for values of PNI calculated from Equation 3 were quite similar (Figure 8-24).

A PNI value representing a maximum allowable standard for acceptable water quality has been developed using values

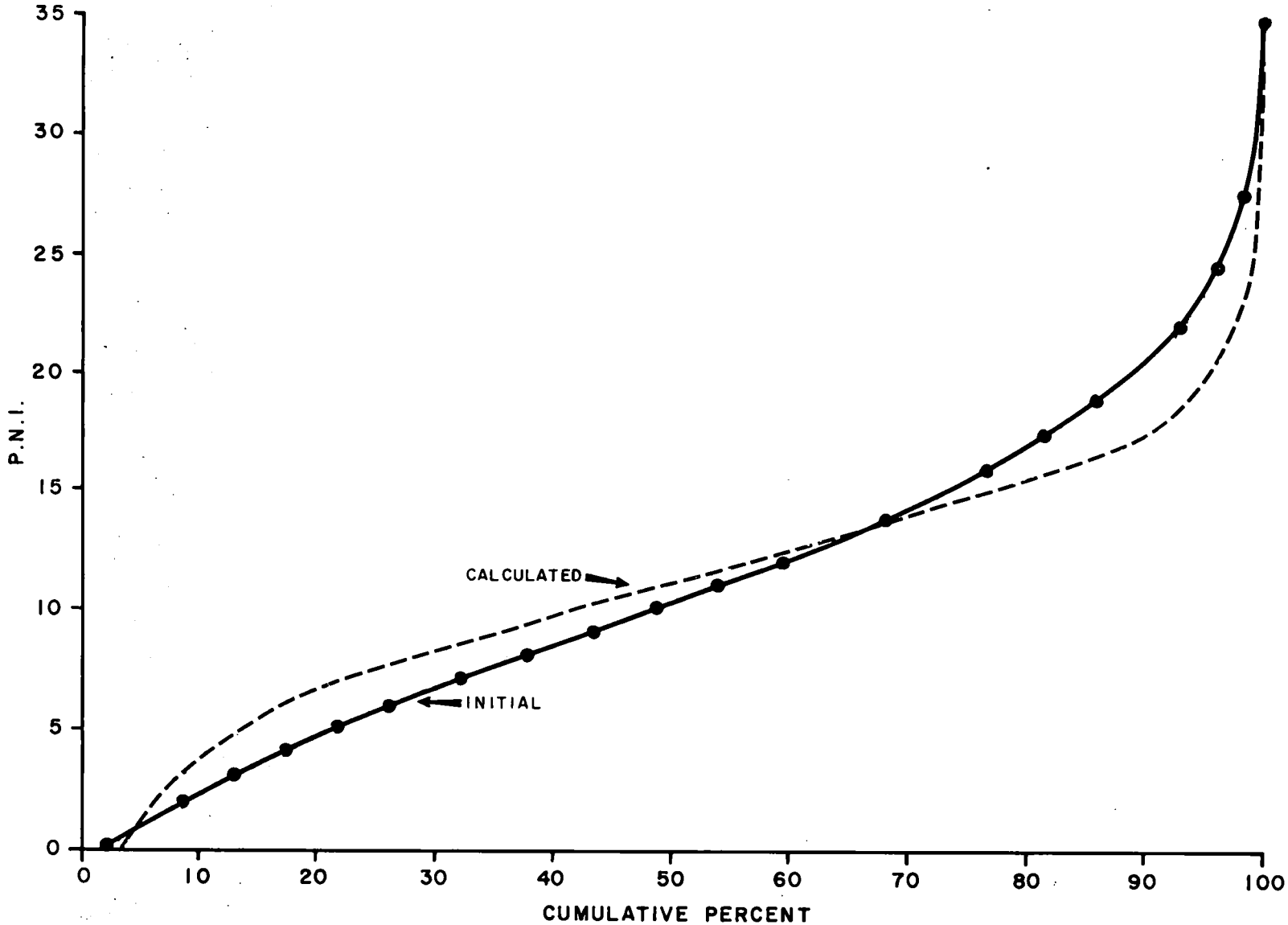


Figure 8-24. Cumulative frequency distribution of initial PNI values and PNI values calculated from multiple regression model.

suggested and the method used in Water Quality Criteria (1972). The Criteria recommend that available nitrogen and phosphorus in waste discharges should not increase the total nitrogen and phosphorus concentrations in the receiving waters above 0.36 and 0.05 mg/l, respectively, to avoid exhausting the oxygen content of the water during critical conditions. The nitrogen and phosphorus values presented above were derived from the work of Redfield, et al., (1963), who gave the following ratios as characteristics of the principal elements present in living marine plankton and the stoichoimetric relationship between these elements and oxygen.

O:	C:	N:	P:
276:	106:	16:	1 by atoms or
138:	40:	7.25:	1 by weight.

Based on the ratio above, the recommended carbon value was estimated to be 2.0 mg/l of total organic carbon.

Although the above concentrations are recommended for critical conditions, in reality, they are too high to be used as a maximum standard. These concentrations could produce enough organic material to reduce the dissolved oxygen concentration in the receiving waters to below the minimum standard of 4.0 mg/l during any flow and temperature conditions. Nevertheless, concentrations of 0.05 mg/l of total phosphorus, 0.36 mg/l of total nitrogen, and 2.0 mg/l of total organic carbon were used to determine a standard PNI value; however, it should be understood that this value is high and problems could occur at lower PNI values. The standard PNI value calculated using Equation 3 was 9.3; to simplify matters, a PNI value of 9.0 will be used as a standard to distinguish between excessive nutrient enrichment and acceptable aquatic conditions with respect to nutrients.

Results and Discussion

Mean PNI values in Escambia Bay during September 23 through September 25, 1969 were generally much greater than the 9.0 standard (Figure 8-25). Mean surface values in northeast Escambia Bay (Stations E3 and E7) were higher than mean surface values at the mouth of the river. This appears due to the industrial discharges located in the northeast area of the bay.

The PNI values in the Pensacola Bay system during diel (24-hour) studies in April and August 1973 generally indicated Escambia Bay was the most nutrient-enriched component of the system (Table 8-15). Pensacola and East Bays had similar mean PNI values and were less nutrient-enriched than Escambia Bay. Mean surface and bottom PNI values in Escambia Bay during the high river inflow studies (I and II) were greater than values in the Escambia River (Station ER10), which tends to indicate resuspension of material from the sediments. During the low flow studies (III and IV), mean surface values in Escambia Bay were generally lower than mean values in the Escambia River (Station

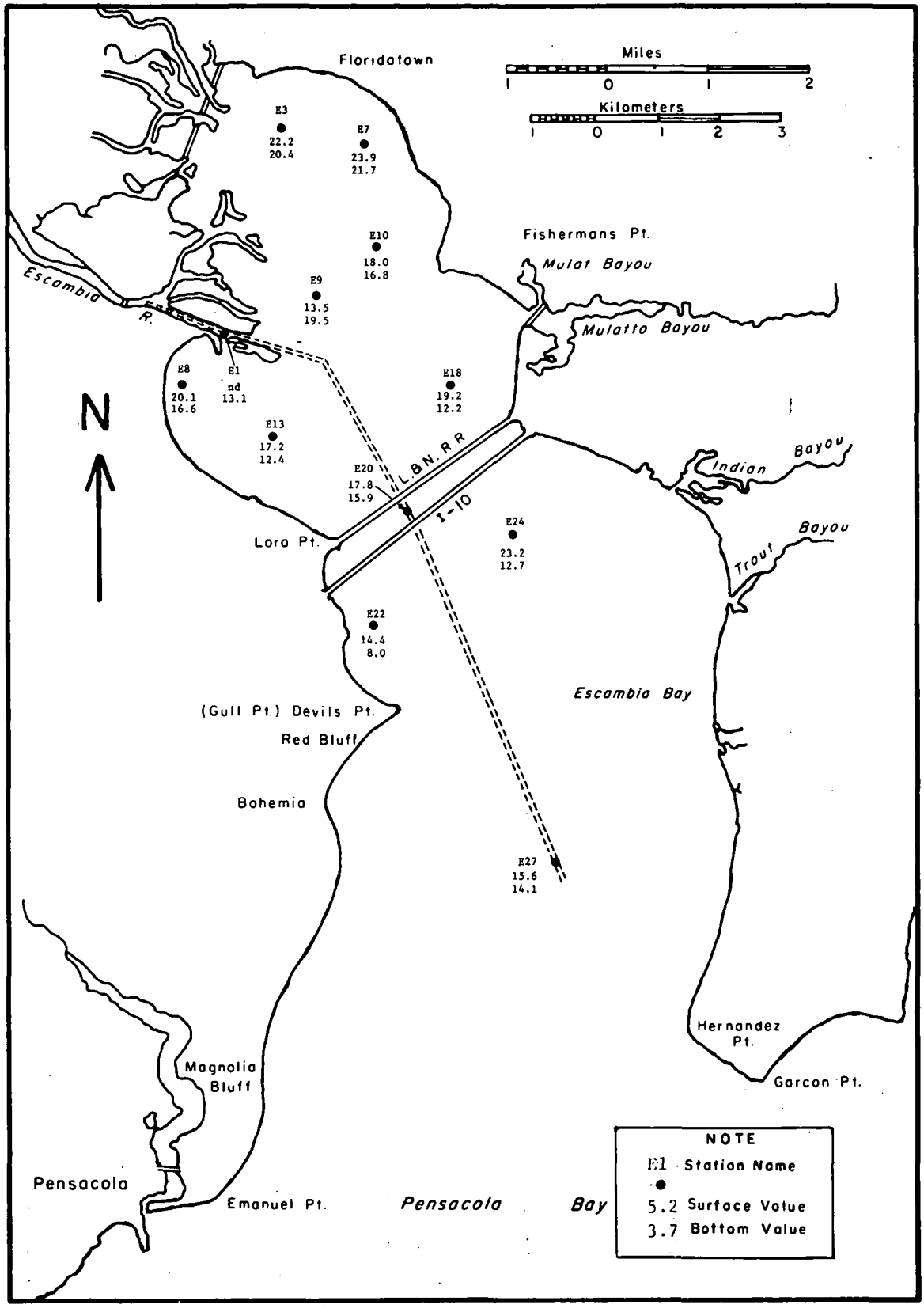


Figure 8-25. Mean surface and bottom PNI values for samples collected during September 23 to September 25, 1969 (USDI, 1970).

Table 8 - 15. Mean PNI values from pooled data for the Pensacola Bay system during studies in April (I and II) and August (III and IV). Number of observations are in parentheses.

Bay	Studies			
	I	II	III	IV
Escambia Bay				
Surface	18.4 (37)	22.9 (44)	18.0 (55)	10.8 (58)
Bottom	21.4 (34)	26.2 (44)	18.0 (52)	17.1 (60)
East Bay				
Surface	11.8 (11)	13.9 (11)	9.8 (12)	6.5 (12)
Bottom	15.3 (12)	18.4 (12)	14.9 (12)	15.3 (12)
Pensacola				
Surface	11.6 (21)	16.6 (24)	13.2 (24)	6.6 (24)
Bottom	15.4 (21)	19.1 (24)	10.0 (24)	5.7 (24)
Escambia River				
Surface	15.1 (3)	19.1 (4)	19.4 (4)	13.7 (4)
Bottom	20.9 (4)	22.8 (4)	21.3 (3)	14.0 (4)

ER10), depicting normal dilution of river inflow by tidal mixing. In addition, mean bottom PNI values in Escambia and East Bays were higher than values in Escambia River inflow, again indicating resuspension of material from the sediments. Only mean surface values in East Bay and mean surface and bottom values in Pensacola Bay, during Study IV, were less than the 9.0 PNI standard.

The PNI values in the Escambia River (Station ER10) were highly correlated to the effective discharge of the Escambia River during January through September 1974 ($r = 0.74$, $df = 11$, $p < 0.05$). Thus, high PNI values occurred when river discharge was high and lower values occurred during low flow periods (Figure 8-26).

The mean PNI value for each bay of the Pensacola Bay system during each 1974 sampling date followed the trend of river discharge (Figure 8-27). High river discharges in the spring caused high mean PNI values in the bays, and conversely, low river discharges caused low PNI values in the bays.

Mean PNI values in Escambia Bay during the 1974 studies generally decreased in a seaward direction (Figure 8-28). There was no increase in PNI downstream of the Monsanto Corporation Plant discharge. In the northeast area of the bay, (Stations EEKV and EGLY) the mean PNI values were about 13 percent higher than values near the mouth of the river, indicating enrichment due to waste discharges in this area. Mean PNI values in Mulatto Bayou were higher than those in Escambia Bay, indicating enrichment in the bayou.

Mean surface and bottom PNI values were similar throughout Blackwater and East Bays and no pattern was evident (Figure 8-28).

In Pensacola Bay, the highest surface mean PNI value occurred near the outfall of the Main Street STP (Station P07) (Figure 8-28). In fact, surface PNI values during all 1974 studies were highest at this location. Mean PNI values generally decreased in a seaward direction. The surface mean value near the Pensacola Beach bridge (Station P04) was considerably higher than the value at the nearest station in Pensacola Bay (P03). This was probably due to discharges from the Gulf Breeze and Pensacola Beach Sewage Treatment Plants, which are located near the bridge.

No pattern of PNI values was observed during the water quality study performed in Choctawhatchee Bay on September 12, 1974 (Figure 8-29). The estimated effective discharge of the Choctawhatchee River was about 120 m^3/sec (4,223 cfs), or about 61 percent of the mean annual flow of 198 m^3/sec (6,981 cfs) during the study.

The water quality of the Pensacola Bay system was evaluated by comparing the PNI values to the standard value of 9.0 (Table

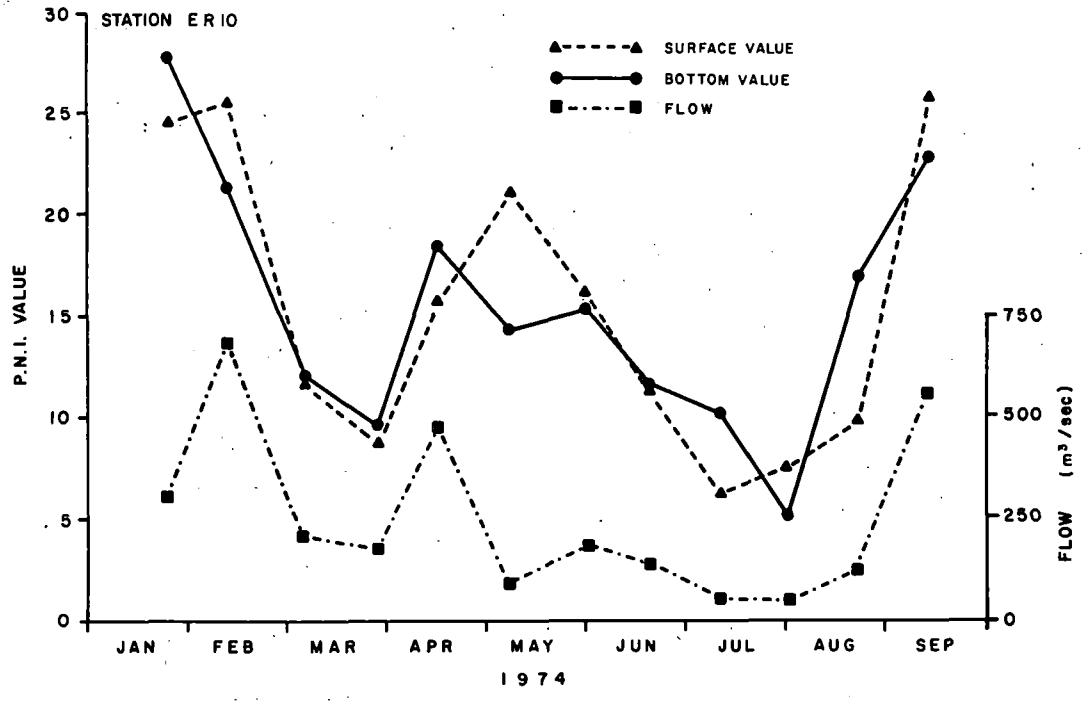


Figure 8-26. PNI values at Station ER10 during the 1974 water quality studies.

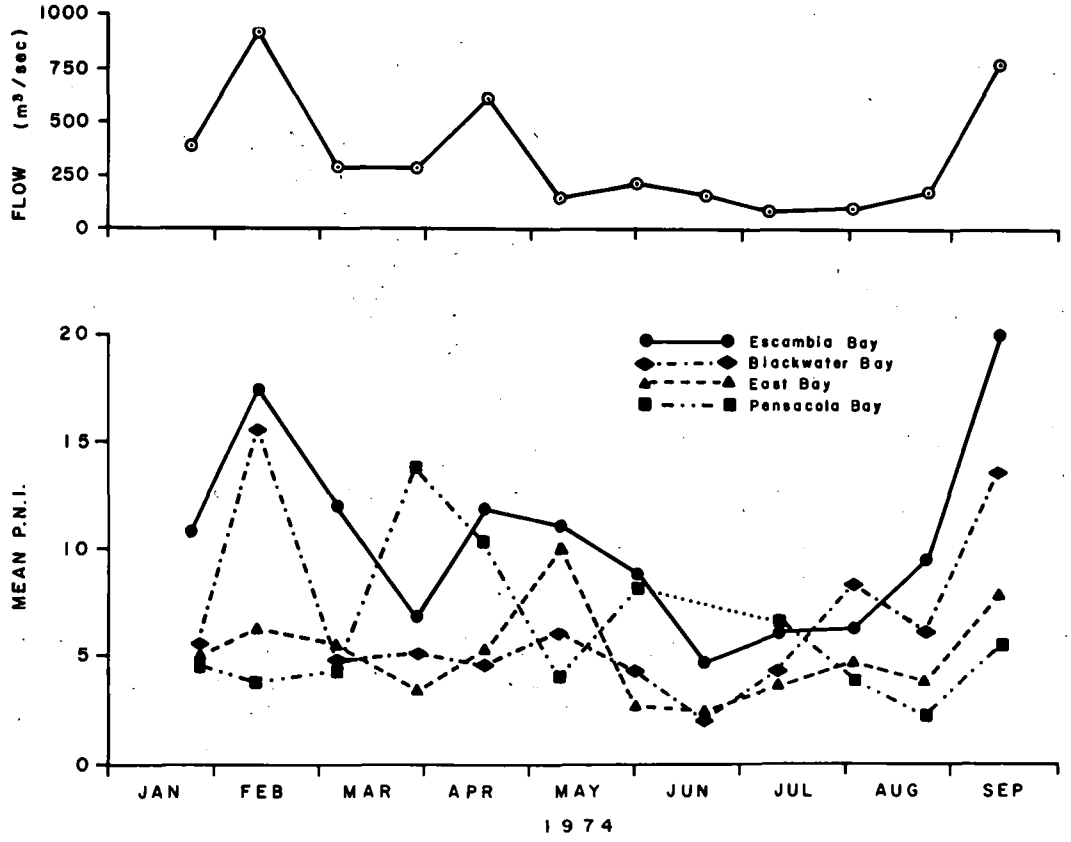


Figure 8-27. Mean PNI values in the components of the Pensacola Bay system during the 1974 water quality studies.

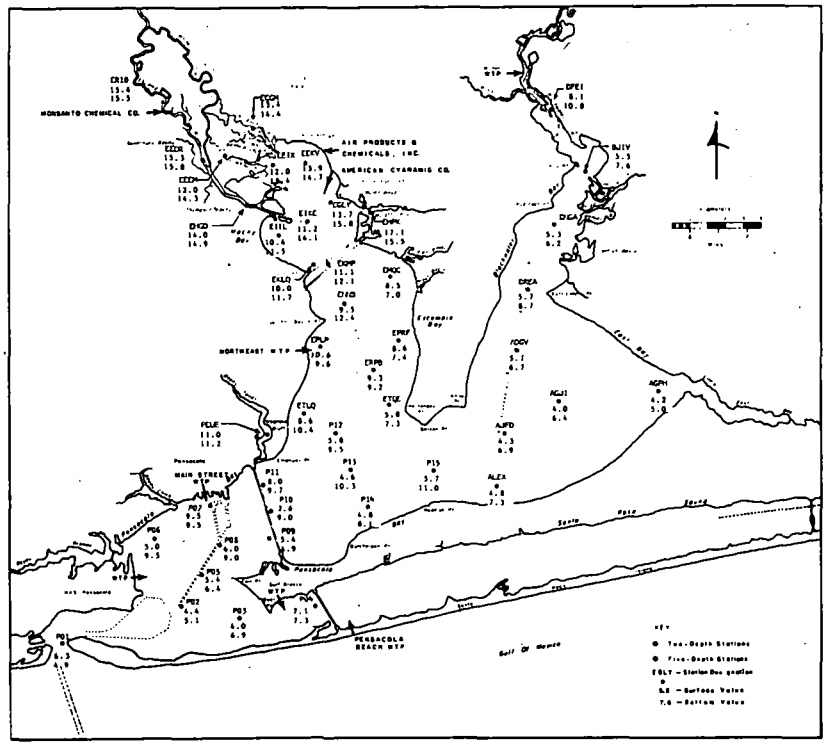


Figure 8-28. Mean PNI values in the Pensacola Bay system at stations sampled during the 1974 water quality studies (Pensacola Bay data from the University of West Florida).

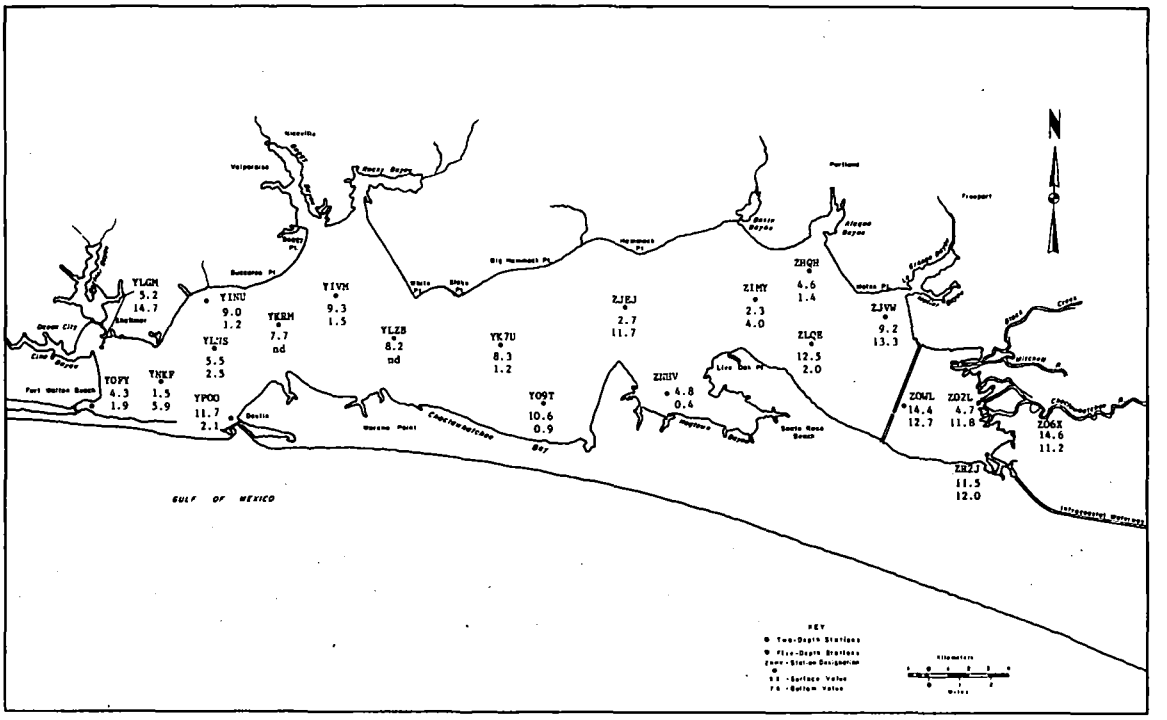


Figure 8-29. Surface and bottom values of PNI in Choctawhatchee Bay on September 12, 1974.

8-16). (The bays should only be compared within study periods - columns on Table 8-16 - because sampling frequency and station locations differed during the various study periods). During September 1969, 91.0 percent of the PNI values were greater than 9.0, indicating nutrient enriched conditions in the bay. In 1973, about twice the percent of PNI values exceeded 9.0 in Escambia Bay than in East Bay. The percent of PNI values that exceeded 9.0 was greater in Pensacola Bay than in East Bay during 1973. Escambia Bay had PNI values during the 1974 studies that exceeded 9.0 in more than 50 percent of the samples, indicating that nutrient-enriched conditions existed more than half of the time. Pensacola and Blackwater Bays had nutrient-enriched conditions during slightly less than 25 percent of the sampling times in 1974. East Bay had the least amount of nutrient enrichment during January through September 1974. Values of PNI in Choctawhatchee Bay indicated that the potential for problems existed, since 28.7 percent of the samples exceeded a PNI value of 9.0.

The water quality of the Pensacola Bay system and Choctawhatchee Bay was also evaluated by comparing mean values (Table 8-17). In order to reduce the fluctuation of PNI values due to changing environmental conditions in the Pensacola Bay system, all PNI data collected in the system from March through August 1974 were pooled and compared to Choctawhatchee Bay PNI data collected during September 1974. Statistical tests indicated that the mean PNI values in Escambia and East Bays were higher and lower, respectively, than the mean in Choctawhatchee Bay, and that the hypothesis that the mean PNI values in Blackwater and Pensacola Bays are equal to the mean value of PNI in Choctawhatchee Bay cannot be rejected. It was assumed in this analysis that the PNI values during September 1974 in Choctawhatchee Bay were representative of summer PNI values. Nutrient enrichment in Escambia Bay was greater than in Choctawhatchee Bay, and nutrient enrichment in East Bay was less than in Choctawhatchee Bay. The nutrient enrichment in Blackwater and Pensacola Bays was not statistically different from that in Choctawhatchee Bay.

Values of PNI in upper Escambia Bay during a two-day diurnal (24-hour) study in September 1969 were statistically compared to values during 1973 and 1974 with comparable river inflows (Table 8-18). Although the 1969 study period was limited, PNI values at that time were always higher than those during the periods of 1973 and 1974. Thus, nutrient enrichment in Escambia Bay has decreased between 1969 and 1974.

Gulf Coast estuaries outside the Pensacola Bay system were included in the PNI data base in order to further evaluate the water quality of the Pensacola Bay system. These estuaries were Perdido Bay, Florida-Alabama, sampled during June 1972 (USEPA, 1972), and Bayou Casotte and Escatawpa River, Mississippi, sampled in July 1972 (Environmental Protection Agency, Athens, Georgia, unpublished data). The evaluation indicated that

Table 8 - 16. Percent of PNI values greater than or equal to 9.0 for the Pensacola Bay system and Choctawhatchee Bay.

Bay	Date		
	September 1969	1973 (1)	January to September 1974
Escambia	91.3	81.4	53.3
East	-	43.8	13.6
Blackwater	-	-	24.1
Pensacola	-	62.4	22.5
Choctawhatchee	-	-	28.7 (2)

(1) Includes surface and bottom values during EBRS diel studies in April and August, 1973, and surface values for UWF biweekly studies.

(2) Values from September 12, 1974 study.

Table 8 - 17. Statistical comparison of mean PNI values in the Pensacola Bay system during studies performed in May through August 1974, with Choctawhatchee Bay on September 12, 1974.

Bay	Mean PNI Value	Calculated t	Degrees of Freedom
Choctawhatchee	6.3	-	-
Escambia	9.8	4.83 (1)	356
East	4.6	2.17 (2)	125
Blackwater	5.3	0.97 (3)	90
Pensacola	5.6	0.94 (3)	221

(1) The hypothesis that the mean PNI in Escambia Bay is greater than that in Choctawhatchee Bay can be accepted with greater than 99 percent confidence.

(2) The hypothesis that the mean PNI in East Bay is less than that in Choctawhatchee Bay can be accepted with greater than 95 percent confidence.

(3) The hypothesis that the mean PNI value of the bays compared are equal can not be rejected.

Table 8 - 18. Statistical comparison of mean PNI values in upper Escambia Bay during September 1969 and given dates in 1973 and 1974.

Date	Mean PNI Value	Change in mean PNI from 1969 (percent)	Percent of 1969 flow	Calculated t	Degrees of Freedom
September 23-25,1969 (3)	17.9	-	-	-	-
August 23-25,1973 (4)	14.9	-17	92	3.32 (2)	106
May 5,1974 (4)	11.2	-37	86	7.15 (2)	49
June 18,1974 (4)	3.7	-79	95	18.40 (2)	71
August 20,1974 (4)	10.7	-40	111	5.58 (2)	78
Summer 1974 (1) (4)	10.6	-41	89	9.00 (2)	177

(1) Mean for studies performed during May through August 1974.

(2) The hypothesis that the mean PNI values on the given dates were less than that in September 1969 can be accepted with greater than 99 percent confidence.

(3) Pooled data stations E1,E3,E7,E9,E10,E18, and E20.

(4) Pooled data stations EEIX,EEKV,EIIL,EKLQ,EIKC,EKMP, and EGLY.

Table 8 - 19. Statistical comparison of mean PNI values in Escambia Bay with other Gulf Coast estuaries.

Estuary	Date	Mean PNI value	Calculated t	Degrees of Freedom	Source
Escambia Bay	May through August 1974	9.8	-	-	EBRS
Perdido Bay	June 1972	9.9	0.17 (1)	389	USEPA, 1972
Bayou Cassotte	July 1972	30.5	17.74 (2)	330	USEPA
Escatawpa River	July 1972	20.8	9.95 (2)	335	USEPA

(1) The hypothesis that the mean PNI values in Escambia and Perdido Bays are equal can not be rejected.

(2) The hypothesis that the mean PNI values in the given estuaries are greater than that in Escambia Bay can be accepted with greater than 99 percent confidence.

Escambia Bay was considerably less nutrient-enriched than Bayou Casotte and the Escatawpa River (Table 8-19), two polluted Mississippi estuaries. The comparison between Escambia and Perdido Bays indicated that nutrient enrichment in these bays during the periods compared was statistically equal.

OXYGEN RESOURCES

Dissolved Oxygen

Introduction

Of all the chemical substances in natural waters, oxygen is one of the most significant as both a regulator of the metabolic processes of communities and organisms, and as an indicator of conditions (Reid, 1961). The dissolved oxygen concentration in waters may be affected by a number of factors.

1. Inflow of tributaries: Rivers discharging into Gulf Coast Estuaries usually flow through swampy areas that contribute water low in dissolved oxygen to the river, and in addition, they receive discharges from subsurface springs or seeps containing water low in dissolved oxygen. These tend to dilute dissolved oxygen concentration in the river before it enters the estuary.

2. Respiration of organics: Respiration of plants and animals while oxidizing organic matter utilizes dissolved oxygen. The organic material will be allochthonous (substances which originate outside of the system such as waste discharges or swamp drainage), and they will be autochthonous (substances originating in the estuary such as organism biomass or recycled material from the sediments). The effects of respiration are more conspicuous at night because they are masked by photosynthesis during the day.

3. Inorganic Reactions: Inorganic activities such as oxidation of iron may cause the loss of oxygen.

4. Photosynthesis: Phytoplankton and attached plants contribute significantly to the oxygen content of an estuary. Since sunlight is required for photosynthesis, oxygen is produced in this manner during daylight hours causing diurnal variation in dissolved oxygen concentrations. Large diurnal fluctuation is an indication of poor conditions in the estuary.

5. Turbulance: Aeration of an estuary, an important source of oxygen, is a function of turbulence which is caused by tidal and river discharge currents and wind forces.

6. Temperature: The solubility of oxygen varies inversely with temperature. Thus, raising the water temperature could result in a loss of oxygen from the estuary. At the same time, an increase in temperature should increase the metabolic rates of the organisms within the estuary. This will increase the rate of both photosynthesis and respiration.

7. Salinity: The solubility of dissolved oxygen is also inversely proportional to the salinity of the water.

Results

Pensacola Bay System - 1974

Mean surface dissolved oxygen levels during January through September 1974 were usually near saturation at stations sampled in the Pensacola Bay system. (Figure 8-30 and 8-31; Appendix 8-16 and 8-17). The mean concentration in Escambia River water entering the bay (Station ER10) was 6.9 mg/l (77 percent of saturation) and the mean deficit was 2.0 mg/l. Mean surface concentrations near the Escambia River Delta (Stations EEIX, EIKC, and EIIL) were slightly greater than 7.0 mg/l, or 80 to 100 percent of saturation. In the remainder of Escambia Bay, mean surface concentrations were slightly greater than 8.0 mg/l, or 100 percent of saturation. Mean surface dissolved oxygen concentrations in East and Blackwater Bays were at similar levels to those in Escambia Bay.

Mean bottom dissolved oxygen concentrations, during January through September 1974, were lower at deeper stations. The mean bottom concentration at a shallow station in upper Escambia Bay (EEKV; mean sampling depth 1.4 m) was 5.7 mg/l and the mean concentration at a deep station in the lower bay (ETLQ; mean sampling depth 4.0 m) was 3.4 mg/l. Mean bottom concentrations in East and Blackwater Bays were again at similar levels to those in Escambia Bay.

Mean surface dissolved oxygen concentrations in Escambia and East Bays, pooled by bay for each survey during the 1974 study period, steadily declined from near 9.0 mg/l in February to about 6.0 mg/l in September (Figure 8-32). Percent of dissolved oxygen saturation for the same period actually increased slightly (Figure 8-33), indicating that the reduction in mean surface concentration was due to increased temperature and salinity. Mean surface dissolved oxygen concentrations in Escambia and East Bays during each study in 1974 were within one mg/l of each other and followed a similar trend throughout the year.

During each study, pooled mean bottom dissolved oxygen concentrations were usually lower than surface concentrations. Mean bottom dissolved oxygen concentrations were usually lower in East Bay than in Escambia Bay during the studies performed from

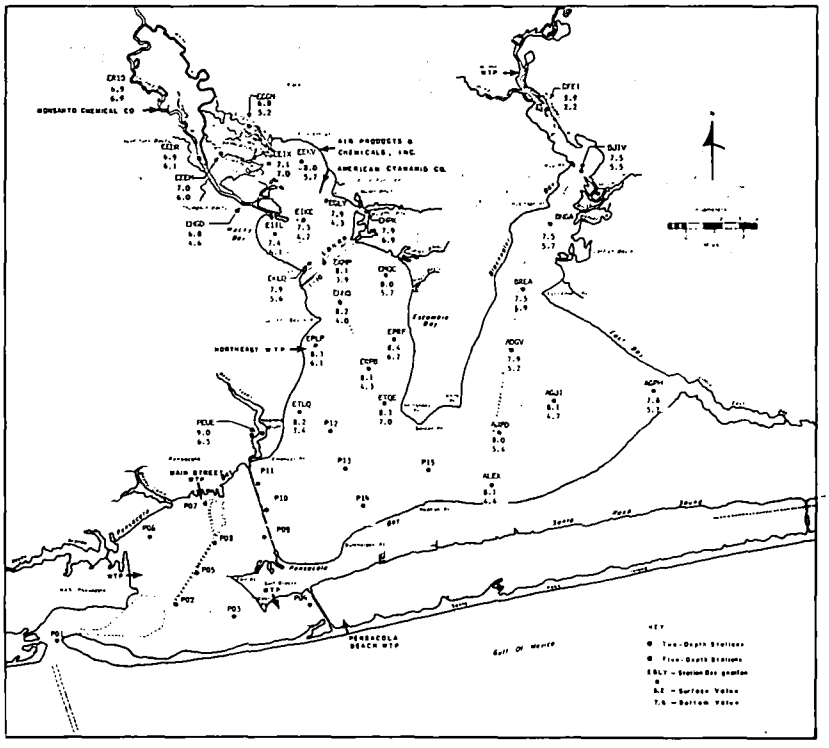


Figure 8-30. Mean dissolved oxygen concentrations (mg/l) in the Pensacola Bay system during January through September, 1974.

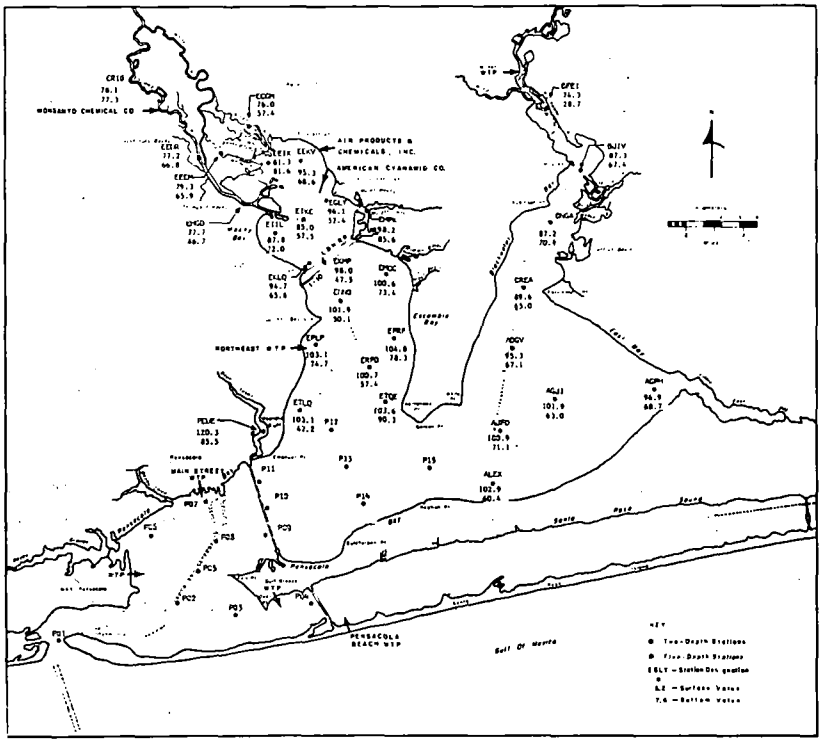


Figure 8-31. Mean values of percent dissolved oxygen saturation in the Pensacola Bay system during January through September, 1974.

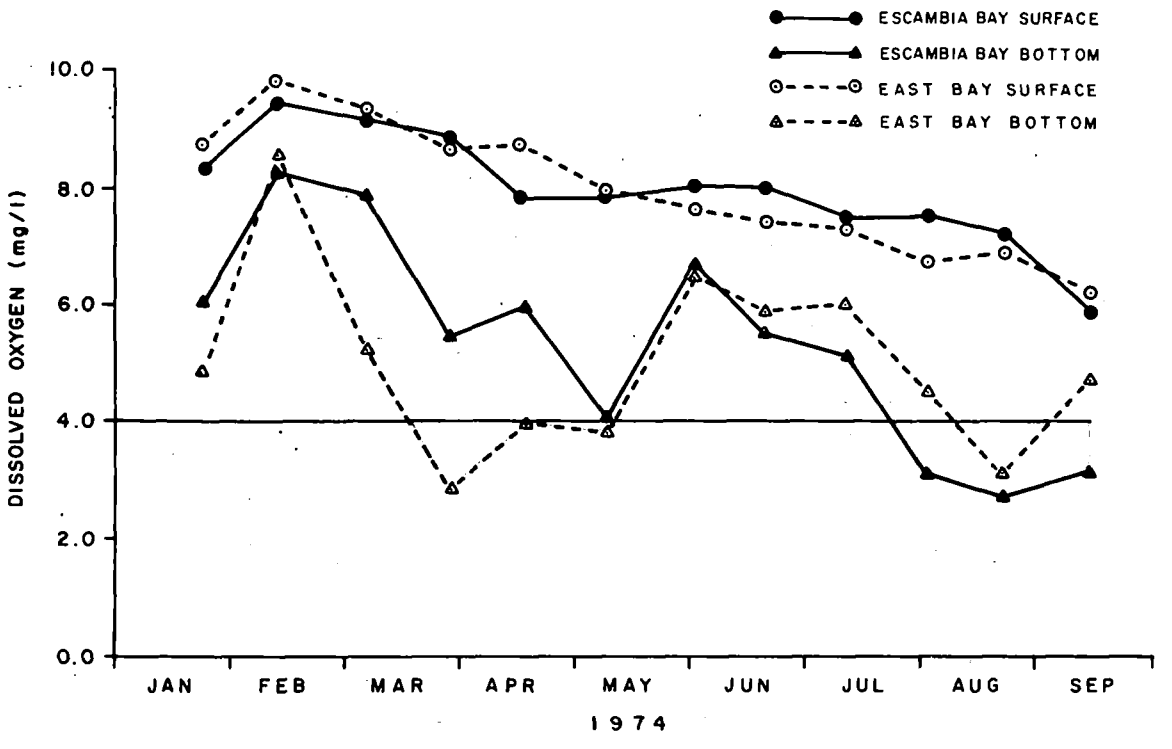


Figure 8-32. Mean dissolved oxygen concentrations in Escambia and East Bays during each study performed in January through September, 1974.

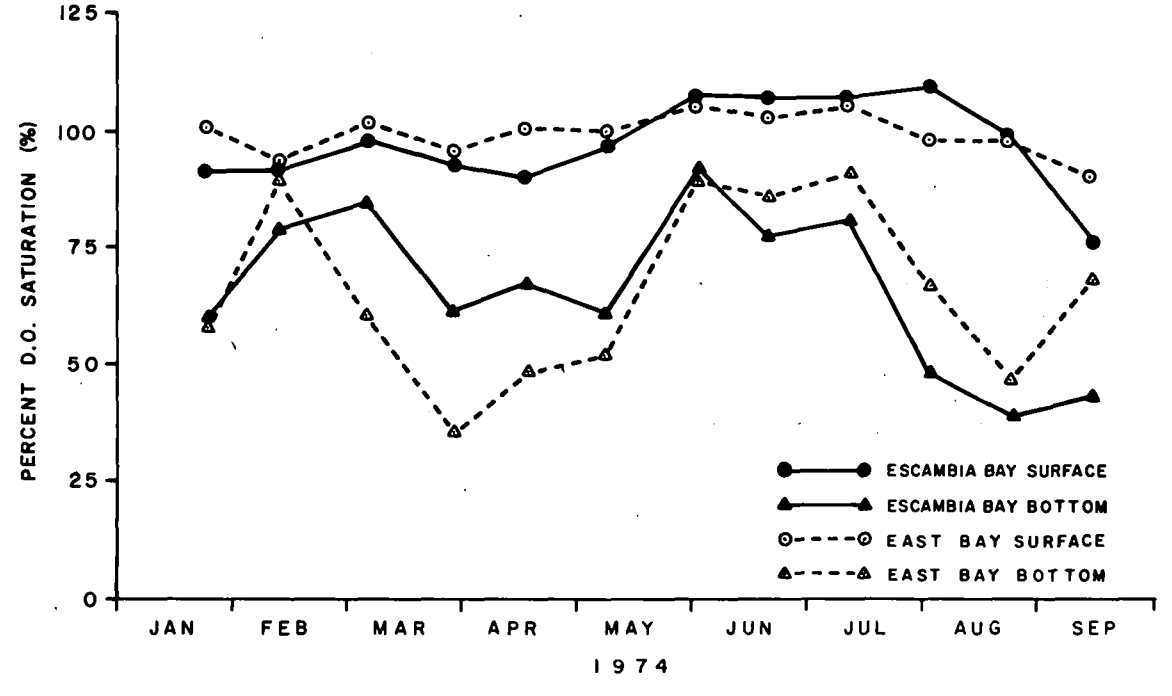


Figure 8-33. Mean values of percent dissolved oxygen saturation in Escambia and East Bays during each study performed in January through September, 1974.

January through May 1974, and higher during all studies after May 1974 (Figure 8-32). Two periods of low bottom dissolved oxygen concentrations occurred during the 1974 study period, one in spring and one in late summer.

Surface dissolved oxygen concentrations were rarely less than 4.0 mg/l (the minimum level allowable in Class II and III waters; see Appendix 8-6) in Escambia and East Bays during the 1974 studies, and bottom concentrations were often below this level (Table 8-20). No surface dissolved oxygen concentrations less than 4.0 mg/l occurred in East Bay and only 1.7 percent of the surface concentrations in Escambia Bay were less than 4.0 mg/l. In East and Escambia Bays, 31.7 and 31.2 percent of the bottom dissolved oxygen measurements, respectively, were less than 4.0 mg/l. Of all the bottom dissolved oxygen samples with concentrations less than 4.0 mg/l collected from Escambia Bay (31.2 percent of the total), 3.8 percent of the total were collected from the bottom of the dredged channel at times when the concentrations at the depth of the natural bottom were greater than 4.0 mg/l. Thus, low dissolved oxygen concentrations occurred throughout the bottom of the bay, and not just in the dredged channel.

A chronological examination of dissolved oxygen concentrations at selected stations indicated there was an inverse correlation between dissolved oxygen and salinity (Figure 8-34). In the freshwater reach of the lower Escambia River (Station ER10), dissolved oxygen concentrations were always above 5.2 mg/l. In central northeast Escambia Bay (Station EEKV; mean sampling depth, 1.4 m), the bottom concentrations were only lower than the 4.0 mg/l minimum standard on three occasions. On the other hand, near the American Cyanamid plant discharge (Station EGLY, mean sampling depth, 2.0 m), bottom dissolved oxygen concentrations were less than 4.0 mg/l in seven of the eleven samples collected. At the entrance to the Escambia Bay channel, (Station ERPB; mean sampling depth, 3.2 m) the bottom dissolved

Table 8 - 20. Frequency distribution of dissolved oxygen concentrations in Escambia and East Bays during January through September, 1974.

Bay	Depth	Number of Observations	% less than 4 mg/l
East Bay	Surface	60	0
	Bottom	60	31.7
Escambia Bay	Surface	240	1.7
	Bottom	240	31.2

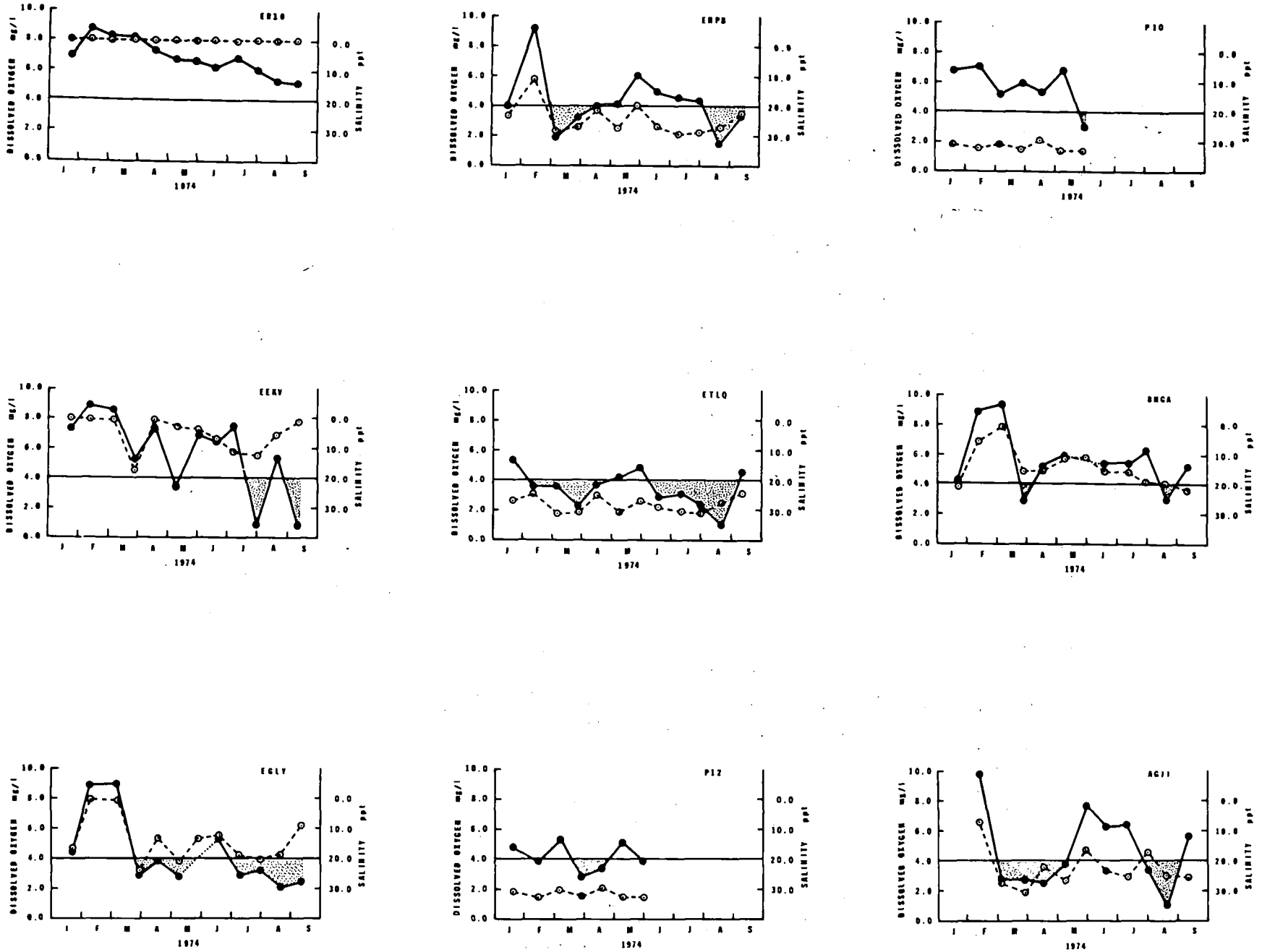


Figure 8-34. Bottom dissolved oxygen and salinity levels during January through September, 1974 at selected stations in the Pensacola Bay system. (Pensacola Bay data from the University of West Florida).

oxygen concentration was only lower than 4.0 mg/l in four of the 12 studies performed during 1974 as shown in Figure 8-34. At the deepest station in lower Escambia Bay (ETLQ; mean sampling depth, 4.0 m) concentrations were below 4.0 mg/l in eight of the 12 samples collected. Dissolved oxygen concentrations of less than 4.0 mg/l occurred during late winter, early spring, and during the entire summer.

University of West Florida (UWF) dissolved oxygen data from Pensacola Bay were compared to Escambia Bay Recovery Study (EBRS) data collected in East, Blackwater, and Escambia Bays. A Delta Scientific dissolved oxygen probe was used for this analysis by UWF while the EBRS used the modified Winkler titration method. Dissolved oxygen concentrations at Stations ETLQ (EBRS) and P12 (UWF), which are 2.7 km (1.7 mi) apart, were strongly correlated during the January 23 through May 29, 1974 studies ($r = 0.96$, $df = 12$, $p < 0.01$). After this study date, there was no correlation between data at the two stations. This indicated that the dissolved oxygen probe was not operating properly after May 29, 1974. Bottom dissolved oxygen samples collected, between January 23, and May 29, 1974, at Station ETLQ in Escambia Bay and Station P10 in Pensacola Bay, showed that the bottom dissolved oxygen concentration at Station ETLQ was consistantly lower than those at P10, indicating that a bottom water mass from Pensacola Bay did not cause low dissolved oxygen concentrations in Escambia Bay during the spring. Figure 8-34 depicts bottom dissolved oxygen concentrations at Stations P12 (mean sampling depth, 5.1 m) and P10 (mean sampling depth 8.4 m).

Bottom dissolved oxygen concentrations were also less than 4.0 mg/l in early spring and late summer in East Bay (Station AGJI; mean sampling depth, 3.0 m) and in Blackwater Bay (Station BNGA; mean sampling depth 2.1 m) (Figure 8-34).

Pensacola Bay System - 1973

Dissolved oxygen concentrations were measured every three hours during diel (24-hour) water quality studies performed in 1973. Studies during both tropic and equatorial tidal cycles were performed during high and low river inflows (Table 8-21). Mean concentrations and percent of saturation at each station sampled are shown in Appendix 8-18.

Mean dissolved oxygen deficits in the Escambia River during each study were similar as shown below:

Study	Date (1973)	D.O. deficit (mg/l)
I	April 13-15	2.4
II	April 19-21	2.7
III	August 16-18	2.7
IV	August 23-25	2.8

Table 8 - 21. Dates of and environmental conditions during the 1973 diel water quality studies.

Study	Dates	Tide Range m	River Inflow m^3 /sec
I	April 13 - 15	0.1	1697
II	April 19 - 21	0.6	757
III	August 16 - 18	0.2	286
IV	August 23 - 25	0.6	208

Table 8 - 22. Frequency of dissolved oxygen concentrations less than 4.0 mg/l during Studies III and IV. (August, 1973).

		STUDY III		STUDY IV	
Bay	Depth	No. of Obs.	% less than 4.0 mg/l	No. of Obs.	% less than 4.0 mg/l
Escambia	Surface	98	2.0	112	0.0
	Bottom	96	56.3	111	63.0
East	Surface	24	0.0	24	0.0
	Bottom	24	75.0	24	95.8
Pensacola	Surface	48	12.5	47	0.0
	Bottom	47	74.5	44	29.5
Gulf	Surface	7	14.3	8	0.0
	Bottom	7	14.3	6	0.0

There were high dissolved oxygen concentrations in the Pensacola Bay system during Study I. Mean surface and bottom concentrations in Escambia Bay ranged between 80 and 90 percent of saturation. Because river discharge was extremely high during this study, Escambia Bay was essentially fresh and there was no vertical stratification. In East Bay, mean surface and bottom dissolved oxygen concentrations were all above 7.0 mg/l, or 75 percent of saturation. Mean surface dissolved oxygen concentrations in Pensacola Bay were all near 90 percent of saturation, and mean bottom concentrations were slightly below 7.0 mg/l, or 80 percent of saturation. No samples collected during this study had dissolved oxygen concentrations less than 4.0 mg/l.

During Study II, dissolved oxygen concentrations were essentially the same as those during Study I. Only one sample collected during this study had a dissolved oxygen concentration less than 4.0 mg/l, and this occurred in upper East Bay (Station ADGV).

During Study III, when the river inflow was about the average annual flow, dissolved oxygen concentrations were lower than those in April 1973. In upper Escambia Bay near the Escambia River delta, mean surface concentrations were 6.0 mg/l, or 75 percent of saturation. In the lower bay, concentrations were near 8.0 mg/l. Two percent of the surface samples collected in Escambia Bay had concentrations of less than 4.0 mg/l (Table 8-22). Mean bottom concentrations in the dredged channel were all less than 2.0 mg/l. Throughout the rest of the bay mean bottom concentrations ranged between 2.1 and 6.3 mg/l, or 36 and 97 percent of saturation. Fifty-six percent of the bottom samples collected in Escambia Bay had concentrations of less than 4.0 mg/l (Table 8-22).

In East Bay, during Study III, all mean surface concentrations were near 100 percent of saturation. Conversely, mean bottom concentrations were extremely low, ranging between 1.4 and 2.7 mg/l or 22 and 43 percent of saturation, and 75 percent of all bottom samples were less than 4.0 mg/l.

In Pensacola Bay, all mean surface concentrations during Study III were slightly greater than 100 percent of saturation and 12.5 percent of the surface samples contained less than 4.0 mg/l of dissolved oxygen (Table 8-22). Mean bottom concentrations varied from 5.0 mg/l at the inlet to 0.7 mg/l in the eastern portion of Pensacola Bay, and 74.5 percent of the bottom samples contained dissolved oxygen concentrations less than 4.0 mg/l.

Study IV was performed during tropic tides and low river inflow conditions and dissolved oxygen concentrations were lower in Escambia and East Bays, and higher in Pensacola Bay than during Study III. Mean surface concentrations in Escambia Bay ranged from 74 to 113 percent of saturation, and no surface

samples had concentrations below 4.0 mg/l (Table 8-22). Samples from stations at the channel bottom had mean concentrations ranging from 1.1 to 2.4 mg/l, and the rest of the bottom stations in Escambia Bay had mean concentrations ranging from 2.4 to 7.1 mg/l or 60 to 100 percent of saturation. Sixty-three percent of all bottom samples collected from Escambia Bay had dissolved oxygen concentrations less than 4.0 mg/l.

Dissolved oxygen concentrations in East Bay were generally lower during Study IV than during Study III. All mean surface concentrations were near 100 percent of saturation and no samples had concentrations less than 4.0 mg/l (Table 8-22). Mean bottom concentrations at stations in East Bay were extremely low, ranging from 20 to 31 percent of saturation, and 95.8 percent of all samples collected had concentrations less than 4.0 mg/l.

Dissolved oxygen concentrations in Pensacola Bay during Study IV were generally higher than those during Study III. Mean surface concentrations were all slightly greater than 100 percent of saturation, and mean bottom concentrations ranged between 43 and 101 percent of saturation. During this study, there were no surface samples with dissolved oxygen concentrations less than 4.0 mg/l (Table 8-22), and 29.5 percent of the bottom samples were less than 4.0 mg/l compared to 74.5 percent during Study III.

Dissolved oxygen concentrations near the bottom of Pensacola Bay were higher during Study IV than during Study III, and this appeared to have been due to tidal exchange. Since the bay was stratified, during these studies dissolved oxygen in the bottom water did not come from reaeration. Thus, the bottom water that existed in the bay seaward of the Pensacola Bay bridge during Study III was diluted by Gulf water transported into the bay by tropic tides (Table 8-22).

Large diurnal variations are an indications of stressed aquatic conditions. There were no large diurnal variations in dissolved oxygen concentrations in the Pensacola Bay system during Studies III and IV (Figure 8-35). Surface diurnal variations were always less than 2.0 mg/l. In northeast Escambia Bay and East Bay there were significant diurnal variations in bottom dissolved oxygen, but since benthic algae were not found in the system, this variation was due to changing tides and winds.

Escambia Bay - 1969

During a study of Escambia Bay on September 23-25, 1969 (USDI, 1970), mean surface dissolved oxygen concentrations were slightly greater than 5.0 mg/l adjacent to the Escambia River delta (Figure 8-36). Mean surface concentrations increased to greater than 8.4 mg/l near the L and N Railroad bridge, and then increased slightly in a seaward direction. Mean bottom dissolved oxygen concentrations of less than 4.0 mg/l occurred over 43

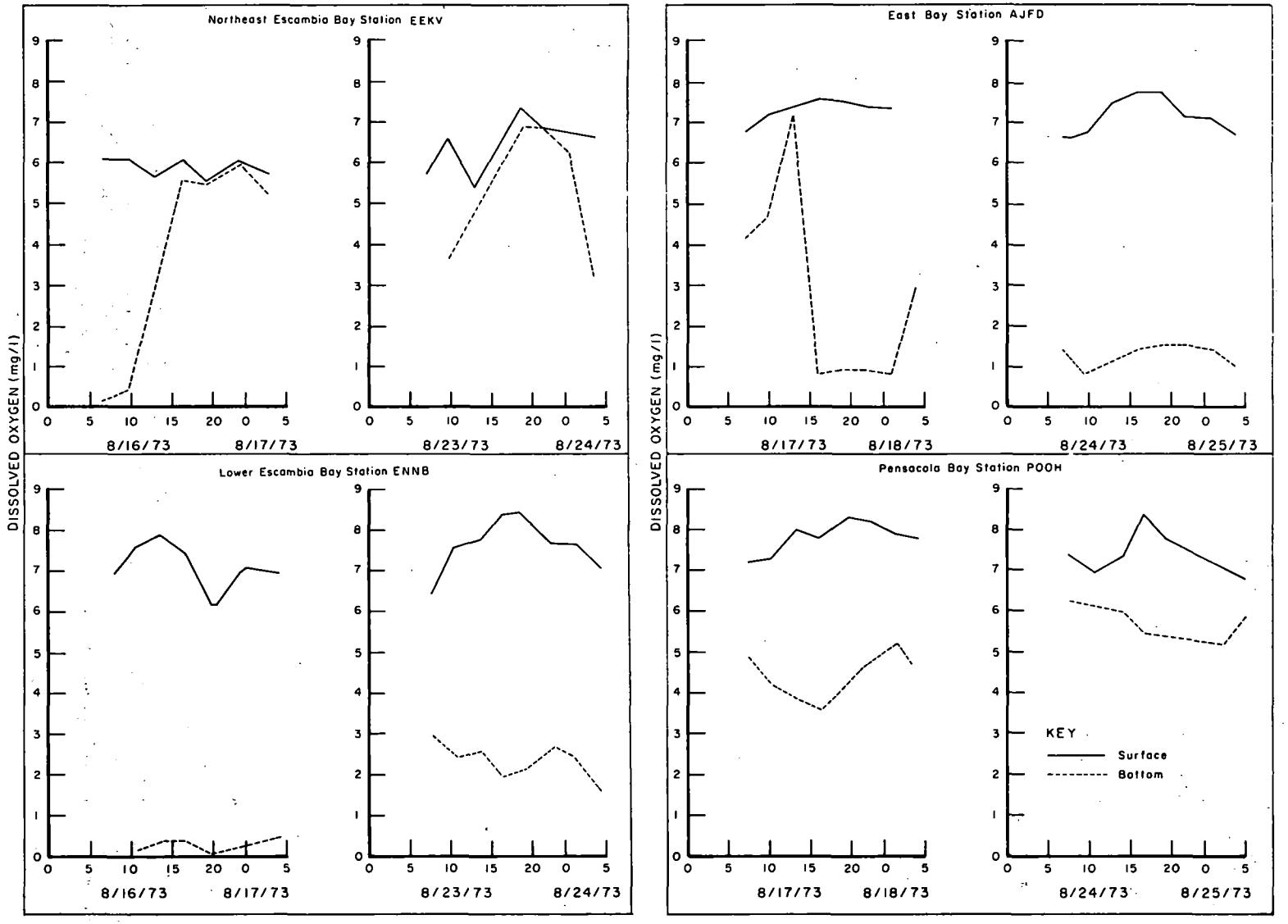


Figure 8-35. Dissolved oxygen concentrations during Studies III and IV (August 1973) for selected stations in the Pensacola Bay system (Pensacola Bay data from the University of West Florida).

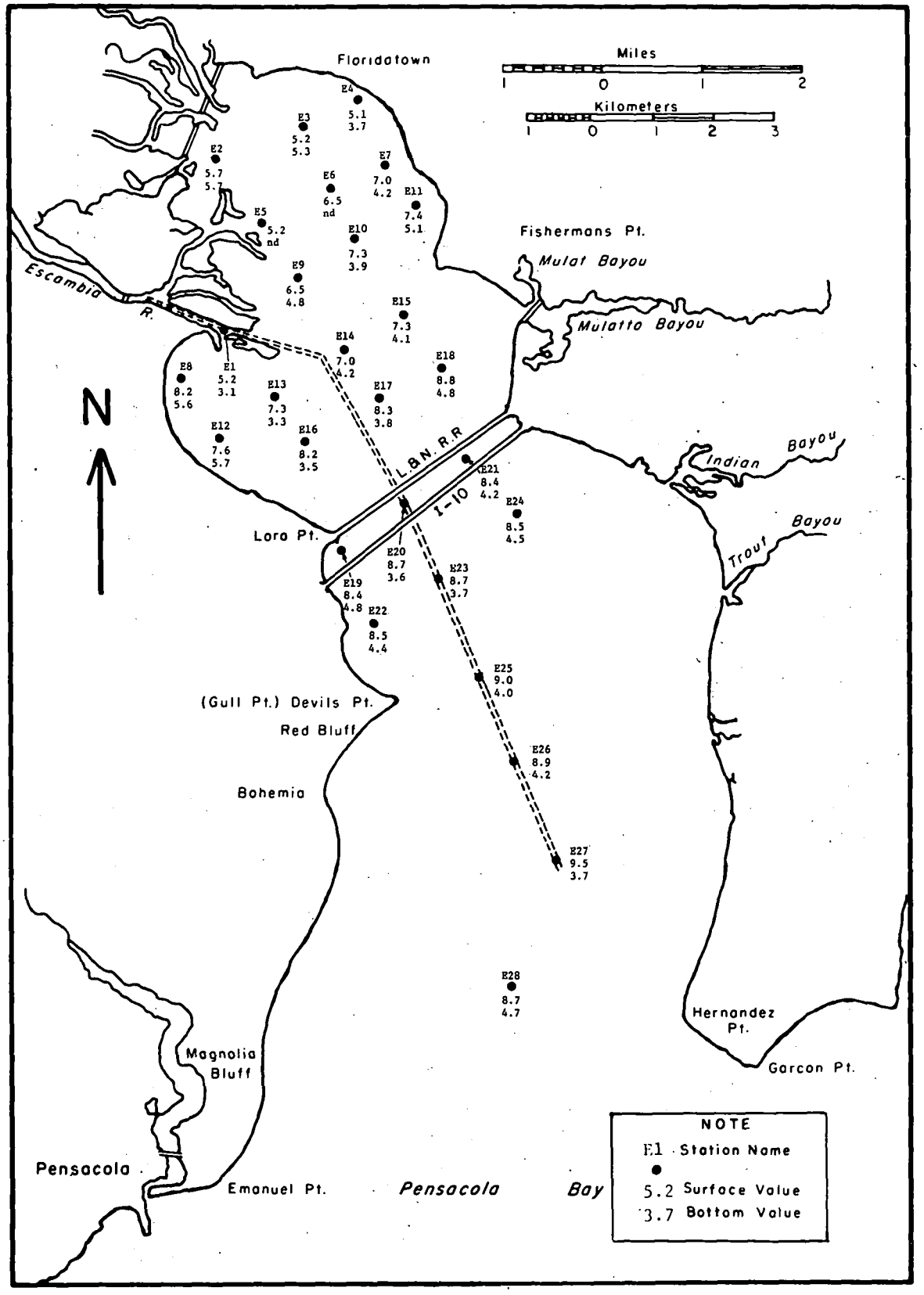


Figure 8-36. Mean surface and bottom dissolved oxygen concentrations in Escambia Bay during September 23 to September 25, 1969 (USDI, 1970).

percent of the area of the bay. This includes all of the central and northern sections of the bay, except for the shallow areas near the delta (USDI, 1970).

Large diurnal variations in dissolved oxygen, indicative of high phytoplankton concentrations, were observed in Escambia Bay during the 1969 study. In the northeastern area of the bay (Station E3), the range was 7.3 mg/l at the surface. The surface range in the central part of the upper bay (Station E9), in the eastern section of the upper bay (Station E18), and in the lower bay (Station E29) were 6.8, 6.8, and 3.5 mg/l, respectively. Large diurnal variations did not occur in August 1973.

Choctawhatchee Bay - 1974

Surface dissolved oxygen concentrations in Choctawhatchee Bay on September 12, 1975 were about 70 percent of saturation near the mouth of the Choctawhatchee River (Figure 8-37 and 8-38). Values increased to greater than 100 percent of saturation by mid-bay. The dissolved oxygen deficit in the Choctawhatchee River was 2.9 mg/l, which was similar to that in the Escambia River. Bottom dissolved oxygen concentrations were considerably lower than surface values, and nine of the 21 bottom samples analyzed (43 percent) were lower than the 4.0 mg/l minimum standard. Bottom dissolved oxygen concentrations were lowest in the deep center section of the bay, and bottom concentrations in this section ranged between 0.2 and 0.9 mg/l.

Discussion

Dissolved oxygen concentrations in Escambia Bay appeared to improve between 1969 and 1973 through 1974. The high diurnal variation in dissolved oxygen observed in 1969 was not observed in 1973. During the 1974 study period, there were two periods of low dissolved oxygen, one in the early spring and other in late summer. The period in early spring occurred after high river inflows and the one in summer occurred when salinities in the system were high, indicating poor flushing. During both periods, lower bottom dissolved oxygen concentration occurred near the industrial discharges in northeast Escambia Bay (Station EGLY). The data that was available for Pensacola Bay during 1974 indicated that low dissolved oxygen concentrations in Escambia and East Bays during the spring of 1974 were not caused by a water mass from Pensacola Bay entering these systems. Benthic oxygen demand from the sediments appeared to have been a significant factor in causing low bottom dissolved oxygen concentrations.

Vertical stratification in the system was observed in the salinity data and also in the dissolved oxygen data. Bottom dissolved oxygen concentrations were always lower than surface concentrations. This occurred because the dissolved oxygen removed from the lower layer by benthic demand was not

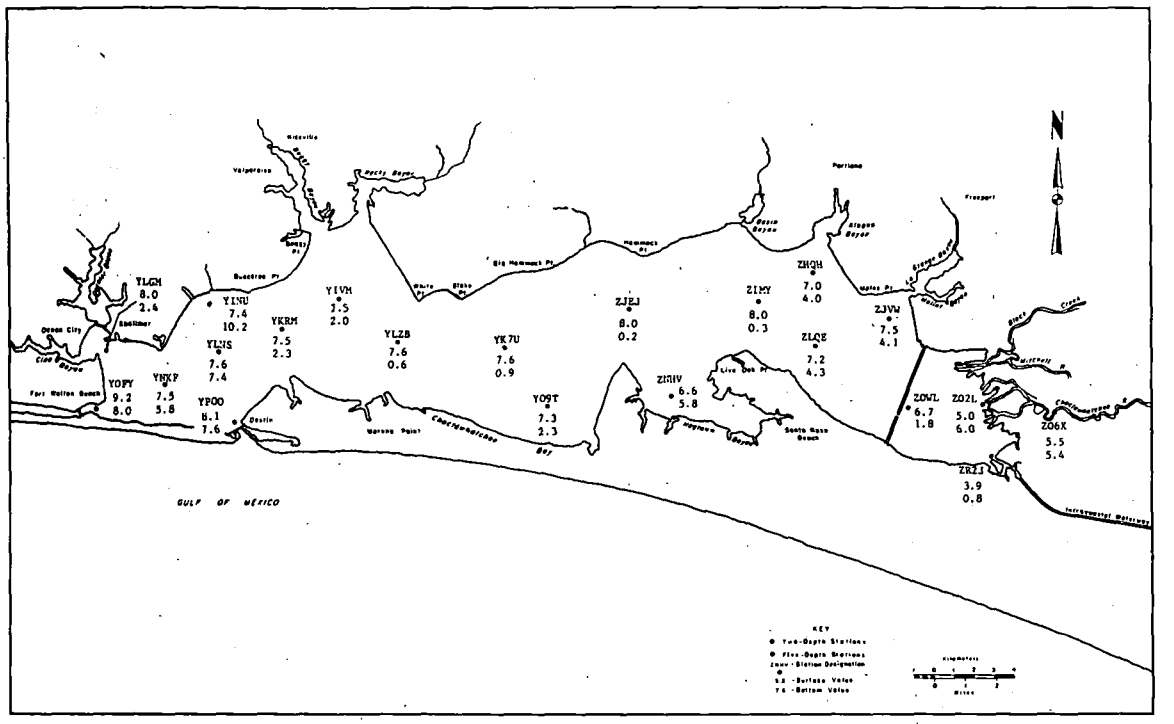


Figure 8-37. Dissolved oxygen concentrations in Choctawhatchee Bay on September 12, 1974.

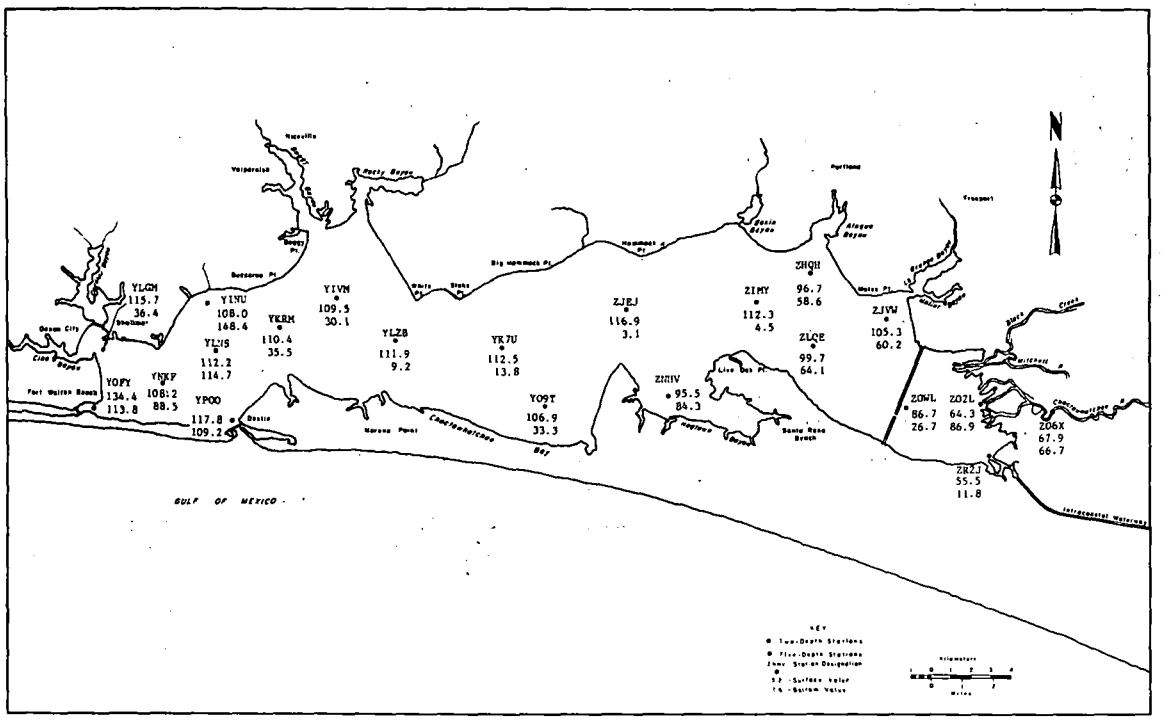


Figure 8-38. Values of percent dissolved oxygen saturation in Choctawhatchee Bay on September 12, 1974.

continuously replaced when the system was stratified, since there was very little exchange between reaerated upper layer water and lower layer water.

Based on dissolved oxygen concentrations in East Bay, low dissolved oxygen concentrations occur during critical periods (high temperatures, low river inflow) even in the bays that do not directly receive point source waste discharges. Consequently, due to naturally poor circulation in the Pensacola Bay system, the assimilative capacity of the system with respect to oxygen resources should be extremely limited.

Biochemical Oxygen Demand

Introduction

Biochemical Oxygen Demand (BOD) is the amount of oxygen used by bacteria while stabilizing biologically degradable material (Sawyer, 1960). As such, it is a reasonably good measure of materials available for biochemical stabilization, as well as an indicator of the oxygen demanding capacity of an aqueous system.

The oxygen demand of polluted waters is exerted by three classes of materials (Std. Methods, 1965): (1) carbonaceous organic material available as a food for microorganisms; (2) nitrogenous material susceptible to microbial oxidation; (3) chemical agents susceptible to chemical oxidation, which belong in the category of Chemical Oxygen Demand. It is generally assumed in the analysis of long-term BOD results that there are two distinct stages in the BOD process; the utilization of carbonaceous material by saprophytic bacteria, followed by oxidation of nitrogenous material by nitrifying bacteria (Sawyer, 1960; EPA, 1971). The reproductive rate of the nitrifying bacteria at 20°C is slow enough that a minimum of 5 to 10 days is usually required to establish a sufficient population to exert an appreciable oxygen demand. This is the basis for the sequential carbonaceous and nitrogenous demands.

Florida Department of Environmental Regulation (FDER) criteria do not give specific limits for BOD in estuaries. They state that BOD in Class II or Class III waters shall not be high enough to cause D.O. (dissolved oxygen) concentrations to be depressed below 4.0 mg/l (Florida Administrative Code, 1973).

There are drawbacks to the BOD test. The conditions under which the BOD test is done in the laboratory are not representative of conditions in the natural environment. Samples are incubated in the dark and algae in the water die off soon after incubation, exerting an oxygen demand as they decompose. Large amounts of algae can significantly affect the BOD results. On the other hand, substances which are toxic to bacteria suppress BOD. This interference is particularly serious in five-day BOD because there is not enough time for tolerant organisms

to become established. Thus, ultimate BOD is preferable to short-term BOD in assessing BOD levels in an aquatic system.

Results and Discussion

Mean ultimate BOD values (Lu) during the 1974 study period were slightly lower in Escambia River than in Escambia Bay (Figure 8-39 and Table 8-23). The mean ultimate BOD at Station EGLY, near Air Products and American Cyanamid, was 4.0 mg/l higher than mean ultimate BOD at Station ER10 in Escambia River. Mean ultimate BOD and rate constants (kc and kn) generally decreased in a seaward direction from Station EGLY to Station ERPB.

In order to determine if BOD values and rate constants were influenced by die-off of algae in the BOD bottles, a correlation was run between chlorophyll a concentrations in all surface water samples in the 1974 water quality studies and ultimate and five-day BOD in the same samples. Very little correlation was found between any type of BOD and chlorophyll a. There was no correlation at all with ultimate BOD (Lc+Ln), and only a correlation of 0.36 with ultimate carbonaceous BOD (Lc). The correlation of chlorophyll a with five-day BOD was only 0.27. Thus, even though many of the patterns observed in these BOD studies were typical of the influence of algae die-off, no correlation could be seen using chlorophyll a as the indicator. Some of these patterns are discussed further in this section.

Mean five-day BOD values in Escambia Bay in 1974 were all quite low (Table 8-24). The overall average for the study period was 1.4 mg/l. Only during one water quality study (May 29, 1974) did the mean five-day BOD exceed 2.0 mg/l. During two studies, it was less than 1.0 mg/l (March 5 and April 16, 1974). The overall average of 1.4 mg/l was very close to the overall 1973 five-day BOD average of 1.8 mg/l.

The data in Table 8-24 and Appendix 8-19 did not reveal any definite patterns in mean ultimate or five-day BOD by month or season. One striking pattern was the unusually high kc values during the August 1974 water quality study. This probably can be attributed to increased algae populations in August. The die-off of algae in the BOD bottles could cause this initial rapid depletion of oxygen.

A comparison of ultimate and five-day BOD with dissolved oxygen values does not explain variations in dissolved oxygen concentrations during the 1974 study period (Figure 8-40). Large decreases in dissolved oxygen values are not accompanied by large increases in BOD. This indicates that BOD is not the controlling factor in monthly dissolved oxygen variations in Escambia Bay. Other factors involved in dissolved oxygen fluctuations are discussed in the dissolved oxygen section.

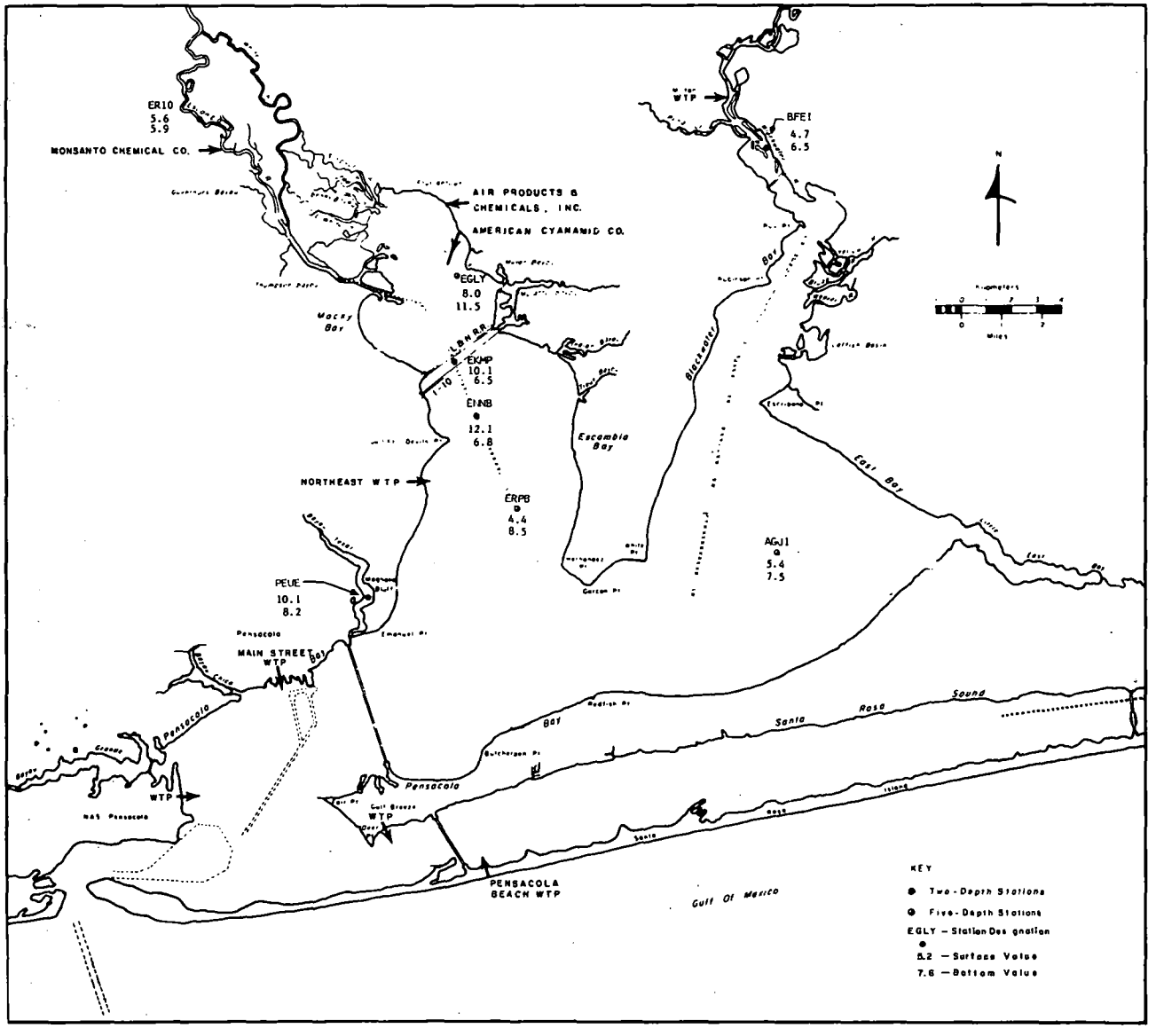


Figure 8-39. Mean ultimate BOD (mg/l) in Escambia, East, and Blackwater Bays during January through September, 1974.

Table 8 - 23. Mean ultimate biochemical oxygen demand data for Escambia Bay stations during January through September, 1974.

Station	Lu (mg/l)	kc (day^{-1})	kn (day^{-1})	Lc (mg/l)	Ln (mg/l)	tn (days)	BOD (mg/l)
ER10 - S	5.6	0.310	0.090	3.1	2.9	24	0.9
ER10 - B	5.9	0.313	0.040	2.7	3.9	22	
EGLY - S	8.0	0.224	0.115	4.4	3.6	23	1.8
EGLY - B	11.5	0.130	0.078	7.9	4.0	20	
EKMP - S	10.1	0.173	0.081	3.3	6.8	24	1.4
EKMP - B	6.5	0.158	0.087	5.0	3.1	20	
ENNB - S	12.1	0.147	0.072	5.0	7.1	24	1.4
ENNB - B	6.8	0.118	0.055	4.1	3.5	22	
ERPB - S	4.4	0.153	0.137	4.0	3.2	23	1.3
ERPB - B	8.5	0.108	0.065	4.3	7.0	22	

note:
Lc = ultimate carbonaceous BOD
Ln = ultimate nitrogenous BOD
Lu = ultimate BOD (Lc+Ln)
kc = carbonaceous rate constant
kn = nitrogenous rate constant
tn = time at which nitrogenous stage begins

Table 8 - 24. Mean biochemical oxygen demand data at Escambia Bay stations during January through September, 1974.

Date	Flow* (m^3/sec)	Lu (mg/l)	kc (day-1)	kn (day-1)	Lc (mg/l)	Ln (mg/l)	BOD (mg/l)	tn (days)
1/23/74	333	7.7	0.136	0.085	4.0	3.7	1.8	27
2/12/74	737	7.5	0.195	0.025	2.3	5.2	1.2	18
3/05/74	226	6.6	0.048	0.055	4.7	1.9	0.8	23
3/27/74	203	6.1	0.333	0.077	1.7	4.4	1.1	14
4/16/74	506	11.9	0.061	0.163	5.7	6.2	0.9	23
5/07/74	114	6.1	0.114	0.062	3.5	2.6	1.1	27
5/29/74	178	6.1	0.224	0.133	3.9	2.2	2.5	19
6/18/74	126	8.5	0.108	0.067	4.5	4.0	1.8	27
7/09/74	71	8.1	0.065	0.109	4.4	3.7	1.2	27
7/30/74	69	8.3	0.058	0.124	5.8	2.5	1.4	27
8/20/74	147	5.6	0.743	0.078	2.4	3.2	1.5	16
9/11/74	784	16.5	0.057	0.051	10.1	6.4	1.0	22
avg. 1974		8.3	0.177	0.103	4.4	3.9	1.4	22
April 1973		5.7	0.011	-	-	-	0.6	-
August 1973		10.5	0.304	0.047	4.0	6.4	2.9	15

note:
* Total effective flow into Escambia Bay.
Lc = ultimate carbonaceous BOD
Ln = ultimate nitrogenous BOD
Lu = ultimate BOD (Lc+Ln)
kc = carbonaceous rate constant
kn = nitrogenous rate constant
tn = time at which nitrogenous stage begins

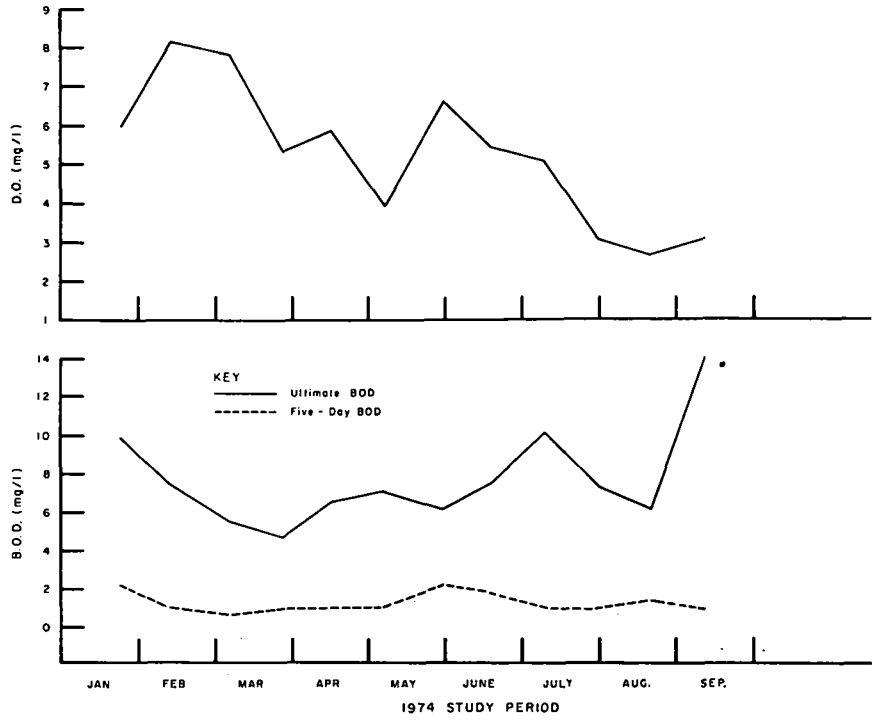


Figure 8-40. Mean bottom ultimate BOD (mg/l) and dissolved oxygen (mg/l) values in Escambia Bay plotted against each date sampled in 1974.

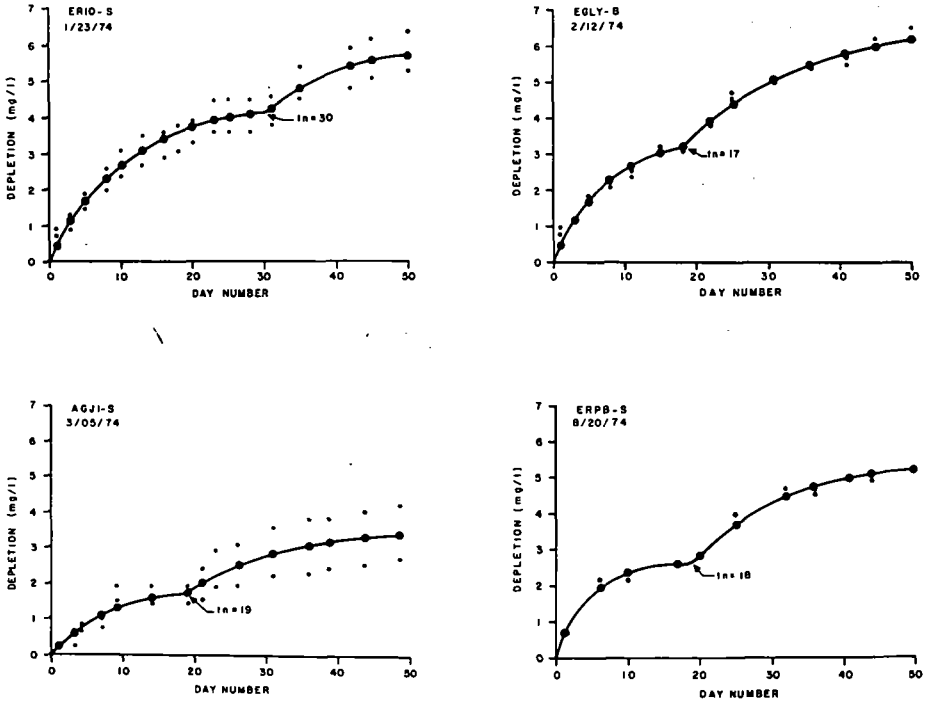


Figure 8-41. Typical long-term BOD curves from the 1974 water quality studies (• = NLINBOD results)

Some examples of typical long-term BOD curves are shown in Figure 8-41. The sequential carbonaceous and nitrogenous phases can be seen in each of these curves, as well as tn, which shows the breaking point between the two phases. The typical pattern is that there is a rapid initial rise in oxygen depletion, followed by a flattening out as available carbonaceous material is stabilized. There is usually not such a rapid initial rise in the nitrogenous phase, and this is reflected in the k values. The point where the flattening out occurs in each phase is the ultimate BOD.

Ultimate BOD was determined on two stations in Choctawhatchee Bay during the September 12, 1974 water quality study. Station ZIMY, near the eastern freshwater end of the bay, had higher surface and bottom ultimate BOD and kc values than Station YNKF at the western saltwater end (Figure 8-42 and Table 8-25). This was the same pattern seen in Escambia Bay. Station ZIMY had a five-day BOD that was more than twice the five-day BOD at Station YNKF. Two stations do not provide sufficient information to generalize about the whole bay, but if ultimate BOD at Station ZIMY is typical of a significant portion of Choctawhatchee Bay, then there was a BOD problem in September 1974.

Mean ultimate BOD, rate constants, and five-day BOD were considerably lower during the April 1973 water quality study than the August 1973 study (Tables 8-26 and 8-27). There were no nitrogenous phases to any of the four samples on which BOD was analyzed during the April study. The average ultimate BOD in August was about twice the average in April, and the average kc value in August was about 30 times the average kc in April. This again could reflect the presence of algae in August, which affect the BOD and kc values by die-off in the BOD bottles. No obvious upper to lower bay pattern could be seen in either study for ultimate BOD or rate constants. Escambia River ultimate BOD in both months was less than in Escambia Bay (Figures 8-43 and 8-44).

In summary, mean ultimate BOD and rate constants did not differ greatly between 1973 and 1974. There was no indication of either deteriorating or improving conditions in Escambia Bay with respect to BOD in 1974. It is possible that much of the BOD observed in this study was due to algae die-off in the BOD bottles, but this cannot be substantiated by correlations of chlorophyll a and BOD.

No definite indication of excessive BOD levels in Escambia Bay in 1974 was observed in this study. A summary of 1974 BOD data by station and date is presented in Appendix 8-19.

Table 8 - 25. Ultimate biochemical oxygen demand data for Choctawhatchee Bay on September 12, 1974.

Station	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	kc (day^{-1})	kn (day^{-1})	tn (days)	BOD (mg/l)
ZIMY - S	6.2	2.0	4.2	0.814	0.026	-	2.3
ZIMY - B	13.6	2.3	11.3	0.149	0.005	27	1.4
YNKF - S	5.2	2.6	2.6	0.146	0.055	32	1.3
YNKF - B	1.8	0.9	0.9	0.121	0.253	33	0.4

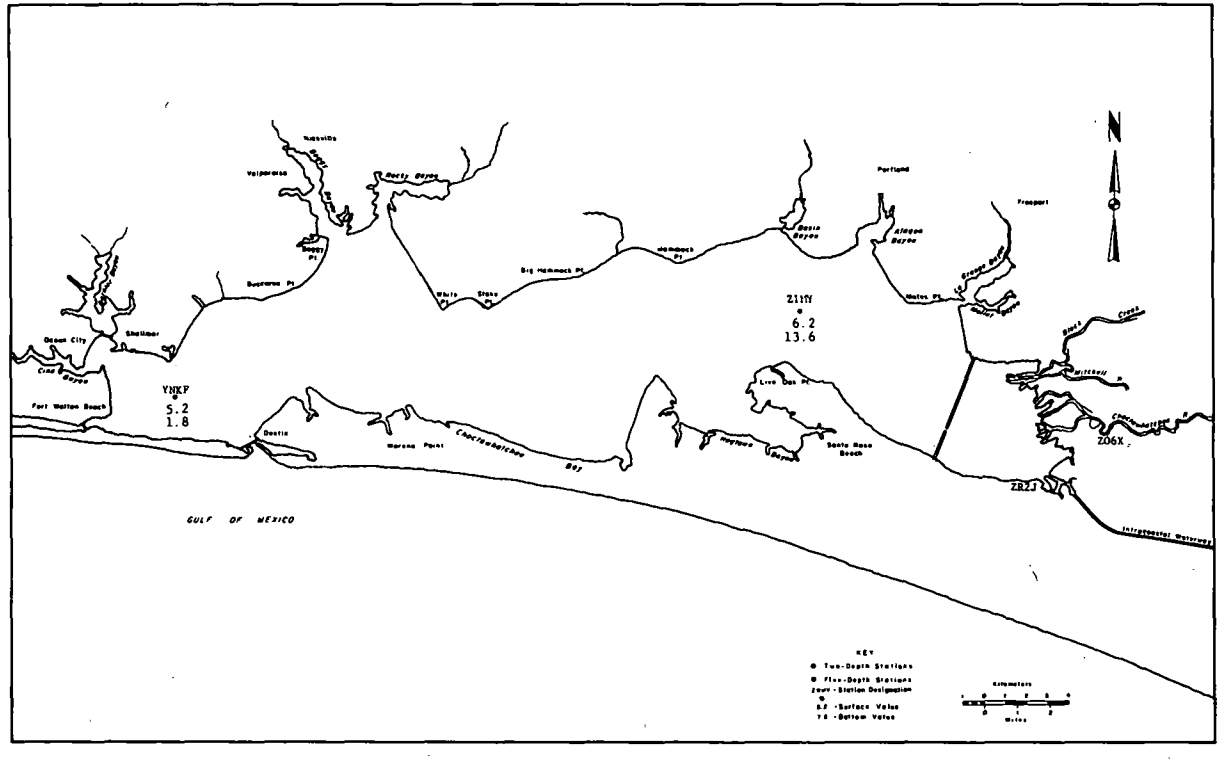


Figure 8-42. Ultimate BOD (mg/l) values in Choctawhatchee Bay on September 12, 1974.

Table 8 - 26. Ultimate biochemical oxygen demand data for Escambia Bay stations during April, 1973 diel water quality surveys.

Station	Date	Tide	Lc (mg/l)	kc (day^{-1})	BOD (mg/l)
ER10 - S	4/19/73	Tropic	4.8	0.012	0.6
ER10 - B	4/19/73	Tropic	3.8	0.008	0.7
EFLU - S	4/19/73	Tropic	5.4	0.009	0.6
EFLU - B	4/19/73	Tropic	5.2	0.010	0.5
EKMP - S	4/19/73	Tropic	6.5	0.010	0.7
EKMP - B	4/19/73	Tropic	5.9	0.011	0.7
ERPB - S	4/19/73	Tropic	9.5	0.007	0.7
ERPB - B	4/19/73	Tropic	4.4	0.017	1.0
average			5.7	0.011	0.7

note:
Lc = ultimate carbonaceous BOD
kc = carbonaceous rate constant

Table 8 - 27. Ultimate biochemical oxygen demand data for Escambia Bay stations during August, 1973 water quality surveys.

Station	Date	Tide	Lu (mg/l)	kc (day^{-1})	kn (day^{-1})	Lc (mg/l)	Ln (mg/l)	tn (days)	BOD (mg/l)
ER10 - S	8/16/73	Equatorial	4.5	0.403	0.146	2.8	1.7	-	3.6
ER10 - B	8/16/73	Equatorial	9.2	0.417	0.041	2.5	6.7	22	2.2
ER10 - S	8/23/73	Tropic	9.5	0.545	0.010	1.9	7.6	6	1.8
ER10 - B	8/23/73	Tropic	6.6	0.382	0.017	1.7	4.9	12	1.4
EIME - S	8/16/73	Equatorial	11.0	0.273	0.032	5.2	5.8	16	3.8
EIME - B	8/16/73	Equatorial	15.1	0.249	0.017	4.0	11.1	11	2.8
EIME - S	8/23/73	Tropic	11.4	0.179	0.097	-	-	-	3.9
EIME - B	8/23/73	Tropic	12.7	0.180	0.046	6.1	6.6	14	3.5
EKMP - S	8/16/73	Equatorial	17.1	0.310	0.009	5.5	11.6	16	4.2
EKMP - B	8/16/73	Equatorial	10.1	0.422	0.036	2.5	7.6	9	2.3
EMQC - S	8/16/73	Equatorial	14.3	0.476	0.010	3.9	10.4	5	3.6
EMQC - B	8/16/73	Equatorial	9.8	0.141	0.039	5.6	4.2	22	2.8
ERPB - S	8/16/73	Equatorial	8.4	0.320	0.028	4.4	4.0	9	3.4
ERPB - B	8/16/73	Equatorial	8.3	0.128	0.090	5.6	2.7	30	2.8
ETLQ - S	8/16/73	Equatorial	11.8	0.323	0.014	4.4	7.4	12	3.6
ETLQ - B	8/16/73	Equatorial	7.5	0.118	0.113	4.2	3.2	29	2.0
average			10.5	0.304	0.047	4.0	6.4	15	3.0

note:
Lc = ultimate carbonaceous BOD
Ln = ultimate nitrogenous BOD
Lu = ultimate BOD (Lc+Ln)
kc = carbonaceous rate constant
kn = nitrogenous rate constant
tn = time at which nitrogenous stage begins

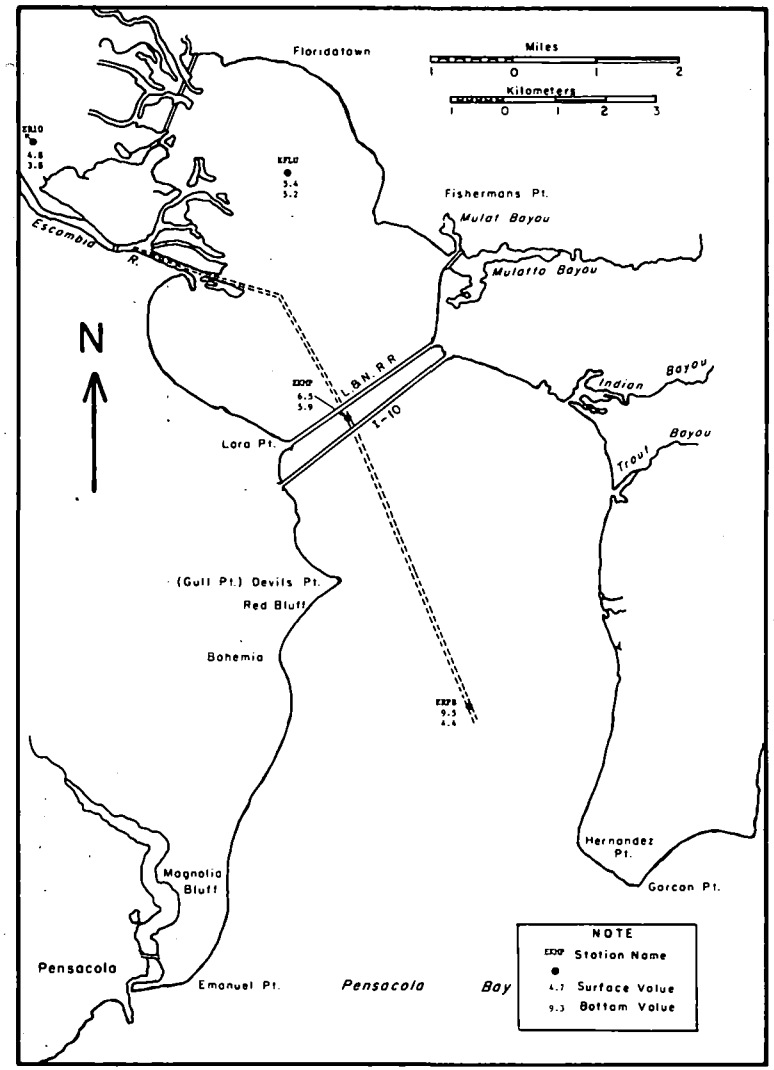


Figure 8-43. Mean ultimate BOD (mg/l) in Escambia Bay during April, 1973.

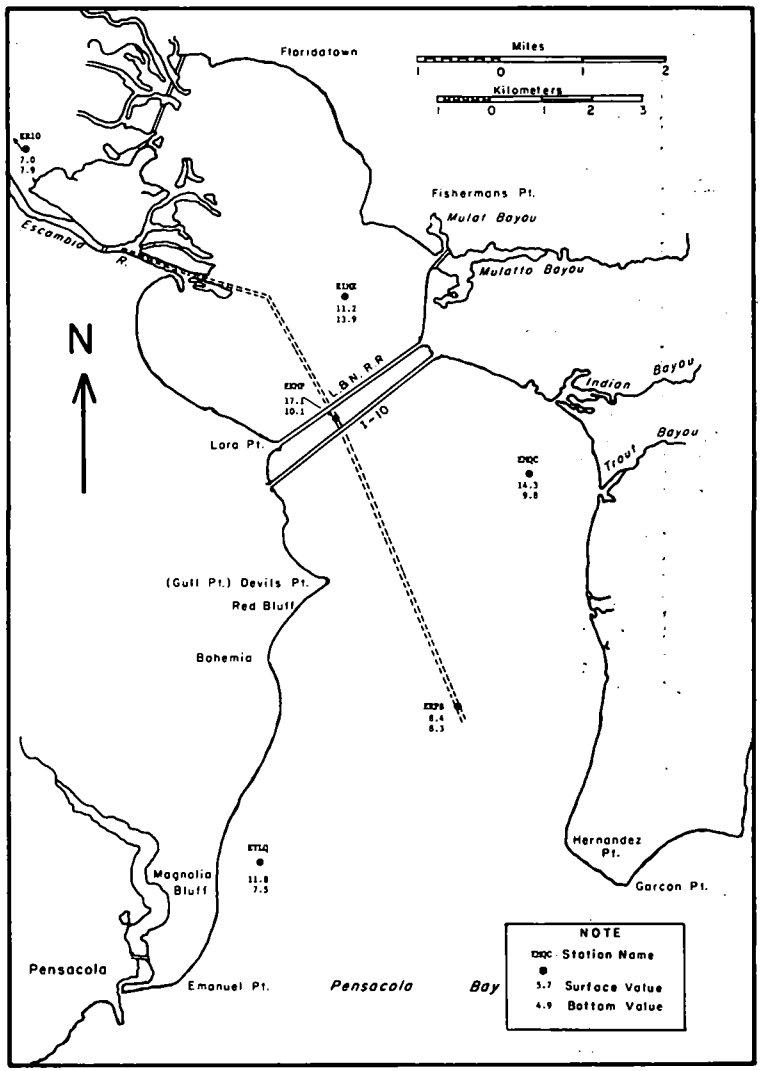


Figure 8-44. Mean ultimate BOD (mg/l) in Escambia Bay during August, 1973.

TOTAL AND FECAL COLIFORM BACTERIA

Introduction

Coliform bacteria have traditionally been used as indicators of the potential presence of enteric pathogens and the degree of fecal pollution of a body of water. Although no correlation of pathogen densities to coliform densities can be made for general use, adherence to the coliform standards set for potable water, recreational water, and shellfish harvesting has contributed to a reduction in the incidence of diseases due specifically to water borne enteric pathogens.

The coliform group occurs in the intestinal tract of warm-blooded animals and are the most numerous group of bacteria found in human excreta. Several bacterial genera with similar biochemical properties comprise the coliform group. Some members of the coliform group occur naturally outside the intestinal tract, a fact that has resulted in the criticism of the total coliform group as indicators of fecal pollution.

Much of the criticism of the coliform group was overcome with the development of the fecal coliform test. The fecal coliform group represents that portion of the coliform group most representative of indicating fecal pollution, and is presently the most reliable indicator of fecal contamination.

Enumeration of both total and fecal coliforms in this study was conducted to determine compliance with water quality standards using both groups, and also to monitor bacterial contamination that resulted from sources other than warm-blooded animals.

Results

Coliform Surveys of Shellfish Waters

A summary of the bacteriological data for shellfish growing area number 32 during the 1970-71 and 1971-72 harvesting season is presented in Tables 8-28 and 8-29. Station locations are shown in Figure 8-45, (State of Florida, Department of Health and Rehabilitative Services, Bureau of Sanitary Engineering, Pensacola, Florida, Unpublished Data).

Water samples analyzed for the 1970-71 harvesting season were collected from October 1970 through May 1971. Median coliform densities for these eight monthly samples ranged from 6 to >1300/100 ml. The median coliform shellfish standard of 70/100 ml was exceeded at Stations 58, 61, and 90 in the area open to oyster harvesting. The highest fecal coliform median densities during the 1970-71 season were 109 and 130/100 ml. These densities were for Stations 93, and 95, respectively, both located outside the area open to oyster harvesting.

Table 8 - 28. Total and fecal coliform data (densities per 100 ml) for oyster harvesting Area 32 during the 1970-1971 season.

Date	10/14/70		11/09/70		11/30/70		01/11/71		03/08/71		04/12/71		05/17/71		05/25/71		Median	
Sta.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.
60	348.	<2.	<2.	<2.	348.	49.	918.	8.	1609.	918.	348.	<2.	542.		<2.		348.	4.
63	918.	<2.	2.	<2.	>2400.	34.	221.	2.	542.	240.	240.	<2.	542.		79.		390.	2.
67	49.	<2.	5.	<2.	>2400.	1609.	>2400.	<2.	79.	13.	33.	<2.	17.		490.		64.	<2.
71	2.	2.	<2.	2.	542.	240.	542.	2.	>2400.	542.	49.	<2.	17.		<2.		53.	2.
74	<2.	<2.	<2.	<2.	>2400.	>2400.	1609.	<2.	49.	23.	240.	<2.	79.		2.		64.	<2.
58	49.	<2.	<2.	<2.	>2400.	4.	1609.	8.	918.	542.	918.	22.			<2.		918.	6.
61	918.	4.	<2.	<2.	542.	7.	130.	5.	>2400.	240.	33.	2.			<2.		130.	5.
64	240.	4.	2.	<2.	49.	13.	22.	2.	542.	79.	23.	2.			<2.		23.	3.
68	918.	4.	5.	<2.	<2.	<2.	79.	<2.	348.	79.	33.	<2.			<2.		33.	<2.
79	<2.	<2.	2.	<2.	130.	<2.	22.	<2.	348.	8.	23.	<2.	7.		2.		15.	<2.
80	<2.	<2.	<2.	<2.	79.	2.	23.	<2.	240.	23.	33.	<2.			<2.		23.	<2.
82	8.	<2.	6.	<2.	<2.	<2.	5.	<2.	49.	22.	23.	2.			<2.		6.	<2.
83	>2400.	26.	5.	<2.	240.	2.	22.	8.	348.	23.	2.	<2.			<2.		22.	5.
86	240.	2.	4.	<2.	23.	<2.	130.	<2.	79.	49.	2.	<2.			2.		23.	2
88	240.	2	9.	<2.	5.	<2.	22.	<2.	348.	8.	5.	4.			2.		9.	<2.
90	>2400.	7.	23.	<2.	>2400.	240.	>2400.	2.	348.	130.	79.	8.			33.		214.	8.
91	918.	27.	13.	2.	1609.	1609.			542.	348.	240.	2.			5.		391.	27.
93	918.	109.	23.	5.	>2400.	>2400.			240.	130.	1609.	<2.			6.		579.	109.
94	1609.	14.	13.	<2.	348.	2.			240.	240.	>2400.	8.			490.		519.	8.
95	>2400.	79.	25.	8.	>2400.	240.			348.	130.	>2400.	221.			130.		>1300.	130.
96	1609.	542.	23.	8.	>2400.	23.			240.	49.	1609.	79.			790.		>1100.	49.

State of Florida, Department of Health and Rehabilative Services, unpublished data.

Table 8 - 29. Total and fecal coliform data (densities per 100 ml) for oyster harvesting Area 32 during the 1971-1972 season.

Date	09/13/71		10/11/71		12/13/71		01/13/72		02/14/72		02/28/72		04/10/72		Median	
Sta.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.	Tot.	Fec.
60	11.	8.	49.	<2.	920.	<2.	<2.	<2.	1600.	79.	920.	240.			484.	4.
63	49.	23.	8.	<2.	49.	<2.	<2.	<2.	540.	33.	1600.	8.			49.	4.
67	130.	13.	350.	<2.	920.	<2.	<2.	<2.	920.	33.	240.	33.			295.	6.
71	14.	<2.	<2.	<2.	49.	<2.	2.	<2.	1600.	130.	79.	49.			31.	<2.
74	5.	<2.	33.	<2.	8.	<2.	49.	5.	540.	5.	23.	5.			28.	3.
58	49.	<2.	2.	<2.	49.	<2.	240.	79.	540.	27.	540.	5.			144.	3.
61	<2.	<2.	<2.	<2.	540.	<2.	>2400.	79.	33.	8.	8.	8.			20.	4.
64	<2.	<2.	2.	<2.	49.	<2.	79.	14.	1600.	34.	13.	2.			31.	<2.
68	2.	<2.	<2.	<2.	130.	<2.	5.	<2.	350.	23.	33.	<2.			21.	<2.
79	5.	<2.	<2.	<2.	<2.	<2.			240.	<2.					3.	<2.
80	<2.	<2.	<2.	<2.	2.	<2.			130.	<2.					<2.	<2.
82	<2.	<2.	<2.	<2.	7.	<2.			240.	2.					4.	<2.
83	350.	8.	540.	<2.	130.	<2.			1600.	130.					445.	4.
88	22.	<2.	79.	4.	79.	<2.	350.	79.	130.	<2.	130.	22.	33.	<2.	79.	<2.
90	14.	<2.	240.	<2.	240.	<2.	13.	<2.	1600.	79.	>2400.	33.	<2.	<2.	240.	<2.
91	350.	<2.	540.	<2.	130.	<2.	240.	33.	1600.	79.	920.	49.	23.	<2.	350.	<2.
93	79.	<2.	>2400.	<2.	1600.	<2.	920.	22.	>2400.	33.	1600.	540.	79.	5.	1600.	5.
94	350.	<2.	1600.	<2.	130.	<2.	920.	350.	920.	23.	920.	8.	240.	<2.	920.	<2.
95	540.	2.	>2400.	<2.	79.	<2.	1600.	350.	>2400.	27.	>2400.	240.	33.	<2.	1600.	2.
96	350.	8.	>2400.	<2.	240.	<2.	350.	130.	>2400.	23.	>2400.	240.	1600.	23.	1600.	23.

State of Florida, Dept. of Health and Rehabilitative Services - unpublished data.

During the 1971-72 harvesting season, (a total of seven sampling periods from September 1971 through April 1972) total coliform densities exceeded the median coliform shellfish standard at four stations out of ten within the harvesting area. These four stations, 58, 83, 88, and 90, were on the outer borders of the oyster beds. The median total coliform density ranged from <2 to 1600/100 ml for all stations, including those not in the harvesting area. The highest mean fecal coliform density was 23/100 ml for Station 96, located outside the area open to oyster harvesting.

Coliform Survey - 1973

In 1973, twenty-six stations were sampled (Figure 8-45). Twelve of the eighteen Escambia Bay stations were sampled only one time in December 1973. No significance can be placed on these densities, since they are based on a single sampling period and are higher than mean densities obtained over an extended period. Most of the total coliform densities at the Escambia Bay stations in December 1973 were above 1000/100 ml and all fecal coliform densities but one were greater than 200/100 ml for that same period (Table 8-30). The East Bay Station, AJFD, had low total and fecal coliform densities for this sample period. One of the three East Bay stations was sampled twice. The other stations were sampled at four-hour intervals during two opposing tidal cycles in April and in August 1973. All of the samples analyzed were surface samples.

During these studies total coliform densities for all but two stations (EEKV and EFLU) were below a geometric mean of 1000/100 ml (Table 8-30). Geometric mean densities of 1140 and 1170/100 ml at these respective stations in upper Escambia Bay slightly exceeded the Class III standard. Total coliform densities at Escambia River Station ER10, also in Class III waters, exceeded 2400/100 ml, the maximum permissible for any day. Total coliform densities at this station complied with a geometric mean of 575/100 ml for the year. The other stations in Class III waters, PIVP, PJPD, PPJV, and PQJQ, are west of the Highway 98 Pensacola Bay bridge. Total and fecal coliform densities at all of these stations complied with the Class III standard, including PJPD, the station at the mouth of Bayou Chico. The bayou formerly received industrial effluent and the station was also located in an area not too distant from the Pensacola Main Street Sewage Treatment Plant outfall.

All of the remaining stations sampled in 1973 were located in Escambia Bay and East Bay in Class II waters for shellfish harvesting. Total coliform densities at East Bay Station AKAA complied with the median of 70/100 ml as stated in the shellfish standards. The standard was exceeded at Station ADGV, with a median density of 77/100 ml, and densities greater than 230/100 ml in 50 percent of the samples. Of the four remaining stations, only EMQC was within the area classified as Class II waters not closed to oyster harvesting. The total coliform density at this

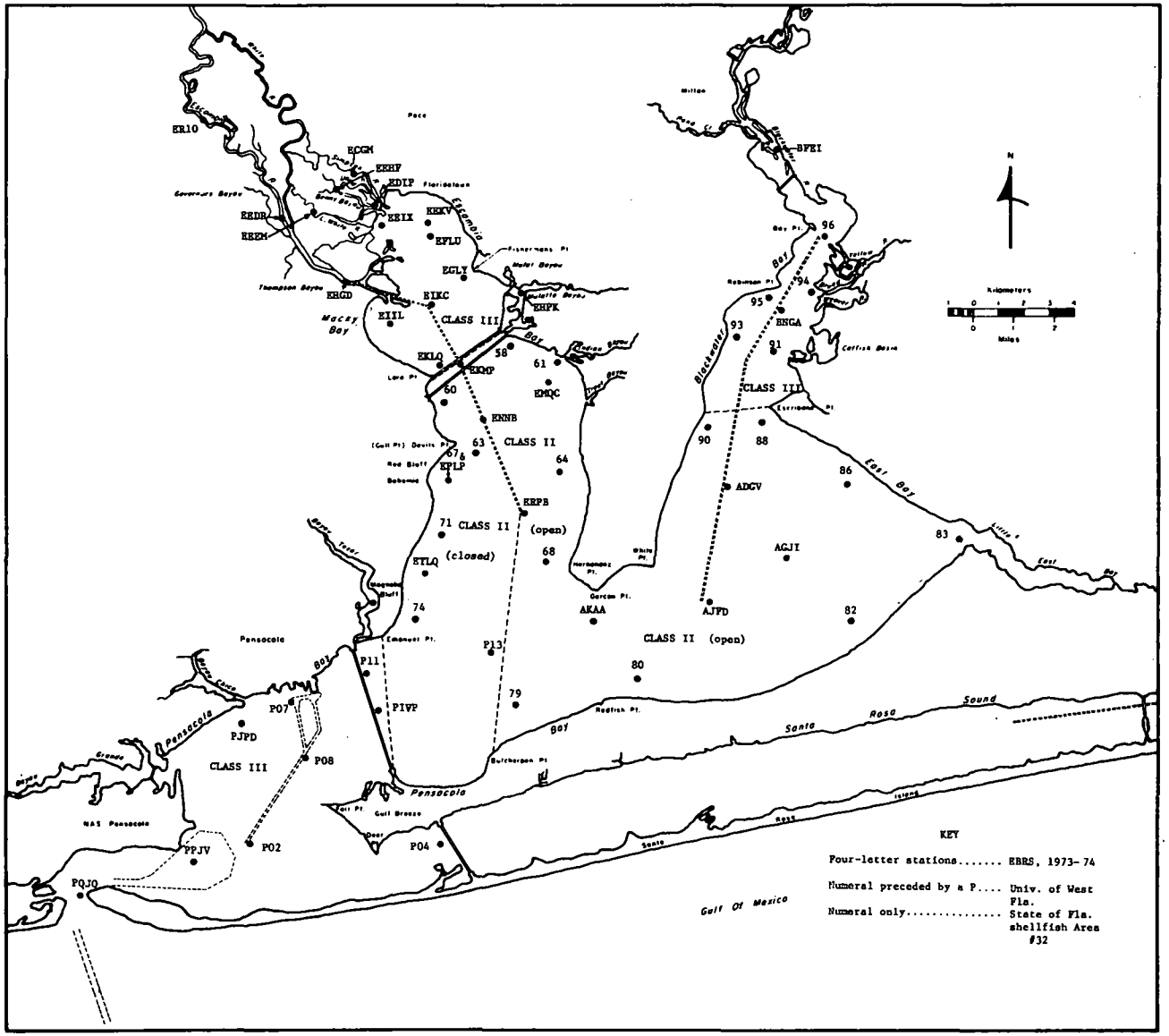


Figure 8-45. Locations of total and fecal coliform bacteria sampling stations (four letter stations are EBRS 1973-74, numerals preceded by P are University of West Florida, numeral only is the State of Florida, Shellfish Area #32).

Table 8 - 30. Summary of the total and fecal coliform data (densities per 100 ml) for the Pensacola Bay system during 1973.

Station	No. of samples	Total Coliform / 100 ml. Maximum	Minimum	Arithmetic Mean	Geometric Mean	Fecal Coliform / 100 ml. Maximum	Minimum	Arithmetic Mean	Geometric Mean
AJFDA	2	5	4	5	4	2	2	2	2
ECGMA	1	3480	3480	3480	3480	542	542	542	542
EDIPA	1	3480	3480	3480	3480	542	542	542	542
EEDRA	1	2400	2400	2400	2400	1600	1600	1600	1600
EEEMA	1	9200	9200	9200	9200	2210	2210	2210	2210
EEHFA	1	5420	5420	5420	5420	700	700	700	700
EEIXA	1	3480	3480	3480	3480	920	920	920	920
EGLYA	1	2210	2210	2210	2210	920	920	920	920
EHGDA	1	3480	3480	3480	3480	348	348	348	348
EHPKA	1	920	920	920	920	130	130	130	130
EIILA	1	1600	1600	1600	1600	348	348	348	348
EIKCA	1	3480	3480	3480	3480	348	348	348	348
EKLQA	1	542	542	542	542	240	240	240	240
EEKVA	9	2780	130	1449	1140	240	2	55	23
EFLUA	8	2210	542	1348	1173	130	33	76	70
EKMPA	17	1600	240	672	590	348	2	92	42
EMQCA	15	920	9	282	141	79	2	24	10
EPLPA	8	542	14	127	71	8	2	5	4
ERPBA	7	920	221	559	497	50	27	39	38
ADGVA	14	348	5	119	75	13	2	5	4
AKAAA	13	348	4	61	24	49	2	7	4
EIVPA	15	1090	2	149	29	79	2	21	8
PJPDA	14	2400	2	754	210	460	2	101	35
PPJVA	6	94	49	72	69	23	5	13	11
PQJQA	8	348	2	94	36	49	2	10	4
EA10A	16	3480	7	1134	575	2400	2	212	62

station exceeded the standard, with a median density of 260/100 ml and densities greater than 230/100 ml in 63 percent of the samples. Stations EKMP and ERPB are channel stations which were on the boundary of the area closed to oyster harvesting. Total coliform densities at these stations violated the standard for Class II waters, but complied with the Class III standard. Station EPLP, in the vicinity of the Northeast Sewage Treatment Plant outfall on the west side of Escambia Bay, was in the portion of the bay closed to harvesting oysters. Total coliform densities at this station were less than the median of 70/100 ml for Class II waters, but exceeded the 230/100 ml maximum in 13 percent of the samples analyzed during 1973.

The geometric mean fecal coliform densities were less than 70/100 ml for these same stations. This was well below the Florida Standard of 200/100 ml specified for Class III waters used for body contact recreation. The geometric mean fecal coliform density for Station EMQC in the oyster harvesting area was 10/100 ml.

Coliform Survey - 1974

Escambia Bay Study

Total and fecal coliform analyses were conducted on surface and bottom water samples at eleven stations in 1974 (Figure 8-45). These stations were sampled a total of 12 times from January through September 1974. During this sampling period, only the surface and bottom water samples of the Escambia River Station ER10 and the surface sample of the Blackwater River Station BFEI exceeded the geometric mean total coliform standard for Class III water (Table 8-31). Bottom samples from Stations EGLY and PEUE, also in Class III water, met the total coliform standard of 1,000/100 ml. The surface samples of these stations exceeded the maximum of 2,400/100 ml allowed for any day.

All of the remaining stations were located in Class II waters but only EMQC in Escambia Bay and AGJI in East Bay were within the area open to oyster harvesting. Total coliform densities at both of these stations complied with the shellfish standard.

Stations EKMP, ENNB, ERPB, and BNGA were on the boundary of areas closed to oyster harvesting in Class II waters. Both the surface and bottom densities at Station BNGA, and the surface samples of EKMP, ENNB, and ERPB were greater than the 230/100 ml total coliforms in more than 10 percent of the samples. Total coliform densities for bottom samples at EKMP, ENNB, and ERPB complied with the Class II standard. At Station EPLP on the west side of Escambia Bay, total coliform densities exceeded the standard in the bottom sample with a median density of 89/100 ml, but complied with a median density of 70/100 ml in the surface sample.

Table 8 - 31. Summary of the total and fecal coliform data (densities per 100 ml) for the Pensacola Bay system during 1974.

Station	No. of samples	Total Coliform / 100 ml. Maximum	Minimum	Arithmetic Mean	Geometric Mean	Fecal Coliform / 100 ml. Maximum	Minimum	Arithmetic Mean	Geometric Mean
ER10A	12	9200	348	1978	1184	5420	23	669	157
ER10E	12	16000	172	3807	1566	2210	46	468	194
EGLYA	12	3480	14	944	322	700	2	157	22
EGLYE	12	2400	6	472	85	1090	2	131	11
EKMPA	12	3480	46	728	357	542	2	116	31
EKMPE	12	2400	4	245	37	240	2	25	5
EMQCA	11	1600	5	329	65	172	2	31	8
EMQCE	11	79	2	35	23	23	2	4	2
ENNBA	12	3480	4	530	98	920	2	135	15
ENNBE	12	109	2	26	13	33	2	6	3
EPLPA	12	1720	5	365	94	348	2	53	13
EPLPE	12	5420	4	540	62	348	2	36	6
ERPBA	12	1600	2	373	48	348	2	45	9
ERPBE	12	79	2	15	8	13	2	3	3
PEUEA	9	5420	79	2125	833	1410	2	301	67
PEUEB	9	1720	79	600	389	542	13	108	59
BFEIA	5	5420	920	2226	1693	542	33	300	162
BFEIE	5	16000	49	3287	240	172	2	49	18
ENGAA	12	9200	49	1852	794	542	5	222	74
ENGAE	12	9200	15	1434	194	920	2	143	12
AGJIA	12	630	2	112	17	94	2	21	6
AGJIE	12	460	2	44	6	109	2	11	3

Fecal coliform analyses of these same stations during 1974 revealed fecal coliform densities at some stations exceeded 800/100 ml, the maximum allowed in Florida for Class III waters. These violations included the surface and bottom water samples from the Escambia River Station ER10, the bottom sample of Station EGLY in upper Escambia Bay, and the surface sample of Station PEUE in Bayou Texar, all in Class III waters. The surface sample of Station ENNB in Escambia Bay and the bottom sample of Station BNGA in Blackwater Bay (both in Class II waters near the boundary of waters closed to oyster harvesting), also had fecal coliform densities greater than 800/100 ml.

The Class III standard for maximum daily permissible fecal coliform density was exceeded at these stations; however, during 1974, the mean fecal coliform densities did not exceed the recommended monthly geometric mean of 200/100 ml for contact recreation.

Fecal coliform densities were very low at stations EMQC and AGJI in Class II waters opened to oyster harvesting. The highest geometric mean density being 8/100 ml, was found for the surface samples of station EMQC. The surface samples of station AGJI had a geometric mean density less than 6/100 ml and the bottom samples for both stations were 3/100 ml.

Pensacola Bay Study

Total and fecal coliform analyses of surface and bottom water samples from six stations in Pensacola Bay were conducted for the University of West Florida during their 1974 study (Figure 8-45). The highest total coliform density was 24,000/100 ml (Table 8-32). This density was found for one bottom sample at Station P04 collected in Santa Rosa Sound. The highest fecal coliform density observed for bottom water at station P04 was 11/100 ml, the same water sample giving the high total coliform density. The highest total and fecal coliform densities observed from the surface samples at this station were 348/100 ml and 33/100 ml, respectively.

A surface sample from Station P07 exceeded the maximum total coliform density permitted in the Florida Standard for Class III waters (2400/100 ml). The maximum total coliform density of 3480/100 ml and fecal coliform density of 240/100 ml for this sample were next to the highest densities observed for all stations sampled in Pensacola Bay. A geometric mean total coliform concentration of 310/100 ml and the fecal coliform density of 42/100 ml for Station P07 were the highest mean densities observed for all the Pensacola Bay surface and bottom samples.

The next highest geometric mean total and fecal coliform densities of 45/100 ml and 11/100 ml, respectively, were observed at Station P11 in Pensacola Bay. The highest fecal coliform

Table 8 - 32. Summary of total and fecal coliform data (densities per 100 ml) for Pensacola Bay during 1974 (data from the University of West Florida).

Station	No. of samples	Total Coliform / 100 ml. Maximum	Minimum	Arithmetic Mean	Geometric Mean	Fecal Coliform / 100 ml. Maximum	Minimum	Arithmetic Mean	Geometric Mean
P-02A	11	920	2	140	26	79	2	15	6
P-02E	11	130	2	30	8	31	2	7	3
P-04A	11	348	2	44	8	33	2	6	4
P-04E	11	24000	2	2186	8	11	2	3	2
P-07A	11	3480	79	585	313	240	2	87	42
P-07E	10	920	5	148	47	79	2	15	6
P-08A	11	1090	2	120	22	94	2	15	6
P-08E	11	109	2	16	5	17	2	3	2
P-11A	11	920	5	175	45	348	2	44	11
P-11E	11	348	4	43	14	17	2	4	3
P-13A	10	278	2	39	8	172	2	19	3
P-13E	10	49	2	12	7	23	2	5	4

density of 350/100 ml was observed in a surface sample collected from this station.

Comparison of 1973-1974 Values

The total coliform analyses of samples collected during 1973 and 1974 in Escambia Bay and contiguous waters had total coliform densities ranging from <2/100 ml to 16,000/100 ml. This excluded the abnormally high density of 24,000/100 ml observed at Station P04 in Santa Rosa Sound. One of the three high counts of 16,000/100 ml was from a bottom water sample taken at Station ER10, the Escambia River station, in January, 1974. The other two were observed in bottom water samples taken at Station ER10, the Escambia River Station, and BFEI, the Blackwater River Station, in September 1974 (Table 8-31).

During the same two-year period, the highest fecal coliform densities, 5,420 and 2,210/100 ml were observed in January 1974 at the Escambia River Station ER10 in the surface and bottom water samples, respectively. In most instances, the stations having the highest fecal coliform densities corresponded to the stations having the highest total coliform densities.

Discussion

The area of Escambia Bay classified as Class II waters and approved for shellfish harvesting by the Division of Health, Florida Department of Health and Rehabilitative Services, included the eastern half from the barge channel to the eastern

shore, south of the L and N Railroad bridge and into the adjoining waters of East Bay (Figure 8-45).

Most stations in the areas open to oyster harvesting meet the shellfish standards for bacteriological quality. The stations which did exceed the 70/100 ml median total coliform density in harvesting years 1970-1971 and 1971-1972 were located near the boundaries separating open and closed areas. Unusually high counts, as was observed on February 14, 1972 (Table 8-29), were attributed to periods of heavy rainfall. The effective flow of the Escambia Bay tributaries for this sampling date was 554 m^3/sec (19,577 cfs) which is more than three times the average flow of 170 m^3/sec (6,000 cfs) for the Escambia River at Century, Florida.

No domestic waste effluents were known to be entering the bay in the area open to oyster harvesting. The only point source of domestic waste entering Escambia Bay was the Pensacola Northeast Sewage Treatment Plant which emptied secondary treated effluent into the west side of the bay. The Escambia Bay Recovery Study Station EPLP in the vicinity of this outfall complied with the Florida Standard for Class II waters in 78 percent of the samples analyzed over the two-year sampling period during 1973-1974. This particular station was in Class II waters, but was not open to shellfish harvesting.

Escambia Bay north of the L and N Railroad bridge and Pensacola Bay west of a line from Emanuel Point to the south end of the Highway 98 bridge at Gulf Breeze are classified Class III waters for recreation, propagation, and management of fish and wildlife.

The geometric mean coliform densities obtained in this study complied with the Class III standard at most of the bay stations. In 1973, total coliform densities at Stations EEKV and EFLU exceeded the geometric mean of 1,000 total coliforms per 100 ml. These stations in the northern end of Escambia Bay were influenced by tributaries which had higher coliform densities. This portion of the bay was also enriched by additional nutrients from the effluents of Air Products and Chemicals, Inc., and American Cyanamid Company. The stations which exceeded the Class III standard most frequently were the tributary stations in Escambia River, Blackwater River, and Bayou Texar. Densities greater than 2,400 total coliforms per 100 ml were found in the channel stations of Escambia Bay and Blackwater Bay.

Station P04 in the University of West Florida, Pensacola Bay Study, is located in the center of Santa Rosa Sound at the bridge connecting Gulf Breeze and Pensacola Beach. The effluent from a small sewage treatment plant on Pensacola Beach enters Santa Rosa Sound approximately 2.6 km (1.4 nautical miles) southeast of this station. Effluent from the Gulf Breeze Sewage Treatment Plant enters Santa Rosa Sound about the same distance (2.2 km or 1.2 nautical miles) northwest of the station. Although the effluent

from the treatment facilities enters Santa Rosa Sound in close proximity to the sample station, they were not likely the cause of the 24,000/100 ml total coliform density observed. A remark on the bench card indicated there was settled sediment in the bottom of the sample bottle. The low fecal coliform density of 11/100 ml, which was observed for this same sample, would indicate the high total coliform density was due to sediment in the sample and not to treatment plant effluent or animal waste. Total and fecal coliform densities at all the stations sampled in Pensacola Bay complied with the Class III water standard, but the mean densities for Stations P07 and P11 were noticeably higher than the other stations sampled.

The highest geometric mean densities in Pensacola Bay were attributed to the effluent from the Pensacola Main Street Sewage Treatment Plant (Station P07). The geometric mean total coliform densities of 310/100 ml and 47/100 ml were for surface and bottom water samples, respectively. The geometric mean fecal coliform density of 42/100 ml for the surface sample at this station exceeded all others. These densities were well within the Class III standard, but they were ten-fold greater than the average mean density for other stations in Pensacola Bay.

Station P11, having the second highest geometric mean total and fecal coliform densities, was located at the north end of Highway 98 bridge near the mouth of Bayou Texar. The coliform discharge from Bayou Texar appeared to be the major contributing factor to the higher counts at this station.

The highest densities were observed in the Escambia River and Blackwater River as discussed previously in this report. The geometric mean densities were 1,150/100 ml total coliform and 150/100 ml fecal coliform at the Escambia River Station (ER10), and 1,690/100 ml total coliform and 160/100 ml fecal coliform at the Blackwater River Station (BFEI). The highest geometric mean density for any Escambia Bay station for total coliforms was 360/100 ml and for fecal coliforms was 31/100 ml at Station EKMP. These high background coliform densities are similar to those reported by West, et al. (1964); Gallagher, et al. (1969); and USEPA (1972) for similar Gulf and East Coast estuaries.

Escambia Bay mean total coliform density easily complied with the state standards for Class III waters, but exceeded the maximum permissible total coliform density of 230/100 ml in greater than ten percent of the surface samples, from areas located in Class II waters which were closed to oyster harvesting. Only one violation from Class II bottom waters was observed in 1974; none were analyzed in 1973.

Total coliform and fecal coliform densities for all stations varied from one sampling time to another. The general tendency was for coliform densities to rise following periods of heavy rainfall. This indicated that the high counts which were more

frequently observed in the tributaries were probably due to land runoff and swamp drainage. The high coliform counts observed in the barge channels could possibly be attributed to the barge traffic, either churning up sediments or from domestic waste discharged from tugs or other watercraft. Whenever violations of the Florida bacteriological standard for total coliforms occurred, they did not appear to be the result of domestic waste discharges. Stations where violations of the Florida Standard for total coliforms were observed seldom showed violations of the fecal coliform standard.

PARTICULATE MATTER

Introduction

Particulate matter diminishes light entering a body of water. The light diminishing effect reduces photosynthesis which, in turn, reduces primary productivity. This can cause a reduction of fish food organisms that can reduce fish production. Diminishing light will also reduce the standing crop of benthic vegetation.

Particulate matter in the Pensacola Bay system was evaluated using turbidity. Turbidity is the degree of opaqueness produced in water by suspended or colloidal particulate matter. It can be produced by microorganisms, organic detritus, mineral substances, clay and silt; and can be caused by natural erosion, man-caused erosion, and waste additions. Turbidity is not equal to suspended or non-filtrable solids, but is an expression of their light diminishing effect.

Results and Discussion

The mean turbidities in Escambia, East, and Blackwater Bays for each water quality study in 1974 followed the same trend as the effective river discharge (Figure 8-46). A correlation analysis of mean Escambia Bay turbidities during all 1974 water quality studies indicated that 72 percent of the variation in turbidity was due to variation in effective flow of the Escambia River ($r = 0.85$, $p < 0.01$). No correlation was found between the mean turbidity in Escambia Bay and the average wind velocity during each day in 1974 that a water quality study was performed. The highest values of turbidity were measured in the bay during the winter and spring when rainfall in the drainage basins of the bays was high. The lowest values were measured in the summer.

Mean turbidities decreased in Escambia Bay in a seaward direction during 1974 studies (Figure 8-47 and Appendix 8-20). The highest mean surface and bottom turbidities of 19.7 and 20.8 JTU, respectively, occurred in the Escambia River (Station ER10). Near the I-10 bridge (Station EKMP), the mean turbidities of 12.9 JTU at the surface and 14.6 JTU on the bottom were lower than river values. Turbidities were considerably diluted by the

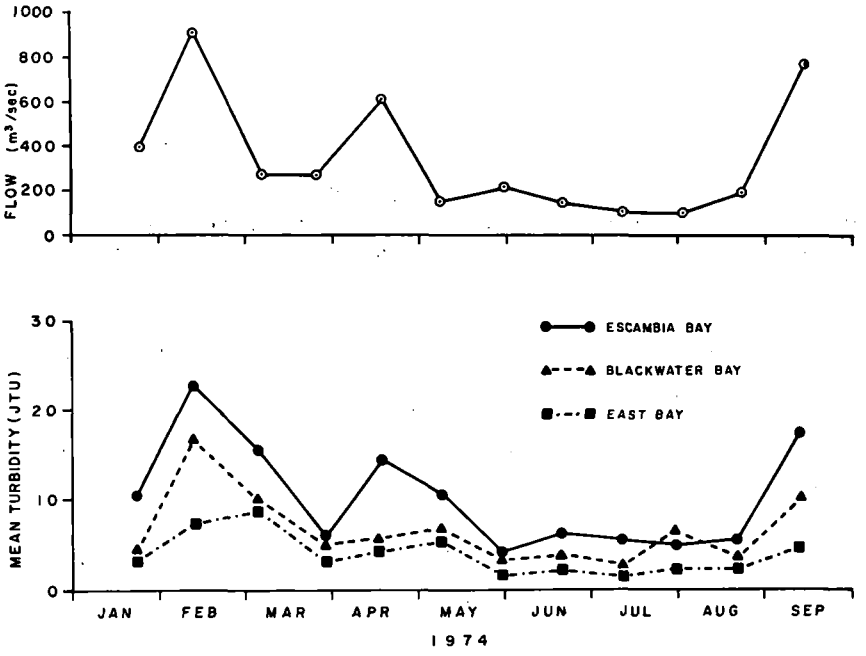


Figure 8-46. Mean turbidity in Escambia, East and Blackwater Bays during each study performed during January through September, 1974, and total effective flow into the Pensacola Bay system during each study.

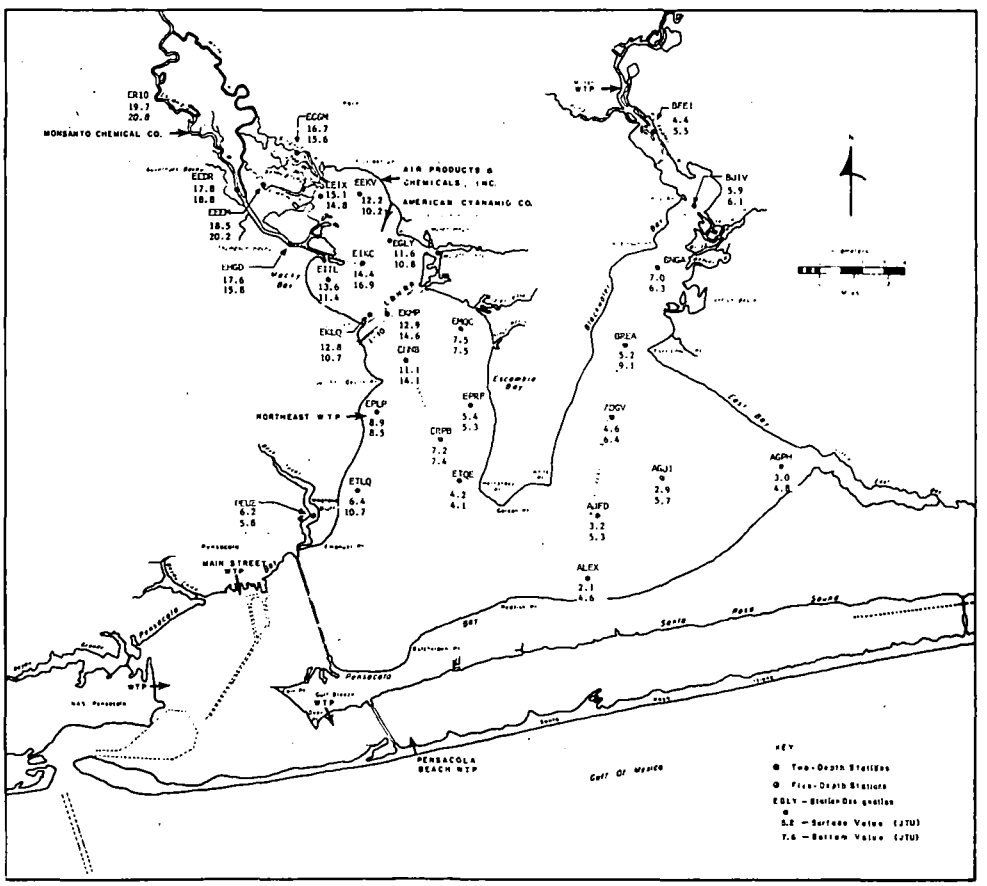


Figure 8-47. Mean turbidity in Escambia, East, and Blackwater Bays during January through September, 1974.

entrance to the Escambia Bay dredged channel (Station ERPB) where the mean surface value was 6.3 JTU and the mean bottom value was 7.4 JTU. Mean turbidities were higher on the western side of the bay than on the eastern side. This occurred because much of the turbidity in the bay comes from the Escambia River; thus, the turbidity distribution is similar to the freshwater distribution in the bay.

The mean surface and bottom turbidities in Blackwater and East Bays were considerably lower than those in Escambia Bay, and there was very little spatial variation throughout both bays. No turbidity data was collected in Pensacola Bay by the University of West Florida.

A frequency analysis for all 1974 data (Table 8-33) shows the magnitude of the difference in turbidities in the bays. All the turbidity distributions were squewed toward lower turbidities. East Bay had the lowest turbidities and Blackwater Bay was slightly more turbid. None of the turbidities measured in any of the bays during the 1974 surveys were greater than the State of Florida water quality standard of 50 JTU. One sample in the Escambia River, at Station EHGD, and one in the Little White River, at Station EEEM, did exceed the turbidity standard.

Turbidity in Choctawhatchee Bay was lower than in Escambia Bay. The mean turbidity in Choctawhatchee Bay was 2.0 JTU during the September 12, 1974 water quality study (Figure 8-48), and the lowest mean turbidity in Escambia Bay of 3.6 JTU occurred on May 29, 1974. Even though these mean turbidities for these dates appear the same in both bays, turbidities in Escambia Bay were statistically higher than those in Choctawhatchee Bay ($t = 3.73$, $df = 89$, $p < 0.01$). The lowest mean turbidity in East Bay of 1.6 JTU was measured on July 9, 1974. This value is not

Table 8 - 33. Percent of the samples in turbidity ranges during the 1974 water quality studies.

Turbidity JTU	Percent within range		
	Escambia Bay	East Bay	Blackwater Bay
0 - 9.9	60.7	93.9	85.4
10.0 - 19.9	22.7	6.1	11.5
20.0 - 29.9	11.7	0.0	3.1
greater than 30.0	4.9	0.0	1.0

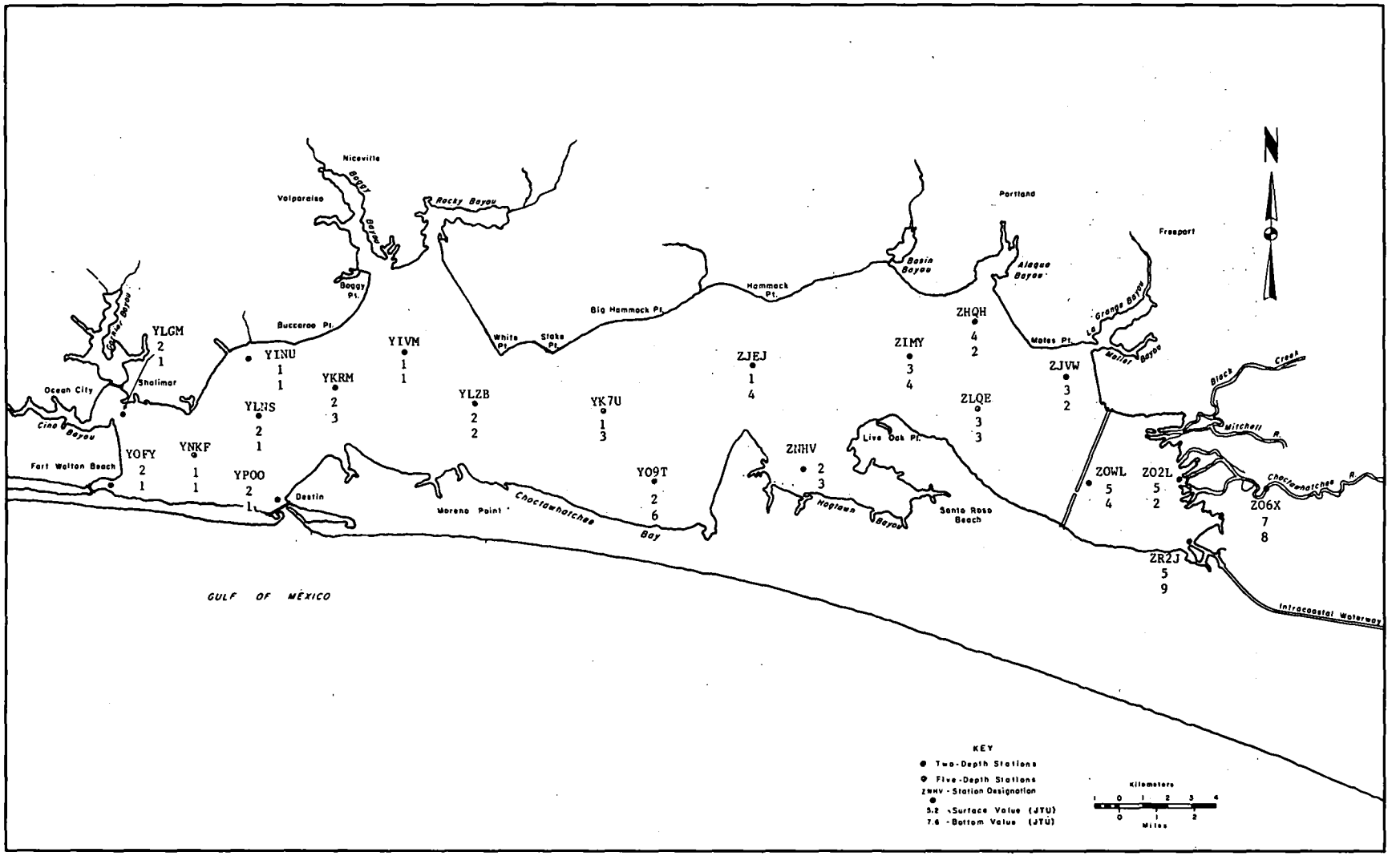


Figure 8-48. Turbidity values in Choctawhatchee Bay on September 12, 1974.

statistically different than the mean value in Choctawhatchee Bay on September 12, 1974 ($t = 0.73$, $df = 62$. Thus, turbidities in East and Choctawhatchee Bays were similar.

Turbidity studies were performed on August 15, 1974, and November 20, 1974 in the drainage basins of the Escambia, Blackwater, and Yellow Rivers to evaluate turbidity differences within these basins. Three replicate samples were collected at a depth of 0.3 m (1.0 ft) at each station. The description of each sampling station is presented in Appendix 8-21. Mean turbidities at each sampling station during each study are shown in Figure 8-49 and all data is presented in Appendix 8-22. Rain occurred during both studies and the river discharges as measured at the furthest downstream stream gages on each river are presented in Table 8-34. Effective river discharges on the Escambia, Blackwater, and Yellow Rivers were almost twice as high on August 15, 1974, than on November 20, 1974, but effective flows for both study dates were below the mean discharges for the period of record.

Turbidities in the Escambia River were statistically greater during the August 15, 1974 study than during the November 20, 1974 study ($t = 2.15$, $df = 70$, $p < 0.05$). The same was true for the Yellow and Blackwater Rivers ($t = 4.09$, $df = 64$, $p < 0.01$). Since flow was higher during the first study, this also indicates that turbidity is proportional to river discharge.

Turbidities were much greater in the Escambia River than in the Yellow and Blackwater Rivers during both studies (August 15, 1974, $t = 8.34$, $df = 67$, $p < 0.01$; November 20, 1974, $t = 5.19$, $df = 67$, $p < 0.01$). Within the Escambia River basin, turbidities were high in the upper reaches of the basin, and increased in the

Table 8 - 34. Effective river discharges for Escambia, Yellow, and Blackwater Rivers.

Date	Effective river discharges m^3/sec (cfs)		
	Escambia River	Blackwater River	Yellow River
August 15, 1974	117 (4140)	19 (687)	51 (1797)
November 20, 1974	67 (2370)	13 (446)	29 (1014)
Mean period of record	170 (6016)	23 (820)	62 (2175)

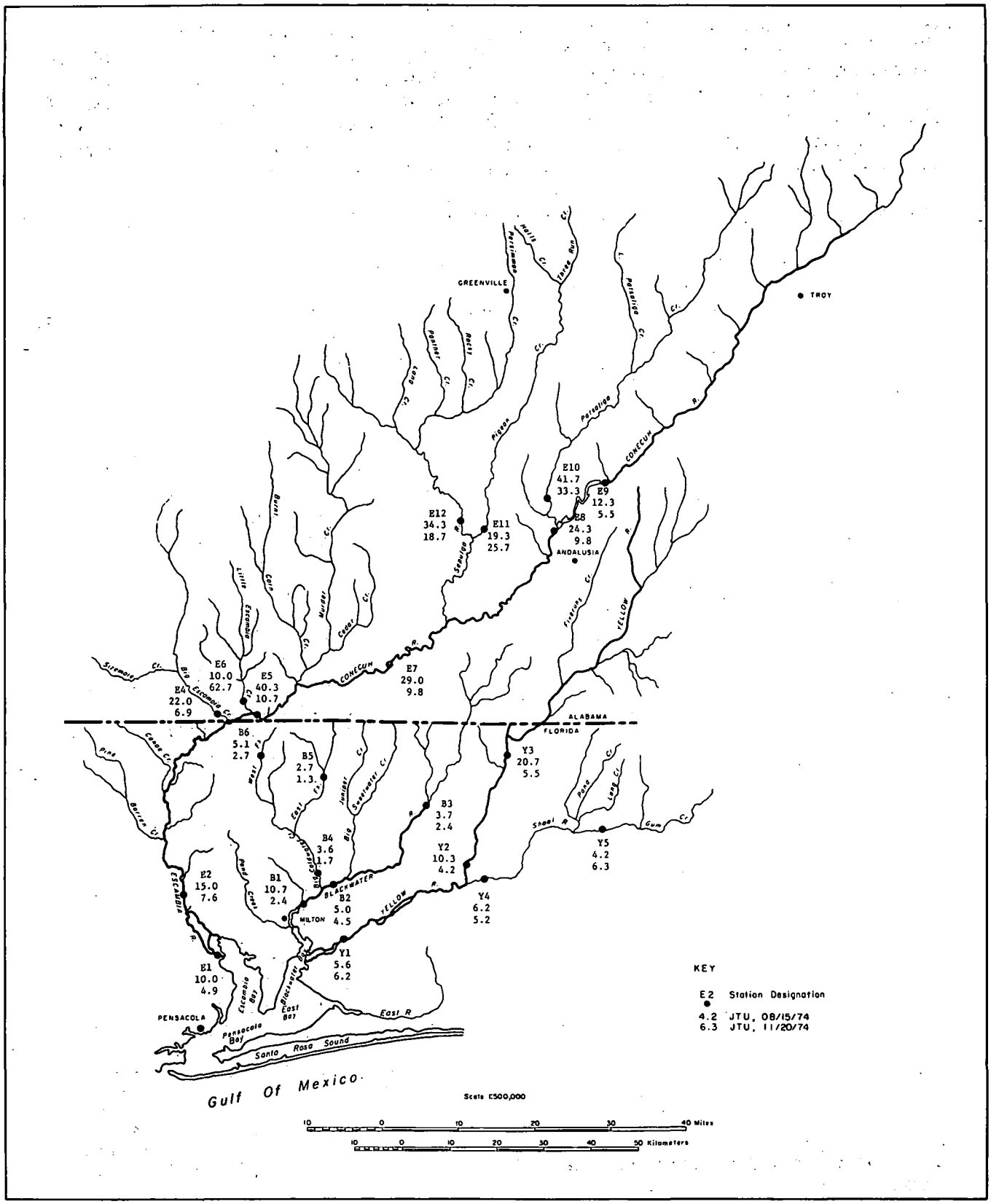


Figure 8-49. Mean turbidity values in the Pensacola Bay system drainage basin during August 15, 1974 and November 20, 1974.

Conecuh River until the Florida State Line. They then decreased in the Escambia River. A significant increase in turbidity in the Conecuh River downstream of the Container Corporation discharge was not observed. The higher turbidities in the upper reaches of the Conecuh-Escambia River basin are due to erosion of clay from the soils. Most of the drainage basins of the Blackwater and Yellow Rivers are in areas with sandy soils. This accounts for the lower turbidities in these rivers.

NUTRIENT LOADINGS INTO THE PENSACOLA BAY SYSTEM

Point sources of waste contributed the greatest portion of the load to the Pensacola Bay system based on NPDES permit limitations during January 1975 and 60-day, 10-year low flows in rivers tributary to the bay system. Tributary rivers and non-point sources of waste followed with decreased loadings. The loadings from tributary rivers were measured at the upper limit of saltwater intrusion.

The nutrient loadings into the bay system from all tributary rivers were estimated from mean concentrations in the lower Escambia River (Station ER10) during January through September 1975 and 60-day, 10-year low flows. Mean concentrations from the Escambia River were used because the greatest amount of data was available for this location, concentrations in all tributary rivers were similar, and there was only slight correlation between concentration and river inflow necessitating the use of a mean concentration.

An analysis of U.S. Geological Survey data from the Escambia and Yellow Rivers during January 1970 through February 1975 (Table 8-35) indicated mean total nitrogen and TOC concentrations in the Escambia River at Century, Florida, and in the Yellow River at Milligan, Florida were not statistically different. Based on the same data, the mean total phosphorus concentration in the Yellow River (0.051 mg/l) was significantly higher than that in the Escambia River (0.032 mg/l), and the mean BOD_5 concentration in the Escambia River (1.0 mg/l) was significantly higher than that in the Yellow River (0.7 mg/l). Even though there was a significant difference between mean total phosphorus and BOD_5 concentrations, the mean values were quite close. A November-December 1971 study comparing the Escambia River with other northwest Florida streams indicated there was strong evidence that the water quality of these streams was comparable, and an analysis of historical STORET data for the same area yielded the same conclusion (USEPA, 1972f). Based on both of the above studies, water quality of the tributary rivers of the Pensacola Bay system was similar.

As expected, nutrient loads in the Escambia River (Station ER10) were lowest during low flow periods (Table 8-36 and 8-37). These low flow periods generally occurred in late summer and early fall when the water temperatures of the bays were highest, the bottom dissolved oxygen concentrations were lowest, the

Table 8 - 35. Comparison of water quality data for the Escambia River at Century, Florida, and the Yellow River at Milligan, Florida. (Data from U. S. Geological Survey)

	Flow (m^3/sec)	Total Phosphorus (mg/l)	Total Nitrogen (mg/l)	BOD5 (mg/l)	TOC (mg/l)
Escambia River					
Mean	140	0.032	0.555	0.98	5.1
Maximum	722	0.060	1.400	2.20	12.0
Minimum	20	0.010	0.300	0.40	3.0
n	26	20	15	26	20
r, conc. vs. flow		-0.16	-0.12	0.24	0.16
Yellow River					
Mean	20	0.051	0.478	0.68	4.25
Maximum	62	0.140	1.400	1.60	8.00
Minimum	5	0.010	0.170	0.30	1.00
n	22	19	12	20	18
r, conc. vs. flow		-0.31	-0.03	0.08	0.61**
Difference between means in rivers					
calculated t		2.6*	0.6	2.4	1.2

* Difference between the means statistically different with greater than 95 percent confidence.
** Correlation coefficient statistically significanty with 95 percent confidence.

Table 8 - 36. Nutrient values in the Escambia River (Station ER10) by date during January through September, 1974.

Date*	Flow	Total Phosphorus		Total Nitrogen		BOD_5		TOC	
	(m^3/sec)	conc. (mg/l)	load (kg/day)	conc. (mg/l)	load (kg/day)	conc. (mg/l)	load (kg/day)	conc. (mg/l)	load (kg/day)
1/23/74	333	0.051	1,467	0.500	14,386	1.6	46,034	8.5	244,555
1/23/74	333	0.070	2,014	0.500	14,386	1.3	37,403	10.0	287,712
2/12/74	737	0.041	2,611	0.502	31,966	0.7	44,574	11.0	700,445
2/12/74	737	0.027	1,719	0.497	31,647	0.8	50,941	10.0	669,606
3/05/74	226	0.044	859	0.315	6,151	0.5	9,763	5.5	107,395
3/05/74	226	0.037	722	0.315	6,151	0.4	7,811	6.5	126,922
3/27/74	203	0.024	421	0.350	6,139	1.3	22,801	6.0	105,235
3/27/74	203	0.032	561	0.360	6,314	1.4	24,555	5.0	87,696
4/16/74	506	0.036	1,574	0.377	16,482	0.9	39,347	7.5	327,888
4/16/74	506	0.038	1,661	0.385	16,832	1.0	43,718	8.2	359,491
5/07/74	114	0.039	384	0.480	4,728	0.7	6,895	8.2	80,767
5/07/74	114	0.033	325	0.485	4,777	0.5	4,925	6.0	59,098
5/29/74	178	0.047	723	0.405	6,229	1.9	29,220	6.5	99,965
5/29/74	178	0.043	661	0.452	6,951	1.6	24,607	5.7	87,661
6/18/74	126	0.038	414	0.355	3,865	0.8	8,709	5.7	62,052
6/18/74	126	0.042	457	0.285	3,103	0.9	9,798	5.7	62,052
7/09/74	71	0.030	184	0.282	1,730	0.5	3,067	2.5	15,336
7/09/74	71	0.033	202	0.420	2,576	0.4	2,454	3.5	21,470
7/30/74	69	0.031	185	0.342	2,039	0.5	2,981	1.0	5,962
7/30/74	69	0.028	167	0.235	1,401	0.5	2,981	2.5	14,904
8/20/74	147	0.044	559	0.225	2,858	0.8	10,161	4.5	57,154
8/20/74	147	0.038	483	0.227	2,883	0.9	11,431	9.0	114,307
9/11/74	784	0.055	3,726	0.449	30,414	0.8	54,190	11.0	745,114
9/11/74	784	0.054	3,658	0.385	26,079	1.0	67,738	9.5	643,507

* First value for each date is for the surface and the second value is for the bottom

chlorophyll a concentrations (phytoplankton) were highest, and when most of the fish kills occurred. Accordingly, the contributions from the tributary rivers during low flow conditions (60-day, 10-year low flow) were used to calculate river loadings and to compare them with other sources of nutrients. The 60-day, 10-year low flow of 72 m^3/sec from all tributary rivers was also used to determine the contributions from tributary rivers because the flushing time of Escambia Bay is approximately 69 days at this level of inflow. Thus, the 60-day, 10-year low flow will affect most of Escambia Bay. The estimated loadings are shown in Table 8-37.

The percent contributions to the Pensacola Bay system from tributary rivers, point sources under January 1975 conditions, point sources when final permit limits are in effect, and non-point sources are presented in Table 8-38. Under January 1975 conditions, for all parameters, point source discharges contributed the greatest amount, with tributary rivers and non-point sources following in decreasing order. When the final permit limitations are in effect, the most significant source or sources will be tributary rivers for BOD_5, tributary rivers and point sources for total nitrogen, and point sources for total phosphorus.

The theory held by many, that point source discharges are insignificant compared to tributary river contributions and non-point sources, is incorrect. Even after all point source discharges are reduced to their final effluent limitations, point source discharges will still be the greatest contributors of total nitrogen and total phosphorus to the Pensacola Bay system.

Table 8 - 37. Summary of nutrient values in the Escambia River (Station ER10) during January through September, 1974 and estimated nutrient loads entering the Pensacola Bay system from the Escambia River and from all rivers.

	Flow	Total Phosphorus		Total Nitrogen		BOD_5		TOC	
	(m^3 /sec)	conc. (mg/l)	load (kg/day)	conc. (mg/l)	load (kg/day)	conc. (mg/l)	load (kg/day)	conc. (mg/l)	load (kg/day)
Station ER10									
Mean	291	0.040	1,070	0.380	10,400	0.9	23,600	6.7	212,000
Maximum	784	0.070	3,730	0.502	32,000	1.9	67,700	11.0	745,000
Minimum	69	0.024	161	0.225	1,400	0.4	2,450	1.0	5.960
n	24	24	24	24	24	24	24	24	24
r, conc. vs. flow		0.34	0.93*	0.46*	0.98*	0.10	0.91*	0.79*	0.99*
Escambia River									
Mean annual flow	189		653		6,200		14,700		109,400
7-day,10-year low flow	28		97		919		2,180		16,200
60-day,10-year low flow	35		121		1,145		2,710		20,200
All tributary rivers									
Mean annual flow	311		1070		10,200		24,200		180,000
7-day,10-year low flow	61		211		2,000		4,740		35,300
60-day,10-year low flow	72		249		2,360		5,600		41,700

* Correlation coefficient statistically significant within 95 percent confidence.

Table 8 - 38. Summary of nutrient contributions to the Pensacola Bay tributary rivers, point sources and non - point sources.

Source	BOD_5			Total Nitrogen			Total Phosphorus		
	(kg/day)	(percent) 1975	final	(kg/day)	(percent) 1975	final	(kg/day)	(percent) 1975	final
Tributary rivers	5,600	38	50	2,360	32	47	249	22	30
Point source waste discharges into estuarine reaches Average Jan. 1975 permit limitations	6,163	41	-	4,395	59	-	672	60	-
Point source waste discharges into estuarine reaches Final permit limitations	2,528	-	22	2,041	-	40	376	-	45
Non - point source discharges	3,111	21	28	676	9	13	205	18	25
Total with 1975 point source load	14,874			7,431			1,126		
Total with final point source load	11,239			5,077			830		

9 - PLANKTON

PHYTOPLANKTON PRODUCTIVITY

The Escambia Bay Recovery Study (EBRS) did no specific studies on either phytoplankton or zooplankton species in the Pensacola Bay system. EBRS, in cooperation with the University of West Florida, did determine chlorophyll concentrations throughout the Pensacola Bay system from January to September 1974. There have been primary productivity studies recently by the University of West Florida (UWF) in 1973 (Hopkins, unpublished data) on East and Escambia Bays.

In Escambia Bay, primary productivity ranged from 0.0 to 2.98 mg C/m^3 per hr, while East Bay ranged from 0.0 to 2.16 mg C/m^3 per hr (Hopkins, et al., unpublished STORET data). The annual mean for Escambia Bay was 0.68 mg C/m^3 per hr while East Bay was 0.62 mg C/m^3 per hr. Paired monthly means during 1973 showed no difference between these two bays ($t = 0.27$, $df = 14$). Monthly data was calculated on a per hour basis and was not extrapolated to a per day production; even so, the relationship between the two bays is relevant and a direct comparison of their productivities is possible. EBRS turbidity data (discussed more fully under the water quality section) for a nine-month period, from January to September 1974, gave an average turbidity value of 3.90 Jackson units for East Bay and 10.27 units for Escambia Bay. The UWF primary productivity data was for the top meter of the water column. Therefore, even though primary productivity means for the surface waters of the two bays were nearly the same, it is likely that total primary productivity, that is, the productivity of the water column from the surface down through the euphotic zone, was higher in East Bay since light penetration was greater there.

Data from Port Royal Sound, South Carolina (Thomas, 1972), for three sampling periods in 1970 averaged 0.0197 g C/m^3 per hr. This was much higher than the values from Escambia Bay. Port Royal Sound was described as a productive estuary capable of contributing to the growth of aquatic organisms (Thomas, 1972). Escambia Bay was several times less productive than Port Royal Sound. Compared to several systems throughout the Gulf coast (Steidinger, 1973), Escambia Bay had a low primary productivity.

PHYTOPLANKTON CROP

Cell Counts

The abundance, seasonality, and spatial distribution of phytoplankton in Escambia and East Bays has been investigated by Hopkins, et al. (unpublished) during the year 1973. This data indicated that the general trend in seasonal succession of phytoplankton within Escambia and East Bays was similar. Dinoflagellates were abundant in the late winter and early spring months. In late spring a small blue-green alga was abundant in

both bays. In early fall, diatoms were the dominant group and they persisted well into midwinter.

Cell counts in Escambia Bay ranged from 17 to 230,000 cells/ml. The range for East Bay was 1100 to 70,000 cells/ml. During the cooler months the counts were in the thousands/ml, whereas in warm months the counts increased a magnitude to tens of thousands. A student t-test indicated no significant difference in the means of East Bay and Escambia Bay for cell counts/ml ($t = 0.87$, $df = 121$). Although there was not an overall difference in cells/ml in the two bays, Escambia Bay had a less uniform distribution. During the high river flow period, plankton was flushed from the areas of greater freshwater influx.

ZOOPLANKTON CROP

Zooplankton was sampled by the University of West Florida six times between February and September 1973, at seven stations in Escambia Bay and six stations in East Bay. Averages of total counts of organisms per m^3 were 36,674 in Escambia Bay and 32,253 in East Bay. A student t-test indicated no significant difference in these means ($t = 0.67$, $df = 75$). Also, monthly means had no consistent trend, either between bays or with time. No differences were noted between the bays within the dominant groups of organisms. *Acartia tonsa*, a calanoid copepod, was the dominant organism in both bays.

CHLOROPHYLL

Introduction

Since all algae contain chlorophyll *a*, this pigment concentration can give an insight into the relative amount of phytoplankton standing crop. The physiological condition of the cells determines the amount of pigment per algal cell, which biases this method of the estimation of biomass; however, it is a widely accepted technique for comparing phytoplankton crops in estuarine waters. In this study, four bays were compared; therefore, the technique has even greater validity since samples were taken concurrently in all bays.

Methods

Water samples were taken 0.3 meters (1.0 ft) below the surface at three-week intervals from January to September 1974, at the stations shown on Figure 9-1. Variable volumes of water (depending on filtering speed) were filtered through a 0.45 micron millipore filter. Residue was dissolved in 90% acetone while cells were ground in a tissue grinder. The method used follows Stickland and Parsons (1972) trichromatic method of spectrophotometric determination of chlorophylls. A Beckman Model DB-6 Spectrophotometer was used to obtain optical absorptions. These readings were used in the SCOR-UNESCO

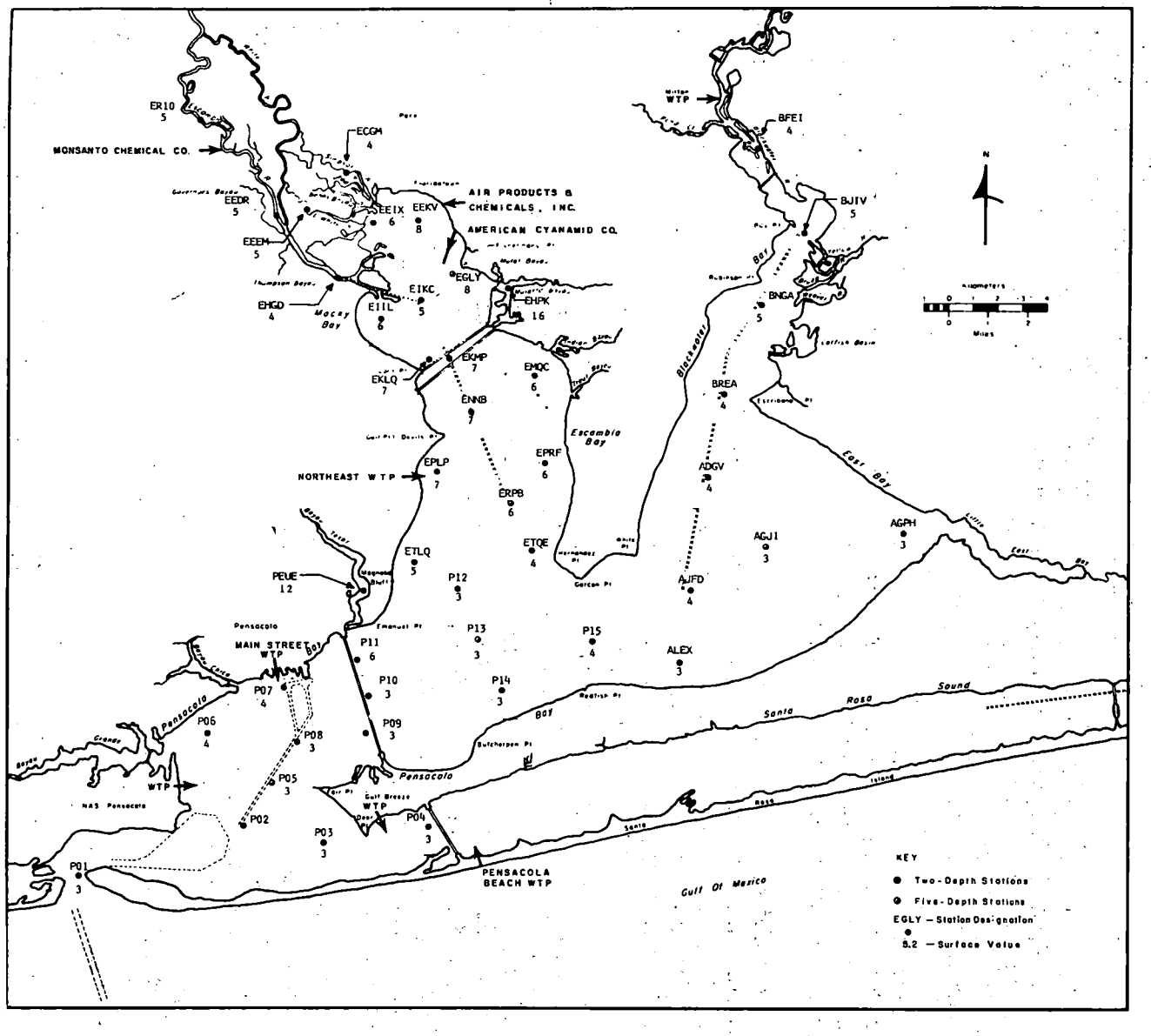


Figure 9-1. Pensacola Bay system stations and chlorophyll a averages (μg/l) from January to September, 1974 (Pensacola Bay data from University of West Florida).

equations to calculate chlorophyll concentrations (Strickland and Parsons, 1972). Corrections were not made for phaeopigments during this study.

Results

Chlorophyll a concentrations in Escambia Bay ranged from 0.6 to 17.9 µg/l during the period January to September 1974. Seasonal trends are shown in Figure 9-2 for pooled data for all stations in the bay. Appendix 9-1 summarizes all data for the Pensacola Bay system for the period of study. There was no significant difference between the upper Escambia Bay compared to the lower bay. The upper bay average for the period was 6.7 µg/l while the lower bay average was 6.0 µg/l. Chlorophyll a concentrations were much higher in the bayous of the system. For example, Mulatto Bayou concentrations averaged 16.0 µg/l and Bayou Texar averaged 12.0 µg/l for the same period. The two highest averages within Escambia Bay occurred near the outfalls from Air Products and Chemicals, Inc. and American Cyanamid Company. Both concentrations here were 8.0 µg/l chlorophyll a.

Escambia and Blackwater Bays had trends toward higher concentrations from January to September as the water temperature rose (Figure 9-2). East Bay tended to remain around 2.5 µg/l throughout this period except for July, August, and September, when there was an increasing trend up to 6.0 µg/l. All three bays had a peak in April and another peak in September. Pensacola Bay had concentrations about equal to Escambia Bay during the winter; however, in the summer the concentrations in Pensacola Bay were the lowest of all four bays (Figure 9-2). Chlorophyll a concentrations averaged 6.3 µg/l in Escambia Bay, 4.5 µg/l in Blackwater Bay, 4.6 µg/l in the Escambia River Delta, 3.5 µg/l in East Bay, and 3.4 µg/l in Pensacola Bay. The station at the inlet from the Gulf (P01) averaged 3.0 µg/l. There was a significant difference ($t = 7.45$, $df = 237$) in the averages for Escambia Bay and East Bay.

Chlorophyll a values for Choctawhatchee Bay were determined for one sample per station (Figure 9-3) on September 12, 1974. Concentrations were higher nearer the river mouth and decreased toward the Gulf inlet. Concentrations ranged from a high of 8.0 µg/l to a low of 0.0 µg/l at the inlet. Concentrations were higher near bayous and the Santa Rosa Sound. The average concentration for Choctawhatchee Bay during this study was 4.2 µg/l.

Discussion

Nutrients from the industrial outfalls were stimulating phytoplankton growth in the northeast sector of Escambia Bay (Figure 9-1). This enrichment affected all of Escambia Bay and caused chlorophyll a concentrations to be higher than in other bays throughout the system (Figure 9-1). These wastes also entered Mulatto Bayou and caused phytoplankton bloom conditions

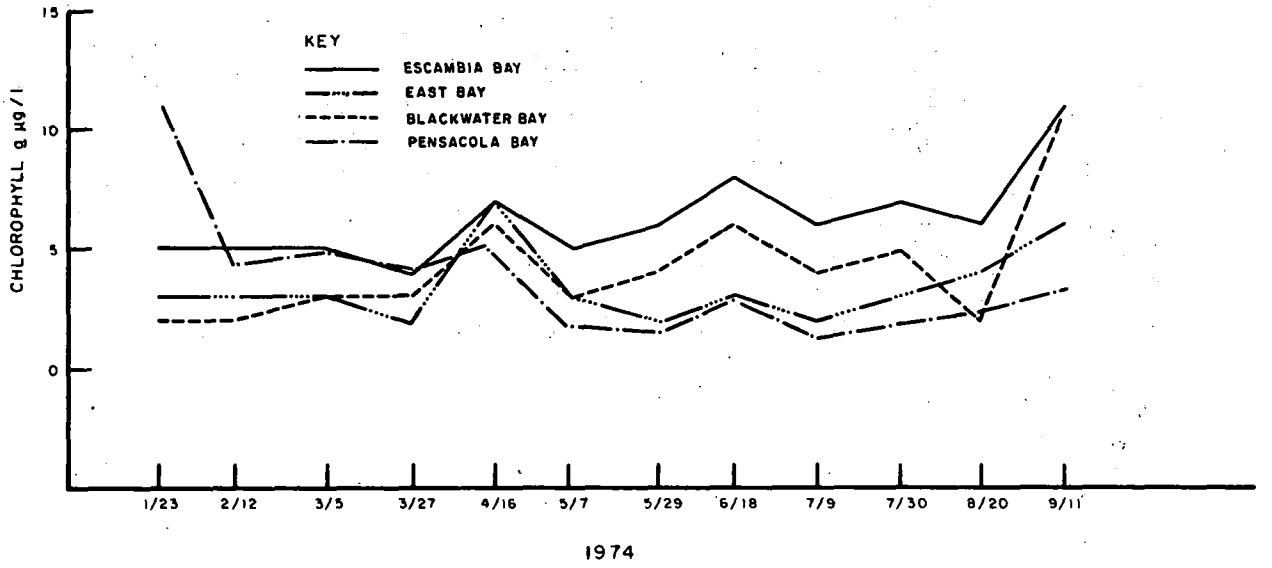


Figure 9-2. Chlorophyll a seasonal concentrations in Escambia, East and Blackwater Bays.

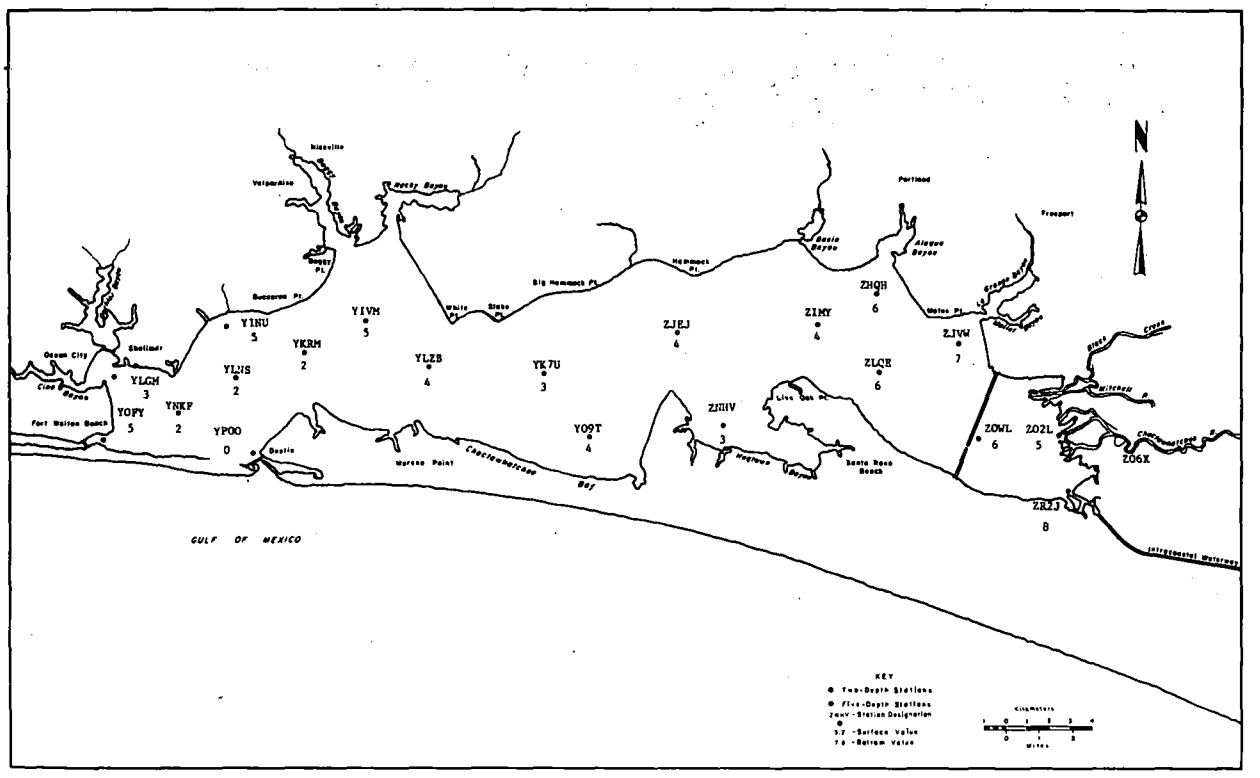


Figure 9-3. Chlorophyll a (µg/l) concentrations in Choctawhatchee Bay on September 12, 1974.

(over 15 µg/l [Hobbie and Copeland, 1975] unpublished) that reached nuisance levels and probably contributed to fish kills during summer periods (Figure 9-1).

Escambia River Delta waters and Blackwater Bay had similar chlorophyll a concentrations (Figure 9-1) and since these waters flow into Escambia Bay and East Bay respectively, it is likely that concentrations in Escambia Bay would be similar to East Bay were it not for the enrichment from industrial waste discharges. Should industrial waste discharges cease, there would be a dramatic decrease in phytoplankton biomass in Escambia Bay. The high phytoplankton populations in Bayou Texar were the result of domestic waste discharges and storm drainage (Hannah, et. al., 1973). Reduced flushing in both Bayou Texar and Mulatto Bayou contribute to the eutrophication problems in these bayous and to expedite their recovery all waste must be excluded. Limited flushing by local rainfall is helpful but this same runoff water has poor water quality and therefore increases enrichment. The bayou inlets are narrow, which restricts the tidal flushing of the bayous.

10 - FISHES AND PENAEIDS OF ESCAMBIA BAY

SURVEY AND STATUS OF THE FISHES, SHRIMPS, AND FISHERIES

Introduction

Escambia Bay, the northwestern extension of Pensacola Bay, is a polluted estuary. The discharge of industrial pollutants, storm drainages, agricultural runoff, and the occasional overflow of domestic sewage have created deleterious conditions in water quality. Consequently, the stressed aquatic environment has led to a serious decline in both sport and commercial fishery yields, as well as to reduced production on the nursery grounds.

Data on the commercial shrimp landings document the declining yields. For example, the penaeid shrimp fishery in Escambia Bay declined from a high of 62,000 lbs (heads-off weight) in 1968 to the eventual collapse of the shrimp fishery in 1972, when no shrimp were harvested from this bay. Commercial shrimp landings in Pensacola Bay, which connects with lower Escambia Bay, declined from over 902,000 lbs in 1968 to 17,000 lbs in 1971 (U.S. National Marine Fisheries Service, 1964-73).

Estuaries are essential for the maintenance of fishery resources in the Gulf of Mexico. The young of numerous finfishes, crustaceans, and other organisms inhabit low salinity waters where there is an adequate food supply and an absence of marine predators; thus, estuaries function as nursery grounds. Many of these species are estuarine-dependent, in that the critical juvenile phase of their life cycles is directly related to the estuaries.

Previous studies on the fishes of Escambia Bay and associated environs provided useful information on species occurrences, on the general biology of selected species, and on a survey of freshwater fishing yields. Unfortunately, many of these reports were of little value in assessing changes in the abundance of estuarine fishes because of pollution, since the baseline data were often not in terms of catch-per-unit-effort. An inclusive species inventory was provided by Cooley (in press) who sampled quarterly with a bottom trawl at two stations in Escambia Bay over a three-year period. The food habits, migration, and relative abundance of the Atlantic croaker (*Micropogon undulatus*) were documented for Escambia Bay (Hansen, 1969). Livingston, et al., (1972) investigated the cause of fish kills in Mulatto Bayou. Aspects of the seasonality and relative abundance of young Gulf menhaden (*Brevoortia patronus*) were investigated in Little East Bay and Pensacola Bay (Tagatz and Wilkens, 1973). Freshwater and euryhaline fishes of the Escambia River system of Florida and Alabama, including the tidal waters at the mouth of the river, were inventoried by Bailey, Winn, and Smith (1954). In 1973, members of the Bream Fishermen Association conducted a

creel census on the Escambia River sport fishery (Hixon, Niven, and Hopkins, 1971). It is anticipated that this data base will be compared with a similar census in the future to evaluate the subsequent role of pollution on the freshwater fishery. Early surveys of the fishes of the Pensacola area were provided by Jordan and Gilbert (1882), Bollman (1886), Gilbert (1891), and Evermann and Kendall (1900).

It is well-established that polluted waters directly influence the species composition, distribution, and abundance of estuarine fishes and shrimps. Shifts in population structure can be employed to detect environmental changes if the population levels are assessed against an adequate data base. The objectives of this investigation were: (1) to develop baseline data on the fishes and shrimps; (2) to relate the distribution of fishes to various environmental variables; and (3) to assess the present status of fish and shrimp populations in the bay. Data obtained from this study will provide background information for the development of fishery management recommendations to accelerate the utilization and recovery of the bay fisheries.

Material and Methods

Sampling Stations, Procedures, and Gear

Fish collections were taken every two months at eleven trawling stations and four seine stations in Escambia Bay and adjacent waters. Designation and location of the trawling stations were as follows: Station I--Delta tributary (Simpson River), Station II AND III--upper reaches of Escambia Bay, Stations V and VI--middle reaches, Stations VII and VIII--lower reaches, Stations IV and IX--bayous (Mulatto and Texar), and Stations X and XI--East Bay. Seine stations were at Floridatown (Station A), Mulatto Bayou (Station B), eastern shore in middle reaches (Station C), and Hernandez Point (Station D). Sampling stations and areas are depicted in Figure 10-1.

To standardize trawling effort, a similar procedure was followed for all collections. The otter trawl was towed in a straight line for a 10-minute period at a speed of 2000 rpm. At the completion of the tow, the trawl was retrieved by hand. Two tows were taken at each trawling station.

Water temperature and salinity were taken with a salinometer for each collection. Surface and bottom readings were taken 0.3 m (1.0 ft) beneath the surface and 0.3 m above the bottom, respectively.

The trawling gear consisted of a 4.9-m (16-ft), semi-balloon, otter trawl (Marinovich Trawl Co., Biloxi, Miss.) that was constructed of 2.54-cm, bar-mesh netting with a 0.64-cm, bar-mesh innerliner in the codend. The trawl was attached to a 30.5 m (100 ft) tow line.

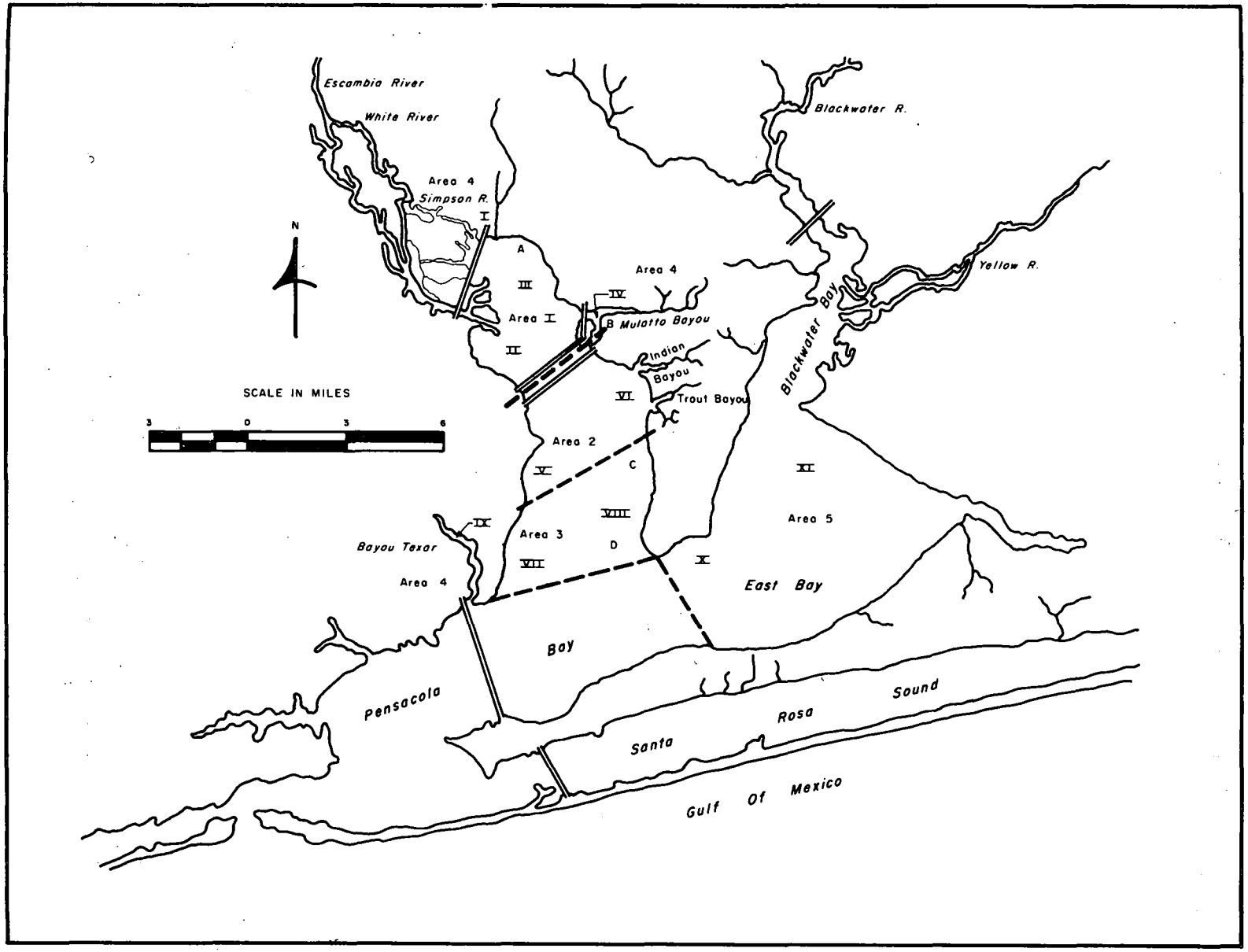


Figure 10-1. Study area in Escambia Bay and adjacent waters.

The 21.3 m (70 ft) bag seine was constructed of a 6.4-mm (1/4 inch), bar-mesh netting in the wings and a center bag of 3.2-mm (1/8 inch), bar-mesh netting. The seine was 1.2 m (4.0 ft) in depth.

Fish collections were taken during the biological year, which extended from October 1973 through September 1974. Large specimens were processed in the field, whereas the more numerous small individuals were preserved in a 10 percent solution of formalin in sea water for subsequent sorting, counting, and identification in the laboratory. All length measurements were of total length (tip of snout to the end of compressed caudal fin) taken to the nearest 1.0 mm, unless noted otherwise.

The names of fishes and their phylogenetic order follow the recommendations of the American Fisheries Society (Bailey, et al., 1970).

Community Structure

Species diversity indices provide a means of assessing the effects of environmental stress or pollution on the structure of fish communities. Also, information on the number of individuals per species is reduced to a single value, which facilitates the analysis of the catch data.

Diversity was calculated using the Shannon-Weaver formula (Shannon and Weaver, 1963). The diversity of the catch sample from the population was estimated by (H'):

$$H' = -\sum \frac{N_i}{N} \log_e \frac{N_i}{N}$$

where N_i is the number of individuals in the $i^{\underline{th}}$ species and N is the total number of individuals in the catch.

Since Shannon-Weaver values may increase in response to similar increases in both number of species and relative abundance or equitability of species, these two components are usually calculated separately. Thus, the "species richness" (Margalef, 1969) component of diversity (D) was calculated by the following equation:

$$D = (S-1) \; / \; \log_e N,$$

where S represents the number of species and N is the number of individuals. This formula gives more weight to the number of species than to the number of individuals. The "evenness" index (J), developed by Pielou (1966), is a measure of relative species abundance that was calculated by:

$$J = H' / H \max = H' / \log_e S,$$

where $\log_e$ S is the maximum value of H' and H' = H' max when all species are equally abundant. Thus, the maximum value of J is 1.0. Similar indices, particularly the Shannon-Weaver formula, were employed in assessing the pollution-stressed, fish communities in the estuarine waters of Patuxent River, Galveston Bay, and Mystic River.

Fish kills

Historical records on the fish kills in the Pensacola Bay system were based on our interpretation of the unpublished log maintained by Mr. William T. Young, Florida State Department of Environmental Regulation (FDER). Starting in 1969, all fish kills observed by personnel of Florida Marine Patrol, by members of Bream Fishermen Association in Pensacola, and by concerned citizens were reported to FDER. Subsequently, a biologist, usually Mr. Young, performed an on-site inspection. In addition, personnel of the Escambia Bay Recovery Study (EBRS) investigated kills that occurred from August 1973 through December 1974. In this report, chronic kills, which often persisted for several days or on occasion, even weeks, and multiple reports of the same event were tabulated as a single fish kill.

Assessing the number of fishes involved in an extensive kill in the estuary is often a difficult task due to the vast areas and often remote shorelines. More accurate estimates of the size of the kills came from the bayou habitats than from those in the open bays.

Commercial landings

Data on the commercial landings from Escambia County and other Florida areas were obtained from reports of the Florida Department of Natural Resources (1964-72) and the U.S. National Marine Fisheries Service (1973). Information on commercial shrimp catches from specific bays was provided by U.S. National Marine Fisheries Service (1964-73).

Results

Relative Abundance

A total of 79,372 individuals, representing 57 species and 32 families, was taken in the bimonthly collections. Of the total catch, 69,876 individuals, or 88 percent, were taken in the otter trawl collections; the remainder were captured with the seine (Table 10-1). An average of 568 individuals was taken per trawl sample during the year. Bimonthly distribution of the total otter trawl effort during the survey is tabulated by station and by area in Appendix 10-1.

In decreasing order of abundance, the most numerous species were bay anchovy, (*Anchoa mitchilli*), Gulf menhaden (*Brevoortia patronus*), spot (*Leiostomus xanthurus*), Atlantic croaker

Table 10-1. Summary of the number of fishes captured with otter trawl and seine during the bimonthly survey in Escambia Bay during 1973 through 1974.

Species	Total trawl catch Number of samples 123	Total seine catch 24	Total catch	Life history stage*
Atlantic stingray (Dasyatis sabina)	2	0	2	JA
Bluntnose stingray (Dasyatis sayi)	2	0	2	A
Longnose gar (Lepisosteus osseus)	29	0	29	A
Ladyfish (Elops saurus)	8	2	10	J
Gulf menhaden (Brevoortia patronus)	9,305	5,499	14,804	J
Scaled sardine (Harengula pensacolae)	255	20	275	J
Threadfin shad (Dorosoma petenense)	15	0	15	A
Striped anchovy (Anchoa hepsetus)	4,693	2	4,695	JA
Bay anchovy (Anchoa mitchilli)	30,566	1,448	32,014	JA
Inshore lizardfish (Synodus foeteus)	11	4	15	JA
Channel catfish (Ictalurus punctatus)	5	0	5	A
Sea catfish (Arius felis)	123	2	125	JA
Gafftopsail catfish (Bagre marinus)	1	0	1	A
Gulf toadfish (Opsanus beta)	1	0	1	A
Atlantic needlefish (Strongylura marina)	0	3	3	J
Sheepshead minnow (Cyprinodon variegatus)	0	6	6	JA
Gulf killifish (Fundulus grandis)	0	70	70	JA
Longnose killifish (Fundulus similis)	0	10	10	JA
Rainwater killifish (Lucania parva)	0	2	2	A
Tidewater silverside (Menidia beryllina)	6	942	948	JA
Chain pipefish (Syngnathus louisianae)	1	0	1	J
Gulf pipefish (Syngnathus scovelli)	1	0	1	A
Largemouth bass (Micropterus salmoides)	0	2	2	JA

* J=juvenile A=adult

Table 10-1 (cont). Summary of the number of fishes captured with otter trawl and seine during the bimonthly survey in Escambia Bay during 1973 through 1974.

Species	Total trawl catch (Number of samples 123)	Total seine catch (Number of samples 24)	Total catch	Life history stage*
Crevalle jack (Caranx hippos)	23	0	23	J
Atlantic bumper (Chloroscombrus chrysurus)	625	299	924	J
Leatherjacket (Oligoplites saurus)	3	5	8	J
Lookdown (Selene vomer)	4	0	4	J
Mangrove snapper (Luthanus griseus)	0	2	2	JA
Spotfin mojarra (Eucinostomus argenteus)	113	61	174	JA
Sheepshead (Archosargus probatocephalus)	11	0	11	A
Pinfish (Lagodon rhomboides)	25	64	89	JA
Silver perch (Bairdiella chrysura)	84	0	84	JA
Sand seatrout (Cynoscion arenarius)	1,587	33	1,620	JA
Spotted seatrout (Cynoscion nebulosus)	11	2	13	JA
Spot (Leiostomus xanthurus)	13,826	171	13,997	JA
Southern kingfish (Menticirrhus americanus)	12	1	13	JA
Gulf kingfish (Menticirrhus littoralis)	5	0	5	J
Atlantic croaker (Micropogon undulatus)	7,915	488	8,403	JA
Atlantic spadefish (Chaetodipterus faber)	1	0	1	J
Striped mullet (Mugil cephalus)	24	317	341	JA
Atlantic threadfin (Polydactylus octonemus)	467	10	477	JA
Violet goby (Gobioides broussonneti)	1	0	1	J
Sharptail goby (Gobionellus hastatus)	17	0	17	JA
Naked goby (Gobiosoma bosci)	0	1	1	J
Code goby (Gobiosoma robustum)	0	1	1	A
Freshwater goby (Gobionellus shufeldti)	1	1	2	A
Atlantic cutlassfish (Trichiurus lepturus)	25	0	25	JA
Spanish mackerel (Scomboromorus maculatus)	3	0	3	J
Harvestfish (Peprilus alepidotus)	20	0	20	J
Bighead searobin (Prionotus tribulus)	2	0	2	J
Bay whiff (Citharichthys spilopterus)	12	1	13	JA
Fringed flounder (Etropus crossotus)	10	1	11	JA
Southern flounder (Paralichthys lethostigma)	6	0	6	JA
Hogchoker (Trinectes maculatus)	8	1	9	JA
Blackcheek tonguefish (Symphurus plagiusa)	1	0	1	J
Least puffer (Sphoeroides parvus)	9	25	34	J
Striped burrfish (Chilomycterus schoepfi)	1	0	1	J
TOTAL	69,876	9,496	79,372	

* J=juvenile, A=adult

(Micropogon undulatus), striped anchovy (Anchoa hepsetus), sand seatrout (Cynoscion arenarius), tidewater silverside (Menidia beryllina), and Atlantic bumper (Chloroscombrus chrysurus) (Table 10-1). The bay anchovy, representing 40 percent of the total catch, was the most abundant species in Escambia Bay. The other seven species accounted for 57 percent of the year's total catch.

Members of three families of fishes represented 96 percent of the total catch with both trawl and seine, and, thus, dominated the catches from Escambia Bay. The most abundant families were Engraulidae (anchovy), Sciaenidae (drum), and Clupeidae (herring). Anchovies, composed of two species, represented nearly half of the total catch. The sciaenids were represented by seven species and accounted for 30 percent of the total catch, while the three clupeid species represented less than one-fifth of the catch. The other 29 families, represented by 45 species, accounted for the remaining four percent of the total catch.

Distribution by Area

Among the five study areas, the largest catches-per-unit-effort (trawling) occurred at the bayou and river stations (Area 4) (Figure 10-2). An annual mean catch of 924 fishes was taken in the waterways adjacent to the bay which represented a two- to three-fold increase over the other areas. In the open waters of Escambia Bay, the annual mean catch ranged from 326 to 498 individuals (Areas 1-3). The largest catch occurred in the upper reaches of the bay (Area 1) in the vicinity of the industrial outfalls. East Bay stations served as a control, since this bay was considered to be less polluted than Escambia Bay. The annual trawl catch of 535 fishes in the control area (Area 5) surpassed the returns from the three areas in Escambia Bay (Appendices 10-2 and 10-3).

Variations in catches among estuarine areas were real differences as indicated by ANOVA ($F = 3.27$, $p < 0.05$). Differentiation of group means (Student-Newman-Keuls multiple range test) revealed that the increased catch in the bayous (Area 4) was significantly different from those of other areas. The catches from the three open water areas in Escambia Bay were statistically similar to each other, as well as to the control area in East Bay. Area comparisons were shown diagramatically as follows:

Area and rank	3	2	1	5	4
Annual mean catch	325.9	481.3	498.5	534.1	923.8

Means enclosed by the range line were not significantly different from each other; means not underlined were significantly dissimilar. It was conclusively shown that the bayous were the most productive waters in the estuary.

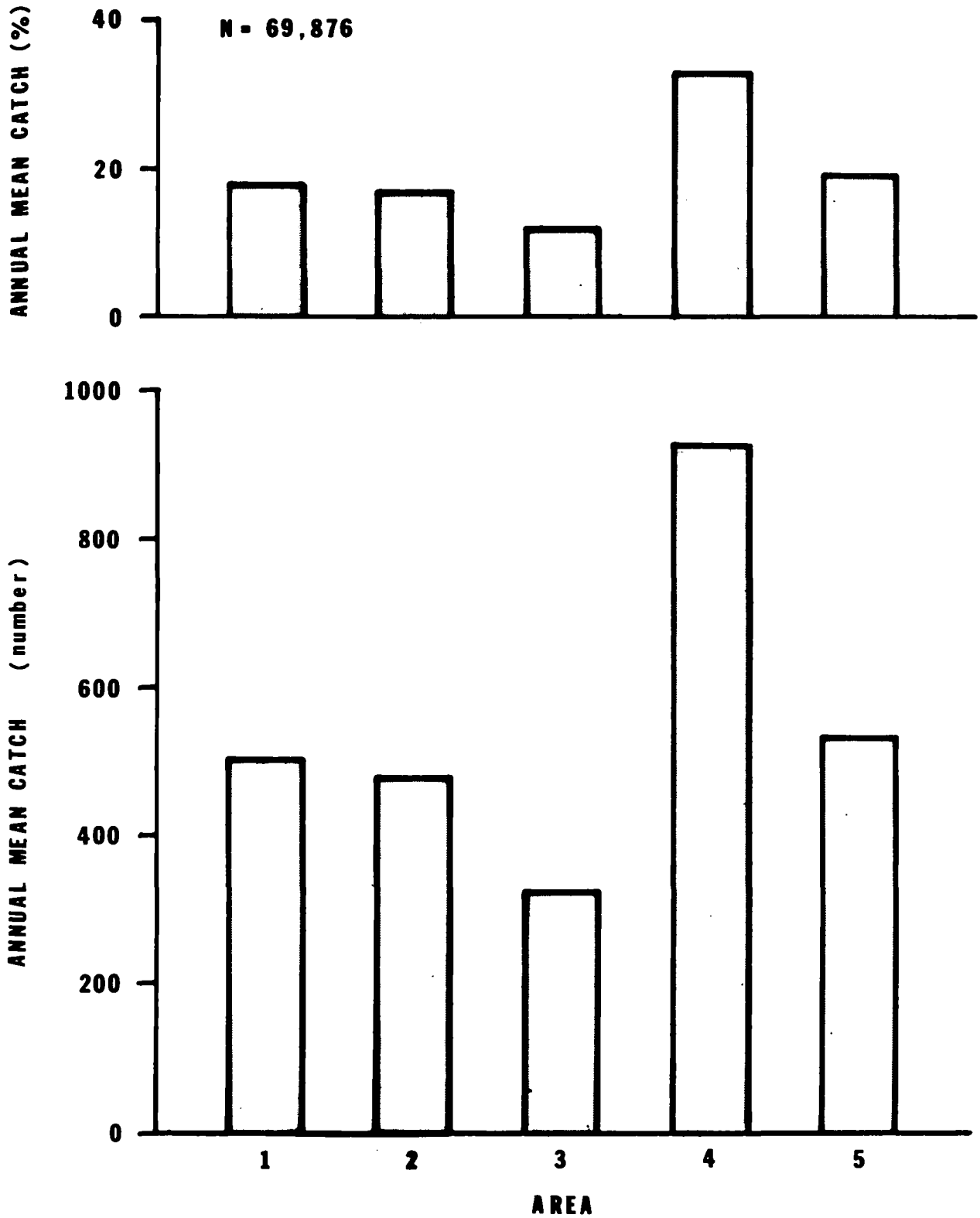


Figure 10-2. Annual mean catch of fishes per trawl sample by number and by percent for each study area, 1973-1974.

Peak bimonthly catches varied among the five areas during the biological year. During October and August, the trawl catches in East Bay (control) exceeded the return from the other areas during October and August (Appendix 10-3). Conversely, the catches in Escambia Bay (Area 1-3) in December, February, and June generally exceeded the catches from the control area (Area 5). December catches were composed largely of pelagic species, whereas in June, the majority of fishes were those that typically inhabit the benthic environment. In August, low levels of dissolved oxygen (0.0 to 6.5 ppm) near the bottom were responsible for the smallest catches of the year at the stations in Area 1-3.

Among the four seine stations, the largest annual catch (945 individuals) occurred at Station A (Area 1) largely due to the occurrence of several menhaden schools at the seining site in October 1973 (Appendices 10-4 and 10-5). Disregarding the catch of juvenile Gulf menhaden, there essentially was no difference in the catches among these stations. Seine collections supplemented the list of species from the shallow shoreline habitat, but these data were not employed in making comparisons on catch-per-unit-effort with other estuaries.

Seasonality

Usually, the seasonal occurrence of two or three species dominated the bimonthly trawl collections (Appendix 10-3). For instance, incoming postlarval and juvenile Gulf menhaden and the resident bay anchovy accounted for 79 percent of the total catch in February. In June, juvenile spot and Atlantic croaker were the most abundant fishes in the bay and represented more than half of the catch. Juveniles of these two species, which were members of a new, incoming year-class, were first captured in December.

Among the clupeid fishes, the Gulf menhaden was seasonally dominant in the bayou and delta tributary stations (Area 4) from February through June (Appendix 10-3). Young menhaden, upon entering the estuary, initially seek out brackish waters within a salinity range from 0.0 to 5.0 ppt.

The major movement of larval fishes from the offshore spawning grounds in the Gulf of Mexico to Escambia Bay generally commences in November with the greatest influx occurring from January through March. Because of prolonged and often overlapping spawning seasons, young of various incoming year-classes reached their greatest abundance on the nursery grounds in early summer. Coinciding with the progressive decrease in water temperatures from October through December, most of the juveniles have migrated back to Gulf waters. This sequence is also applicable to most estuarine fish species across the northern Gulf of Mexico.

Distribution Records

There were several new distribution records for the ichthyofauna of the Pensacola Bay system, as well as for Escambia Bay. Fishes collected for the first time from the estuarine waters near Pensacola included the bluntnose stingray (Dasyatis sayi), violet goby (Gobioides broussonneti), freshwater goby (Gobionellus shufeldti), pink wormfish (Microdesmus longipinnis) (See Chapter 11), and least puffer (Sphoeroides parvus). It should be noted that Bailey, Winn, and Smith (1954) collected Gobionellus shufeldti in the lower freshwater portions of the Escambia River. In addition, the single specimen of the violet goby represented the first time that this species had been taken along the west coast of Florida. This specimen, which measured 287 mm SL, is cataloged as Accession No. 1913 in the museum of the U.S. Environmental Protection Agency, Gulf Breeze Environmental Research Laboratory, Gulf Breeze, Florida.

Fishes not previously reported from Escambia Bay included the gray or mangrove snapper (Lutjanus griseus), southern kingfish (Menticirrhus americanus), Gulf kingfish (M. littoralis), Atlantic spadefish (Chaetodipterus faber), guaguanche (Sphyraena guachancho) (see following section), Atlantic treadfin (Polydactylus octonemus, bighead searobin (Prionotus tribulus), fringed flounder (Etropus crossotus), and striped burrfish (Chilomycterus schoepfi).

Community Structure

Among the five areas of the estuary, average species diversity values, as calculated from the trawl data and expressed by the Shannon-Weaver formula (H'), ranged from 0.707 to 0.923. The lowest annual diversity occurred in the upper reaches of Escambia Bay (Area 1), whereas the highest diversity was recorded from the control area (Area 5) in East Bay. Apparent dissimilarities among at least some of the areas were not statistically significant, as indicated by an ANOVA test ($F = 0.922$, $p > 0.05$).

Seasonal fluctuations in H' were apparent with the highest readings (mean, 1.100) occurring in the summer months and the lowest (mean, 0.540) in the fall. The spring (April) and summer (June and August) and the fall (October) and winter (December and February) diversity values formed two homogeneous groups which differed significantly from each other (Table 10-2). Seasonal shifts were largely related to the influx of larval and juvenile fishes (both species and numbers) into the estuary during the spring and the exodus of young fishes in the fall. Annual cycle of H' from three habitats (Escambia Bay, Bayous and River, and East Bay) paralleled each other (Figure 10-3).

Past pollution studies have established, as a general rule, that with an increase in distance from the point sources, there is a corresponding increase in diversity, i.e., community structure. Although the H' values from the three stations on the

Table 10 - 2. Seasonal means and significance of species diversity indices as determined by Student-Neuman-Keuls multiple range test. Means not underlined are significantly different from each other at the 95 percent level of confidence.

Diversity index	Fall	Winter	Spring	Summer
H'	0.540	0.599	1.056	1.100
D	0.618	0.814	0.795	1.132
J	0.365	0.351	0.606	0.564

eastern side of Escambia Bay were homogeneous, a plot of the annual mean values showed the presence of a diversity gradient, which increased from a value of 0.76 in the upper bay to 0.98 in the lower bay. The H' values of Stations III, VI, and VIII, and the distance of these stations from the discharge points, are plotted in Figure 10-4 with statistics on sampling variations. Presumably, the inhibitory or toxic effects of industrial wastes in the upper bay were responsible for the depression of species diversity.

"Species richness" diversity (D) is more a measure of the addition or subtraction of species than of changes in abundance. Thus, seasonal movements should be reflected more often in D, than in H', values. This interpretation agrees with the observations of McErlean, et al. (1973).

The seasonality of D was shown by the low values in the winter which steadily increased during the spring and summer and peaked in the summer (Figure 10-5). Multiple range tests showed that the fall through winter seasons were homogeneous and significantly different from the summer period (Table 10-2).

"Species richness" values for the three areas of Escambia Bay, bayous, and East Bay did not differ significantly from each other. However, environmental stress in Escambia Bay may account for the lower species values in that bay in comparison to East Bay.

The "evenness" index (J) in regard to the three estuarine areas was non-significant. However, the J values tended to be higher in East Bay than in Escambia Bay and in the bayous (Figure 10-6).

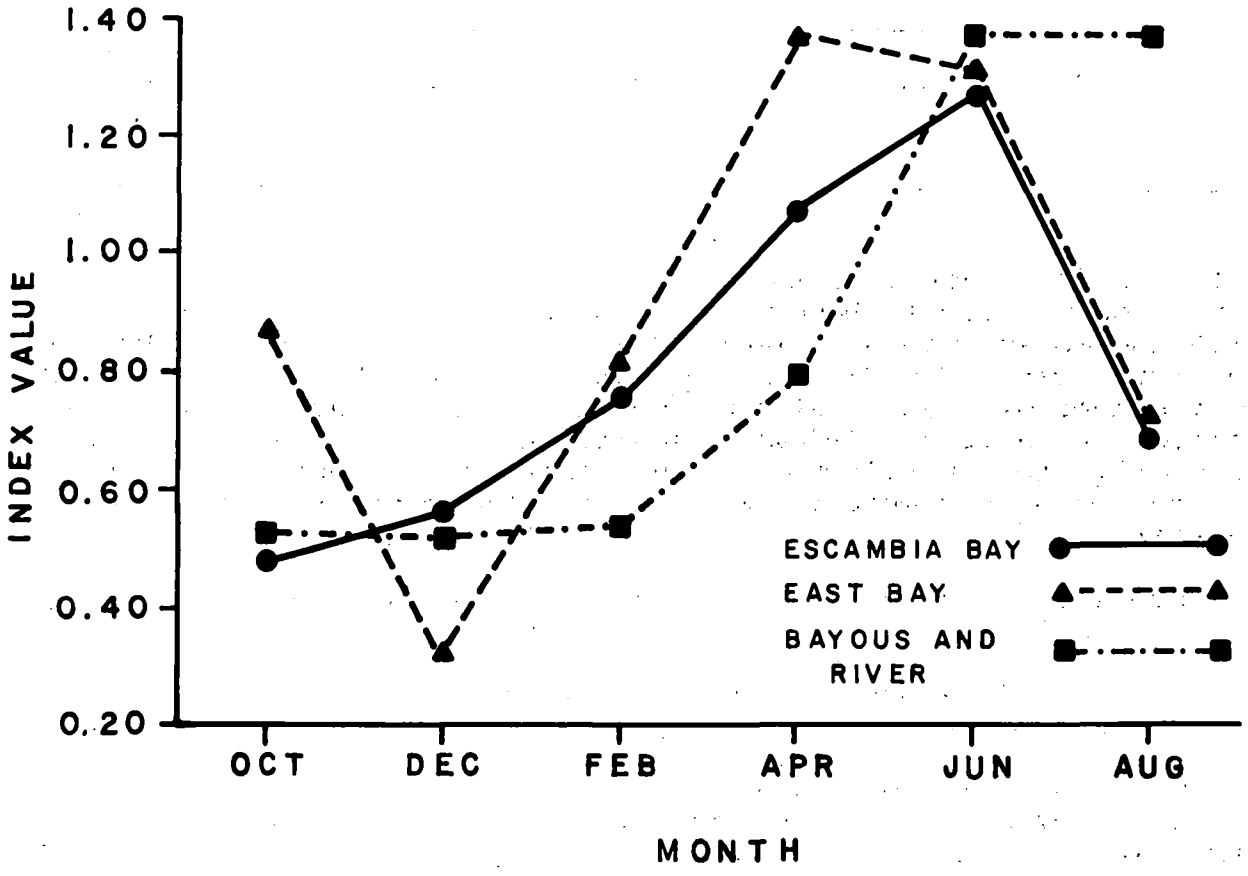


Figure 10-3. Temporal distribution of species diversity index (H') in three estuarine areas, 1973-1974.

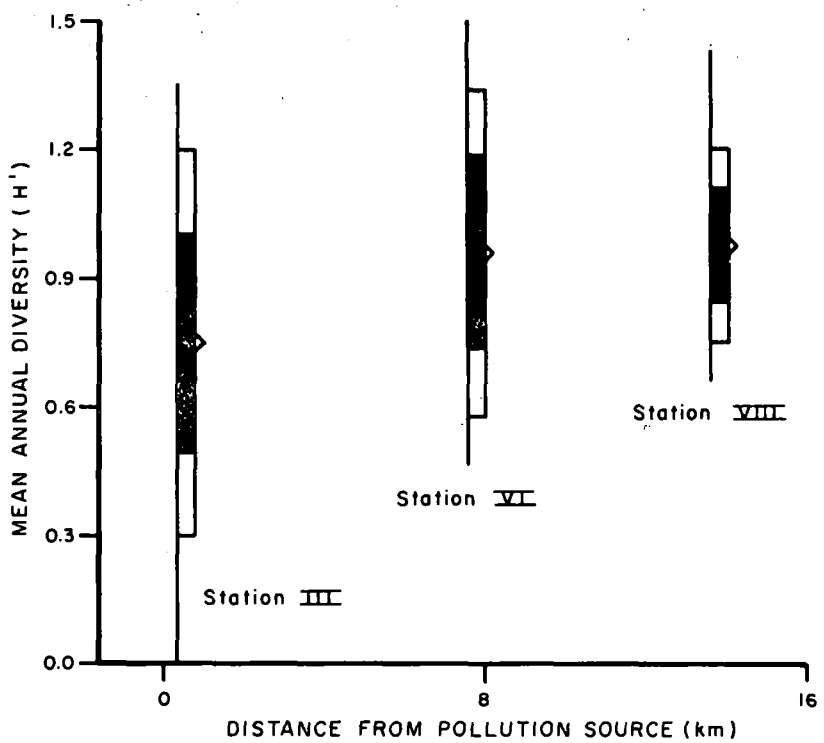


Figure 10-4. Relationship between species diversity (H') and distance of three stations (1.6 km = 1 mile) from major point sources of pollution in Escambia Bay.

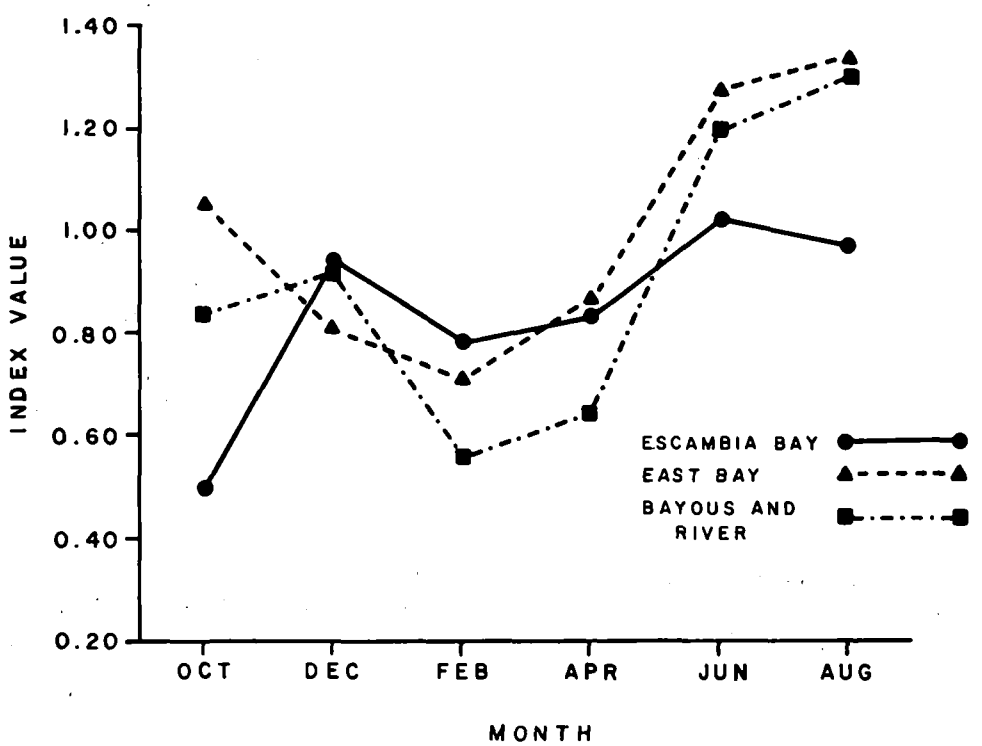


Figure 10-5. Temporal distribution of species diversity index (D) in three estuarine areas, 1973-1974.

The seasonal aspects of "evenness" index (J) were apparent, with the lowest values occurring in the fall and winter and the highest in the spring and summer (Table 10-2). Thus, the relative species abundance was significantly different during the warm months in comparison to the colder periods.

Seasonal increases in both the D and J indices paralleled similar changes in H' diversity. It was evident that the higher H' values reflected increases in both the number of species, as well as their relative abundance. This observation is contrary to those of Dahlberg and Odum (1970), who, during a survey of the fishes in a Georgia estuary, found that "species richness" (D) was homogeneous with respect to seasons. Along the Gulf Coast, both juvenile and adult fishes evidently exhibit stronger migration responses than do the Georgia species.

Environmental Relationships

It is always of interest to inquire into the possibility that the distribution of fishes may be influenced by various environmental factors. For instance, fishes must be able to tolerate continual shifts in salinity due to tidal flow. At the time of sampling with the otter trawl, salinity values ranged from 0.0 to 32.0 ppt. The lowest salinities occurred in February and April in the bay due to heavy rains; the highest salinities were recorded in December. Freshwater flow from the Escambia River and delta tributaries influences the salinity gradient, which gradually increases from the upper to the lower reaches of the bay. Erratic catches of estuarine fishes at Station I near the mouth of the Simpson River were attributed to abrupt changes from highly saline conditions in December to freshwater conditions in February and April. Salinity and temperature values at four typical trawling sites (Stations III, IV, VI, and VIII) are depicted in Figure 10-7.

Environmental variables (bottom readings) consisting of salinity, temperature, sediment organic content, principal nutrient index (PNI), and dissolved oxygen were tested statistically against the numerical catch. None of these six variables was significantly correlated with fish numbers. The fact that salinity has no significant influence on the total distribution was not entirely unexpected, since most estuarine fishes are euryhaline, i.e., they possess physiological adaptations which permit survival during wide fluctuations in salinity.

Among the above variables, species diversity (H') was significantly correlated only with PNI ($r = -0.470$, $p < 0.01$) and temperature ($r = 0.327$, $p < 0.01$). Water temperatures paralleled the seasonal cycle of H' diversity. The "principal nutrient index" (PNI) combined total nitrogen, total phosphorus, and total organic carbon into a single value (Refer to Chapter 8). The presence of a high PNI had a negative effect on species diversity, whereas a low PNI improved H'. Multiple regression

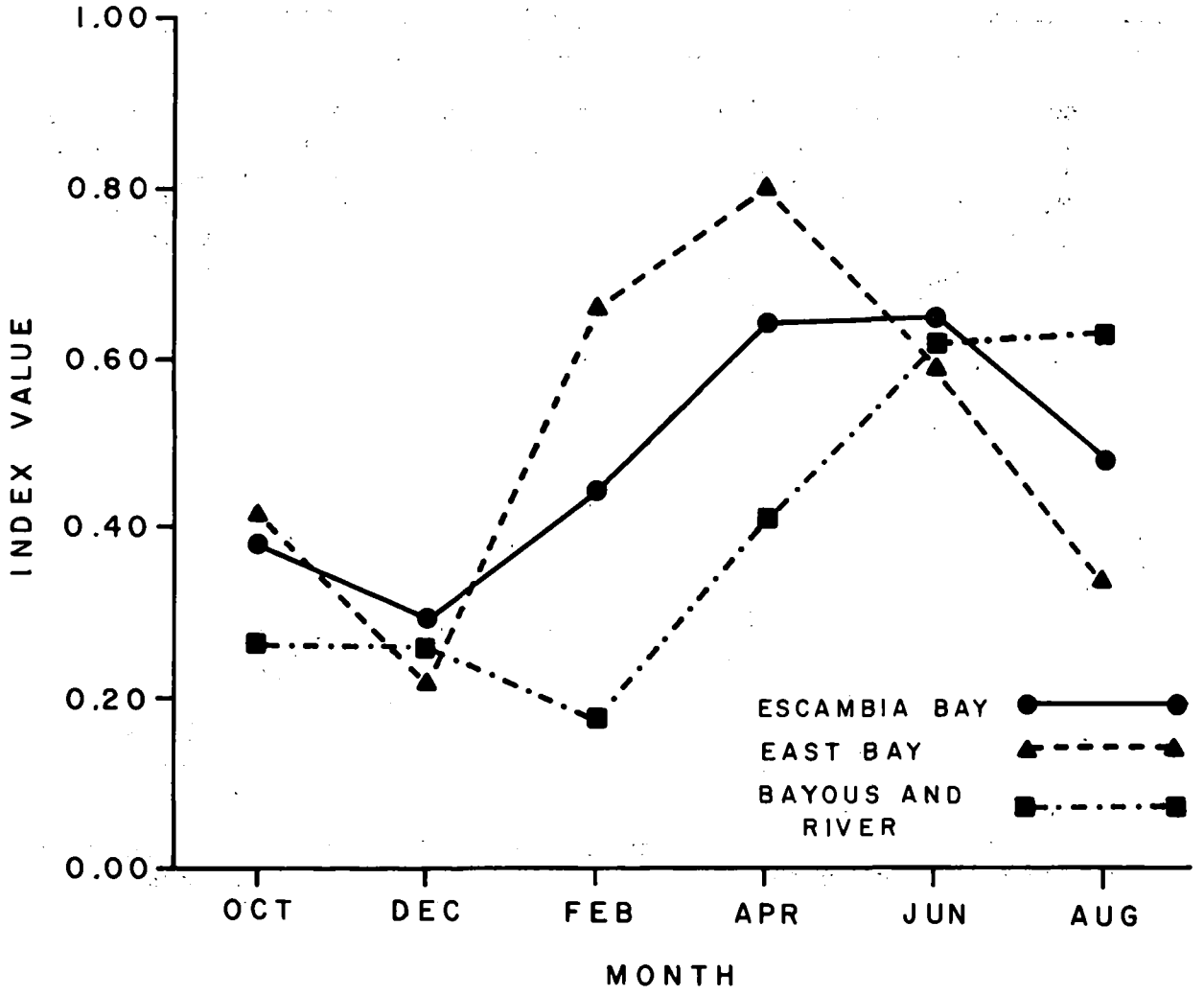


Figure 10-6. Temporal distribution of species diversity index (J) in three estuarine areas, 1973-1974.

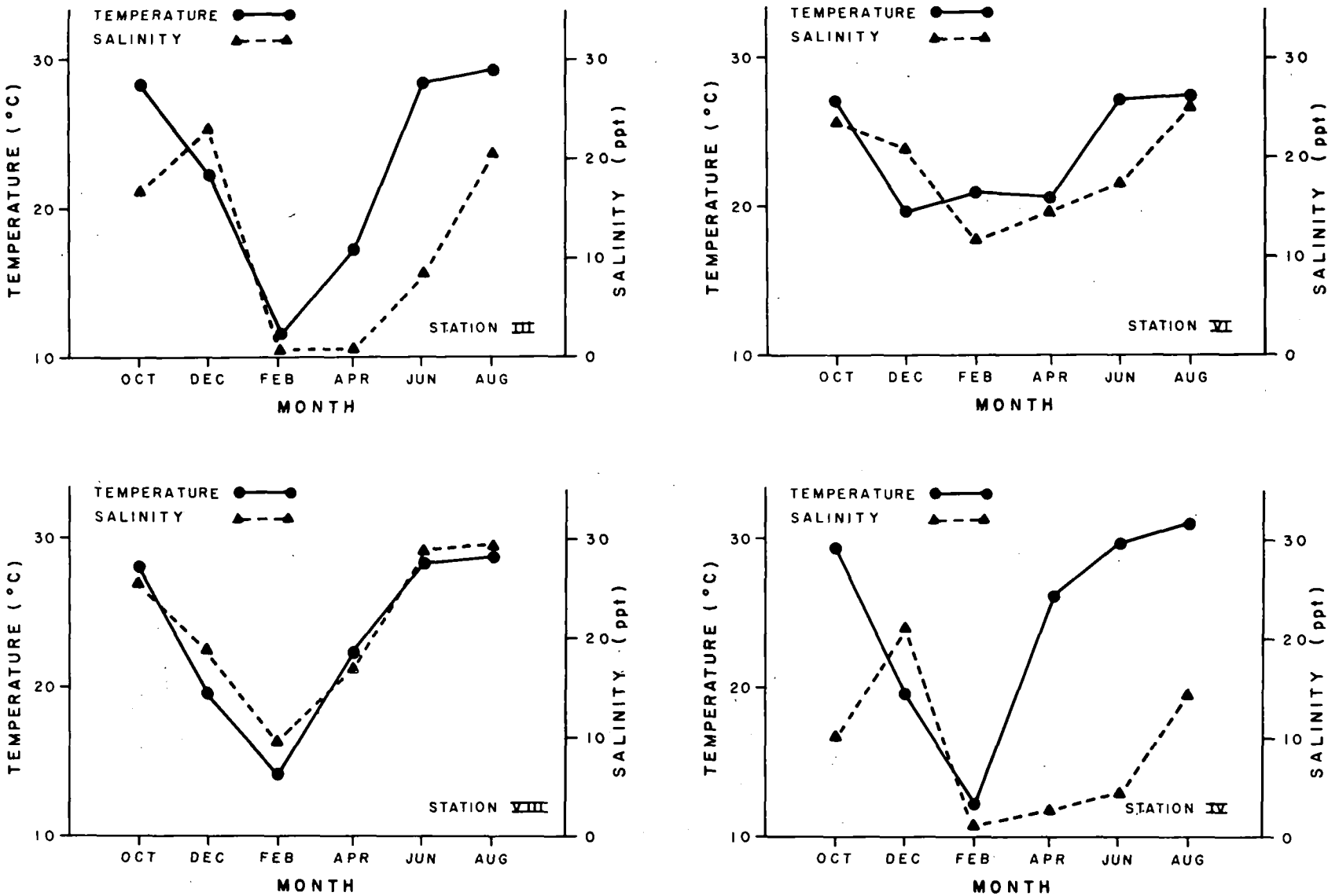


Figure 10-7. Water temperature and salinity readings on the bottom for trawl stations III, VI, and VIII in the open waters of Escambia Bay and Station IX in Mulatto Bayou, 1973-1974.

analysis revealed that nutrients contributed 42 percent to the variance of species diversity and temperature contributed 24 percent. The remaining 34 percent of the variance was related to undetermined factors, such as biological interactions.

Shrimp Distribution

During the survey in Escambia Bay, the penaeid catch was composed of 75 percent brown shrimp (Penaeus aztecus), 17 percent white shrimp (P. setiferus), and 8 percent pink shrimp (P. duorarum) (Appendix 10-6). Brown and white shrimp are also the dominant species in other estuaries of the northern Gulf. The low percentage composition of pink shrimp in our catches was expected since the Pensacola area is on the northern fringe of its distribution. Major concentrations of pink shrimp are located off the southwestern coast of Florida (Farfante, 1969).

The average sample catch was 3.9 penaeid shrimp per trawling effort during 1973-1974. Again, as in the case of the abundance of fishes, the largest collections were taken in the productive bayous (Area 4) with an average catch of 7.0 shrimp per trawl sample (Figure 10-8). However, none of the catches among the five areas (Area 1-5) was statistically different from each other ($F = 1.84$, $p > 0.05$). The homogeneous catches from the upper, middle, and lower reaches of Escambia Bay indicated that distribution of the shrimp was not related to the major point sources of pollution in the upper bay.

Shrimp were most abundant in June when the average sample catch was 10.3 individuals (Appendix 10-7). In fact, over half the total shrimp catch was caught during the June survey, which coincided with the peak bimonthly catch of fishes.

Commercial shrimp landings provide an indirect method of evaluating past and present conditions within a given bay and among bays. Since the bottom area of various bays differ, the only valid comparisons are provided on a catch per-unit-effort basis; in this instance, the calculated poundage per trip. A single trip is reported for each voyage. Pounds of shrimp are reported as heads-off weight (U.S. National Marine Fisheries Service, 1964-73).

In the estuarine waters near Pensacola, the shrimp landings declined sharply in 1969 and collapsed in Escambia Bay and East Bay in 1970. In Escambia Bay, the annual five-year catch decreased from 150 pounds per trip during 1964-68 to 57 pounds during the 1969-73 period, a decline of 62 percent (Appendix 10-8). During the same period, the number of fishing trips dropped by nearly two-thirds. In both East Bay and Pensacola Bay, the average catch per trip declined by 94 and 83 percent, respectively, during the second five-year period compared with the 1964-68 period (Appendices 10-9 and 10-10). The total value of the shrimp catch in the Pensacola Bay system decreased from

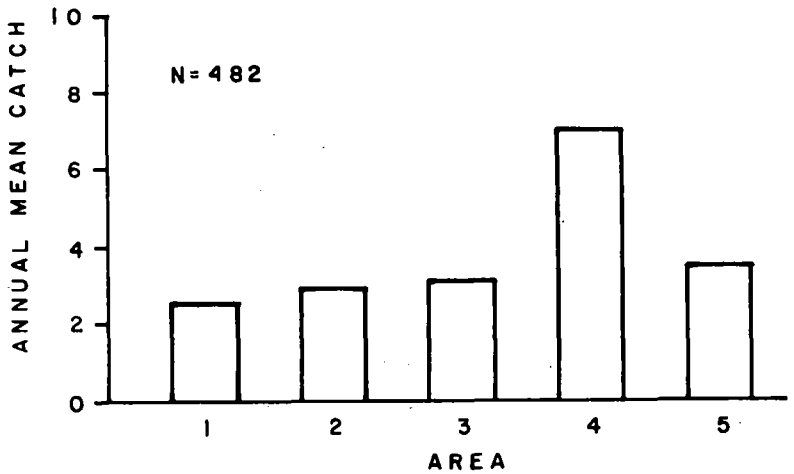


Figure 10-8. Average catch of penaeid shrimp per trawl sample (catch-per-unit-effort) for the various estuarine areas in Escambia Bay, 1973-1974.

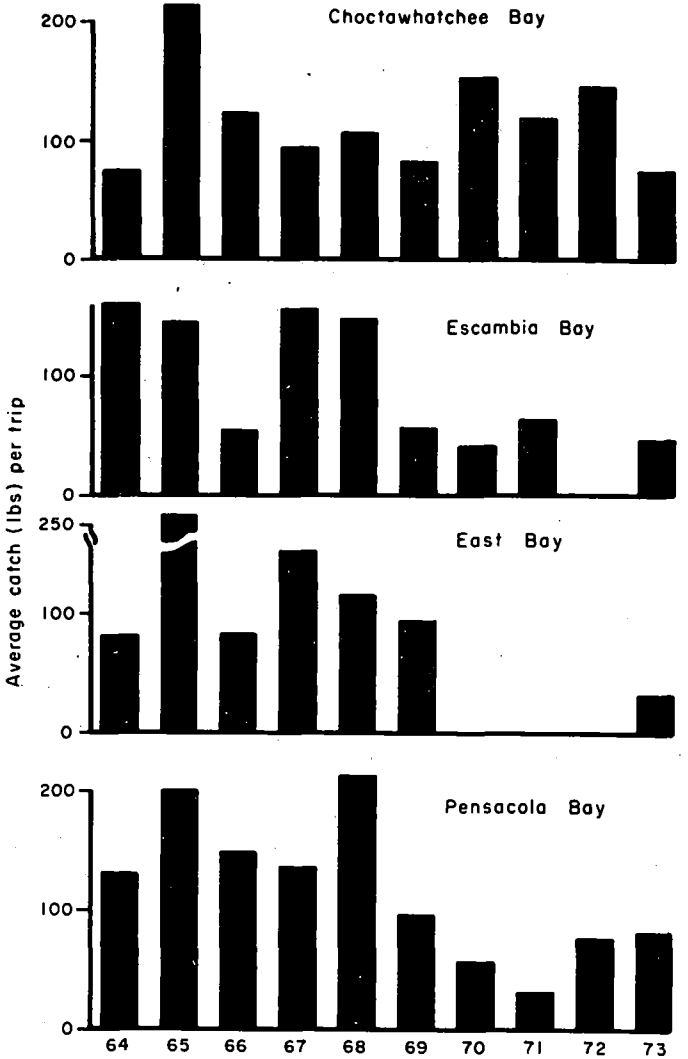


Figure 10-9. Average catch of penaeid shrimp per commercial fishing trip Pensacola Bay system and Choctawhatchee Bay (control), 1964-1973.

342,421 dollars per year (1964-68) to 89,352 dollars per year (1969-73), an average decline of 74 percent (Figure 10-9).

The decreased yields apparently were not a reflection of weak year-classes, since the annual catch per trip in Choctawhatchee Bay remained essentially unchanged between the five-year average catch in 1964-68 and in 1969-73 (Appendix 10-11). Choctawhatchee Bay, which served as a control area, is a relatively non-polluted estuary about 40 miles east of Pensacola. Thus, the decline in the commercial catch in the Pensacola Bay system was attributed to the polluted status of the bays.

Fish kills

Recurring fish kills have occurred in the bays, bayous, and rivers in the Pensacola Bay system since the late fifties. In the five-year period from 1970 through 1974, 166 individual kills were recorded, mainly from estuarine waters. Of this total, 81 (49 percent) of the fish kills occurred in the Escambia Bay sub-system, 15 (9 percent) in the East Bay sub-system, and 70 (42 percent) in the Pensacola Bay sub-system (Table 10-3 and Figure 10-10).

Traditionally, the most frequent kills have taken place in the eutrophic waters of Escambia Bay and contiguous waters. Since 1970, 30 kills (37 percent) occurred in the open waters of the bay, while the remainder (63 percent) took place in a total of 13 separate protected areas adjacent to the bay (Table 10-3). For instance, nearly one-fourth of the kills in the Escambia Bay sub-system occurred in Mulat-Mulatto Bayou complex, which is near the industrial outfall area. Semi-enclosed bodies, such as this bayou complex, often have restricted entrances which tend to impede water circulation and confine the buildup of pollutants to the waterway.

During the past five years (1970-74), more than half of the fish kills occurred during the summer months and nearly two-thirds of the kills happened from July through September (Appendix 10-12). The seasonal increase in the temperature of the waters coincides with the frequency of kills. High temperatures accelerate metabolic rates and lower dissolved oxygen levels, which create additional stresses on the aquatic environment. Conversely, few kills (less than two percent) were recorded during the cold winter months (December through February).

Pollution-caused fish kills have been attributed to excessive levels of nutrients, toxic metals, sewage, pesticides, and other industrial by-products. Eutrophication stimulates high algal production (or blooms) during the summer which, in turn, often causes the depletion of dissolved oxygen concentrations during the night. Low dissolved oxygen levels were believed to be the main cause of death, particularly among menhaden. Other kills were attributed, either alone or synergistically, to industrial

Table 10 - 3. Temporal and spatial distribution of fish kills in the Pensacola Bay system during 1970 through 1974.

Location	1970	1971	1972	1973	1974	Total
Escambia Bay subsystem						
Escambia Bay	8	14	2	3	3	30
Escambia River	0	0	1	0	0	1
Thompson Bayou	1	0	0	0	0	1
Governors Bayou	0	1	0	0	0	1
Saultsman Bayou	0	2	0	0	0	2
Dead River	1	0	0	0	0	1
Simpson River	0	1	0	0	0	1
Bass Hole Cove	2	5	0	0	0	7
Judges Bayou	1	4	0	0	0	5
Mulat Bayou	6	2	1	1	1	11
Mulatto Bayou	4	0	1	2	1	8
Trout Bayou	7	0	0	0	0	7
Indian Bayou	2	0	0	1	0	3
Racoon Bayou	3	0	0	0	0	3
Subtotal	35	29	5	7	5	81
East Bay subsystem						
East Bay	0	0	3	0	2	5
Blackwater Bay	0	0	5	0	0	5
Little East Bay	0	0	2	0	0	2
Yellow River	0	0	1	0	0	1
East Bay River	0	0	2	0	0	2
Subtotal	0	0	13	0	2	15
Pensacola Bay subsystem						
Pensacola Bay	0	2	3	2	1	8
Bayou Texar	4	1	6	1	0	12
Bayou Chico	8	1	2	1	2	14
Star Lake	0	0	0	2	0	2
Bayou Grande	3	1	3	0	1	8
Hoffman Bayou	2	2	2	1	0	7
Woodland Bayou	3	0	0	1	0	4
Gilmore Bayou	1	2	0	0	0	3
Santa Rosa Sound	0	4	1	4	3	12
Subtotal	21	13	17	12	7	70
Total	56	42	35	19	14	166

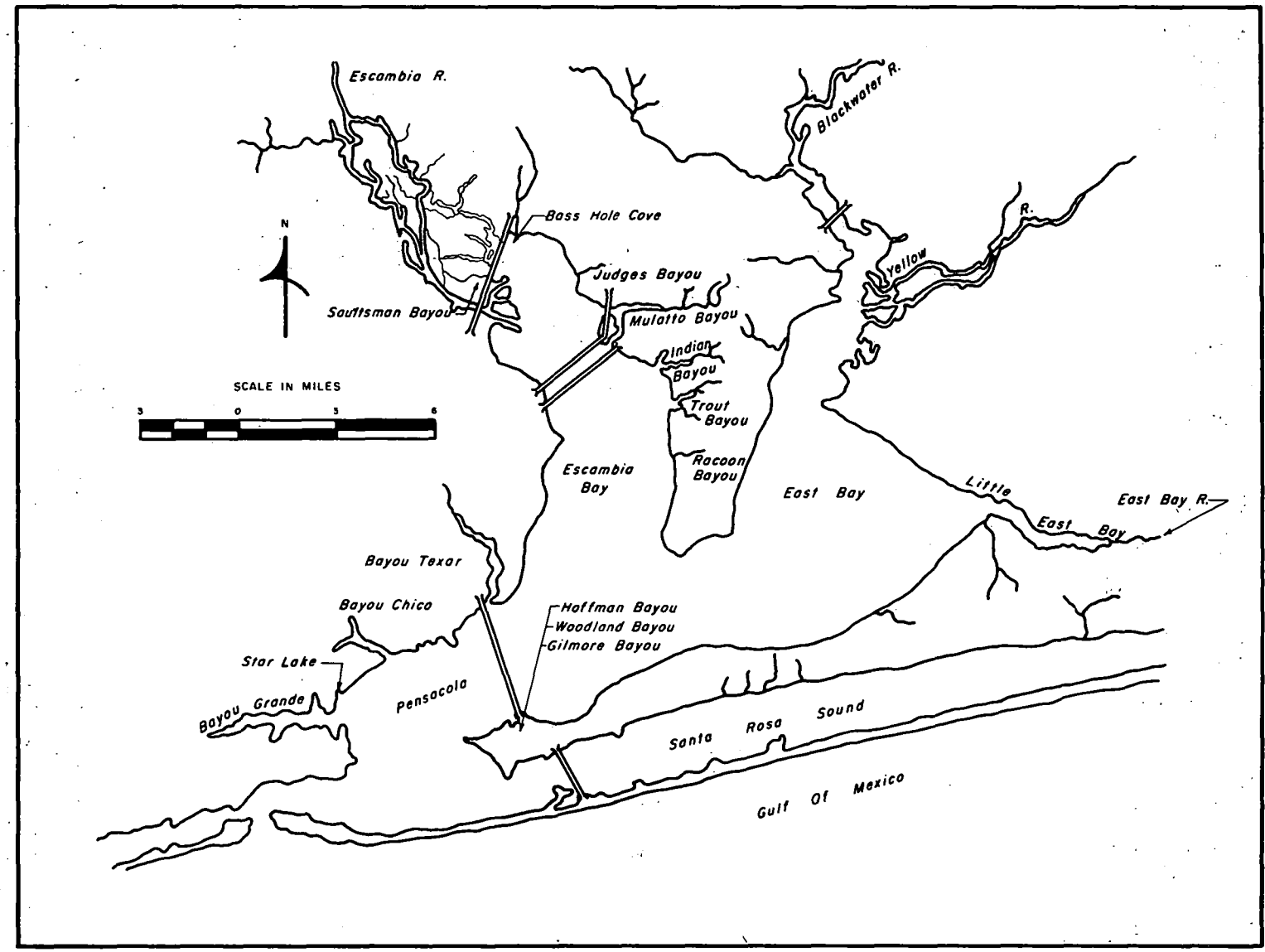


Figure 10-10. Location of fish kill sites in the Pensacola Bay system, 1970-1974.

chemicals, pesticides, and other toxic substances. Hansen and Wilson (1970) found that residues of DDT and its metabolites (DDD and DDE) sometimes reached levels up to 1.3 ppm in many estuarine fishes from Escambia Bay and Pensacola Bay. Determination of the exact cause of fish kills in Bayou Chico was compounded by stresses due to the presence of phenols, oils, resins, and heavy metals. The major pollutant in Bayou Texar was domestic sewage which had repeatedly overflowed from an upstream lift station, but runoff from residential lawns and from nearby shopping center parking lots also contributed stresses.

In 1972 in Escambia Bay, a chronic fish kill, mainly menhaden, was attributed to a nonhemolytic streptococcus infection (Plumb, et al., 1974). They felt that environmental stresses had lowered the resistance of the fishes, thereby increasing their susceptibility to infection. No characteristic symptoms of this streptoccocal disease, such as saddle-shaped discolorations on the dorsal and lateral surfaces of the fishes, were observed during any of the kills in 1973 and 1974. Although bacterial and parasitic infections may at times cause death in isolated fishes, these organisms are seldom the cause of large-scale kills in nature.

Numerous dead and dying fish and crustacean species were observed during various kills. Most mortalities were multi-species kills. However, deaths of Gulf menhaden, often mistakenly called the alewife in the Pensacola area, occurred in more fish kills than any other species. In fact, many extensive kills in which thousands of individuals died, might more aptly be called "menhaden kills." The estuarine-dependent nature of this species, its planktonic food habits, preference for low salinity waters, schooling behavior, and apparent inability to withstand moderately low levels of dissolved oxygen for short periods, are conditions that contribute to the concentration of menhaden in bayou areas, where the majority of kills have occurred since 1970. Other species frequently occurring in various kills included striped mullet, Atlantic croaker (locally known as ronker), spotted seatrout, spot, pinfish, sea catfish, sheepshead, crevalle jack, sand seatrout, tidewater silverside, bay anchovy, various flounders, and shellfishes, such as blue crab and penaeid shrimps. During the period from 1968 through 1971, large adult fishes, transients from the Gulf, such as the bluefish (Pomatomus saltatrix), crevalle jack, ocean sunfish (Mola mola), as well as a bottlenose dolphin, were often associated with late summer and fall kills in the open bays (William T. Young, personal communication).

In 1974, only five fish kills occurred in Escambia Bay and adjacent bayous (Table 10-3). These were: (1) a chronic kill, mostly adult striped mullet, that occurred throughout the open waters of Escambia, East, and Pensacola Bays from mid-April until early June; (2) an acute, multi-species kill was investigated in Mulat Bayou on June 14; (3) several species died in a small kill in the upper northwest corner of Escambia Bay on June 27; (4) an

acute, single species kill of juvenile Gulf menhaden in the south entrance canal to Mulatto Bayou also on June 27; and (5) an acute, multi-species kill off the Floridatown Beach in the northeast corner of Escambia Bay on September 3.

During the prolonged mullet kill, prevailing winds and waves caused dead fish to drift towards the windward side of the bays. We were unable to obtain any distressed fish for a critical examination. It was estimated that 10,000 to 15,000 fishes, mostly striped mullet, perished during April and May. All of the mullet were adult individuals; many were in the 0.9 to 1.4 kg (2.0 to 3.0 lbs) size range.

Although the cause of the kill was not established, the commencement of the mullet die off occurred concurrently with a spill of sodium thiocyanate from industrial waste ponds on April 13 and again on April 30. Subsequently, all 58 water samples, that were collected throughout Escambia Bay and East Bay on May 7, contained concentrations of thiocyanate ranging from 0.02 to 1.70 ppm (mean, 0.28). However, no cause and effect relationship could be shown between the striped mullet kill and the thiocyanate.

The second and third kills during 1974 in Mulat Bayou and Escambia Bay, respectively, were both small kills. In Mulat Bayou, around 4,300 fishes were found on the beach, as well as floating in the water. The species composition of dead fishes was 80 percent juvenile Gulf menhaden, with the rest composed of Atlantic croaker, sand seatrout, and a single striped mullet. A lack of dissolved oxygen following a phytoplankton bloom caused the kill. No specific cause was found for the kill in Escambia Bay (third) which involved about 55 individuals (longnose gar, striped mullet, crevalle jack, and ladyfish).

Approximately 50,000 juvenile Gulf menhaden died in the fourth kill of 1974 in Escambia Bay at Mulatto Bayou. Death was attributed to low dissolved oxygen concentrations. The morning following the kill, oxygen levels were still depressed in the bottom waters; at six of eight locations throughout the south entrance canal, oxygen concentrations were between 0.2 and 3.9 ppm. Two conditions that contribute to the low oxygen levels are the submerged borrow pits and dead end finger canals. Livingston, et al., (1972) described the environmental impact of dredging in this area.

In the fifth fish kill of 1974 in Escambia Bay at Floridatown, approximately 3,000 fishes and crustaceans, distributed among 11 species, perished in September. The species composition and estimated percent occurrence of the organisms were as follows:

Species	Percent occurrence
Spot	80
Atlantic croaker	10
Bay whiff	5
Southern flounder	
Hogchoker	
Gulf menhaden	5
Sea catfish	
Tidewater silverside	
Stingray (Dasyatis sp.)	
Blue crab.	

Although this fish kill was near the industrial outfall area, no specific cause could be determined for the mortality.

A gradual reduction in the frequency, as well as the magnitude, of the kills in the Pensacola Bay system has taken place in the past five years (Figure 10-11). Overall, the number of kills per year have declined from 56 to 14, a decrease of 75 percent. The occurrence of major kills peaked in 1970, when over 59 million individuals were estimated to have died (Appendix 10-13). By 1974, fewer than 200,000 fishes perished during the year. Fish kills in Escambia Bay and adjacent waters have shown a dramatic decline of 86 percent since 1970. Similar encouraging trends were also noted in the waters of East Bay and Pensacola Bay sub-systems.

Freshwater Sport Fishery

An active freshwater sport fishery is located in the lower Escambia River and delta tributary streams. The major source of data on this fishery was obtained during two creel surveys conducted by members of Bream Fishermen Association (BFA) from April 25 through May 30, 1970 (Hixson, Niven, and Hopkins, 1971) and from May 4 through June 2, 1974 (W. Carroll Hixson, personal communication). The survey area extended from the mouth of the Escambia River northward to the township of Molino, Florida, which represents approximately 80 miles of fishing waters.

The dominant group of fishes in the creels were sunfishes (Centrarchidae). Representatives of this family, in decreasing order of abundance, included bluegill (Lepomis macrochirus), redear sunfish (L. microlophus), warmouth (L. gulosus), spotted sunfish (L. punctatus), longear sunfish (L. megalotis), largemouth bass (Micropterus salmoides), and black crappie (Pomoxis nigromaculatus), which accounted for over 90 percent of the total catch in 1974. Other fishes in the creel included bowfin (Amia calva), catfishes, gars, chain pickerel (Esox niger), and several estuarine fishes from the tidewater portion of the river.

From a preliminary analysis of the creel survey data, it was apparent that, overall, few changes have occurred in the fishery.

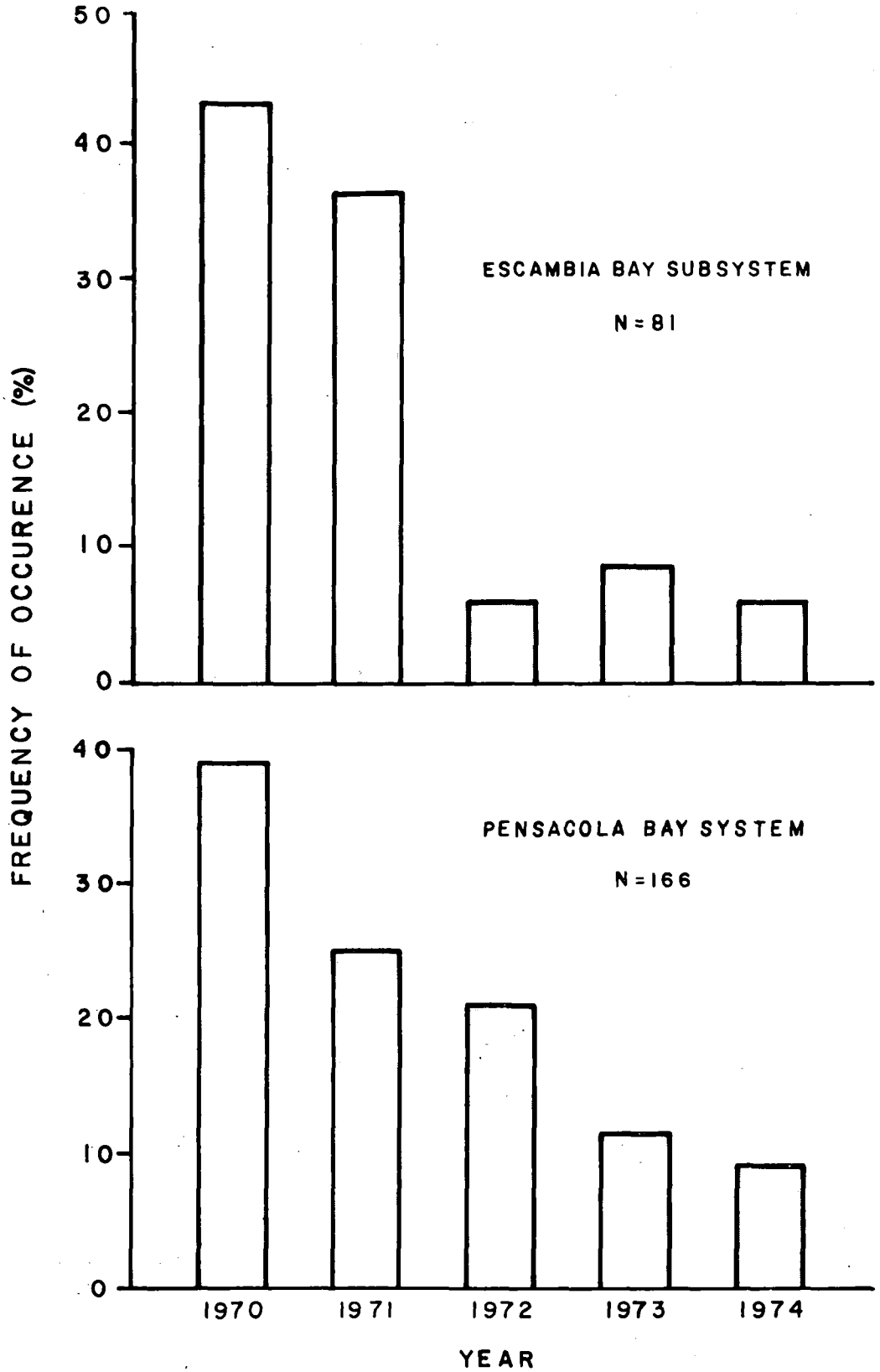


Figure 10-11. Annual distribution of fish kills in Escambia Bay subsystem and total Pensacola Bay system, 1970-1974.

Similar catch rates were recorded with 0.94 fish per fishing hour in 1970 and 1.06 fish per hour four years later (Table 10-4). Catch rates are reliable indicators of angling success. No abrupt gains or losses occurred in the percent occurrence of individual species in the creels. However, the occurrence of the three most popular sport fish (bluegill, redear sunfish, and largemouth bass), as a group, shifted from 81 percent in 1970 to 62 percent in 1974. The meaning of this shift is unclear, but the downward trend was alarming. The spring season is considered one of the better fishing periods, when fishermen seek out the productive spawning areas, such as the "shellcracker beds" in Thompson Bayou (now a refuge area), Ferry Pass Bayou under Highway 90 bridge, and marsh grasses near the mouth of the river (Hixon, Niven, and Hopkins, 1971). The similarity in fishing pressure during both surveys indicated that the fishermen's attitude toward the river remained essentially unchanged during the first half of the 1970 decade.

Biology of Major Species

Gulf menhaden (*Brevoortia patronus*)

A total of 14,804 Gulf menhaden, the second most abundant species in the bay, was collected during our survey. This annual catch consisted of 9,305 individuals that were caught with the trawl and 5,499 with the seine. The average trawl catch was 65.4 individuals in the upper Escambia Bay, 11.2 in the middle bay, 10.6 in the lower bay, 22.1 in East Bay, and 231.9 in the bayous and river. The largest catches of juvenile fish occurred in February and April.

The life history of the Gulf menhaden is well-known (Gunter and Christmas, 1960; Fore, 1970; Fore and Baxter, 1972; and Tagatz and Wilkens, 1973). In Escambia Bay, members of the 1973-74-year-class were captured from December through April, which verified the winter spawning period of this species. After the juveniles had spent approximately 6 to 10 months (depending on the date of entry) in the estuarine nursery, they had grown to 92 to 137 mm (mode, 122 mm) in length (Appendix 10-14). The emigration of this species to offshore waters coincides with the commencement of the adult spawning season.

Gulf menhaden fishery is the most valuable finfish fishery in the Gulf of Mexico. In 1973, 486,555.6 metric tons, valued at 44.6 million dollars, were landed in the northern Gulf (U.S. National Marine Fisheries Service, 1974). By-products from menhaden, a non-edible fish, include fish meal, oils, and solubles. Processing plants in the northern Gulf are located in Louisiana and Mississippi coastal waters. A former plant at Appalachicola, Florida ceased operations following the 1969 fishing season. There is no active menhaden fishery in the Pensacola area, which accounts for the minuscule landing (200 lbs in 1973) in Escambia County.

Table 10 - 4. Summary of two creel surveys of freshwater sports fishery on the lower Escambia River, April 25 to May 30, 1970 and May 4 to June 2, 1974.

Item	1970	1974
Number of fishing parties	760	751
Average number of fishermen per party	2.09	2.01
Number of man-hours spent fishing	9251	8730
Total number of fishes caught	8671	9223
Average catch per man-hour	0.94	1.06
Median catch per man-hour	0.69	0.73

Data supplied by W. Carroll Hixson, BFA

Atlantic bumper (Chloroscombrus chysurus)

The Atlantic bumper, a non-commercial species, was the most abundant carangid in the collections from the bay. A total of 625 were taken in the trawl collections and 299 in the seine hauls. The occurrence of these fish showed a disjunct distribution; over 60 percent were caught in East Bay, the remainder in Escambia Bay, and none in the bayous.

Young of C. chysurus moved into Escambia Bay during the summer and re-entered the Gulf with the onset of cooler temperatures in the fall. Length-frequency distribution showed that the population consisted entirely of juvenile individuals (Appendix 10-15). Most of the population was present only from August until October. MacFarland (1963) previously reported that this species was absent from Texas waters during the fall and winter months.

Sand seatrout (Cynoscion arenarius)

This species was the sixth most abundant species in our catches. Of the total catch of 1,620 individuals, 1,587 were taken in trawl collections and 33 in seine hauls. The average trawl catch was 6.8 specimens in Escambia Bay, 9.6 in East Bay, and 30.5 in the bayous and river. Distribution was widespread throughout the estuary and specimens were taken in all sampling months. In a survey of fishes in Alabama estuaries, Swingle (1971) found that Cynoscion arenarius was the eighth most abundant species in his collections.

Length-frequency distribution of sand seatrout showed that there was a wide size-range in this estuarine population (Appendix 10-16). Analysis of our data confirms the prolonged spring and summer spawning season of this species.

Sand seatrout and probably a few silver seatrout (C. nothus) constituted approximately five percent of the composition of the industrial bottomfish catches in the northern Gulf of Mexico (Roithmayr, 1965). In 1973, 195,590 lbs were landed in Escambia County, which represented 8.8 percent of the total landings along Florida's west coast.

Spotted seatrout (Cynoscion nebulosus)

Eleven spotted seatrout were taken with trawling gear and two with seine. Trawl collections occurred in Areas 2, 4, and 5; the largest number were taken in the bayous. Most of the catch consisted of young fish. Few adults were taken as they are more readily caught in gill and trammel nets. The loss of grass flats, an essential habitat for the young, severely limits the production of this species in Escambia Bay.

The spotted seatrout often spends its entire life cycle in the estuary. This species spawns at night in the deeper holes of

bays, lagoons, and sounds over grass beds (Tabb, 1966). Spawning occurs in Florida waters when spring water temperatures reach 25.5°C (78°F). Following spawning, the fertile eggs are demersal and are found attached to submerged vegetation and debris. Hatching period lasts several weeks. Tabb (1966) reported that at six to eight weeks, juveniles form schools and this schooling behavior persists until the age of five to six years, at which time the adults acquire a semi-solitary existence. The bulk of this predator's diet consists of forage fishes and penaeid shrimp. Spotted seatrout are basically non-migratory, but they will move offshore to escape winter cold and sudden drops in salinity.

Spotted seatrout, or "speck", is a favorite of sports fishermen in the Pensacola area. Artificial lures, live pinfish, and live shrimp are the most popular baits. After an absence of several years, this species is again being caught near the railroad trestle in Escambia Bay. No records are available on sport fishing harvests.

The west coast of Florida produced an annual commercial catch of 2.3 million pounds from 1969 to 1973. The average landings from Escambia County during the same years were almost 70,000 lbs, or 3.1 percent, of west coast landings (Table 10-5). The 1973 poundage (89,528 lbs) in Escambia County represented nearly a three-fold increase over the low returns in 1966 and 1967.

Spot (Leiostomus xanthurus)

The spot was the second most abundant species in our bimonthly survey. A total of 13,997 individuals were taken by trawl and 171 by seine. This species constituted approximately 20 percent of the total trawl catch. Specimens occurred throughout the estuary, but were most abundant on the shallow mud bottoms at the bayou stations. The smallest catches were made in February, the largest in June. This species is abundant along both the Atlantic and Gulf Coasts. Nelson (1969), while studying the biology of the spot in Mobile Bay, observed that the spot decreased in abundance, moving from east to west in the northern Gulf. This westerly decline was in agreement with the comparison of our bimonthly catches from Escambia Bay, with catches in Mobile Bay, Alabama, and Biloxi Bay, Mississippi (Table 10-6).

Spot, 15 to 25 mm, were first taken in December, and these members of 1974-year-class continued to enter the estuary until April. The length-frequencies of juvenile and adult spot taken during the bimonthly surveys are presented in Appendix 10-17. The spawning season lasts from December through March, which agrees with Swingle's (1971) findings from Mobile Bay. During the fall months, the adults emigrate to offshore waters in preparation for the spawning season.

Along the Gulf Coast, the spot is not an important food fish, as it is along the Atlantic Coast. However, in the Gulf of

Table 10 - 5. Summary of commercial landings of spotted seatrout, Cynoscion nebulosus, along the west coast of Florida and Escambia County from 1964 through 1973.

Year	Landings		Percentage of west coast landings
	Fla. west coast (lbs)	Escambia Co. (lbs)	
1964	2,798,659	75,809	2.7
1965	3,369,726	45,094	1.3
1966	3,173,816	31,611	1.0
1967	2,636,888	31,074	1.2
1968	3,065,206	55,327	1.8
1969	2,418,704	52,437	2.2
1970	2,642,810	66,397	2.5
1971	1,960,866	67,606	3.4
1972	2,140,127	72,812	3.4
1973	2,226,180	89,528	4.0
Annual avg.	2,643,298	58,769	2.2
Five-year average (1964-1968)	3,008,859	47,781	1.6
Five-year average (1969-1973)	2,277,737	69,756	3.1

Table 10 - 6. Comparison of the average bimonthly trawl catches of spot from three estuaries in the northern Gulf of Mexico.

Month	Biloxi Bay, Miss. 1968-69 (Christmas and Waller, 1973)	Mobile Bay, Ala. 1968 (Swingle, 1971)	Escambia Bay, Fla. 1973-74 (present study)
	Average catch/trawl sample		
October	7.0	6.1	93.7
December	0.5	96.7	21.6
February	0.0	1.0	86.7
April	3.8	46.6	132.3
June	13.5	220.2	279.6
August	0.5	6.9	42.7
Bimonthly average	4.1	62.9	109.4

Table 10 - 7. Summary of commercial landings of spot, Leiostomus xanthurus, along the west coast of Florida and Escambia County, 1964 through 1973.

Year	Landings: Fla. west coast (lbs)	Landings: Escambia Co. (lbs)	Percentage of west coast landings
1964	353,078	23,431	6.8
1965	314,516	15,300	4.9
1966	348,350	11,776	3.4
1967	293,915	13,713	4.7
1968	311,396	24,205	7.8
1969	297,319	39,436	13.3
1970	249,764	61,313	24.6
1971	432,216	80,092	18.5
1972	245,893	71,223	29.0
1973	183,293	89,528	48.8
Annual average	302,976	42,702	14.1
Five-year average (1964-1968)	324,251	17,285	5.3
Five-year average (1969-1973)	281,701	68,318	24.2

Table 10 - 8. Comparison of the average bimonthly trawl catches of Atlantic croaker, Micropogon undulatus, from three estuaries in the northern Gulf of Mexico.

Month	Biloxi Bay, Miss. 1968-69 (Christmas and Waller, 1973)	Mobile Bay, Ala. 1968 (Swingle, 1971)	Escambia Bay, Fla. 1973-74 (present study)
	Average catch/trawl sample		
October	2.8	6.8	10.6
December	2.0	9.9	4.2
February	4.5	889.3	19.0
April	55.0	244.6	98.7
June	268.5	209.3	190.1
August	75.5	51.9	41.0
Bimonthly average	68.0	235.3	60.6

Mexico, this species constitutes a large portion of the industrial bottomfish fishery (Roithmayr, 1965). Along the west coast of Florida, the annual commercial catch from 1969-73 averaged 281,701 lbs. The landings in Escambia County, during the same five years, averaged 68,318 lbs, or 24 percent of the west coast landings (Table 10-7). Spot landings have steadily increased in Escambia County since 1968 and represented nearly half of the Florida west coast landings of spot in 1973.

Atlantic croaker (Micropogon undulatus)

Atlantic croaker, the fourth most abundant fish in our survey, was evenly distributed throughout the study area. Of the total catch of 8,403 individuals, 7,915 were taken with the trawl and 488 with the seine. Specimens were taken at all salinities, from freshwater conditions (zero salinity reading with the salinometer) in the Simpson River in April to 29.6 ppt in the lower portions of Escambia Bay in August.

The largest catches of M. undulatus were taken in June and the smallest in December in Escambia Bay, which paralleled the bimonthly catches in Biloxi Bay, Mississippi (Christmas and Waller, 1973). The high catches from Mobile Bay, Alabama (Swingle, 1971), possibly were indicative of an unusually successful year-class in 1968 (Table 10-8).

Analysis of the length-frequency distribution for Atlantic croaker showed that new young-of-the-year were initially recruited into our trawl catches in December and continued to enter the estuary until April (Appendix 10-18). In Louisiana, Perret, et al., (1971) reported that incoming juveniles were encountered from October through April. Three age classes were present in Escambia Bay in June that had modal lengths of 77, 139, and 227 mm. Adults generally leave the estuary during the colder months.

Since 1966, the catch of Atlantic croaker has become increasingly important to the commercial interests in Escambia County (Table 10-9). In 1973, almost two million pounds were landed in Escambia County, which represented 83 percent of the total landings of this species along Florida's west coast. Interest in harvesting Atlantic croaker has accelerated since the development of the bottomfish fishery (Roithmayr, 1965) and the use of large croakers for food.

Striped mullet (Mugil cephalus)

The striped mullet was the tenth most abundant species. Twenty-two were taken by trawl and 317 by seine. This species is an agile fish that usually eludes the trawl. The majority of the mullet catch consisted of juvenile fishes from the seine hauls along the sandy beaches of Escambia Bay. Mullet are found throughout the estuary, although the smaller juveniles tend to concentrate along the shoreline of the bay and in the bayous.

Table 10 - 9. Summary of commercial landings of Atlantic croaker, Micropogon undulatus, along the west coast of Florida and Escambia County from 1964 through 1973.

Year	Landings		Percentage of west coast landings
	Fla. west coast (lbs)	Escambia Co. (lbs)	
1964	64,596	1,123	1.7
1965	35,489	745	2.1
1966	49,889	2,036	4.1
1967	87,228	57,098	65.5
1968	146,980	77,012	52.4
1969	409,694	221,387	54.0
1970	936,075	603,170	64.4
1971	1,003,522	762,632	76.0
1972	1,587,769	1,395,757	87.9
1973	2,357,172	1,954,920	82.9
Annual average	667,841	507,588	76.0
Five-year average (1964-1968)	76,836	27,603	35.9
Five-year average (1969-1973)	1,258,846	987,573	78.4

Table 10-10. Summary of commercial landings of striped mullet, Magil cephalus, along the west coast of Florida and Escambia County during 1964 through 1973.

Year	Landings		Percentage of west coast landings
	Fla. west coast (lbs)	Escambia Co. (lbs)	
1964	34,995,616	771,598	2.2
1965	31,367,895	673,144	2.2
1966	26,957,866	583,769	2.2
1967	23,283,184	617,637	2.6
1969	25,473,111	812,308	3.2
1970	23,138,324	1,098,278	4.8
1971	23,817,999	853,184	3.6
1972	26,863,573	1,016,167	3.8
1973	26,653,642	921,664	3.5
Annual average	26,291,428	813,053	3.1
Five-year average (1964-1968)	27,393,527	685,786	2.5
Five-year average (1969-1973)	25,189,330	940,320	3.5

Fish often observed jumping out of water in the estuary are generally mullet.

The life history of striped mullet in Florida's waters was reviewed by Futch (1966). Spawning occurs offshore in the Gulf from October through February. Adult females may extrude from 1.2 to 2.7 million eggs at a single spawning and fertile eggs usually hatch in 48 hours. Generally, ocean currents transport the postlarvae from the spawning ground to estuarine nurseries. In the fall, adults usually form large schools before returning to sea.

The mullet is an excellent food fish and an active mullet fishery exists along both Florida coasts. Mullet are taken commercially by gill nets and by seines. A five-year average (1969-73) of over 25 million pounds was taken along the west coast of Florida. During the same period, an average of over one million pounds was landed yearly in Escambia County (Table 10-10). Most of these fish came from local inshore waters.

Spanish mackerel (Scomberomorus maculatus)

Only three Spanish mackerel were taken in the trawl collections. They were caught in the middle reaches of Escambia Bay in October. All were juveniles ranging from 78-85 mm in length, which indicated that these specimens were spawned near the Pensacola area.

Adults seldom venture into the lower salinity waters of Escambia Bay, but large schools were frequently observed during the summer and fall in Pensacola Bay and in the Gulf waters near the outer beaches where they are actively pursued by the sports fishermen. Spanish mackerel is not an estuarine-dependent species, but occasional usage is made of inshore waters.

This species supports a valuable commercial fishery in Florida waters. Along the west coast, the five-year (1969-73) average landing was 7,258,857 lbs with the largest catches occuring between Tampa and the Florida Keys. In Escambia County, the five-year catch from 1969-73 averaged 136,883 lbs, which was down from the 1964-68 period (Table 10-11).

Discussion

Much of this investigation was addressed toward answering several intriguing but nonetheless interwoven and complex questions concerning the status of finfish and shellfish populations and their respective fisheries. How does Escambia Bay compare with other estuarine systems? There are no proven guidelines in the field of pollution-ecology for finding answers to these questions in terms of absolute number, percentage, or rank. However, from a fisheries standpoint, it was evident that a valid appraisal of present conditions could be obtained by using selected biological indicators, whose status, although

Table 10 - 11. Summary of commercial landings of Spanish mackerel, Scomberomorus maculatus, along the west coast of Florida and Escambia County during 1964 through 1973.

Year	Landings		Percentage of west coast landings
	Fla. west coast (lbs)	Escambia Co. (lbs)	
1964	3,879,384	206,975	5.3
1965	4,883,400	162,647	3.3
1966	7,004,241	270,544	3.9
1067	5,867,500	241,140	4.1
1968	7,065,588	140,476	2.0
1969	8,174,574	174,651	2.1
1970	8,009,947	172,893	2.2
1971	7,383,233	65,618	0.9
1972	6,532,300	89,111	1.4
1973	6,194,232	182,141	2.9
Annual average	6,499,440	170,620	3.0
Five-year average (1964-1968)	5,740,023	204,356	4.0
Five-year average (1969-1973)	7,258,857	136,883	1.9

frequently in relative terms, often required the development of novel and innovative approaches in the comparatively new area of estuarine assessment and rehabilitation.

Data were comparable on catch-per-unit-effort among estuaries when the other studies employed similar gear and sampling procedures. In Escambia Bay, the annual average trawl catch was 568 fishes per 10-minute tow. This return was in agreement with other recent surveys in Gulf estuaries. Average catches in Alabama waters of 517 and 426 individuals were reported from Mobile Bay and Perdido Bay, respectively (Swingle, 1971). Trawl catches from Biloxi Bay, Mississippi contained an average of 664 fishes (Christmas and Waller, 1973). The similarity in both the annual numerical catches and species composition revealed that Escambia Bay is functioning as a productive estuarine nursery for young fishes. It was not possible to obtain precise information on past abundances in Escambia Bay, since no comparable data were available.

Diversity indices have been successfully employed in the assessment of environmental quality (Bechtel and Copeland, 1970; and Wilhm and Dorris, 1968). Of a number of possible formulas for the measurement of diversity, the Shannon-Weaver index (H') has been employed with fish populations more often than any other. At present, the evaluation of diversity from one estuary to another has mainly relied on a comparison of ranges. During an investigation of the fishes in the more polluted portion of Galveston Bay (Bechtel and Copeland, 1970), the seasonal changes in H' (pooled) were 0.13 to 0.91, compared to a range of 1.05 to 1.75 in Escambia Bay. In the polluted estuarine section of the lower Mystic River, which flows through downtown Boston, seasonal diversity values ranged from 0.33 to 1.03 (Haedrich and Haedrich, 1974). The species composition of the trawl collections from Escambia Bay was composed of 48 species, whereas only 23 species contributed to the diversity of the Mystic River. The Patuxent estuary, a polluted waterway, had H' values from 0.2 to 1.2 (McErlean, et al, 1973). In an essentially non-polluted estuary near Sapelo Island, Georgia, Dahlberg and Odum (1970) reported that species diversity (H') ranged from 0.7 to 1.8.

Few annual pooled H' values appear in the literature. To make comparisons with Escambia Bay, it was necessary to calculate such values from the numerical totals of other trawl studies. An annual H' provides an objective, quantitative evaluation of environmental conditions not possible with range values that often overlap. Other advantages of an annual pooled H' are that it employs all the available data on species and numbers in the determination, compensates for chance sampling variations, and is adaptable for making comparisons, since H' is independent of gear selectivity and sample size. This is frequently not true of catch-per-unit-effort data. During the past five years, annual diversity values obtained from estuaries with dissimilar levels of environmental quality were:

Location	Pooled Annual H'	Source
Mystic River, Mass.	1.19	Haedrich and Haedrich (1974)
Mobile Bay, Ala.	1.29	Swingle (1971)
Escambia Bay, Fla.	1.63	Present study (1973-74)
Vermillion Bay, La.	1.97	Perret and Caillouet, Jr. (1974)
Estuary near Sapelo Island, Ga.	2.10	Dahlberg and Odum (1970).

Lower diversities were associated with polluted waters, whereas the higher values were representative of presumably undisturbed environments. The position of the pooled H' value from Escambia Bay indicated that pollution-oriented stresses still exist in the bay.

The role of industrial discharges, particularly nutrients, in estuarine environments is often difficult to ascertain. In Escambia Bay, species diversity was inversely related to nutrient levels. In other words, H' diversity was significantly depressed during periods of high PNI (nitrogen, phosphorus, and organic carbon content). To our knowledge, this was one of the few instances where the buildup of nutrients in a bay has been shown to have a measurable influence on community structure. Future scheduled reductions of these pollutants to the bay should benefit this biological community.

In addition to nutrient pollutants, both salinity and benthic grasses influenced the annual H' value. Salinities in Escambia Bay were at the lower half of the expected salinity range for temperate estuaries. A larger number of fish species normally inhabit the higher salinity portions of an estuary. This potential depression of annual diversity in Escambia Bay, due to location of the sampling sites in the upper reaches of the estuary and not to any statistical association between salinity and distribution, should be recognized when making comparisons with fish surveys conducted throughout an entire system. Since the surveys in Mobile Bay, Alabama (Swingle, 1971) and the estuary off Sapelo Island, Georgia (Dahlberg and Odum, 1970) fell into this category, their annual values of H' were apparently somewhat inflated compared to Escambia Bay.

Marine meadows are recognized as irreplacable habitats for numerous species. The loss of grass beds apparently due to toxic conditions - and subsequently, their faunal assemblages - in Escambia Bay largely accounted for the general absence of

pinfish, gobies, pipefishes, young of spotted seatrout, and decreased abundance of other species. Hoese and Jones (1963) stated that pinfish and penaeid shrimp were the major fish and invertebrate species with the greatest biomass in the grass communities of Texas bays. Thus, the depressed diversity was due partially to the absence of these typical grass bed inhabitants from the bay's faunal community.

Comparison of the sample shrimp data with catches in other Gulf estuaries provided an indication of the condition of the shrimp grounds in Escambia Bay. For instance, Perret, et al., (1971) caught an average of 53.8 penaeid shrimp per trawl sample in Louisiana waters, 13 times greater than the average catch from Escambia Bay. The species composition in Louisiana was 30 percent white and 70 percent brown shrimp. In the estuarine waters of Mobile Bay, Alabama, the average catch (10.3 penaeids per collection) was 2 1/2 times the catch from Escambia Bay (Swingle, 1971). The small catches in Escambia Bay were indicative of the depauperate condition of the shrimp habitat.

The disappearance of the shrimp fishery from Escambia Bay coincided with the initial discovery in 1969 of high concentrations of a polychlorinated biphenyl (PCB), known as Aroclor 1254, in the water column, sediments (up to 30.0 ppm) and tissues of shrimps (up to 14.0 ppm), fishes, and blue crab (Duke, Lowe, and Wilson, 1970; and Nimmo, et al., 1975). The source of the PCB was an accidental spill which entered the effluent from a chemical plant on the lower Escambia River. Nimmo, et al., (1971a) demonstrated that Aroclor 1254 was readily absorbed by penaeids from contaminated bay sediments. Laboratory bioassays showed that Aroclor 1254 killed juvenile pink shrimp at about 1.0 ppb range in water in 15 days. Mortality of the less susceptible adults occurred at concentrations of 2.4 to 4.3 ppb (Nimmo, et al, 1971b). Adult shrimps were more sensitive to Aroclor 1254 than were fishes. However, the larval sheepshead minnow was the most sensitive organism tested; few larvae survived PCB concentrations greater than 0.1 ppb (Schimmel, Hansen, and Forester, 1974).

Besides measurements of mortality (LC_{50}), sublethal levels must be weighed in any consideration of harmful effects. Sublethal concentrations of PCB were shown to alter behavior, physiology (osmoregulation and enzyme systems), and cellular structures. Also, the bio-accumulation of a 2.5 ppb concentration of PCB in water by pink shrimp was 1,800 times in two days and 7,600 times in nine days, whereas spot concentrated PCB (1.0 ppm in water) 17,000 times in four weeks (Duke and Dumas, 1974).

The synergistic effect of a man-made and a natural stressor was shown to cause mortality. PCB stress in brown shrimp (residues of 14 ppm) and the additional stress of low saline waters produced death (Nimmo and Bahner, 1974). Due to the diurnal tides in Escambia Bay, salinities are continually

shifting between the daily low and high periods. Nimmo and Bahner (1974) postulated that PCB residues found in feral shrimp from the Escambia estuary in conjunction with salinity stresses (such as that imposed in the laboratory) would have been lethal.

No one should implicate Aroclor 1254 for being the sole cause of the shrimp decline in Escambia Bay. Circumstantial evidence, however, strongly suggests that PCB's and other unidentified toxic substances played a role in the degradation of shrimp habitat. Fortunately, since the 1969 spill, PCB residues in the sediments have shown a 100-fold decline from former concentrations. Low PCB concentrations in the sediments in 1974 (Chapter 7) implied that this persistent chemical may still be suppressing the shrimp populations.

Creel surveys are recognized valid indicators of the status of a "hook-and-line" sport fishery, and thus by implication, of environmental quality. However, this biological indicator in 1974 was largely unchanged since the 1970 survey in the lower Escambia River. The yield to the average angler in 1974 remained roughly one fish per hour spent fishing on the river. This catch-per-unit-effort was low in comparison to many of the other coastal rivers in northwest Florida and south Alabama. Since the resident fishes in the creel are adult-sized individuals, an additional period of time apparently must pass before the gradual improvements in water quality (Chapter 8) will be reflected in this freshwater fishery. Present status of the fishery was aptly summarized by Hixson (personal communication) when he stated, "The river continues to have a relatively bad reputation with local fishermen."

In summary, the status of finfish populations and fisheries in Escambia Bay were judged to be in an intermediate stage of recovery, whereas the shrimp nursery and fishery apparently were in an early recovery stage. Various biological parameters demonstrated that environmental conditions have undergone vast improvements during the past five years. At present, fish populations are compatible with other Gulf estuaries and the bay is serving as a productive nursery for young fishes. Fish kills, visible indicators of estuarine quality, documented the deplorable past and the improved present. However, the continued suppression of the shrimp populations was apparently related to low concentrations of toxic and nutrient materials in the bay waters and sediments. In the water column, higher nutrient levels acted as stressors which limited the diversity of fish communities. Future recovery is largely dependent on reductions in these waste discharges. The data base on fishes and shrimps will provide a sound, reproducible format for the assessment of future trends, as well as needed guidelines for studies in other damaged estuarine ecosystems.

FISH COMMUNITIES OF OYSTER-SHELL AND MUD BOTTOMS IN A POLLUTED ESTUARY WITH COMMENTS ON SUBSTRATE ALTERATION

Introduction

The degradation of estuarine waters in Escambia Bay was caused by the discharge of industrial and municipal pollutants. The subsequent deterioration of the aquatic environment has led to a reduction in the usage of the nursery areas by young fishes and penaeid shrimps, to massive fish kills, and to reduced catches for both sport and commercial fishermen.

A major biological value of estuaries is that they function as irreplacable feeding and growing areas for juveniles of important marine species, many of which are estuarine-dependent. It was felt that the alteration of the existing bottom sediments, such as the dominant soft, mud or compact, shell substrates, might provide a means of increasing the carrying capacity of the nursery grounds. Since there is no pertinent information on this topic in the literature, the objectives of this study were:

1. to investigate the fish communities associated with mud and shell substrates in a polluted estuary, and

2. to determine the feasibility of altering the bottom sediments to increase the utilization of the nursery grounds.

Methods

Description of Study Area

This study was conducted in the middle reaches of Escambia Bay, the northwest extension of Pensacola Bay (Figure 10-12). Escambia Bay is relatively shallow and the bottom gradually slopes to a depth of 4.6 m (15 ft) in the middle. The freshwater flow from the Escambia River enters the north end of the bay; the south end is contiguous with Pensacola Bay.

Two study areas were selected because, except for the bottom composition, they possessed several desirable similarities. A uniformly flat bottom with a water depth of 2.4 m (8.0 ft), as determined with a recording fathometer, characterized both areas. Their location in the middle reaches of the bay insured that a similar range of environmental factors, such as salinity and temperature, were present at the time of sampling.

The oyster-shell and mud bottoms were the major variables in each habitat. The compact shell bottom was largely composed of fragmented and whole shells, with a few small clusters of live oysters scattered about. This shell area, on the east side of the bay, was on the fringe of a very productive and elevated

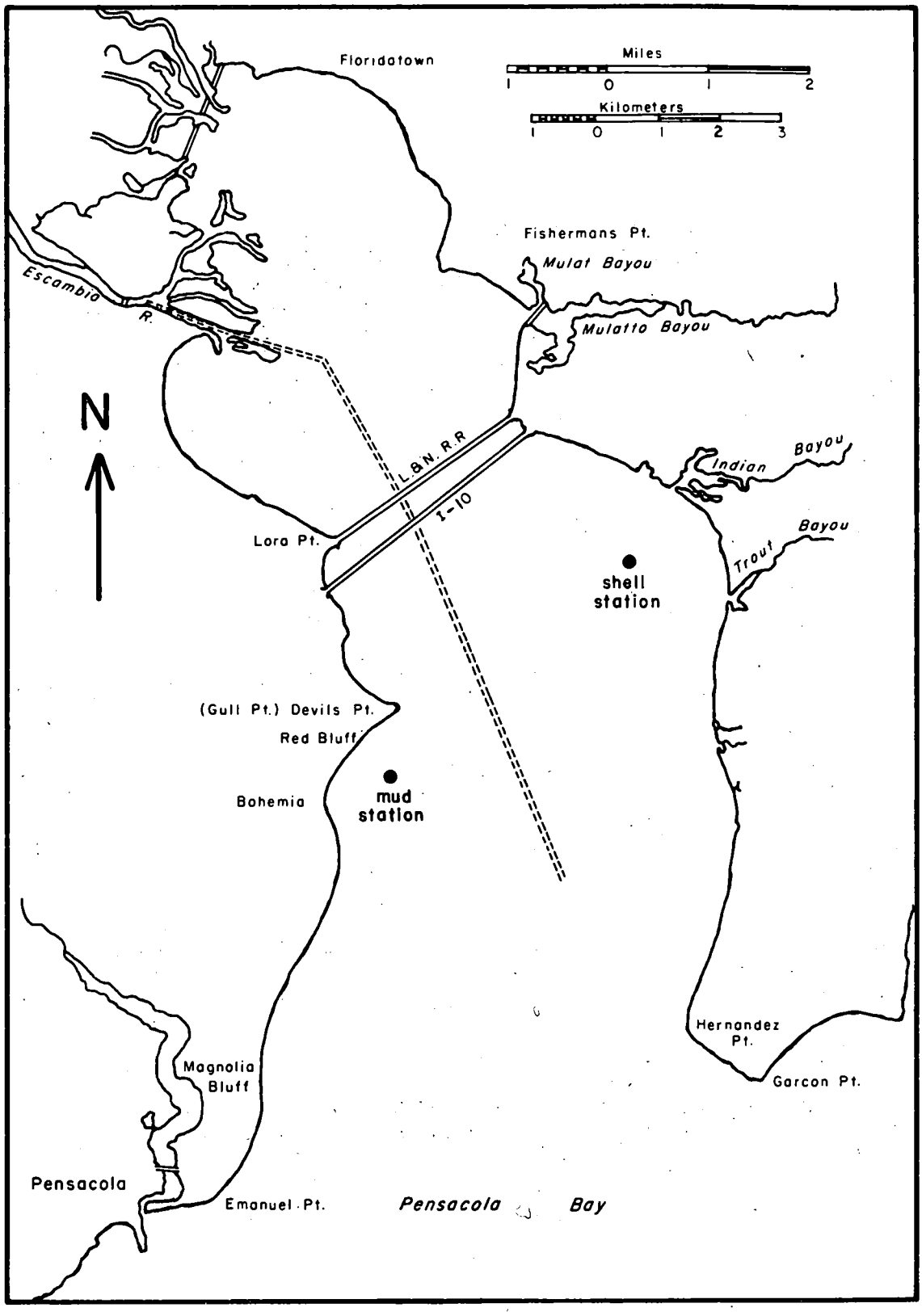


Figure 10-12. Study area and sampling sites in Escambia Bay.

oyster reef, which had been rehabilitated in 1971 when the Florida Department of Natural Resources spread thick layers of clam (Rangia cuneata) cultch on this formerly non-productive bed. The mud substrate area consisted essentially of soft, black mud.

Sediment Analysis

Characterization of the bottom sediments was performed by taking eight samples (three pooled grabs/sample) from each area with a weighted Ekman dredge. Only the upper 2.0 cm of sediment were used in the analyses. Subsequently, the particle-size distribution was obtained by sifting the sediment through a graded series of sieves (U. S. Standard Mesh Nos. 8, 10, 35, 120, and 230) and following the procedures described by Folk (1968).

Sampling Procedure

All fish collections were taken with a semi-balloon, otter trawl, which the shrimpers call a try-net. The otter trawl, constructed of 1.9-cm, bar-mesh netting, was 4.9 m (16 ft) wide, with a 0.64-cm, bar-mesh liner in the codend. The tow line was 30.5 m (100 ft) long.

A standardized sampling procedure was followed each month. The otter trawl was towed in a straight line for a period of ten minutes, using a 4.9 m fiberglass boat with an 80 hp outboard motor running at 2000 rpm. An average distance of 1400 m was covered during each tow. At the completion of the tow, the net was retrieved by hand.

The monthly sampling effort was equally divided between both stations, a total of either four or ten tows (two or five collections/station) being taken in a given month. At each station, multiple tows were taken on parallel tracks and readings of water temperature and salinity were obtained with a salinometer.

Larger specimens were processed in the field, whereas the more numerous smaller individuals were preserved in 10 percent solution of formalin in sea water and later sorted, identified, and enumerated in the laboratory.

Names of fishes and phylogenetic arrangement follow the recommendations of the American Fisheries Society (Bailey, et al., 1970).

Results

Sediments

Sediment analyses provided a precise description of the two substrates. Almost 72 percent of the dominant components at the mud station were silt and clay (Table 10-12). By definition, mud is composed of the silt and clay fractions. No shell material was present at the mud station. At the other sampling area, oyster shell (whole and fragments) and an occasional clump of living oysters characterized the bottom. Shell material accounted for 74.1 percent of the sediment composition. Most of the clay and silt fractions were located near the south end of the sampling area where the shell fringe intergrades with a mud flat. Thus, it was quite evident that at each site, the major textural class adequately described the bottom habitat.

Fish Collections

A total of 22,611 fishes, representing 32 species and 18 families, were tabulated from 58 trawl collections (29 collections at each station) in Escambia Bay (Table 10-13).

There was nearly a two-fold difference in the fish catches from the two stations. Sixty-three percent (14,349 individuals) of the fishes were captured over the mud bottom, whereas 8,262 individuals (37 percent) were taken in the trawl collections over the shell bottom. The yearly mean catches were 491 and 285 fishes per trawl sample over the mud and shell bottoms, respectively (Table 10-13). There was a statistically significant difference ($t = 2.11$, $p < 0.05$) between the mean catches over the two substrates.

Table 10 - 12. Sediment composition at the mud and shell stations.

Grain size (mm)	Textural class	Sediment composition Mud station (%)	Shell station (%)
2.38	Granule (shell)	0.0	64.5
2.01 - 2.38	Granule (shell)	0.0	9.6
0.51 - 2.00	Coarse sand	0.6	3.7
0.126 - 0.50	Fine sand	8.9	18.0
0.0626 - 0.125	Very fine sand	18.6	1.6
0.0626	Silt and clay	71.9	2.7

Table 10 - 13. Comparison of the number of fishes caught by otter trawl over oyster-shell and mud bottoms in Escambia Bay from October 1973 to September 1974.

Species	Bottom type	Oct.	Dec.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
		Number of trawl samples										
		4	4	4	10	4	10	4	10	4	4	
Lagodon rhomboides (Pinfish)	mud											
	shell				2							2
Bairdiella chrysura (Silver perch)	mud		2	6			2	1	2			13
	shell		7		1							8
Cynoscion arenarius (Sand seatrout)	mud	9	6	5			111	41	92	10		274
	shell		6				77	80	39			202
Cynoscion nebulosis (Spotted seatrout)	mud		1		2			1	1			5
	shell											
Leiostomus xanthurus (Spot)	mud		21	35	299	296	774	1644	996	2		4066
	shell		22	112	63	43	796	213	5			1254
Micropogon undulatus (Atlantic croaker)	mud	2	8	131	58	271	785	396	503	76	1	2231
	shell	3	8	89	39	138	701	240	111	1		1330
Polydactylus octonemus (Atlantic threadfin)	mud						318	81	51			450
	shell						12	64				76
Trichiurus lepturus (Atlantic cutlassfish)	mud						5	3	3			11
	shell											
Scomberomorus maculatus (Spanish mackerel)	mud	3										3
	shell											
Peprilus alepidotus (Harvestfish)	mud							1	71			72
	shell	3				1			4			8
Citharichthys spilopterus (Bay whiff)	mud											
	shell							1		1		2
Etropus crossotus (Fringed flounder)	mud		2									2
	shell		1									1
Lepisosteus osseus (Longnose gar)	mud										1	1
	shell							1				1
Brevoortia patronus (Gulf menhaden)	mud			13	563	108	4	11	8			707
	shell			4	68	131	7	3				213
Harengula pensacolae (Scaled sardine)	mud	1							5			6
	shell								7			7
Anchoa hepsetus (Striped anchovy)	mud	148	16				1			3	4	172
	shell	47	1059				1		15			1122
Anchoa mitchilli (Bay anchovy)	mud	489	1167	664	358		494	305	2647	12		6136
	shell	241	1858	598	188	226	45	115	487	15		3773
Synodus foetans (Inshore lizardfish)	mud					1	1		7			9
	shell		3							1		4
Arius felis (Sea catfish)	mud	1					36	5	52	10	4	108
	shell	1				1	3	8	31	4		48
Caranx hippos (Crevalle jack)	mud							1	2		1	4
	shell											
Chloroscombrus chrysurus (Atlantic bumper)	mud						3		46		6	55
	shell	158	1						16	22		197
Selene vomer (Lookdown)	mud								11			11
	shell											
Archosargus probatocephalus (Sheepshead)	mud	1	1	1								3
	shell	1	1		1	1	3		1	1		9
Sphoeroides parvus (Least puffer)	mud								7			7
	shell								1			1
Other species*	mud					1	1		1			3
	shell		1		1	1	1					4
Total	mud	854	1223	855	1251	677	2535	2490	4535	113	17	14349
	shell	454	2967	903	363	542	1646	725	717	45		8262

* Includes single specimens of Atlantic stingray (Dasyatis sabina), Ladyfish (Elops saurus), Gulf toadfish (Opsanus beta), Southern kingfish (Menticirrhus americanus), Atlantic spadefish (Chaetodipterus faber), guaguanche (Sphaeroides guachancho), and code goby (Gobiosoma robustum).

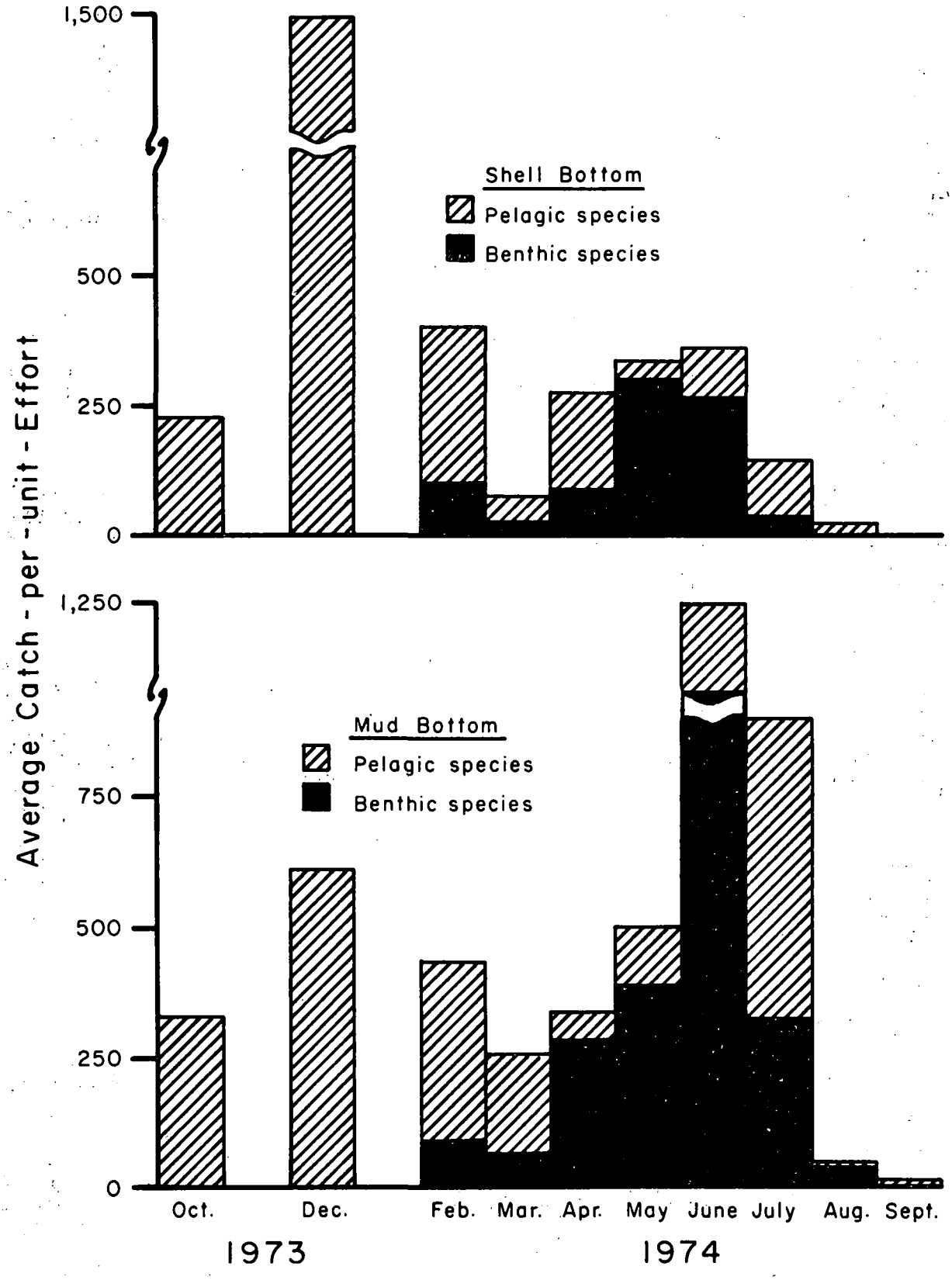


Figure 10-13. The average monthly catch of pelagic and benthic fishes over mud and shell bottoms.

Because of the significant dissimilarity in the abundance of fishes at the two sites, the possibility existed that certain species with similar behavioral traits may have shown a perference for a given habitat. This hypothesis was tested by separating the catches on the basis of the portion of the water column that the various species typically inhabit (Figure 10-13). Thus, the pelagic species, such as anchovies, Gulf menhaden, scaled sardine, Atlantic bumper, and spotted seatrout, did not show a preference for either substrate at the 95 percent level of confidence ($t = 0.81$). However, benthic species, such as spot, Atlantic croaker, sea catfish, and Atlantic threadfin, were more than three times more abundant over the mud than over the shell bottom ($t = 2.38$, $p < 0.05$). An interpretation of the benthic vs. pelagic distributions indicated that the pelagic species were swimming in the upper water column with little regard to the bottom type, whereas the mud bottom was preferred over shell by fishes that live in close association with the benthos.

The preponderance of fishes in the catches from the two sites were members of the drum family (Sciaenidae). The sciaenid catch, composed of five species, totaled 9,383 individuals in the collections, 70 percent being taken at the mud station and the remainder over the shell (Table 10-13). Sciaenid fishes are the dominant species in estuaries of the northern Gulf of Mexico.

Juveniles of both Atlantic croaker and spot were the major benthic species in the catches. The mud bottom was preferred as a nursery area by both species: 63 percent of the Atlantic croaker and 76 percent of the spot were captured in this habitat. Peak catches occurred in the month of June with an average catch of 198 Atlantic croaker and 822 spot over the mud bottom compared to 107 spot and 120 croaker per trawl sample over the shell bottom. During the year, an average of 140 spot/trawl sample from the mud habitat differed significantly from the average catch of 43 individuals/trawl over the shell ($t = 2.28$, $p < 0.05$). Although more Atlantic croaker occurred in the collections over the mud bottom than over the shell, the difference between the annual catches was non-significant ($t = 1.67$, $p > 0.05$).

Distribution of Shrimps

Three species of commercial shrimp that frequented the waters of Escambia Bay were the white (Penaeus setiferus), the brown (P. aztecus) and, to a limited extent, the pink shrimp (P. duorarum). The brown shrimp was the most abundant species (Table 10-14).

Since penaeid shrimp often burrow into the substrate with only their antennae extended, one would expect that certain bottom materials would be selected over others. Analysis of the shrimp collections by species showed that a highly significant increase existed in the number of shrimp from the mud station compared to the shell station ($F = 35.1$, $p < 0.05$). Subsequently, a highly significant difference was obtained

Table 10 - 14. Comparison of the number of penaeid shrimp caught by otter trawl over oyster-shell and mud bottoms in Escambia Bay from October 1973 to September 1974.

Species	Bottom type	Oct.	Dec.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Total
		Number of trawl samples										
		4	4	4	10	4	10	4	10	4	4	
Penaeus aztecus	mud	6	2	13	7	9	47	13	29	0	0	126
	shell	1	0	1	0	2	31	4	5	0	0	44
Penaeus duorarum	mud	0	0	6	3	0	0	0	0	0	0	9
	shell	0	0	1	1	0	0	0	0	0	0	2
Penaeus setiferus	mud	0	5	0	4	1	2	0	0	1	0	13
	shell	0	4	0	0	0	0	0	0	0	0	4
Total	mud	6	7	19	14	10	49	13	29	1	0	148
	shell	1	4	2	1	2	31	4	5	0	0	50

between the group means of the penaeid distributions (Student-Newmann-Keuls mutliple range test), which showed that brown shrimp inhabited the mud more frequently than the shell bottom. The distributions of the white and pink shrimps were non-significant possibly due to their sparce occurrence. As a group, there was a three-fold increase in the number of penaeids captured over the mud, as opposed to the shell substrate.

Discussion

The mud-bottom habitat was more heavily utilized as a nursery ground than was the shell bottom. Presumably, benthic fishes could forage more readily on the soft, mud bottom for bottom-inhabiting invertebrates. Darnell (1958) stated that the harpacticoid copepods, polychaetes, isopods, amphipods, mysids, and shrimps were important foods in the diet of juvenile spot and Atlantic croaker, the two dominant species in the bay. In a study of the food habits of the Atlantic croaker in Escambia Bay, Hansen (1969) reported that annelid worms were the dominant organism in their diet, accounting for 60 percent of the total food volume. Although not entirely unexpected, the pelagic fishes, as a group, did not show a preference for either habitat.

The substrate itself, as a source of cover, exerts an influence on the distribution of shrimp. In a series of laboratory tests, Williams (1958) showed that white and brown shrimp (Penaeus spp.) burrowed more readily into soft, muddy substrates, whereas pink shrimp most often occupied coarser, shell-sand material. The tendency of brown shrimp to seek out muddy substrates partially explains why the shell area was generally avoided in Escambia Bay.

In Chincoteague Bay, Maryland, the bottom habitat was altered by spreading oyster shell over old, silt-covered, oyster bars (Arve, 1960). Subsequently, more fishes were trapped over the planted areas than over the control. The dominant species was the black sea bass (Centropristes striatus), which represented over half the total catch. The black sea bass is a typical reef inhabitant in high salinity waters. The distribution of spot in Chincoteague Bay agreed with our data in that this species was twice as abundant over the control area than over the shell plantings. Arve concluded that fishes were attracted to, and concentrated around, the dense oyster-shell plantings. However, the Chincoteague Bay project differed from the present study in that (1) the fish communities were dissimilar and (2) there was no evaluation of the nursery function of the shell areas. Presumably, the improved carrying capacity mainly benefited the adult populations.

In Escambia Bay, the evidence indicated that neither the mud nor the shell substrates should undergo major alterations. At present, the mud-bottom habitat is very productive and should be maintained as a nursery area. Conversely, compact, shell areas are an important habitat for selected species, such as the

sheepshead, and the adjacent reefs serve as the center of an active oyster fishery. Thus, it was concluded that large-scale, artificial changes in the existing substrates would not improve the carrying capacity of the bottom habitat for young fishes and penaeid shrimps.

11 - BENTHIC MACROINVERTEBRATES

INTRODUCTION

Since there are no published studies on the benthic fauna within Escambia Bay, an objective of the present study was to determine if distinct communities existed in Escambia Bay and the distribution of these communities. Sedimentation studies discussed in Chapter 7 revealed three major benthic habitats in Escambia Bay: (1) a broad central plain of mud sediments, (2) the transition zone close to shore, where the gradient changes to a steeper slope with sediments grading from mud to sand, and (3) a sandy shelf along the bay margin. In this study, macroinvertebrates in the following eight habitats were categorized and sampled: (1) sand shelf, (2) transition zone, (3) mud plain, (4) oyster bed, (5) grass bed, (6) near a sewage treatment plant discharge, (7) near industrial discharges, and (8) mud in the deepest part of the bay. Macroinvertebrates are defined as organisms one mm or larger while meiofauna are those organisms of smaller size.

Other objectives of this study were to determine the effects of recovery techniques such as revegetation of grass beds on the benthic fauna, and to determine the effects of domestic or industrial waste discharges on the nearby benthic fauna.

Comparisons were made between assemblages of organisms in Escambia Bay and other bays in the Pensacola Bay system as well as other bays in the Gulf of Mexico.

METHODS

Sampling Locations

Most benthic macroinvertebrate sampling stations were selected on previously selected sediment sampling transects to represent each type of sediment; that is, sand, mud, or transition. If two stations were established in the mud plain, the shoreward station (B) was located to show the shoreward edge of the mud plain. The other station (A) was established well out in the mud plain. Station C was typically in the transition zone and Stations D and E were on the sand shelf (Figure 11-1). Benthic macroinvertebrate stations in Escambia Bay are shown on Figure 11-2, and stations throughout the Pensacola Bay system are shown in Figure 11-3.

To determine differences in benthic populations in summer versus winter, six stations were sampled in both periods. Transects G and O, each with three stations, were selected in Escambia Bay. During the summer, transects G and O, with stations A, B, C, and D were sampled; however, in winter, stations A, B, and D were sampled. Therefore, only three

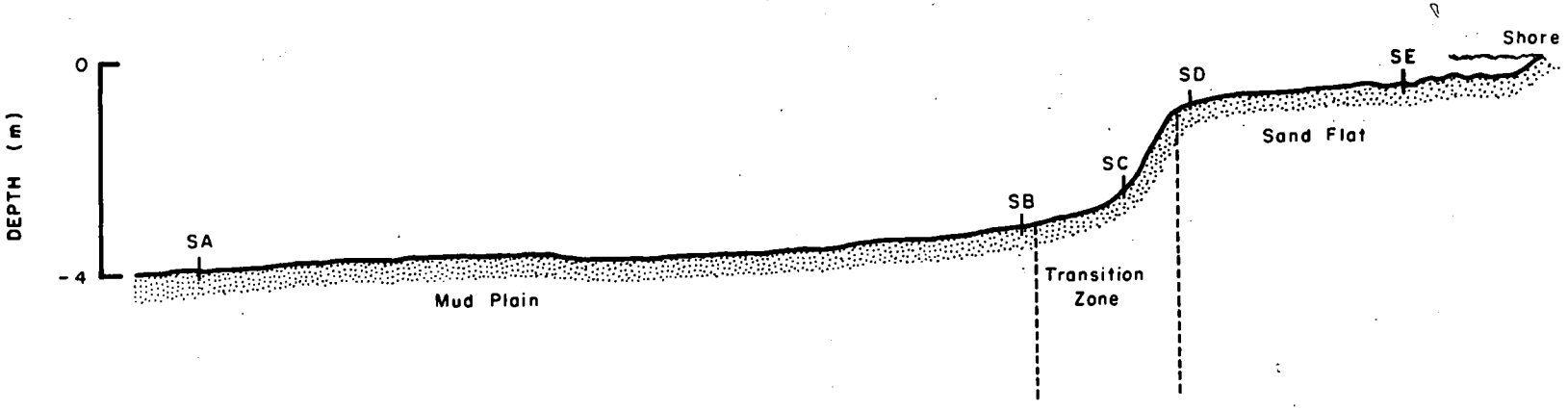


Figure 11-1. Fathometer tracing of transect 'S' showing the three sampling zones.

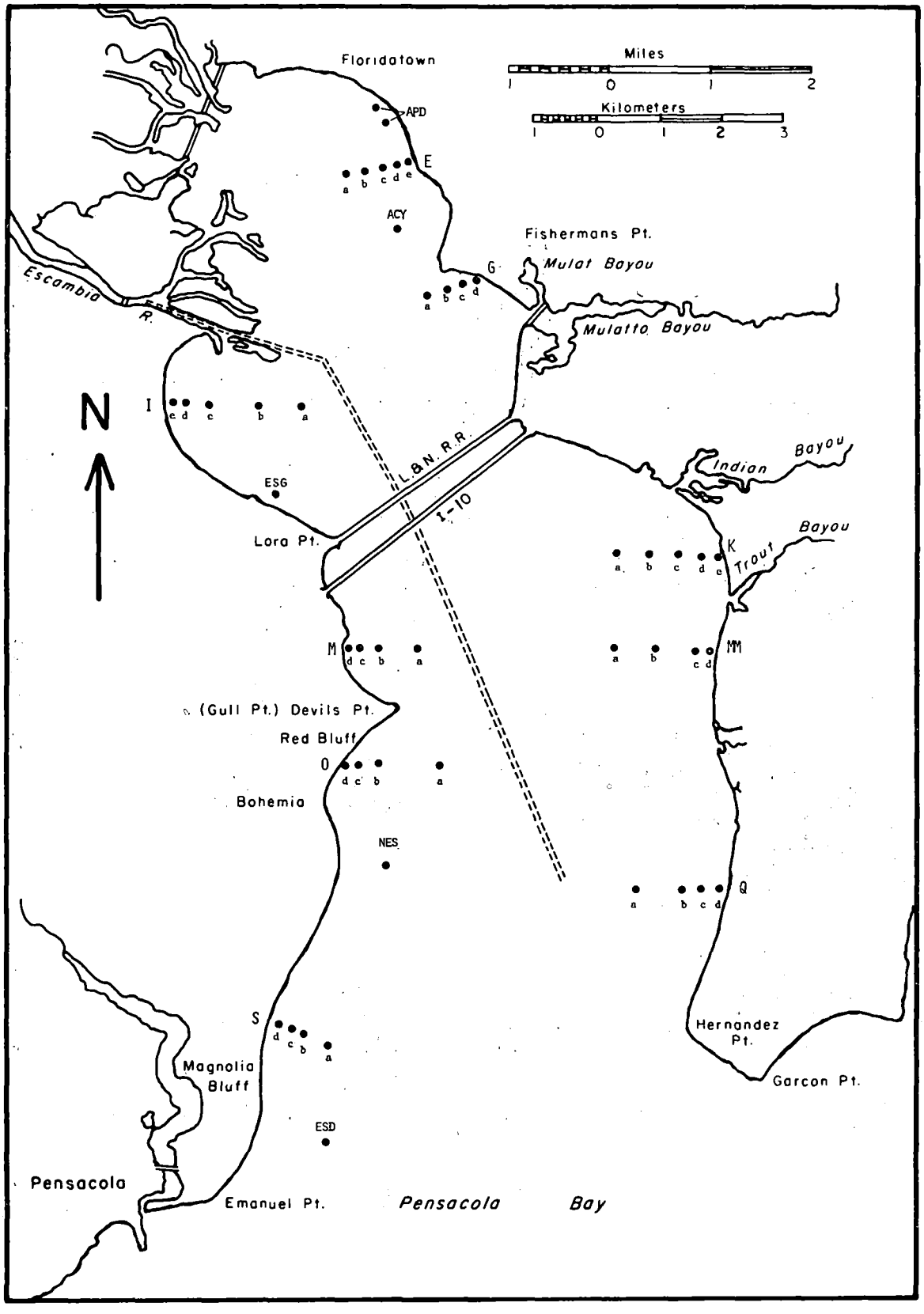


Figure 11-2. Benthic macroinvertebrate station locations in Escambia Bay.

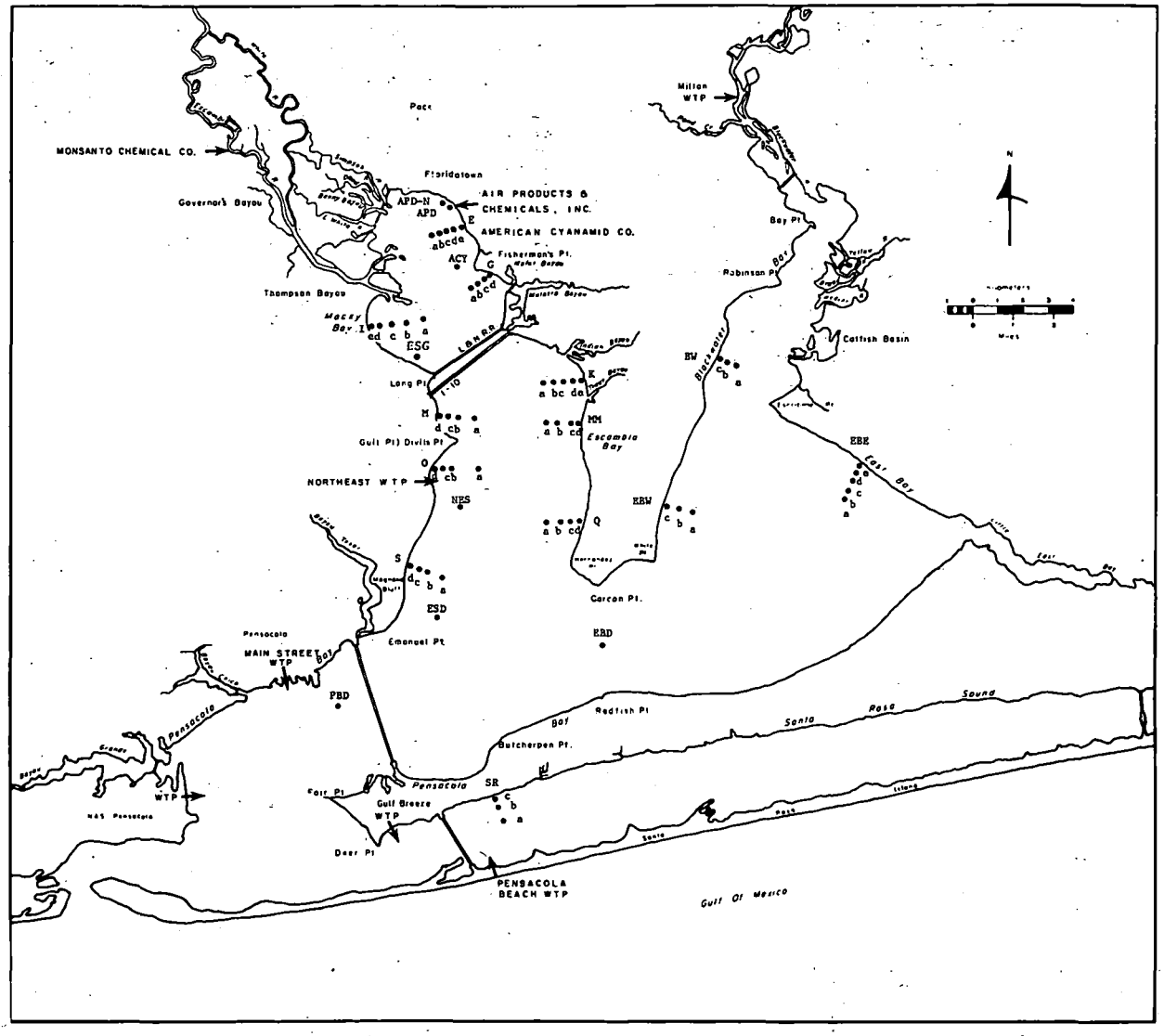


Figure 11-3. Benthic macroinvertebrate station locations in the Pensacola Bay system.

stations in common for both periods were considered in this particular discussion. In both transects, for the summer, A represented a mud station, C a transition station, and D a sand station. In the winter A was a mud station, B was a transition station and C was a sand station for both transects.

The upper bay was defined as the area above the Interstate 10 bridge, conversely the area below the bridge was the lower bay. There were three transects in the upper bay (E, G, and I). Transects K, M, MM, O, Q, and S were in the lower bay.

Sampling and Analytical Techniques

Two types of benthic grabs were used to sample the benthic fauna. The Van Veen grab was used to sample all stations that were in at least one m (three ft) of water. This grab sampled a 0.16 m^2 area to a depth of approximately 40 cm. The soft muds allowed the Van Veen to sink below the mud-water interface, thus allowing a bite deeper than the 28 cm depth possible in harder sediments. A screen on top of the grab, with one mm openings, helped prevent washout (shock wave) and assured that organisms were not lost from the sampled mud column. The 35 foot R/V Dolphin (loaned by the EPA, Gulf Breeze Environmental Research Laboratory) was used for all stations at depths of one m or greater. A ponar grab was used from a 16 foot boat in the shallow inshore stations. This grab took a 0.05 m^2 sample to a depth of about eight cm in sand. Sanders (1956) suggested this depth is the lower limit for most infaunal invertebrates.

At each station sampled with the Van Veen grab, five replicates were taken, encompassing a total area of 0.80 m^2 per station. Stations sampled with the Ponar grab usually had 12 replicates for a total area of 0.60 m^2.

The samples collected were seived and preserved in the field, and sorted and identified in the laboratory. The sieves used to separate organisms from sediments had one mm mesh openings. Special sieving sinks with two shower heads, one fixed and spraying upward, and the other free and used downward to break up the sediment lumps, greatly reduced sieving time. Retained organisms were preserved with an eight percent formalin-rose bengal stain solution. The stained organisms were sorted in white enamel pans with the aid of magnifiers.

Of those macroinvertebrates retained by the one mm sieve, only those specimens with a body thickness equal to or greater than one mm were quantified and identified. This procedure facilitated analyses, but regretably excluded a certain recognized segment of the benthos which this project was not prepared to examine. Several commonly collected polychaetes were totally excluded as a result of this method, including Mediomastus sp. and probably two spionid species. A nemertean worm was also not enumerated, since it seldom attains a one mm

size. Biomass determination, however, included all organisms retained by a one mm sieve, regardless of individual size. Less than five percent of all retained individuals were less than one mm in diameter; therefore, biomass values were essentially congrous with values for all individuals one mm or greater in diameter.

Many organisms were not collected because of the sieve size (one mm) used in this study. One millimeter was the arbitrary size break between the meiofauna and macrofauna. If meiofauna (less than one mm) are sampled, a decision must be made to how small an organism is to be sampled in this group. With decreasing size of seives used, the amount of mineral particles retained on the sieve increases, thus compounding the sorting problem. Larger sample areas decrease the effect of "patchiness" and assure a more complete sampling of the assemblages of organisms. It is usually necessary to compromise sieve size or sampling area because of manhour restrictions.

For this study of the Pensacola Bay system, the hemichordates, eight species of dermersal fishes, and Branchiostoma caribaeum (a Lancelot), were taken by benthic grabs and were included in the summary tables and diversity calculations as though they were macroinvertebrates. These species were infrequently encountered and were not significant in this study.

To obtain biomass, organisms were dried in the oven at 105°C for 24 hours, weighed, and then burned in a muffel furnace at 550°C for one hour. Residues were cooled in dessicators and weighed on a Metteler balance. Thus, biomass was defined as the ash-free weight.

The majority of the benthic sampling was completed in August, 1973; however, samples were also taken in the winter of 1974 to determine seasonal variation. Additional samples were taken in the summer of 1974. The listing in Appendix 13-1 gives the dates various stations were sampled.

The Morisita index for faunal affinity between communities (Morisita, 1959) was calculated by the following formula:

$$C_\lambda = \frac{2 \sum_{j=1}^{\infty} \left(\frac{n_{1j}}{N_1}\right)\left(\frac{n_{2j}}{N_2}\right)}{\sum_{j=1}^{\infty} \left(\frac{n_{1j}}{N_1}\right)^2 + \sum_{j=1}^{\infty} \left(\frac{n_{2j}}{N_2}\right)^2}$$

where: n_1 = number of individuals in j^{th} species in sample 1

n_2 = number of individuals in j^{th} species in sample 2

N_1 = total number of individuals in sample 1

N_2 = total number of individuals in sample 2

C_λ = index of similarity between communities

C_λ = 1 for same communities

C_λ = 0 when there are no common species

Diversity was calculated using the Shannon-Weaver formula (Shannon and Weaver, 1963). The diversity at each station was estimated by (H'):

$$H' = -\sum \frac{N_i}{N} \log_e \frac{N_i}{N}$$

Where: N_i is the number of individuals in the i^{th} species and N is the total number of individuals in the sample.

Sampling Adequacy

Previous studies by various workers have used many sample sizes and techniques to determine an estimate of the benthic macroinvertebrate population. Thorson (1957) stated that a benthic fauna sample should cover at least 0.1 m^2. Later workers have followed this advice, either by design or through expediency of manpower and time restraints. Some workers have studied fauna within mud sediments (Holland, et al., 1973; Stauffer, 1937). Others have worked within sand sediments or sand-vegetation habitats (Bloom, et al., 1972; Santos and Simon, 1974; Nichols, 1970). Young and Rhoads (1971), Sanders (1958), and Taylor (1973) sampled both mud and sand sediments for benthic organisms. Also, various workers have sampled multiple substrates such as sand, mud, transitional, gravel, and vegetation (O'Connor, 1972; Lie and Kelly, 1970).

The studies cited above took from one to four samples per station and covered an area ranging from 0.016 to 0.6 m^2. The present study sampled sand, mud, transition, and vegetation substrates and took either five samples with the Van Venn grab or 10 - 18 samples (mostly 12) with the Ponar grab. These samples encompassed 0.6 to 0.8 m^2 per station with the Ponar and Van Veen grabs, respectively.

To characterize sampling adequacy, species-area curves were developed for several benthic habitats and these are in the discussion below.

RESULTS

The results of analyzing samples from the Ponar and Van Veen grabs during the course of this study are discussed below. Each habitat is considered and the number of species, biomass, number of individuals, and diversity are discussed under each habitat. Also, comparisons within Escambia Bay and within bays of the Pensacola Bay system are discussed for each habitat. Appendix 11-2 lists all species taken during this study throughout the Pensacola Bay system.

Sand Shelf Assemblage

The sand shelf on the perimeter of the bay comprises approximately 25 percent of the bay. The sand shelf macroinvertebrate population during the summer was dominated by Mulinia lateralis and Grandidierella bonnieroides which made up 60 percent of the total number of organisms. These two species, along with Laonereis culveri, Odostomia sp A., Tagelus plebeius, and Haustorius sp., made up 89 percent of the total organisms. Grandidierella bonnieroides was found only in sandy sediments throughout the bay. Distribution of this amphipod was patchy with aggregations as high as 1000 per m^2. The next most abundant sand inhabitant was the bivalve mollusk Mulinia lateralis, which reached a population of 693 per m^2. Populations of this bivalve varied greatly within a sampling area.

Seasonal variations in benthos included a reversal of the two summer dominants so that in the winter Grandidierella bonnieroides was the most dominant and Mulinia lateralis was the second most dominant. Two other winter dominants were Neanthes succinea and Monaculodes edwardsi. Tagelus pleheius was a summer dominant. At sand stations for both summer and winter, the same species tended to be dominant; however, they did shift their order of dominance.

Species-area curves for sand shelf stations during the winter of 1974 indicated sampling was adequate, except at Stations EBED and BWC (Figure 11-4), and, therefore, accurate conclusions can be determined from the data. Summer curves for sand shelf stations exhibited the same trend; however, five of the eleven stations were not quite adequately sampled. Therefore, the number of species, biomass, and numbers of individuals in the sand shelf sediments during the summer of 1973 were underestimated and with better sampling would have had even higher values.

The average number of species collected at the eleven stations on the sand shelf was thirteen. Table 11-1 gives a comparison of species at various substrates and habitats within Escambia Bay. Three stations on transect G and three on transect O were sampled in both the summer and winter to determine seasonal variation. The average number of species in the summer for both transects was 13 per station; and in the winter, the

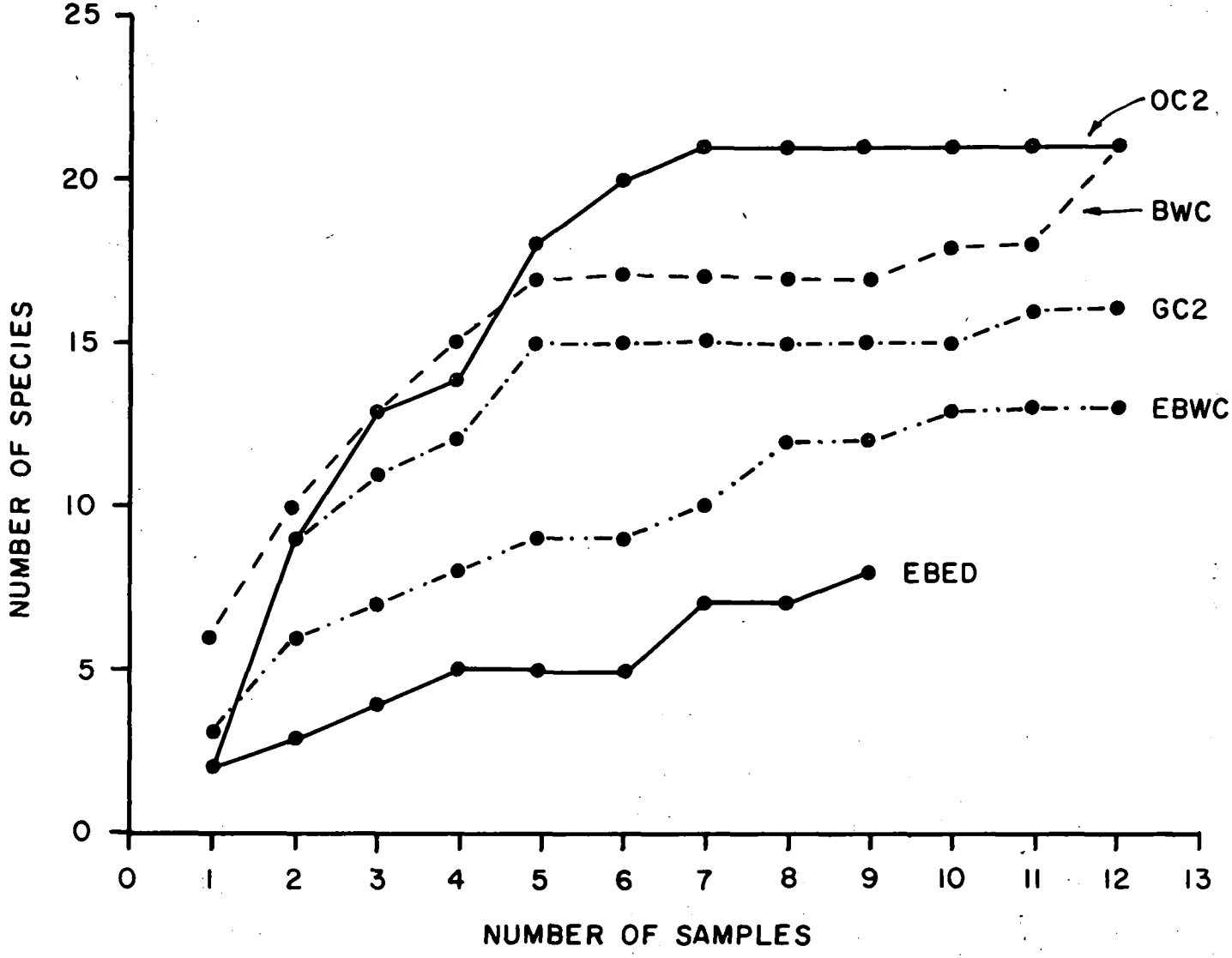


Figure 11-4. Cumulative curves of species taken per grab at sand shelf stations with the Ponar dredge during the winter of 1974 in the Pensacola Bay system.

average was 18.5 per station (Table 11-2). There were 36 species collected at the 11 sand shelf stations during the summer and 24 species taken at two stations in the winter. Thus, the average number of individuals per station during the summer at eleven stations was 486 per m^2 (Table 11-1). The two stations in common for both summer and winter yielded values of 337 individuals/m^2 and 1064 per m^2 respectively (Figure 11-2). These data indicated substantial seasonal differences, with winter having about three times as many individual organisms as summer.

The biomass (ash weight) per station averaged 0.65 g/m^2 for the 11 stations in summer. Biomass at Stations GD and OD averaged 0.95 g/m^2 in the summer and 0.21 g/m^2 in the winter. These sand shelf stations were the only stations that decreased in biomass during the winter; mud and transition stations increased in winter.

Comparisons of Sand Areas Within Escambia Bay

Sand stations within Escambia Bay had similar numbers of species and biomass but not numbers of individuals. In the upper part of the bay there were 12.0 species per station, while the lower bay had 13.6 species per station (Table 11-3). Biomass was 1.33 and 0.27 grams/m^2, respectively, for the upper and lower bay (Table 11-3). The number of individuals per m^2 were 638 in the upper bay and 400 in the lower bay (Table 11-3). Although the biomass and number of individuals were higher in the upper bay there was no statistical difference between the upper and lower bays at the 95 percent level of confidence for number of species, biomass, and numbers of individuals.

There was a trend toward higher numbers of individuals in the upper bay to lower numbers in the lower bay on both sides of the bay.

The trend for biomass was also from higher values in the upper bay to lower values in the lower bay on both the east and west sides.

Stations on the east side of Escambia Bay were compared to those on the west side of the bay for sand habitats (Table 11-4) and no differences were found at the 95 percent level of confidence for the number of species and biomass. There was, however, a significant difference between the number of individuals found on the east side verses the west side ($t = 1.99$, $df = 9$).

Diversity (H') was not significantly different on the east side compared to the west side of the bay ($t = 2.15$, $df = 9$). Whereas the trend for numbers of individuals and biomass decreased from north to south on both sides, the diversity had no definite trend. Diversity values are given in Appendix 11-3 for each station during the study.

Table 11 - 1. Habitats and related benthic macroinvertebrate data in Escambia Bay for the summers of 1973 and 1974.

Habitat	Year Sampled	Substrate	Number of Stations	Species/station			Individuals/m^2		
				mean	range	s.d.	mean	range	s.d.
sand	1973	sand	11	13	10-22	3.1	486	61-1553	476.4
transition	1973	sand to clayey silt	10	10	1-17	5.1	100	8-239	71.1
mud	1973	sand to clay	14	4	2-8	2.3	41	4-160	41.4
oyster	1973	sand to clayey sand	4	19	16-21	1.2	352	135-652	191.0
grassbed	1974	sand	1		23			924	
S.T.P.	1974	silty sand	1		25			778	
industry	1974	sand to clayey sand	3	9	7-11	1.6	249	168-341	70.9

Habitat	Year Sampled	Substrate	Number of Stations	Biomass/m^2			Diversity (H')		
				mean	range	s.d.	mean	range	s.d.
sand	1973	sand	11	0.65	0.03-3.05	0.88	1.64	1.08-2.36	0.01
transition	1973	sand to clayey silt	10	0.33	0.02-1.84	0.51	1.59	0.41-2.27	0.57
mud	1973	sand to clay	14	0.08	0.01-0.36	0.10	1.06	0.56-1.68	0.65
oyster	1973	sand to clayey sand	4	84.6	0.98-228.1	93.3	2.07	1.88-2.40	0.20
grassbed	1974	sand	1		5.45			1.93	
S.T.P.	1974	silty sand	1		0.43			1.40	
industry	1974	sand to clayey sand	3	0.28	0.18-0.48	0.14	1.40	0.83-1.73	0.40

Table 11 - 2. Seasonal comparison of benthic macroinvertebrates at stations located on G and O transects in Escambia Bay during 1973 to 1974.

Habitat	Season	Number of Stations	Number of Individuals no/m^2	Biomass g/m^2	Species no/m^2
Mud Plane	Summer	2	112.0	0.20	5.5
	Winter	2	231.0	0.58	14.5
Transition Zone	Summer	2	89.1	0.16	8.5
	Winter	2	1090.2	0.43	19.5
Sand Shelf	Summer	2	337.0	0.94	13.0
	Winter	2	1063.5	0.21	18.5

Table 11 - 3. Comparison of biomass, species, and number of individuals in upper and lower Escambia Bay.

	Habitat		
	Mud	Transition	Sand
NUMBER OF SPECIES PER STATION			
Upper Bay	4.1	13.2	12.0
Lower Bay	4.6	10.0	13.6
BIOMASS (grams/m^2)			
Upper Bay	0.04	0.59	1.33
Lower Bay	0.10	0.15	0.27
NUMBER OF INDIVIDUALS per m^2			
Upper Bay	45.8	133.4	638.0
Lower Bay	37.4	92.1	400.0

Table 11 - 4. Comparison of biomass, species, and number of individuals near the east shore and the west shore of Escambia Bay.

	Habitat		
	Mud	Transition	Sand
NUMBER OF SPECIES PER STATION			
East Shore	5.0	13.2	13.5
West Shore	3.7	7.5	12.4
BIOMASS (grams/m^2)			
East Shore	0.07	0.18	0.41
West Shore	0.08	0.42	0.95
NUMBER OF INDIVIDUALS per m^2			
East Shore	57.1	135.6	243.9
West Shore	19.5	90.3	776.8

Transition Zone Assemblage

The transition zone is defined in this report as a narrow band, paralleling the shore, between the sand shelf and the mud plain. It is characterized by a much steeper slope than the very gradual sloping mud plain. Sediment types in this zone included six different classifications varying between sandy mud and fine sand. Figure 11-3 is a profile of transect S which illustrates the three areas.

Species-area curves for transition zone stations during the winter of 1974 in the Pensacola Bay system showed two of the five were adequately sampled. Only five of the ten stations sampled in the summer of 1973 were adequately sampled and estimates of the population will be conservative.

Ten stations in the transition zone yielded a total of 34 species and averaged 9.8 species per station (Table 11-1). The dominant species, by number of individuals, in this zone were Mulinia lateralis and Parandalia fauveli. These two species constituted 43 percent of the total organisms found. These two, plus Odostomia sp A., Laonereis culveri, Cerebratulus lacteus, Grandidierella bonnieroides, and Amphicteis gunneri floridus, constituted 80 percent of the total. There was little change of dominant species between the summer and winter samples. However, the number of individuals taken in summer, 89.1 per m^2, was about one-tenth of the 1090.2 per m^2, collected in winter (Table 11-2). Species increased to 19.5 per station in winter compared to 8.5 in summer for the two stations that were sampled in both seasons. Biomass of the benthic organisms was intermediate of the sand and mud areas with 0.33 g/m^2. Winter samples at the two stations averaged 0.43 g/m^2, while the same two stations in the summer were 0.16 g/m^2. Therefore, species, number of individuals, and biomass increased during winter in the transition zone.

Comparison of Transition Areas Within Escambia Bay

Transition zone stations in Escambia Bay had similar numbers of species per station, biomass, and numbers of individuals. There were no statistical differences at the 95 percent level of confidence in stations in the upper bay compared to the lower bay or in the east side compared to the west side of the bay for the three parameters stated above. Table 11-3 lists data for the transition zone at both the upper and lower portions of the bay. Table 11-4 lists transition zone data for the east and west sides of the bay. Diversity (H') was similar in the upper bay compared to the lower bay and the east side was similar to the west side. In summary, there was some variation in benthic macroinvertebrates at transition stations, but in general they were similar throughout the bay.

Mud Plain

The mud plain covers approximately 70 percent of Escambia Bay. Typically, there is a thin flocculant soupy layer at the mud surface which changes in firmness with sediment depth. Generally, at a sediment depth of 15 cm, the mud has the consistancy of a sticky gel. At greater depths, interstitial water is reduced and the mud is firmer. High winds and increased currents can cause this surface sediment to be resuspended.

The two most dominant species throughout the mud sediment were the polychaete worms Sigambra bassi and Paraprionospio pinnata. These made up 18.3 and 17.5 percent, respectively, of the total individuals sampled. Other dominant species included Odostomia sp A., the Nemeretean Cerebratulus lacteus, the Hemichordate species, Parandalia faureli, and Haplosoloplos fragilis. All of these species combined were 85 percent of the sampled community. All mud plain stations were adequately sampled except OA and EBEA. The latter two stations needed additional grabs to obtain an adequate sample. In general, the mud plain stations were adequately sampled. The average number of species per station within the mud plain was 4.4 (Table 11-1).

Stations on the G transect and the O transect were sampled both summer and winter. At these two mud plain stations there were 5.5 species per station in the summer and 14.5 species per station in the winter (Table 11-2). Dominant species in the summer were Parandalia fauveli, Paraprionospio pinnata, and in the winter Tellina sp., Mulinia lateralis, Glycinde solitaria, Mactra fragilis, and Paraprionospio pinnata were dominant. This indicates a shift from hemichordates and polychaete worms in the summer to mollusk and polychaetes in the winter.

Average biomass per station for the fourteen mud stations was 0.08 g/m^2 (Table 11-1). Summer-winter comparison of G and O transects were 0.20 g/m^2 in the summer and 0.58 g/m^2 in winter (Table 11-2).

Numbers of individuals per station averaged 41/m^2 in the mud plain sediments (Table 11-1). The summer average at the G and O transect stations was 112/m^2 while the winter average at the same sites was 231/m^2 (Table 11-2). Thus, number of individuals, biomass, and species increased during the winter sampling.

Comparison of Mud Stations in Escambia Bay

Biomass, number of individuals, and number of species found at mud plain stations showed no statistical differences between the upper and lower bay or in the east side compared to the west side of the bay. Data for these stations are summarized in Tables 11-3 and 11-4. Diversity (H') averaged 0.94 in the upper bay and 1.14 in the lower bay and 1.04 on the east side of the

bay and 1.07 on the west side. Therefore, diversity was similar throughout the bay within the mud plain.

Oyster Bed Assemblage

Oyster beds provide one of the most productive habitats in Escambia Bay for an assemblage of macroinvertebrates. Oysters are found on pilings throughout Escambia Bay; however, normal beds occur only in the central portion of the bay near the east and west shores. These beds represent a normal distribution relative to salinity, hydrology, and other influencing factors for oyster production. Profiles of beds found on the east side of the bay are shown in Figure 7-4 on the MM and Q transects. Oyster bed stations include MMA, MMB, MMC and QC. Beds shown on transect Q were established by the Florida Department of Natural Resources as experimental cultch material (Mr. Ed Little, personal communication). At Station QC, near the experimental bed, the sediment was similar to the surrounding area since the bed has not been active long enough to alter the sediments. Percent volatile organics in the sediment at QC was 0.5 but at MMA and MMB (natural oyster beds), the percent volatile organics were 9.0 and 3.6, respectively.

Quantitative sampling of oyster habitats is a difficult task. Most benthic dredges are inadequate on oyster beds and allow grab samples to escape by not closing properly. Oysters also tend to exist in a clumped distribution. If sampling effort is adequate to collect 90 percent of the species in a sand or mud habitat, this same effort might not be adequate in oyster beds. Therefore, sampling effort must be greatly increased or modified. In this study, oyster tongs were used to augment the Ponar grab; five grabs taken with each sample. Generated data indicated more intensive sampling of oyster habitats would have been desirable and would yield a greater number of species.

All oyster bed stations were inadequately sampled and all data generated from these grabs will be an underestimate of the population dynamics.

The dominant species by number of individuals included: Neanthes succinea, Brachidontes recurvus, B. exustus, Cerebratulus lacteus, Paraprionospio pinnata, Melita nitida, Parandalia fauveli, Glycinde solitaria, Marphysa sanguinea, and Gyptis capensis. These nine species represented 89 percent of the habitat total. Thirty-five different species were collected in the four oyster bed stations in Escambia Bay. This compared to 25 different species found at one station in an oyster bed in East Bay. There was an average of 19 species per station in Escambia Bay and 25 species per station in East Bay. Biomass on Escambia Bay oyster beds was higher than for any other habitat in the bay. The average biomass per station was 84.6 g/m^2 (Table 11-1). Biomass of the oyster bed station in East Bay (EBEC) was 4.6 g/m^2 per station (Appendix 11-3). Although the number of species and the number of individuals per station were much

higher in East Bay, the biomass was low in comparison to Escambia Bay. At oyster bed stations, the two bays had 16 species in common, while 28 were collected only in Escambia Bay. Of the ten species dominant in Escambia Bay, two species, Neanthes succinea and Brachidontes exustus, were also among the dominants in the East Bay bed. These species are often dominant in oyster beds elsewhere along the Gulf. Paraprionospio pinnata and Marphysa sanguinea, both dominant in Escambia beds, were not collected at the East Bay station. M. sanguinea was not found anywhere else in Escambia Bay, except at the oyster habitats. Conversely, several dominant East Bay species were not represented in Escambia Bay. Two relatively common boring type bivalve mollusks, Martesia cuneiformis and Martesia smithi, were found boring into oyster shell. Therefore, since so many common species were not collected in both bays, these four stations were not adequately sampled to yield a meaningful comparison. However, even with inadequate sampling, it was still obvious that an oyster bed had greater diversity than any other habitat during the present study.

Grass Bed Assemblage

At present, there are no marine grasses in Escambia Bay. Vallisneria americana, a fresh to brackish species, does, however, exist in the upper reaches of the bay. V. americana was found fringing the delta area of the Escambia River and one isolated bed (ESG) was located approximately one mile south of the delta on the west shore of the bay. This isolated bed produced 23 macroinvertebrate species while a similar bed in Blackwater Bay (BWG) had 24 species (Appendix 11-3). A marine grass bed (EBEE) of Halodule wrightii in East Bay produced 26 macroinvertebrate species.

Biomass of organisms from both Escambia Bay (ESG) and Blackwater Bay (BWG) beds was similar at 5.45 g/m^2 and 5.2 g/m^2, respectively (Appendix 11-3). Biomass of the vegetation in the bed from Escambia Bay was 106.6 g/m^2 and 213.9 g/m^2 in the bed in Blackwater Bay.

The total individuals collected in Escambia Bay grass was 924 per m^2 compared to 705 per m^2 in Blackwater Bay and 1527 per m^2 from East Bay (Appendix 11-3).

Comparing the 24 species found in Blackwater Bay with 23 species from Escambia Bay, there were 16 species (52 percent) in common. Of the seven dominant species in Escambia Bay compared to the seven dominant species in Blackwater Bay, six were in common. These seven dominants constituted 87 percent of the total individuals in the Escambia Bay bed and 93 percent in the Blackwater Bay bed. V. americana habitats in both bays had essentially the same invertebrate assemblages. There were five species from the total bay system found only in the V. americana beds: a grass shrimp, Palaemonetes sp. and four fishes,

Gobiosoma sp., Trinectes maculatus, Myrophis puntatus, and Gobiosoma bosci.

The seven dominant species of the East Bay Halodule wrightii bed composed 90 percent of the total individuals found there. Thirteen species, or 50 percent, of those found in H. wrightii were not in either Vallisneria bed. Erichsonella filiformis and Leptochelia sp. were found only in the Halodule bed. This study indicated quite different communities existed in the two types of grass beds. The two species found in both types of grasses and no other habitats were Palaemonetes pugio and Gammarus mucronatus. Therefore, there were nine species found only in grass beds of Escambia, Blackwater, and East Bays.

A comparison of before and after the loss of Zostera marina in Woods Hole, Massachusetts revealed the benthic macroinvertebrates species were reduced one-third (Stauffer, 1937). The present study indicated it is possible to have a reduction of one-half of the total species in the bay with the loss of Vallisneria from Escambia Bay. A comparison of a sand station (EBED) and a Halodule bed station (EBEE) in East Bay indicated there could be a loss of 69 percent of the species if the grass were eliminated. However, a conservative approach by using data from another sand station across East Bay (EBWC) would indicate a species loss of 54 percent with a loss of grass.

All three stations for submerged vegetation were adequately sampled and no new species were added with additional sampling effort. All data generated from these stations were a true estimate of the total population according to these sampling techniques.

Sewage Treatment Plant Discharge Assemblage

The Northeast Pensacola STP discharges into Escambia Bay about 366 m offshore in two m of water (Figure 11-1). This plant provides secondary treatment and chlorination for 4,000 m^3/day of wastewaters. Sediments at this station were silty sand with some organics. Sand particles ranged from very fine sand to particles larger than one mm. Ten grabs with a Ponar dredge were made, with the first grab 20 feet from the outfall and each succeeding grab on 0.9 m (3.0 ft.) intervals southward.

This station (NES) was sampled in August 1974; therefore, any comparisons of data from this station must consider annual variations in benthic populations since summer samples at other stations were taken in 1973. The river flow, water quality, local rainfall, and other factors must also be considered when comparing these data with 1973 values at nearby stations.

A species-area curve indicated this station (NES) was not adequately sampled and the estimate of the population will be an underestimate.

Ash free dry weight of the benthic invertebrates was 0.43 g/m^2 and there were 25 species and 778.1 individuals/m^2 at this station (Table 11-1).

Paraprionospio pinnata, the most dominant species at this station and the other dominant species were also common at mud and transition stations throughout the bay.

As shown on Table 11-1, the benthos at the STP discharge area had higher numbers of individuals and biomass than other transition stations in the bay. The number of species at the STP site was also higher than other transition sites. The water quality of the discharge is apparently responsible for the increases by providing food, altering the sediment BOD, and in general, raising the productivity level. However, as stated before, the STP station (NES) was sampled a year later than other transition stations, which could account for some of the difference.

Diversity (H') was 1.4 at the STP station compared to the mean of 1.5 for all other transition stations in the Bay (Table 11-1). However, based on the range of 0.4 to 2.27 for H' at the other ten transition stations, the 1.4 value for the STP station was normal and diversity of the macroinvertebrates was not reduced.

Industrial Discharge Assemblage

Three stations represented the area near discharges of two industrial effluents. Station ACY was near the American Cyanamid Company discharge and APD and APDN were near the Air Products and Chemicals, Inc., discharge. These stations were sampled in the summer of 1974. Physical and chemical characteristics of the sediments at these stations appeared to be normal for stations at these depths, distances from shore, and mud content, with two exceptions. Copper concentrations in the sediments were higher at 10 and 12 µg/g than at nearby stations that have equal sediment characteristics. Aroclor 1254 (PCB) was higher at these three stations than at nearby stations. Particles of synthetic matter ranging in size from one mm to three cm were common at Station ACY.

Based on species-area curves, none of the three stations were adequately sampled and any conclusions from the data will be underestimates of the total population of invertebrates near the discharges. Also, any interpretations of these data should consider the dates of sampling; that is, ACY, APD, and APDN were sampled in 1974 and other stations with comparable sediment types were sampled in 1973.

Dominant species at industry stations ACY, APD, and APDN were the polycheate worms Laenoreis culveri, Paraprionospio pinnata, and Parandalia fauveli, while the dominant organisms in sand stations elsewhere throughout Escambia Bay were Mulinia

lateralis, a mollusk, and Grandidierella bonnieroides, a crustacean. The dominant specie in the transition-zone throughout the bay was Mulinia lateralis. Therefore, there was a shift in dominance of species from mollusea and crustacea throughout the sand and transition stations in the bay to polychaete worms near the industrial discharges. The ecological signficance of this shift is that dissolved or suspended materials from the discharges are such that they act directly as a food source or secondarily by altering the sediments to favor the production of polychaete worms. Finer grained and higher organic sediments are favored by polycheate worms as shown by worms being the dominant species in mud sediments of Escambia Bay. Also polychaete worms can tolerate stressed environments because of physiological adaptations; they often become dominant in polluted situations.

Transect E, consisting of Stations EA, EB, EC, ED, and EE, was between ACY and APD and was therefore near the industrial discharges (Figure 11-1). Sediments at these stations included primarily mud at EA and EB, the mud plain stations, and also mud at EC the transition zone station. Sand shelf stations (ED and EE) consisted of fine sand. Sediments at these E transect stations appeared normal when compared to other Escambia Bay stations in Appendix 7-1. Mud stations (EA, EB) had two and four species per station, respectively, while the other 12 mud plain stations in the bay averaged 4.7, with a range of two to eight species per station. The transition zone station (EC) had nine species while the nine other transition stations averaged 9.9 with a 1 to 19 range. Station ACY was considered a transition zone station and had 11 species. Sand shelf stations (ED, EE) had 12 species each and the nine other sand shelf stations averaged 13.2 with a range of 10 to 22 species per station. If Station MMD, which was in an oyster bed complex, was excluded from this sand shelf group, the average would be 12.1 species per station and would have a range of 10-15 species per station. Stations APD and APDN were sand shelf stations and had nine and seven species per station, respectively. The above data suggest that species per station are slightly reduced around Stations APD and APDN, which is an area near-shore where Air Products and Chemicals, Inc. Plant has a waste discharge. It must be considered, however, that these stations were inadequately sampled.

Mud stations near the industrial discharges included EA and EB which had 5.2 and 11.7 number of individuals per m^2, respectively. These values compared with a range of 3.9 to 160.0 and an average for 12 other mud stations of 46.4 individuals per m^2. Transition zone station EC had 144.4 individuals per m^2 and seven other transition stations averaged 106.2 with a range of 9.1 to 239.4. Station AGY was transition and had 239.8 individuals per m^2. Sand stations ED and EE had 314.9, and 593.5 individuals per m^2 and nine other sand shelf stations averaged 493.2 and had a 61.1 to 1553.2 range. Stations APD and APDN had sand substrates and 167.6 and 340.6 individuals per m^2,

respectively. All eight stations near the industrial discharges had numbers of individuals per m^2 that fell within the range of values at other like substrates throughout the bay; therefore, the distribution of numbers of individuals near the discharges appeared normal. Biomass per m^2 at mud stations (EA, EB) were 0.01 and 0.03 grams while the average of 12 other mud stations in the bay was 0.09 and the range was 0.01 to 0.36 grams per m^2. Stations EC and ACY were transition zone stations with biomass values of 0.16 and 0.48 grams per m^2, respectively. These two values fell within the range (0.02 to 1.84) of nine other transition zone stations within the bay. Biomass values at sand Stations ED and EE were 0.30 and 0.34 grams per m^2, respectively, and Stations APD and APDN had values of 0.19 and 0.18 grams per m^2, respectively. The values for APD and APDN appear to be low when compared to ED and EE, since all four stations had similar sediments and varied only in distance from the waste discharge. However, these four values fell within the range (0.03 to 3.05) of nine other sand shelf stations in other parts of the bay.

The species number, biomass, and numbers of individuals of benthic macroinvertebrates around the industrial discharges were altered only in a narrow band parallel to shore in the vicinity of the discharge from Air Products and Chemical, Inc.

Polinices duplicatus, a mollusk, was collected in the Pensacola Bay system only at Stations ACY and NES (near an outfall of a waste treatment plant) and is therefore tolerant of stressed conditions.

Deep Water Mud Station Assemblage

In order to determine if any difference existed in specie composition between the mud plain as defined above and the deeper water mud assemblages, one station was sampled at the mouth of Escambia Bay (Figure 11-1). This station (ESD) had a sediment composition of 68 percent clay and a silt content of 30 percent. Depth of water was 5.6 meters (18.5 ft) at this station. These samples for macroinvertebrates were taken in January 1974, as were other deep water samples from East Bay (EBD) and Pensacola Bay (PBD). Species-area curves indicated ESD was adequately sampled but PBD and EBD were not adequately sampled. This problem must be considered in any interpretation of the data. Eight species were collected at ESD with the three dominant species Sthenalais boa, Sigambra bassi, and Oxyurostylis smithi making up 75 percent of the individuals collected. There were 52.04 individuals per m^2.

At EBD in East Bay, the percentage of mud was 97.75, clay content was 66.66 percent and the classification was clay. Water depth at this station was 7.0 m (23 ft). The three most dominant species were Mactra fragilis, Sigambra bassi, and Paraprionospio pinnata, which made up 75 percent of the total sample. There were 81.96 individuals per m^2 and 10 species were collected at this station.

The other deep water station (PBD) was in Pensacola Bay south of the Port in 8.4 meters (27.5 ft) depth. Sediment classification here was mud with the mud content at 97.47 percent and clay at 60.05 percent. Dominant species were Oxyurostylis smithi, Sthenalais boa, and Sternaspis fossor, which comprised 78 percent of the total number of individuals. There were 154.83 individuals per m^2 and 12 species at this station.

There were three species in common between Stations ESD and PBD. Two of these three species were among the most dominant species found at both stations. There were six species in common between Stations ESD and EBD.

Station PBD was nearer the Gulf Inlet and had higher salinities than East Bay or Escambia Bay. Two species found at this station require higher salinities and consequently, these species, an Ophiuroid and a Hydroid, were not taken riverward in the estuary.

Although the deep water stations did not have the same specie assemblages, they did have some dominant species in common. There was a trend toward more species with an increase in salinity from Escambia to East to Pensacola Bays.

High Salinity Area Assemblage

The Pensacola estuary has expansive areas where the macroinvertebrate community is influenced to a large extent by consistently higher salinity water than Escambia or East Bays. This study sampled a site at the west end of Santa Rosa Sound to compare its macroinvertebrate assemblage with the upper estuary.

Three stations were sampled in conjunction with winter 1974 sampling in upper bays. The three stations included a deep water sand site (SRA), a transitional sand (SRB), and a shallow sand flat with sparse Halodule wrightii (SRC). All stations consisted of greater than 97 percent sand. Salinity ranged from 15 to 30 ppt at these stations. All three species-area curves indicated sampling was not adequate, especially at station SRC. Even though these three stations had by far the greater number of species than stations in the Pensacola Bay system, they would have had even more species with additional sampling.

Macroinvertebrate data for these three stations were compared with other sand habitats elsewhere in the estuary in table 11-5. Values for the three stations were higher than any other stations in the system. The number of species ranged from 67 to 83, while the highest species per station elsewhere in the bay was only 21. Individuals per m^2 averaged 1748 whereas East Bay averaged 1192 individuals per m^2 (Table 11-5). Biomass ranged from 0.61 to 2.95, while the highest value elsewhere was only 0.34 (Table 11-5). Diversity (H') ranged from 2.89 to 3.01, which was higher than any other station throughout the system (Appendix 11-3).

Table 11 - 5. Macroinvertebrate data for sand stations sampled in the Pensacola Bay system during the winter of 1974.

		Species/station			Individuals/m^2			Biomass/m^2			Diversity
	Stations	mean	range	s.d.	mean	range	s.d.	mean	range	s.d.	(H')
Escambia Bay	2	19	16-21	2.6	1064	211-1916	852.2	0.21	.08-.34	0.13	1.78
East Bay	2	10	8-12	2.0	1192	789-1596	403.5	0.15	.12-.17	0.03	3.36
Blackwater Bay	1		21			413			0.1		2.10
Santa Posa Sound	3	73	67-83	7.3	1748	1527-1938	170.1	1.80	.61-2.94	0.95	2.97

The 14 most dominant species at the Santa Rosa Sound stations made up 69 percent of the total organisms collected. All fourteen species were unique to the sound except Polymesoda caroliniana, which was also found in upper Escambia Bay. Santa Rosa Sound stations had a total of 133 different species collected.

The more-stable salinity and improved water quality are beneficial to the benthic macroinvertebrates and promotes many species, but not an overabundance of any one species or group of species; thus a balanced assemblage persists in Santa Rosa Sound.

Sandy sediments in the Pensacola Bay system produced by far the most species and individuals compared to a muddy sediment. Gage (1972) found diversity to be greater in sandy mud than soft mud. Boesch (1972) found that benthic diversity increased down the estuary. The Pensacola Bay system also had greatest diversity down the system toward the Gulf.

Comparison of Diversity Indicies in the Pensacola Bay System

Diversity indicies are useful for comparing one community to another, and are often used to show changes in a community structure caused by alterations in that system such as a pollutional discharge. Since various sediment types are used to delineate portions of the Pensacola Bay system, diversity indicies of benthic organisms at these various sediments further show the relationship of areas in the system.

The Morisita Index was calculated for all possible combinations of pairing 44 stations in Escambia Bay in order to compare one specie assemblage to another. The Morisita Index indicated many assemblages throughout Escambia Bay were related and therefore, there was no North-South gradient of changes in assemblage structure. Although there was a salinity gradient in the North-South direction, assemblage structure did not reflect this trend. Also, the less saline west side did not differ from the more saline east side in assemblage structure within comparable habitats. However, the Morisita Index has serious limitations in that it reflects only proportions of individuals

to species and does not adequately account for the species in common between the two assemblages. As such, the use of this index is confined to the above statement and the Shannon-Weaver formula for diversity is used to further show the assemblages of benthic macroinvertebrates.

Escambia Bay stations in the mud plain had an average H' diversity of 1.06. This compares to 1.62 for the transition zone and 1.65 for sand shelf stations. The mean for mud stations was significantly different from the transition zone mean but the means were not significantly different for the transition and sand stations. This indicates the mud plain assemblage is likely different from the transition zone assemblage but the sand shelf and transition zone assemblages may be similar. The mud plain had the lowest diversity of benthic macroinvertebrates in Escambia Bay. Diversity values for all assemblages in Escambia Bay are shown in Appendix 11-2.

Greatest diversity within Escambia Bay occurred in the oyster beds at 2.07, with grass bed diversity next highest at 1.93.

Diversities for industrial discharges and the STP discharge (Table 11-1) were intermediate of the transition zone and mud plain values. This order of values is reasonable since the sediments at the discharge sites are intermediate of fine sand and mud. Since the H' values at the discharges were higher than the mud plain H', the invertebrate assemblages are not impovished when comparing 1973 data at the transition and mud stations to 1974 data for the industrial and domestic discharge stations.

Oyster reef stations had the highest H' of all assemblages in Escambia Bay (Appendix 11-3). Stations on the MM transect are at old established beds, while Station QC represents cultch material that was planted by man within the last three years. Although Station QC is not natural, it nevertheless had an index similar to the natural reefs (Appendix 11-3).

The grass bed of Vallisneria americana in Escambia Bay had an H' of 1.93. This compared favorably to the same type of grass bed in Blackwater Bay with an index of 1.81. There was no apparent difference in the diversity within like grass beds in the two bays. The Halodule wrightii bed in East Bay, however, had a somewhat lower diversity at 1.32.

When comparing Escambia Bay to other bays in the system, only stations on transects G and O that were sampled in February, 1974 were considered, since stations in the other bays were sampled in 1974. The H' developed from mud plain stations in Escambia Bay was 2.10. The East Bay value was also 2.10; therefore, diversity was equal in mud stations for both bays. In the transition zone stations, the Escambia Bay H' was 2.12 while East Bay was 2.03. These values are considered close enough to indicate no difference in the transition zone between the two bays. Sand shelf stations in Escambia Bay had an H' of 1.79 compared to 0.36

for similar stations in East Bay. The diversity of sand stations, unlike the mud and transition stations, were quite different in the two bays.

The deep water mud station (ESD) had an H' of 1.72 compared to a deep water station in East Bay (1.79) and Pensacola Bay (1.76). The depth of the Escambia Bay station was 5.6 m (18.5 ft), East Bay station was 7.0 m (23 ft) deep, and Pensacola Bay station was 8.4 m (27.5 ft) (Figure 11-1). All three of these stations were sampled in the winter of 1974. In comparison, mud plain stations in Escambia Bay that were sampled at the same time yielded an H' of 2.10. East Bay mud plain stations had an H' of 2.10 also. A mud plain station in Blackwater Bay had an H' of 2.44.

The highest H' found in the Pensacola Bay system was the averaged values of Stations SRA, SRB, and SRC in Santa Rosa Sound. This high salinity area had an H' value of 2.97 during the winter of 1974 (Table 11-5).

Diversity (H') values indicate that within like sediments in Escambia Bay there exists communities of like diversity throughout the bay. The communities in Escambia Bay were similar to those in East Bay within like sediments. Diversity around the STP and industrial discharges appeared normal when compared to similar sediments at other stations. Therefore, according to diversity values (H'), the macroinvertebrate of Escambia Bay appear to be normally distributed throughout the bay.

Comparison of Diversity Indicies in Gulf of Mexico Coastal Systems

Holland, et al., (1973) did macroinvertebrate work in Galveston Bay at mud stations during both the summer and winter. Calculations made using their data show a mean H' of 1.62 for winter samples and 1.31 for summer. Mud stations in Escambia Bay had seasonal H' values of 1.98 for winter and 1.06 for summer. Taylor (1973) studied five different sediment types in Hillsborough Bay and determined H' at all stations. From these data, 12 stations on three of his transects have been selected as having similar salinities and sediments as Escambia Bay stations. Eight mud stations in Hillsborough Bay had an average H' value of 2.40 while mud stations in Escambia Bay averaged 1.06. The numbers of individuals collected in Hillsborough Bay were over eight times higher than those in Escambia Bay at similar sediment types. A partial reason for more organisms present in Hillsborough Bay is that Taylor used a 0.7 mm sieve compared to 1.0 mm in the present study in Escambia Bay. However, sieve size alone probably does not account for all the differences in the two bays. Apparently Escambia Bay has a more stressed ecosystem from salinity fluctuations, lower dissolved oxygen, greater turbidity, and more polluted sediments than the sampled portion of Hillsborough Bay. Galveston Bay had less diversity than Escambia Bay in the winter, but a greater diversity than Escambia Bay in the summer. Therefore, the benthos of Escambia Bay seems to have H' values lower than Hillsborough Bay and Galveston Bay during the critical summer period within comparable mud stations.

Four of Taylor's (1973) sand stations in Hillsborough Bay gave an average H' of 2.93 compared to the H' of 1.65 for sand stations in Escambia Bay. Hillsborough Bay diversities were higher in both sand and mud sediments than values from Escambia Bay.

Simon (1974) worked on benthic invertebrates in Tampa Bay at four stations, all with a greater than 70 percent sand composition. Diversity (H') calculated from his data (Simon, 1974) indicated a range from 2.03 to 3.21. These values are similar to Taylor's (1973) values for Hillsborough Bay (adjacent to Tampa Bay), but higher than values from Escambia Bay.

Comparing diversity (H') in the Escambia Bay system to Hillsborough, Tampa, and Galveston Bays, diversity in Escambia Bay was lower during the critical summer period.

12 - BENTHIC MACROFLORA

SEAGRASS DISTRIBUTIONS

Introduction

The Pensacola estuary had productive grass beds in all bays of the system (Figure 12-1). These plants have true roots, stems and leaves, and reproduce by means of flowers, fruits, and seeds. They grow completely submerged with only the lowest tides exposing some species to the air. Within the northern Gulf of Mexico Continental Shelf, Humm (1973) listed five abundant seagrasses (1) Thalassia testudinum, (2) Syringodium filiforme (3) Halodule wrightii, (4) Halophila baillonis, and (5) Halophila engelmanni. These marine plants are continuous from the Florida Keys to the Mississippi Sound (Humm, 1956) and extend from the intertidal zone out to depths of several meters (Humm, 1973). Within the northern Gulf bays and sounds, these plants grow from the MLHW to depths of about 2.0 m (6.0 ft) (McNulty, et.al., 1972; Eleuterius, 1973). In the Pensacola Bay system, the three most abundant species are Thalassia testudinum and Halodule wrightii, marine to brackish species, and Vallisneria americana, a fresh to brackish specie. Ruppia maritima is also fairly common in the fresh to brackish waters of the estuary.

Seagrasses within the estuary are a major component of the total system and especially important within the role of the estuary as a nursery ground for commercial finfish and shellfish of the Gulf. In the Pensacola Bay system the seagrasses provide:

1. oxygen production through basic primary productivity;
2. a food source, either directly or through the detrital food chain;
3. protection from predators and cover for all ages of organisms;
4. a habitat and substrate for both flora and fauna; and
5. a sediment trap which stabilizes the bottom sediments.

Seagrasses, therefore, increase the total diversity and also enhance sport fishing success through concentration of certain fishes.

Studies in the Benthic Macroinvertebrate section have shown the fauna assemblages within these grass beds to have much higher diversity than areas void of vegetation. Consequently, it is desirable to reverse the trend of losing vegetation to one of expanding present beds and revegetating areas that once had

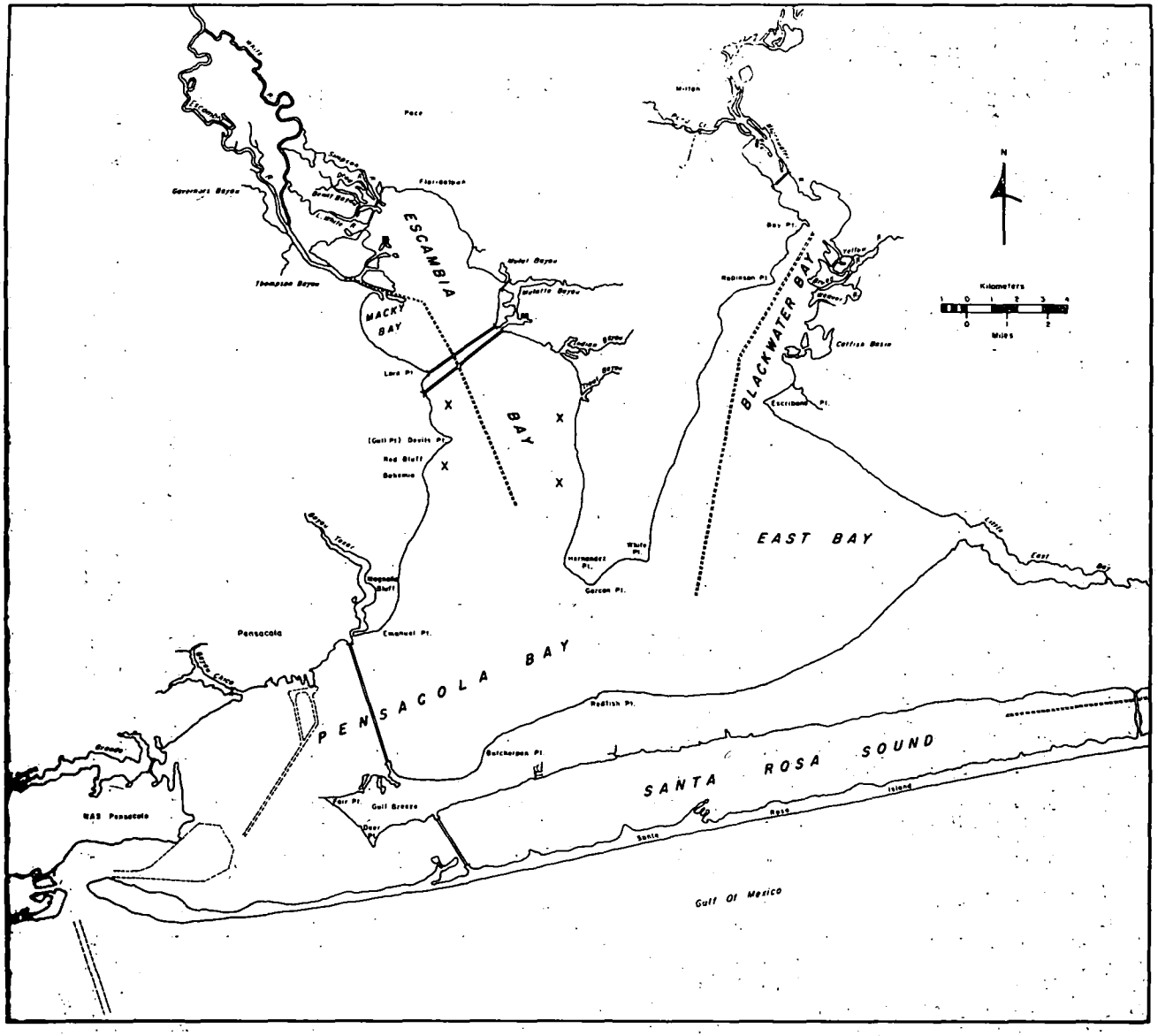


Figure 12-1. The Pensacola Bay system and revegetation sites in Escambia Bay.

seagrasses. Seagrasses are one of the basic building blocks necessary for recovery and rejuvenation of an estuary.

An objective of this study was to provide a baseline of the present vegetation distribution in the system and to review the changes that have occurred in this distribution over the last 23 years. This study should also provide coastal zone managers with facts that will enable viable planning in the estuary.

Methods

Photographs obtained from the Florida Department of Transportation were used to develop maps of the grass beds. Their file of aerial photographs of Escambia and Santa Rosa Counties dated back to 1949. Over-flights of the bays were made sporadically, and occurred more frequently over areas of greater highway construction. When a section of shoreline was omitted, no data was available for that area. Aerial over-flights were made in 1974 by project personnel using hand held 35 mm cameras with either Plus X black and white film or Kodachrome II color film. A polorizing filter was used on the camera. The black and white film permitted prints to be made inexpensively, while the color exposures gave good color saturation for best grass bed delineation. Both films penetrated to the depths of all grass beds and were adequate for interpretation in all cases. All flights were made at 1,219 meters (4,000 ft) altitude. Anchored floats were a point of reference which allowed scaling and determination of a grass bed size.

Results and Discussion

Escambia Bay

A recession and dissappearance of most of the Escambia Bay grass beds has occurred over the past 25 years (Figure 12-2). The Escambia River delta area is shown in 1951 and in 1974 in this figure. This shows *Vallisneria americana* in most shoreline margins of the delta. Increased water turbidity in the delta made the photos taken in the late 1950's and 1960's uninterpretable. Most likely *Vallisneria* beds were present to some degree during this period. With this exception, photo interpretation was not hindered at all due to turbidity. Most flights were actually made in winter, the time of lowest turbidity and best visibility. The delta area is the least altered area in Escambia Bay over the years.

In 1974 *V. americana* was more abundant than in the last several years according to bay front residents. In 1975 there was an even greater abundance of *Vallisneria* in the delta area as warmer weather progressed.

V. americana also inhabited the Macky Bay area north of Laura Point on the west shore of Escambia Bay. At the present time there exists only one small bed about one mile north of the point

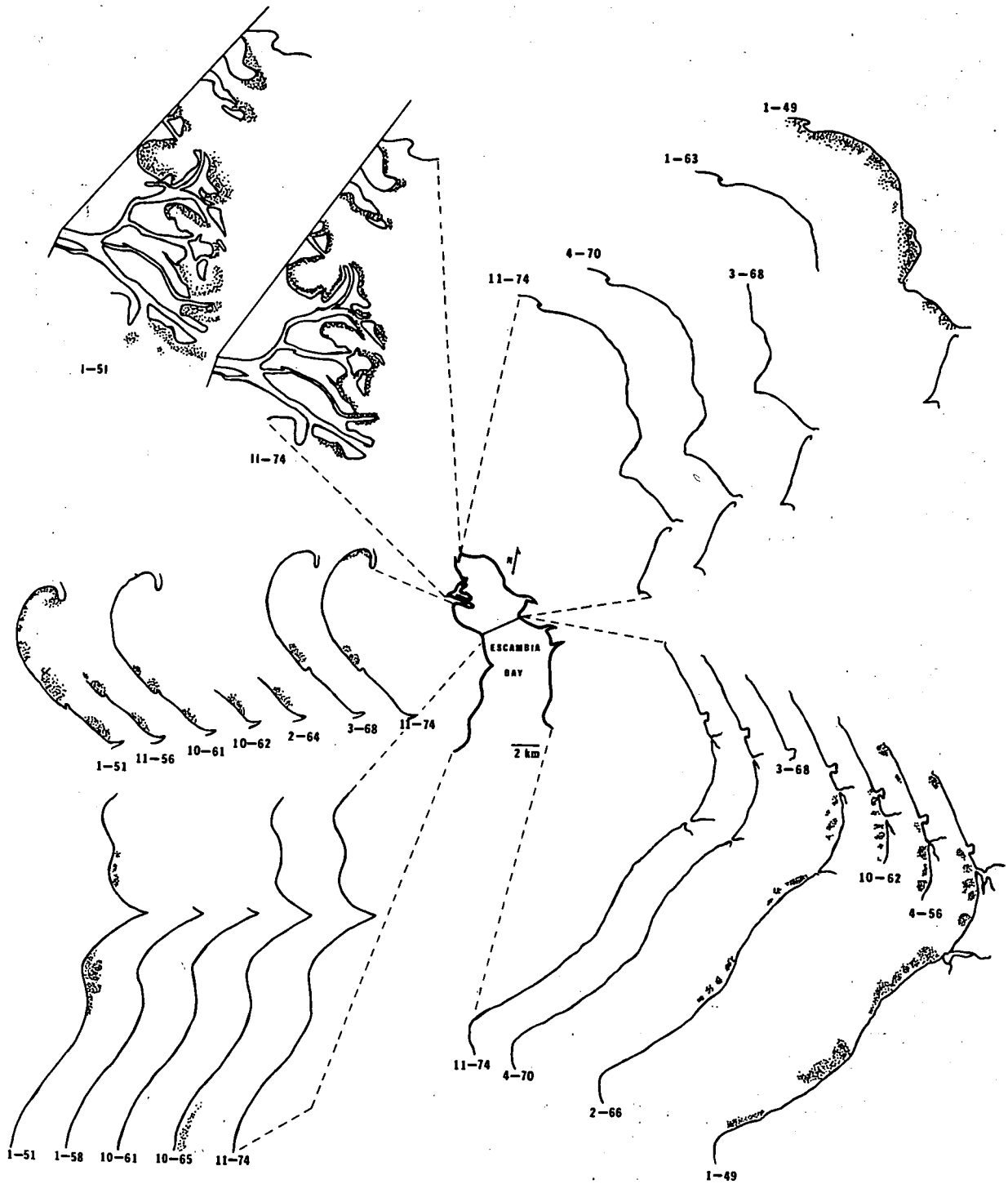


Figure 12-2. Escambia Bay grassbeds 1949-1974.

in four discontinuous patches. Historically, it has undergone recession. However, during the past year, expansion has occurred with new growth around each patch. During the summer and fall of 1974, turbidity levels in Escambia Bay were lower than usual, and therefore, beneficial to grass growth.

The Floridatown shoreline, in the northeast corner of the bay, had extensive submerged grasses in 1949. Although the species are unconfirmed, interpretation of the photographs indicated Vallisneria was dominant. Their greatest extent was from Basshole Cove south to Fisherman's Point, and also small patches near Mulatto Bayou. The next record indicated grasses ceased existence by 1963, concurrently with industries starting operations nearby on the bay.

Grass beds below Interstate 10 were most likely composed solely of Halodule wrightii (shoal grass). It is the most euryhaline of grasses found in this system. There were no records of the presence of any other marine species nor are there other species now present below the I-10 bridge. Sparse growth was observed in 1965 along the southwest Magnolia Bluff area. It extended for 1.6 km (1.0 mi) and was 0.64 km (0.4 mi) wide (van Breedveld, 1966). A dense bed existed north of Magnolia Bluff where the Northeast Pensacola STP outfall pipe was laid. Halodule seems to have flourished best along the lower southeast shore above Hernandez Point. It extended in discontinuous areas from the point up to Interstate 10. Ground truth reconnaissance revealed none in 1974.

Figure 12-2 shows a gradual loss of seagrass over a 17-year period from 1949 to 1966. By 1970 all of the seagrass had disappeared. Ground truth searches in 1973-74 revealed no vegetation along this shoreline.

In summary, Escambia Bay had extensive grass beds along all shores in 1949, except for sparse areas along the southwest shore. By 1974 all had disappeared except a small patch of V. americana along the upper western shore where there was a significant influence by freshwater flow from the Escambia River.

Pensacola and East Bays

The history of several small beds near the north side of Pensacola Bay bridge was first recorded in 1951 (Figure 12-3). The disappearance of these small beds near the port facilities is likely attributable to dredging. Enlargement of the Port of Pensacola (Phase I) involved extensive dredging and filling in 1960. Additional work was done in 1967. Figure 12-3 indicates the filled areas, before and after the port expansion, and the related distribution of seagrasses. Other beds were adjacent to the Pensacola Bay bridge and Bayou Texar. All traces of these beds were gone by October 1961.

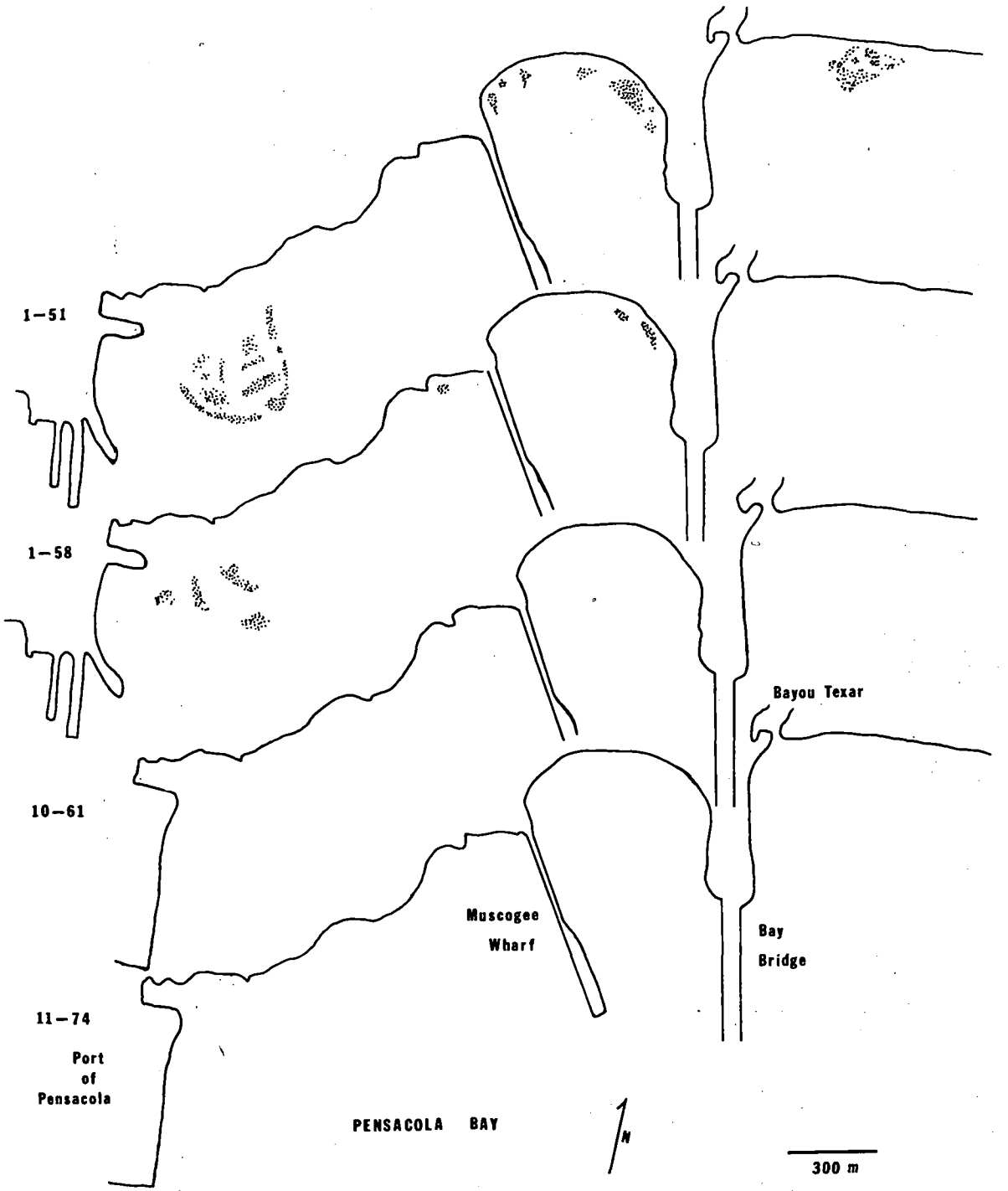


Figure 12-3. The north shore of Pensacola Bay with ship terminal and the Pensacola Bay bridge, 1951-1974.

The south shore of Pensacola Bay west of the bay bridge was not historically mapped. East of the bridge a nearly continuous 22.5 km (14 mi) grass bed extended to Tom King Bayou (Figure 12-4). Ground truth in 1966 indicated the species as Thalassia testudinum beginning in Butcherpen Cove extending eastward one mile (van Breedveld, 1966). At some point eastward toward Tom King Bayou, Halodule probably replaced Thalassia as the existent species. From 1949 to 1966, approximately half of the seagrasses were gone. From 1966 to 1974, in two year intervals, the record showed (Figure 12-4) an accelerated lost. Between 1966 and 1968 well over half of the seagrass was lost. It seems that this loss may have been primarily Halodule and that the Thalassia was reduced only slightly. However, over the next two intervals, Thalassia continued to diminish until 1974 when none was found. Salinity studies during 1974 indicated a range of 4.0 to 20 ppt at a nearby station. Thalassia cannot tolerate this low salinity range over an extended period (Phillips, 1960).

Two records of the northeast area of East Bay are shown in Figure 12-5. This figure shows a decline in lateral extension; however, the width of the central area of the bed seems to have remained fairly constant.

Blackwater Bay

Blackwater Bay has lower salinities than the other bays. Consequently, the grass beds were composed of Vallisneria americana for the most part with some Ruppia intersperced. Records show the beds to occupy virtually the same areas in 1974 as in the early 1950's.

SEAGRASS REVEGETATION

Introduction

There is no question that removal of grass beds from a bay system will adversely affect its ecology. Several workers have documented the utilization of seagrasses by vertebrates and invertebrates (Kikuchi, 1974; Stauffer, 1937; Hoese and Jones, 1963; O'Gower and Wacasey, 1967). This study (Benthic Macroinvertebrates section) discusses in detail the species, number of individuals, and biomass within Vallisneria and Halodule beds. An increase in seagrasses in Escambia Bay would increase invertebrate diversity. Stauffer (1937) studied the change in invertebrate population with the loss of Zostera marina and showed one-third of the species associated with the seagrasses were eliminated.

The loss of grass beds in Escambia Bay is documented in the above section. The objective of the present revegetation effort is to reintroduce a species to Escambia Bay not presently found there. No transplanting work was done with Vallisneria since it currently occupies substantial areas in the delta. Transplanting of Ruppia martima (Widgeon grass), only sparsely evident in

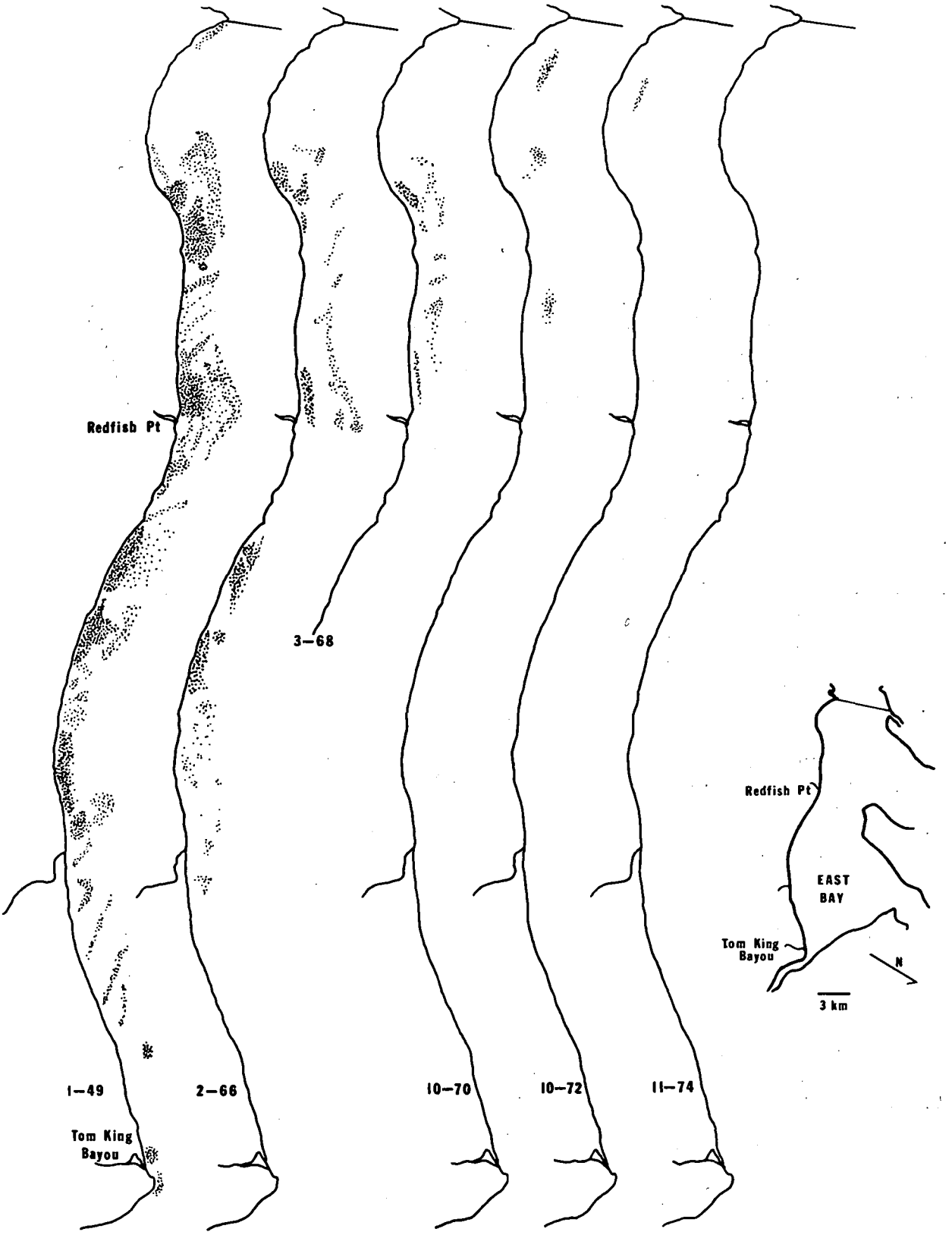


Figure 12-4. The south shore of East Bay from the Pensacola Bay bridge to Tom King Bayou, 1949-1974.

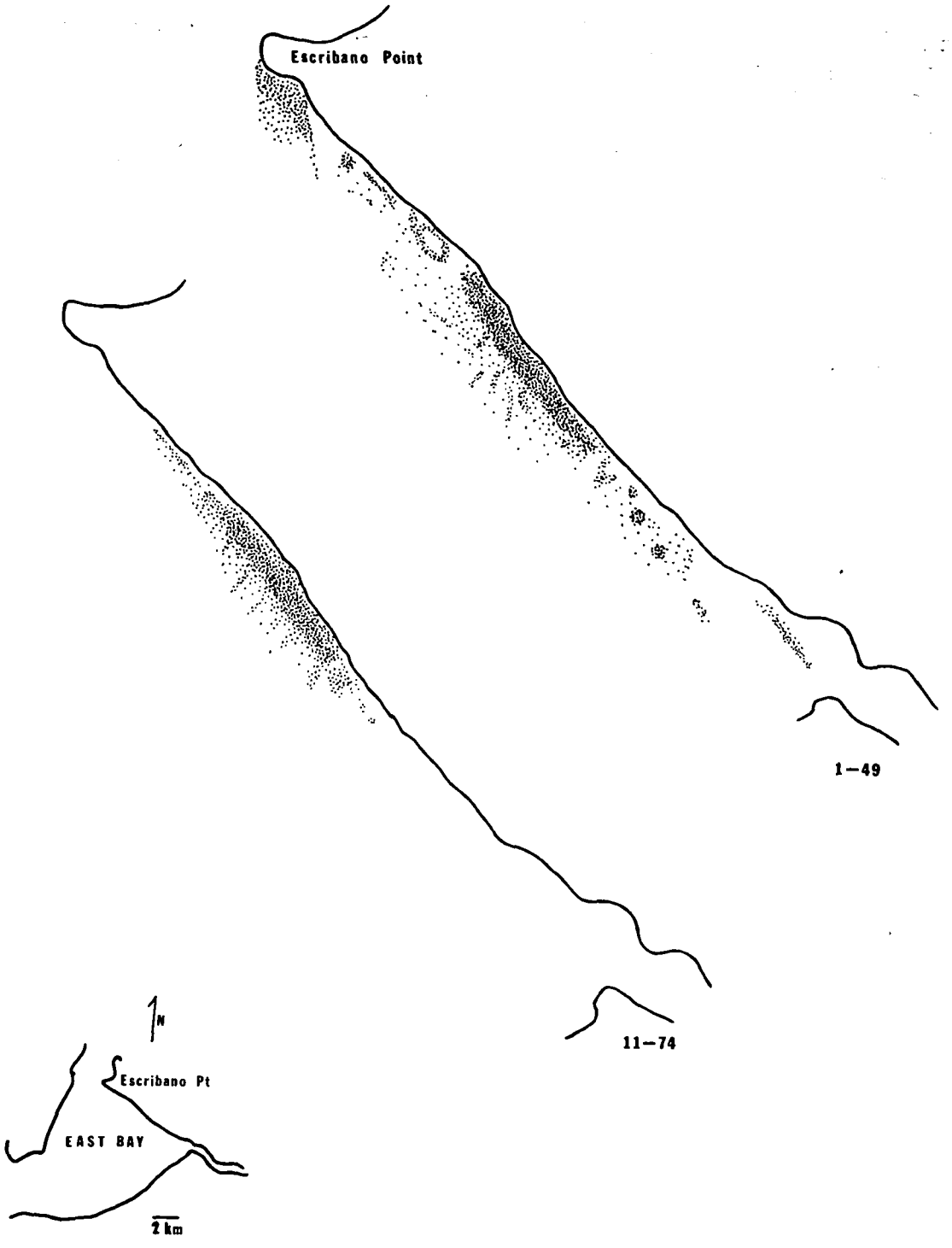


Figure 12-5. The northeast shore of East Bay from Tom King Bayou to Escribano Point, 1949-1974.

Vallisneria beds in the estuary, was not deemed feasible because of lack of plants. Thalassia testudinum exists in the more saline Santa Rosa Sound. It was not transplanted because no indications were found of prior existence in Escambia Bay. Salinity averages in Escambia Bay are believed to be too low for this species. Halodule wrightii, the most euryhaline species, is considered to have the best potential for survival in the bay's fluctuating salinity regimes. This species is hardy, being able to inhabit intertidal areas and survive short exposures to air. It occupies the largest geographical distribution of any seagrass on the northern Gulf Coast (Humm, 1956). Descriptions of grasses by long time residents around the bay indicate that vegetation south of Interstate 10 was Halodule wrightii. Figure 12-1 shows the Pensacola Bay system and the revegetation sites.

Submerged revegetation work is in experimental stages elsewhere. Viability studies of Thalassia testudinum and Halodule wrightii in the Tampa Bay area were performed by Fuss and Kelly in 1966. Twelve months in situ tank culturing indicated T. testudinum recovered after initial decline following transplantation (Fuss and Kelly, 1969). Kelly, Fuss, and Hall (1971) successfully transplanted T. testudinum into Boca Ciega Bay, Florida. Thalassia revegetation was successful on a larger scale in lower Biscayne Bay, Florida (Thorhaug, 1974). Here, seedlings were obtained from mature plants, treated with a growth stimulator, and planted. Vigorous growth of plantings was reported. Phillips (1974) reported moderate success on his transplants of Halodule into Tampa Bay, Florida in 1960. However, most work to date has been disappointing on Halodule (Fuss and Kelly, 1969). Eleuterius (personal communication) is engaged in submerged vegetation work along the Mississippi Coast. His information that Halodule inhabits low salinity sandy shelf areas, 0.3 to 1.2 meters deep, compares well with East Bay beds (0.5 to 1.1 m). This species inhabits the Mississippi Sound in continuous beds with interspersed sandy patches devoid of seagrass. It also never occurred there in mixed aggregations with other species of seagrass (Eleuterius, 1973).

Methods

With the help of the Bream Fishermen Association of Pensacola, transplanting was performed in July 1974 and again in September 1974. Locations of experimental plantings are shown in Figure 12-1. Two of the sites are known to have had viable beds in the past. The others were considered to have qualities conducive to seagrass survival. Transplants were placed at five depths ranging from 0.3 to 1.0 meter (1.0 to 3.0 ft) MSL at 0.15 meter (0.5 ft) intervals. Ten plugs were planted at each depth during the two plantings. A total of 100 plugs per site and 400 plugs in all were planted in Escambia Bay.

A plug with a 7.5 cm (3.0 inch) diameter and 12.5 cm (5.0 inch) depth of Halodule wrightii was obtained from the healthy bed in East Bay, and placed into snug fitting burlap bags. Light

tight containers were used to transport the plugs, which were replanted within three hours.

Results

Survival for the July transplants observed in October after 13 weeks in Escambia Bay was 51 percent. Plugs transplanted in September and observed after being planted six weeks showed 67 percent survival. Survival would have been higher had mass mortality not occurred at site 4 where transplanted plugs were covered with three inches of drifting sand. Excessive sand transport occurred along western parts of the shoreline, making it unsuitable for revegetation. Transplants were observed again in May 1975 after overwintering and data revealed 37 percent had green leaves at one site. Two of the sites were badly covered with sand, and the third site had less than 10 percent survival. However, the leaves observed were free of encumberance, indicating recent new growth. Therefore, it is assumed this is spring growth and other plugs may yet sprout as the water warms. Observations should be made later in the spring to determine fully the results of overwintering.

Discussion

Reestablishment of Halodule wrightii grass beds will be significant in the recovery of Escambia Bay. The beds would act as a near-shore sediment stabilizer and tend to retain nutrients for beneficial utilization by animals. By providing additional food source and a unique habitat for certain groups of invertebrates and small fishes, grass beds broaden the lower segments of the food web, thereby ultimately enhancing the commercial and recreational fisheries. This study's Benthic Macroinvertebrate section discusses and exemplifies this point.

The technique of plugging allows the plants within a plug to be in a desirable sediment for a long period of time after transplanting to a new location. Thus, plants within a plug could conceivably prosper for two years or longer in a location that has toxic sediments or other undesirable qualities. Therefore, with plugging, it will take years before a successful transplant is fully documented.

This transplanting effort was repeated in June 1975. This earlier-in-the-year planting took advantage of the spurt of spring growth that was observed in the field during 1974 and should increase the percentage of successful transplants.

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14 - APPENDICES

Appendix 1-1. Steering Committee

The Steering committee of the Escambia Bay Recovery Study consisted of representatives of the Following organizations outside of USEPA, Region IV:

Florida Department of Natural Resources
Florida Department of Environmental Regulation
Florida Game and Freshwater Fish Commission
Florida State University Marine Laboratory
Monsanto Chemical Company
Northwest Florida Regional Planning Council
Southeastern Fisheries Association, Inc.
University of West Florida
USEPA, Gulf Breeze Environmental Research Laboratory

Appendix 1-2. Recommendations of 1972 Enforcement Conference (USEPA, 1972e).

To reduce or eliminate the accelerated eutrophication of Escambia Bay and Mulat-Mulatto Bayou, and to provide water quality suitable for a wide diversity of desirable uses, the conferees make the following recommendations without prejudice to the rights of the State of Alabama and Florida to enact more stringent requirements. These recommendations would be accomplished by not later than December 31, 1972, except as otherwise specified.

1. There shall be reductions of 90 percent 5-day BOD, 94 percent nitrogenous wastes, and 90 percent phosphorus wastes discharged to Escambia River and Bay from major sources in Florida, including American Cyanamid Company, Monsanto Company, and Air Products, Inc. Due to the distance from Escambia Bay of Container Corporation of America's plant site, a reduction of 90 percent 5-day BOD waste will be required. These percent reductions permit the following allowable daily waste effluents.

Container Corporation: 5-day BOD 4,850 pounds, total nitrogen not applicable, total phosphorus not applicable.

Monsanto: 5-day BOD 605 pounds, total nitrogen 248 pounds, total phosphorus 46 pounds.

American Cyanamid: 5-day BOD 425 pounds, total nitrogen 323 pounds, total phosphorus not applicable.

Air Products: 5-day BOD 17 pounds, total nitrogen 477 pounds, total phosphorus 35 pounds.

The foregoing allowable waste loads shall be obtained by December 31, 1972. If further investigation shows that these limits are excessive, Monsanto, American Cyanamid, and Air Products must develop a plan to completely remove their discharges from the bay.

There shall be maximum feasible reduction of carbonaceous organic material. All waste dischargers shall monitor effluents to ensure reductions, conduct feasibility studies, and submit a plan of abatement for carbonaceous waste to the conferees by February 15, 1972.

Container Corporation shall provide further secondary treatment of bleach plant and woodyard wastes.

The American Cyanamid Company shall immediately cease discharging acrylonitrile.

2. The Environmental Protection Agency and the State of Florida technical staffs shall schedule a series of in-plant

investigations into treatment techniques and process control of the Monsanto, American Cyanamid, and Air Products plants to determine the effectiveness of present attempts to meet conference requirements. A report of such investigations shall be made to the conference as soon as possible, but not later than May 1, 1972. These investigations are not in lieu of continued efforts by the company to effect the results as outlined in paragraph 1 above. In addition, any other industrial waste sources which may discharge into Escambia River and Bay or its tributaries shall be reported on, with recommendations for abatement.

The City of Pensacola shall submit to the conferees by May 1, 1972, operating data on the effects of the plant modifications made to the Northeast Sewage Treatment Plant showing its compliance with the recommendations of this conference. The City of Pensacola and the County Commissioners of Escambia shall report to the conferees by May 1, 1972, the status of the 5-year master plan developed by the Escambia-Santa Rosa Planning Council and adopted by the city and county. The status report should include estimated dates for the implementations of the 5-year plan.

3. An alternative for accomplishing these objectives is the construction of a sewer collection system or systems around the entire bay to intercept wastes from American Cyanamid, Escambia Chemical, Monsanto and Northeast Sewage Treatment Plant as well as future and minor present effluents. This is consistent with the concept of metropolitan planning for waste management. All domestic and industrial wastes could be treated at a central facility with discharge away from Escambia Bay after the recommended carbon, nitrogen, and phosphorus reductions have been accomplished.

4. The Environmental Protection Agency's Gulf Breeze Laboratory shall monitor the effluent and adjacent areas of the Monsanto plant to determine the presence of any polychlorinated biphenyls and provide monthly reports to the conferees.

5. The conferees recognize the critical situation concerning the life cycle of Menhaden and are forwarding copies of the report of the Menhaden Conference to NOAA and the Southeast Fisheries association urging a plan for protection of the valuable commercial species.

Because of the additive problems attendant to dead fish decomposing and recycling nutrients into the bay, as well as presenting a health hazard, the conferees recommend that the Governor of the State of Florida take actions as he deems necessary for the immediate removal of such fish in the future until such time as corrective measures are completed.

6. Color in the Escambia River at the Alabama-Florida State line as measured at the Highway 4 bridge near Century, Florida,

shall be reduced to levels meeting Alabama, Florida, and Federal standards. The conferees require that the Container Corporation of America shall present a progress report by April 1, 1972, with its recommendations for color removal.

7. It is recognized the Department of Transportation of the State of Florida has retained a consultant group to evaluate and make recommendations concerning the Mulat-Mulatto Bayou and the I-10 Canal System. The Department of Transportation shall provide the conferees by March 1, 1972, with their evaluations, recommendations, and a plan of implementation for corrective measures as recommended by their consultant. Upon approval or modification by the conferees, this plan will be referred to the Governor of Florida for appropriate action.

8. No further construction dredging shall be permitted in Escambia Bay and Mulat-Mulatto Bayou until the artificial buildup of organic sediment deposits ceases and stabilizes. Maintenance dredging of existing channels shall be by hydraulic pipeline or by hopper dredge. Disposal of all dredged materials from hydraulic dredging shall be done in a manner and to spoil sites acceptable to the conferees.

9. The conferees recommend that the Environmental Protection Agency in cooperation with the University of West Florida and the State of Florida conduct field studies to determine the effects of thermal discharges from Monsanto and Gulf Power Companies on the biota of Escambia Bay and River and report their findings to the conferees by September 15, 1972.

10. Century, Florida, and East Brewton, Alabama, shall install by not later than December 31, 1972, secondary waste treatment facilities acceptable to their respective State water pollution control agencies. These municipalities shall report to their respective State water pollution control agencies on progress being made beginning March 1, 1972, and each 90 days thereafter.

11. Because of the many questions which have been brought to the attention of the conferees regarding the overall ecology and over-enrichment of Escambia Bay, the conferees recommend that a recovery study team be organized under the overall direction of the Environmental Protection Agency. This recovery team shall include the University of Florida System, working through the University of West Florida, the Florida Department of Environmental Regulation, the Environmental Protection Agency, and any other public or private agency, institution, or industry with an essential contribution to make. Specific plans for the recovery study--including staffing, financing, and basic investigative methods--shall be submitted to the conferees by April 1, 1972. Independent plans for gathering information in the next several months that would complement the basic objectives of the recovery program are encouraged to proceed.

Appendix 5 - 1. NPDES effluent limitations for principal source discharges into Pensacola Bay and its tributaries.

Plant		BOD_5 kg/day	BOD_5 ppd	Total Suspended Solids kg/day	Total Suspended Solids ppd	Total Nitrogen kg/day	Total Nitrogen ppd	Total Phosphorus kg/day	Total Phosphorus ppd	Other kg/day	Other ppd	Dates Effective
CONECUH RIVER												
Container Corp. of America	Winter	2750	6060	4990	11,000	-	-	-	-			Until Sep.1978
	Summer	2200	4850	4900	11,000	-	-	-	-			
ESCAMBIA RIVER												
Monsanto Chemical Co.	Final	454	1000	-	-	227	500	20	45			Until Dec.1978
ESCAMBIA BAY												
Northeast STP	Interim	199	438	156	393	-	-	-	-			Until June 1975
	Final	53	116	53	116	63	139	15	32			June 1975 to June 1977
Air Products and Chem. Co.	Interim	150	330	284	625	953	2100	27	60			Until Dec.1976
	Final	91	200	284	625	227	500	16	35	Cyanide		Jan.1977 to Sep.1978
American Cyanamid Co.	Interim	3083	6796	599	1232	1314	2897	-	-	6.8	14.9	Until Nov.1975
	Final	297	650	511	1120	274	600	-	-	0.2	0.4	Dec.1975 to Dec.1978
PENSACOLA BAY												
Main Street STP	Interim	1022	2250	1022	2250	-	-	-	-	Phenols		Until Aug.1976
	Final	378	834	378	834	227	500	76	168	3.78	8.3	Aug.1975 to June 1979
NAS Pensacola												Not issued as of Apr.1974
BLACKWATER RIVER												
Milton, Florida STP												Not issued as of Apr.1974
NAS Whiting Field		119	263	119	263	-	-	-	-			Oct.1974 to Mar.1979

Appendix 5 - 2. Point source industrial discharges and plant descriptions.

Source	Type of Operation	Treatment Process	Type of Discharge	Receiving Stream
CONECUH RIVER				
Container Corporation of America		Aeration and Oxidation		Conecuh River
T. B. Miller	Lumber Preservative proc.	Evaporation Percolation Pond	Cooling water	Burder Creek
Exxon Corporation	Natural Gas Treating fac.	Drainage is only source	Cooling water	Little Escambia Cr
ESCAMBIA RIVER				
Alger-Sullivan Lumber Co.	Sawmill	Holding Pond	Log spray, lamin. wash, cooling water	Escambia River
Gulf Power	Electrical Generation	Ash Pond	Domestic, cooling, boiler blowdown.	Escambia River
Monsanto Chemical Co.	Chemical and fiber mfg.	Deep well injection	Domestic effluent, once through cooling water.	Escambia River
ESCAMBIA BAY				
Air Products and Chemical Co.	Industrial Chemicals plastics and fertilizers	Percolation and Biological treatment ponds	Process water plus surface drainage	Escambia Bay
American Cyanimid Co.	Mfg. of acrylic fibers	Neutralization ponds and Spirahoff for domestic flow	Domestic effluent, process water	Escambia Bay
BLACKWATER RIVER				
NAS Whiting Field	Aircraft Maintenance	Trickling filters	Domestic effluent, process water	
PENSACOLA BAY				
NAS PENSACOLA	Aircraft Maintenance	Neutralization, chemical and biological treatment and polishing ponds	Domestic effluent process water	

Appendix 5 - 3. Point source Industrial discharges (loadings in kg/day).

Source	BOD_5	Total Suspended Solids	Total Nitrogen	Total Phosphorus	Remark
CONECUH RIVER					
Container Corporation of America	2200	4990	-	-	(3)
T. R. Miller	-	-	-	-	
Exxon Corporation	-	-	-	-	
Subtotal	2200	4990	0	0	
ESCAMBIA RIVER					
Alger-Sullivan Lumber Co.	-	-	-	-	
Gulf Power	-	-	-	-	
Monsanto Chemical Co.	454	-	227	20	(4)
Subtotal	454	0	227	20	
ESCAMBIA BAY					
Air Products and Chemical Co.	150	284	953	27	(1)
American Cyanamid Co.	3083	599	1314	-	(1)
Subtotal	3233	883	2267	27	
BLACKWATER BAY					
NAS Whiting Field	119	119	93	40	(2)
PENSACOLA BAY					
NAS Pensacola	341	341	264	114	(2)
Total	6347	6333	2851	201	

(1) Interim NPDES permit limits.
(2) BOD_5 and TSS interim NPDES permit limits, total nitrogen and total phosphorus estimated using 23 and 10 mg/l respectively.
(3) Summer interim permit limits.
(4) Final NPDES permit limits.

Appendix 5 - 4. Point source domestic municipal treatment facilities.
(Henningson, Durham, Richardson and Hart, 1975).

Source	Design Flow tcmd (4)	Process Description	Receiving Stream	BOD5 kg/day	Total Suspended Solids kg/day	Total Nitrogen kg/day	Total Phosphorus kg/day	Remarks
ESCAMBIA _ CONECUH RIVER								
Andalusia, Alabama								
North Side Disposal Plant	2.7	Secondary	Prestwood Creek	81	81	63	27	(1)
West Side Treatment Plant	0.4	Intermediate	Coker Mill Cr. trib	12	12	9	4	(1)
South Side Disposal Plant	2.7	Secondary	Bay Branch	81	91	63	27	(1)
Brantley, Alabama STP (3)	0.8	Secondary	Conecuh River	23	23	18	8	(2)
Brewton, Alabama STP	3.8	Secondary	Murder Creek	114	114	89	38	(1)
East Brewton, Alabama STP	1.1	Secondary	Murder Creek	34	34	26	11	(2)
Evergreen, Alabama								
Plant No. 1	3.8	None	Murder Creek	114	684	89	38	(2)
Plant No. 2	1.0	None	Murder Creek	25	255	19	8	(2)
Fort Deposit, Alabama STP	9.1	Secondary	Pigeon Creek	273	273	212	91	(1)
Greenville, Alabama STP	5.7	Secondary	Persimmon Cr.	171	171	133	57	(1)
Luverne, Alabama STP	3.8	Secondary	Patsalaqua Cr.	114	1025	89	38	(2)
Troy, Alabama								
East Side STP	5.7	Secondary	Walnut Creek	425	340	133	57	(2)
West Side STP	2.3	Secondary	Conecuh River	170	136	54	25	(2)
Century, Florida	1.0	Stabilization Pond	Escambia River	28	23	22	9	(1)
Univ. of West Florida	1.9	Extended Aeration with Polishing Pond	Escambia River	57	57	44	19	(1)
			SUBTOTAL	1722	3316	1063	458	
ESCAMBIA BAY								
City of Pensacola, Northeast	3.2	Trickling Filter	Escambia Bay	199	156	84	36	(2)
PENSACOLA BAY								
City of Pensacola, Main St.	34.1	Activated Sludge	Pensacola Bay	1022	1022	784	340	(2)
Warrington	7.6	Extended Aeration	Bayou Chico	227	227	176	76	(1)
Pen Haven	1.1	Trickling Filter	Bayou Chico	95	95	74	32	(1)
			SUBTOTAL	1344	1344	1033	448	
SANTA ROSA SOUND								
Gulf Breeze, Florida	3.4	Extended Aeration	Santa Rosa Sound	102	102	79	34	(2)
Pensacola Beach, Florida	1.5	Trickling Filter	Santa Rosa Sound	121	182	71	30	(2)
			SUBTOTAL	223	284	150	64	
BLACKWATER RIVER								
Milton, Florida	6.4	Trickling Filter	Blackwater Bay	193	193	150	64	(1)
YELLOW RIVER								
Crestview, Florida	5.7	Secondary	Trammel Creek	170	170	132	57	(1)
			TOTAL kg/day	3851	5463	2623	1127	
			(ppd)	8491	12045	5783	2485	

(1) Estimated assuming 30,30,23,and 10 mg/l in the effluent for BOD5,TSS, Total Nitrogen and Total Phosphorus.
(2) BOD5 and TSS from interim permit limits; Total Nitrogen and Total Phosphorus estimated assuming 23 and 10 mg/l in the effluent.
(3) Proposed plant to be completed June 1975.
(4) thousand cu. meters per day

Appendix 6 - 1. Summary of salinity (ppt) data for the Pensacola Bay system during January through September, 1974.

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	8.1	1.8	14.8	48.9
ADGV	C	12	11.8	2.2	22.7	53.5
ADGV	E	12	18.8	3.3	29.4	39.0
AGJI	A	12	13.1	3.8	18.7	38.4
AGJI	B	12	13.3	4.8	19.5	37.7
AGJI	C	12	14.3	4.9	25.3	40.3
AGJI	D	12	16.2	5.4	26.3	37.3
AGJI	E	12	22.8	7.0	30.3	28.3
AGPH	A	12	13.3	5.1	18.1	33.1
AGPH	C	12	13.9	5.0	24.8	39.2
AGPH	E	12	20.2	5.5	28.9	29.9
AJFD	A	12	12.5	3.6	19.5	43.8
AJFD	C	12	15.5	3.6	26.0	46.2
AJFD	E	12	23.5	6.2	28.8	25.7
ALEX	A	12	13.8	4.0	20.0	35.8
ALEX	C	12	18.7	6.8	27.9	36.0
ALEX	E	12	27.5	24.1	29.9	7.5
BFEI	A	5	0.9	0.1	1.6	60.3
BFEI	C	5	1.7	0.2	3.5	68.1
BFEI	E	5	10.4	0.2	17.3	64.3
BJIV	A	12	1.9	0.0	4.5	80.3
BJIV	C	12	2.8	0.0	9.2	96.6
BJIV	E	12	8.3	0.0	16.8	75.0
BNGA	A	12	3.0	0.0	6.5	69.1
BNGA	C	12	7.0	0.0	19.3	90.9
BNGA	E	12	14.2	0.2	22.0	44.6
BREA	A	12	5.9	0.2	18.2	80.2
BREA	C	12	12.2	0.7	23.3	57.7
BREA	E	12	17.7	2.8	27.2	38.9
ECGM	A	12	0.3	0.0	1.9	192.4
ECGM	C	12	2.9	0.0	15.8	194.8
ECGM	E	12	4.6	0.0	16.0	126.5
EEDR	A	12	0.2	0.0	0.9	195.9
EEDR	C	12	1.3	0.0	13.6	300.4
EEDR	E	12	2.8	0.0	17.3	230.9
EEEM	A	12	0.3	0.0	1.7	175.4
EEEM	C	12	1.4	0.0	14.6	293.9
EEEM	E	12	2.3	0.0	14.9	231.1
EEIX	A	12	1.7	0.0	7.8	153.6
EEIX	C	8	2.4	0.0	12.4	174.0
EEIX	E	12	3.2	0.0	12.4	134.2
EEKV	A	12	3.8	0.0	12.3	110.5
EEKV	C	11	5.2	0.0	13.9	106.3
EEKV	E	12	9.4	0.0	18.8	83.0
EGLY	A	12	4.2	0.2	12.4	101.3
EGLY	B	12	5.4	0.2	13.3	90.5
EGLY	C	12	7.0	0.3	16.8	89.0
EGLY	D	12	11.4	0.3	22.2	71.3
EGLY	E	12	14.2	0.3	25.3	53.7
EHGD	A	12	0.3	0.0	2.0	202.8
EHGD	C	12	5.6	0.0	18.1	125.1
EHGD	E	12	11.1	0.0	22.3	89.9
EHPK	A	12	5.8	0.3	13.6	73.3
EHPK	C	11	6.4	0.3	13.7	73.4
EHPK	E	12	8.2	0.2	18.0	67.8
EIIL	A	12	3.3	0.0	11.1	113.7
EIIL	C	12	4.2	0.0	15.4	115.8
EIIL	E	12	7.8	0.1	20.9	91.3
EIKC	A	12	2.7	0.0	8.8	112.3
EIKC	C	12	4.5	0.0	13.2	101.7
EIKC	E	12	11.8	0.0	20.0	66.9
EKLQ	A	12	3.8	0.1	12.0	102.7
EKLQ	C	12	4.9	0.2	12.9	91.5
EKLQ	E	12	9.0	0.3	18.9	65.1
EKMP	A	12	4.7	0.2	13.6	97.1
EKMP	B	12	6.4	0.2	14.9	79.4
EKMP	C	12	15.1	0.2	24.9	53.3
EKMP	D	12	18.3	0.2	25.6	46.9
EKMP	E	12	18.2	0.3	25.9	45.0
EMQC	A	12	8.4	0.3	15.2	62.9
EMQC	C	12	12.4	0.3	21.3	52.8
EMQC	E	12	17.4	0.3	25.1	46.2
ENNB	A	12	6.2	0.3	14.2	84.2
ENNB	B	12	7.2	0.2	16.0	77.1
ENNB	C	12	15.7	0.2	23.7	56.1
ENNB	D	12	19.3	0.2	26.9	45.0
ENNB	E	12	19.8	0.2	27.5	44.7
EPLP	A	12	7.4	0.2	16.2	72.3
EPLP	C	12	8.9	0.3	17.5	66.5
EPLP	E	12	15.5	0.3	25.5	60.7
EPRF	A	12	9.6	1.8	17.5	55.4
EPRF	C	12	15.0	4.2	23.9	45.6
EPRF	E	12	18.0	5.8	27.6	44.4
ERPB	A	12	9.0	1.0	17.6	65.3
ERPB	B	12	9.8	1.9	18.4	57.0
ERPB	C	12	15.1	4.9	27.3	52.1
ERPB	D	12	21.0	6.3	28.9	36.6
ERPB	E	12	24.6	10.9	29.5	21.5
ER10	A	12	0.0	0.0	0.0	0.0
ER10	C	12	0.0	0.0	0.0	0.0
ER10	E	12	0.0	0.0	0.0	0.0
ETLQ	A	12	9.9	1.4	18.8	64.2
ETLQ	C	12	14.8	1.4	26.4	49.6
ETLQ	E	12	28.1	24.2	31.0	9.3
ETQE	A	12	11.3	2.5	19.3	47.2
ETQE	C	12	12.6	5.2	23.6	45.2
ETQE	E	12	16.8	6.8	27.1	38.9
PEUE	A	9	11.2	6.0	17.5	36.0
PEUE	C	9	13.3	5.9	21.1	32.6
PEUE	E	9	16.0	6.5	24.0	34.7
P01	A	12	24.4	9.5	35.5	36.7
P01	E	12	32.6	29.4	36.0	6.0
P02	A	12	16.8	5.6	26.2	40.5
P02	E	12	32.4	30.4	34.8	4.1
P03	A	12	19.5	6.1	26.4	31.0
P03	E	12	28.3	11.5	33.8	21.7
P04	A	12	19.7	8.1	26.4	27.1
P04	E	12	27.4	15.3	33.0	18.4
P05	A	12	16.7	4.4	25.1	37.3
P05	B	12	23.0	10.7	33.4	31.7
P05	C	12	29.1	18.6	34.5	16.6
P05	D	12	32.0	29.6	35.0	4.6
P05	E	12	32.5	30.7	34.8	3.7
P06	A	12	15.9	4.5	28.0	48.2
P06	E	12	30.7	26.0	34.8	8.5
P07	A	12	15.1	4.3	27.6	46.8
P07	E	12	29.9	25.0	34.5	8.8
P08	A	12	15.5	4.4	25.9	43.2
P08	E	12	32.1	29.9	35.0	4.7
P09	A	12	16.0	6.3	24.5	37.5
P09	E	12	24.7	16.5	33.2	23.6
P10	A	12	14.4	4.4	24.7	45.8
P10	E	12	31.7	29.0	34.5	4.9
P11	A	12	12.5	4.2	22.6	51.8
P11	E	12	30.3	26.3	34.3	6.9
P12	A	12	11.2	1.2	19.7	57.4
P12	E	12	28.2	21.6	33.5	11.3
P13	A	12	13.2	1.9	21.4	49.1
P13	B	12	14.0	3.7	25.2	48.7
P13	C	12	19.5	4.3	32.2	42.7
P13	D	12	26.9	15.4	33.5	19.8
P13	E	12	30.2	28.2	34.0	5.9
P14	A	12	15.3	4.7	23.9	39.4
P14	E	12	29.1	26.1	33.0	7.3
P15	A	12	13.0	2.8	20.0	46.3
P15	E	12	28.3	20.6	32.3	10.9

Appendix 6 - 2. Variables used in calculating the flushing times of Escambia Bay during 1973

Variable	Units	Study I	Study II	Study III	Study IV
Estimated total effective river discharge	m^3/sec	1398	600	173	122
Tidal Range U. S. Highway 90 bridge	m	0.1	0.6	0.2	0.6
Mean Tide Level from MSL	m	0.0	0.3	-0.1	0.0
Volume of bay	mill. m^3	247	275	233	235
S_u	ppt	0.0	0.0	8.5	18.0
S_1	ppt	2.0	1.5	26.0	25.5
Qu - outflow	m^3 /sec	1398	600	257	415
Q_1 - inflow	m^3 /sec	0.0	0.0	84.0	293
Flushing Time - T	days	2.04	5.3	10.5	6.6
Volume Displacement Time	days	2.04	5.3	15.6	22.3

Appendix 6 - 2. (cont.) Variables used in calculating the flushing times of Pensacola Bay during 1973.

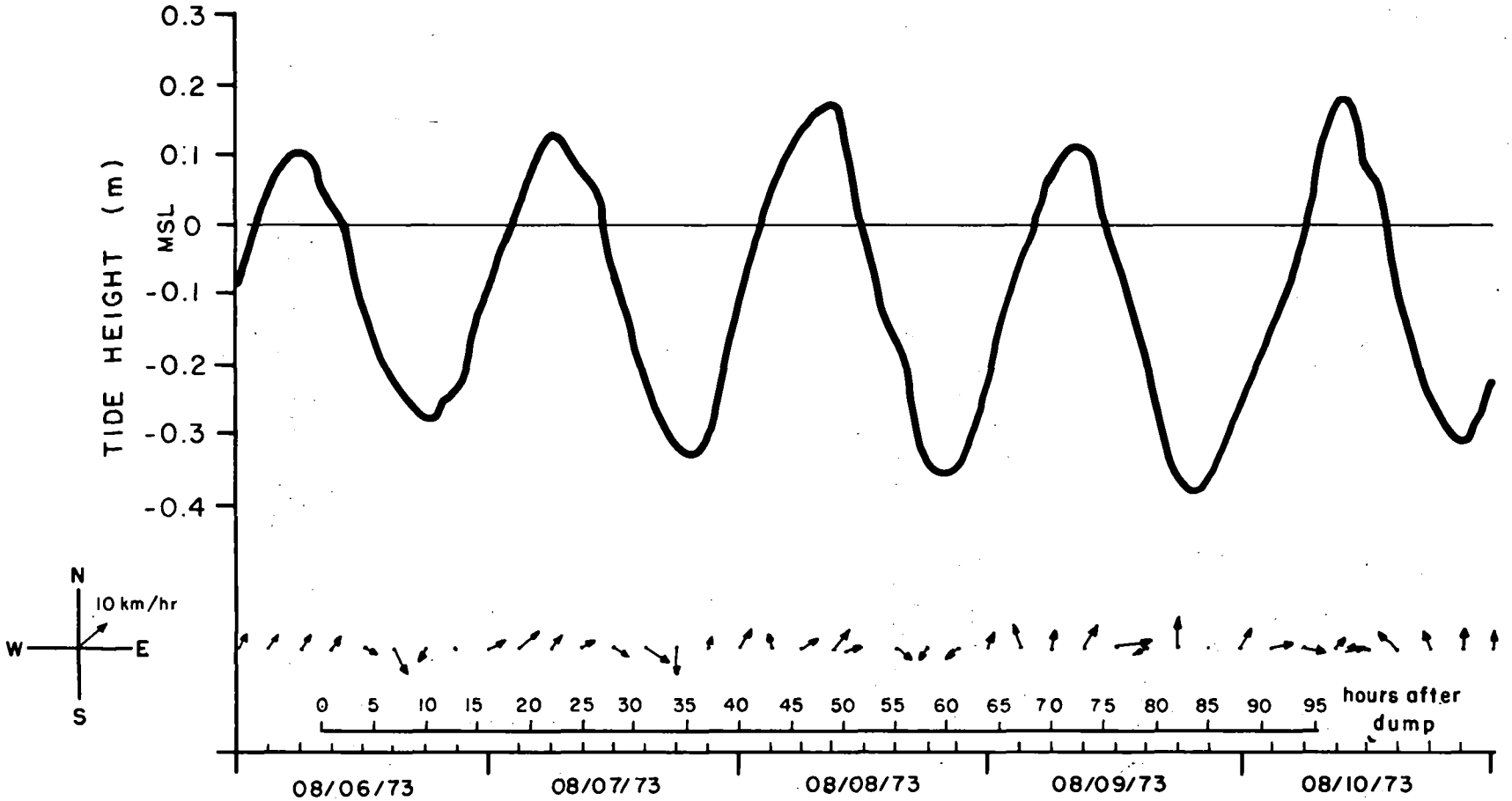
Variable	Units	Study I	Study II	Study III	Study IV
Estimated total effective river discharge	m^3 /sec	1697	757	286	208
Tidal Range U. S. Highway 90 bridge	m	0.1	0.6	0.2	0.6
Mean Tide Level from MSL	m	0.0	0.3	-0.1	0.0
Volume of bay	mill. m^3	838	880	817	822
S_u	ppt	4.5	11.5	18.5	26.5
S_1	ppt	32	31	31.5	30
Qu - outflow	m^3 /sec	1969	1203	693	1782
Q_1 - inflow	m^3 /sec	272	446	407	1574
Flushing Time - T	days	4.9	8.5	13.6	5.3
Volume Displacement Time	days	5.7	13.4	33.1	45.7

Appendix 6 - 2. (cont.) Variables used in calculating the flushing times of Pensacola Bay during 1973.

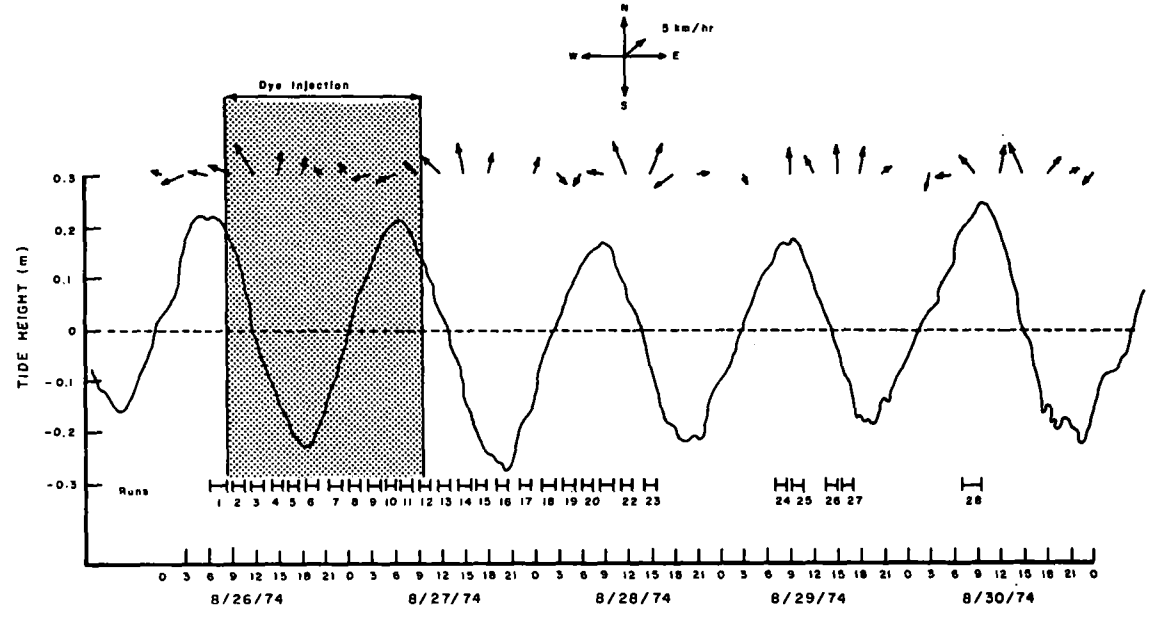
Variable	Units	Study I	Study II	Study III	Study IV
Estimated total effective river discharge	m^3 /sec	1697	757	286	208
Tidal Range U. S. Highway 90 bridge	m	0.1	0.6	0.2	0.6
Mean Tide Level from MSL	m	0.0	0.3	-0.1	0.0
Volume of bay	mill. m^3	838	880	817	822
S_u	ppt	4.5	11.5	18.5	26.5
S_l	ppt	32	31	31.5	30
Q_u - outflow	m^3 /sec	1969	1203	693	1782
Q_l - inflow	m^3 /sec	272	446	407	1574
Flushing Time - T	days	4.9	8.5	13.6	5.3
Volume Displacement Time	days	5.7	13.4	33.1	45.7

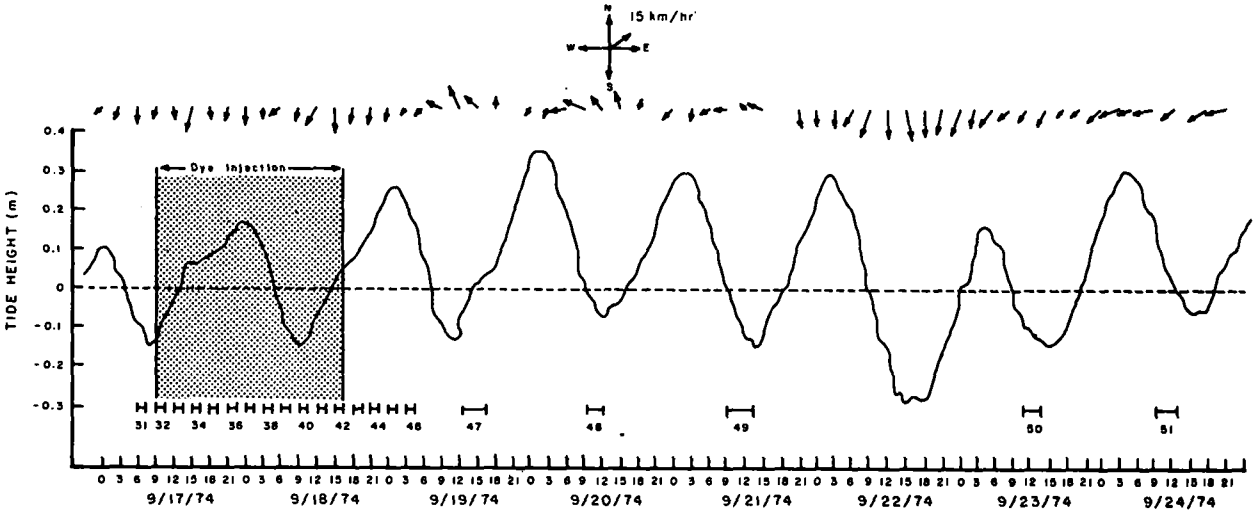
Appendix 6 - 3. Summary of temperature (deg. C.) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%	Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	23.0	11.1	29.3	25.5	EKMP	E	12	23.6	13.0	30.5	25.7
ADGV	C	12	23.1	11.4	29.5	25.7	EMQC	A	12	24.5	14.5	32.1	25.1
ADGV	E	12	23.7	13.2	29.9	24.5	EMQC	C	12	24.0	13.5	30.7	24.8
AGJI	A	12	23.3	12.0	29.8	25.6	EMQC	E	12	24.1	13.3	30.8	24.5
AGJI	B	12	23.3	12.1	29.8	25.5	ENNB	A	12	24.3	14.3	32.9	26.1
AGJI	C	12	23.3	12.0	29.8	25.4	ENNB	B	12	23.6	13.7	31.3	25.5
AGJI	D	12	23.4	12.1	29.9	25.1	ENNB	C	12	23.5	11.9	30.4	26.6
AGJI	E	12	23.7	12.9	30.1	25.4	ENNB	D	12	23.8	13.2	30.4	25.1
AGPH	A	12	23.3	12.0	29.3	26.3	ENNB	E	12	23.9	14.6	30.4	23.5
AGPH	C	12	23.5	12.2	29.5	25.3	EPLP	A	12	24.3	13.9	31.6	25.3
AGPH	E	12	23.4	12.2	29.5	25.7	EPLP	C	12	23.7	12.8	30.9	26.0
AJFD	A	12	23.4	12.3	30.0	25.3	EPLP	E	12	23.6	12.0	30.8	27.4
AJFD	C	12	23.3	12.2	30.0	25.6	EPRF	A	12	24.0	14.9	30.6	23.8
AJFD	E	12	23.4	12.3	29.9	25.4	EPRF	C	12	23.9	13.9	30.1	24.1
ALEX	A	12	23.5	12.5	30.0	25.1	EPRF	E	12	23.8	13.3	30.0	24.8
ALEX	C	12	23.3	12.8	29.7	25.4	ERPB	A	12	23.7	13.6	30.0	24.2
ALEX	E	12	23.7	16.6	29.5	22.1	ERPB	B	12	23.4	12.4	29.8	25.4
BFEI	A	5	25.8	23.4	27.1	5.5	ERPB	C	12	23.3	12.5	29.9	25.6
BFEI	C	5	26.3	23.5	28.8	7.2	ERPB	D	12	23.5	12.8	29.7	25.4
BFEI	E	5	27.8	23.5	30.2	9.1	ERPB	E	12	23.5	13.8	29.7	25.0
BJIV	A	12	22.3	11.1	29.0	25.5	ER10	A	12	21.1	10.8	28.2	26.3
BJIV	C	12	22.6	11.1	30.4	26.3	ER10	C	12	21.2	11.1	28.1	25.9
BJIV	E	12	23.4	11.4	30.2	26.6	ER10	E	12	21.1	11.1	28.0	25.9
BNGA	A	12	22.3	11.1	28.6	25.8	EITLQ	A	12	23.8	13.3	30.2	24.4
BNGA	C	12	23.1	11.3	30.0	27.1	EITLQ	C	12	23.1	11.9	30.0	26.2
BNGA	E	12	23.6	11.8	30.0	26.4	EITLQ	E	12	23.6	16.8	29.4	21.9
BREA	A	12	22.7	11.4	29.2	25.5	ETQE	A	12	23.8	14.0	30.3	24.2
BREA	C	12	23.1	12.1	29.6	25.7	ETQE	C	12	23.7	12.8	29.9	25.4
BREA	E	12	24.0	14.7	29.8	22.9	ETQE	E	12	23.7	13.0	29.9	24.9
ECGM	A	12	21.5	11.1	29.0	26.7	PEUE	A	9	26.7	16.5	30.7	18.2
ECGM	C	12	21.9	11.0	31.1	28.8	PEUE	C	9	26.0	16.5	29.4	17.1
ECGM	E	12	22.2	11.0	31.0	28.5	PEUE	E	9	25.8	16.2	29.2	17.5
EEDR	A	12	21.4	11.1	29.0	26.3	P01	A	12	22.9	13.7	28.1	21.5
EEDR	C	12	21.6	11.2	30.1	27.0	P01	E	12	22.7	16.3	28.8	19.9
EEDR	E	12	21.7	11.1	30.3	27.6	P02	A	12	23.0	13.3	28.5	23.5
EEEM	A	12	21.4	11.3	28.9	26.1	P02	E	12	22.9	16.4	29.0	20.6
EEEM	C	12	21.5	11.3	30.8	27.4	P03	A	12	23.3	14.1	29.3	23.4
EEEM	E	12	21.7	11.3	30.8	28.0	P03	E	12	22.7	15.3	29.0	22.6
EEIX	A	12	21.8	11.2	29.5	26.9	P04	A	12	23.2	13.4	29.1	24.2
EEIX	C	8	21.5	11.2	30.2	29.6	P04	E	12	22.9	13.7	29.2	23.8
EEIX	E	12	22.2	11.2	30.1	28.2	P05	A	12	23.3	13.7	29.5	23.6
EEKV	A	12	22.8	12.1	30.7	27.7	P05	B	12	22.9	13.9	28.8	22.6
EEKV	C	11	22.3	12.3	30.5	27.7	P05	C	12	23.1	16.8	29.1	20.6
EEKV	E	12	23.3	11.6	30.8	27.3	P05	D	12	23.0	17.1	29.0	19.7
EGLY	A	12	23.3	12.7	30.6	26.2	P05	E	12	22.8	16.8	28.9	20.4
EGLY	B	12	23.2	12.4	30.7	26.1	P06	A	12	23.2	13.1	29.4	24.2
EGLY	C	12	23.2	12.2	30.8	26.7	P06	E	12	23.0	16.7	29.2	20.1
EGLY	D	12	23.6	11.7	31.1	27.2	P07	A	12	23.4	13.6	29.7	23.6
EGLY	E	12	23.9	12.0	30.9	26.0	P07	E	12	23.1	16.5	29.3	20.9
EHGD	A	12	22.1	11.4	29.3	27.4	P08	A	12	23.3	13.8	29.2	23.8
EHGD	C	12	22.3	11.4	30.3	28.0	P08	E	12	22.9	16.9	28.9	20.4
EHGD	E	12	22.8	11.8	30.2	27.2	P09	A	12	23.1	13.9	29.2	24.1
EHPK	A	12	24.3	13.5	31.2	24.9	P09	E	12	23.1	14.5	28.8	23.4
EHPK	C	11	23.7	13.3	31.1	25.1	P10	A	12	23.4	13.8	29.5	23.4
EHPK	E	12	24.4	12.2	31.0	25.1	P10	E	12	23.0	16.8	29.1	20.4
EIIL	A	12	22.9	12.4	30.9	26.5	P11	A	12	23.5	14.7	29.8	23.5
EIIL	C	12	22.7	12.5	30.2	25.9	P11	E	12	23.1	16.7	29.3	20.7
EIIL	E	12	22.8	12.2	30.5	27.0	P12	A	12	23.1	13.9	29.5	23.3
EIKC	A	12	22.7	12.7	30.5	26.9	P12	E	12	23.2	16.0	29.4	21.4
EIKC	C	12	22.6	12.3	30.4	27.3	P13	A	12	23.5	13.6	29.7	23.8
EIKC	E	12	23.1	14.0	30.5	25.6	P13	B	12	23.3	13.1	29.4	23.9
EKLQ	A	12	23.5	13.8	30.7	25.5	P13	C	12	23.2	13.2	29.7	24.0
EKLQ	C	12	23.0	13.7	30.1	24.9	P13	D	12	22.8	14.9	29.2	23.8
EKLQ	E	12	22.9	12.0	30.5	26.7	P13	E	12	23.2	16.6	29.3	20.8
EKMP	A	12	23.3	13.9	31.3	25.6	P14	A	12	23.6	14.1	30.0	23.8
EKMP	B	12	23.1	13.6	30.7	25.5	P14	E	12	23.4	16.5	29.3	21.3
EKMP	C	12	23.3	12.0	30.7	27.1	P15	A	12	23.7	13.6	29.6	22.1
EKMP	D	12	23.6	12.3	30.5	26.3	P15	E	12	23.2	16.5	29.3	22.4

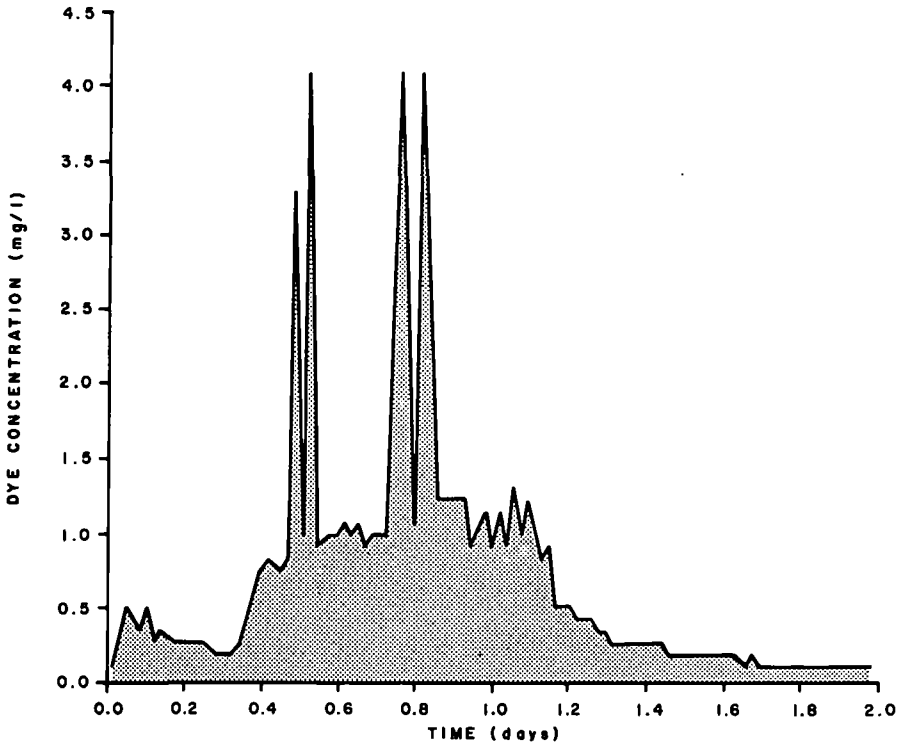


Appendix 6-4. Tide and wind conditions during the August 1973 dye study.

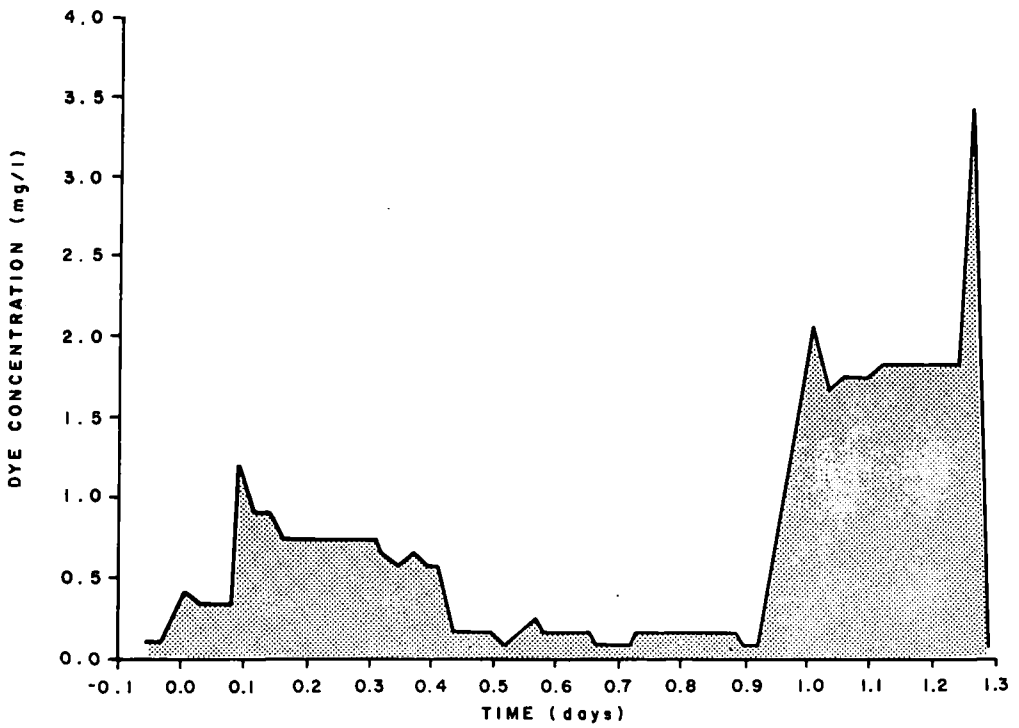




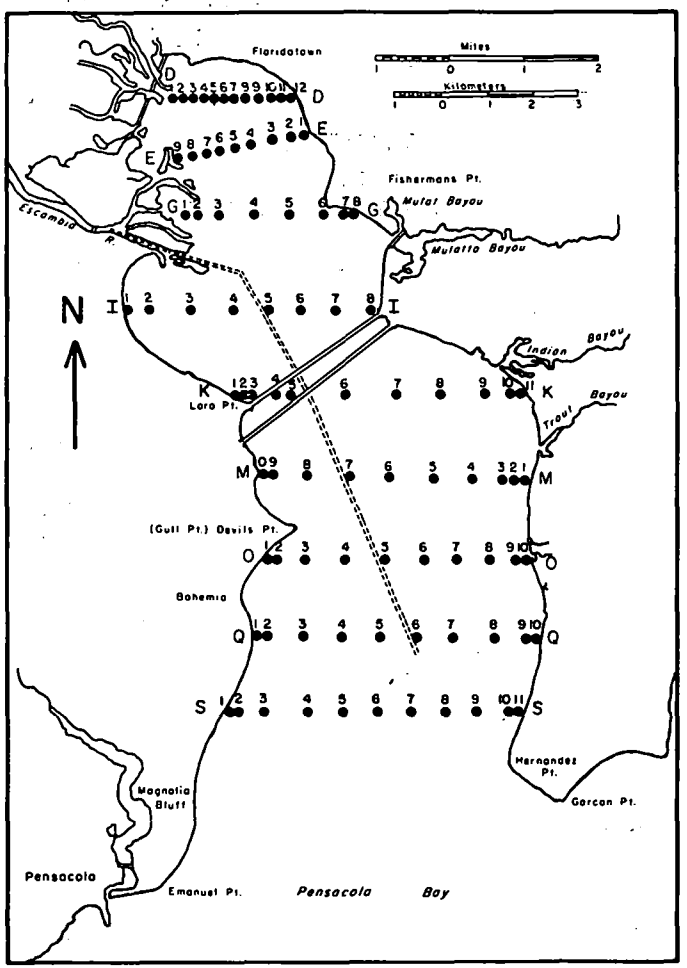
Appendix 6-5. Tide and wind conditions during the Air Products and American Cyanamid dye studies.



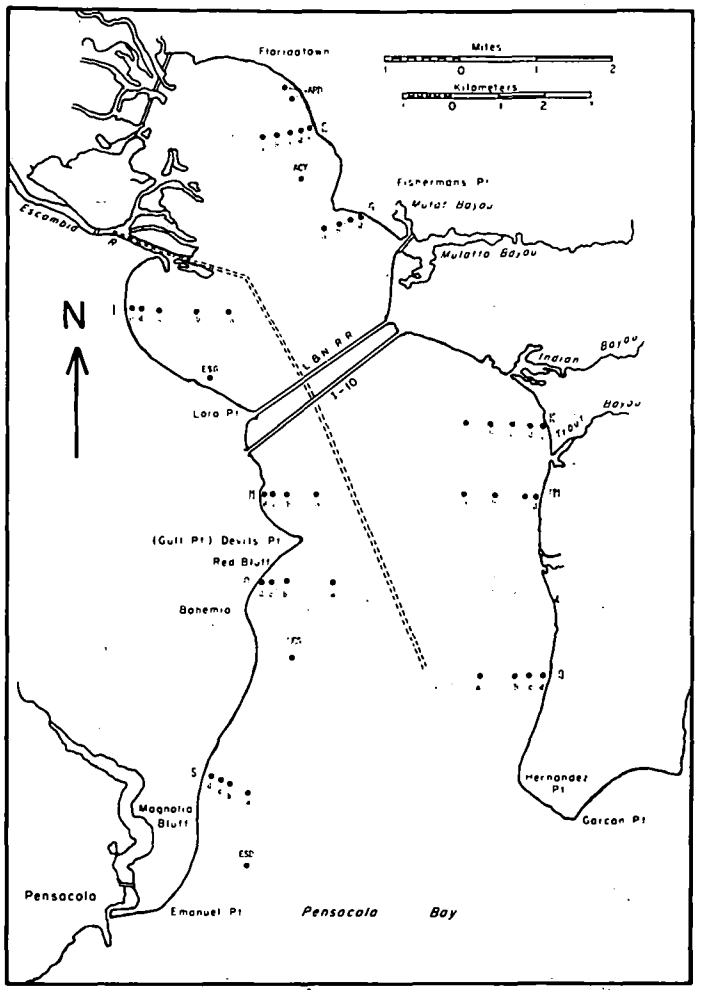
Appendix 6-6. Effluent dye concentrations during American Cyanamid dye study.



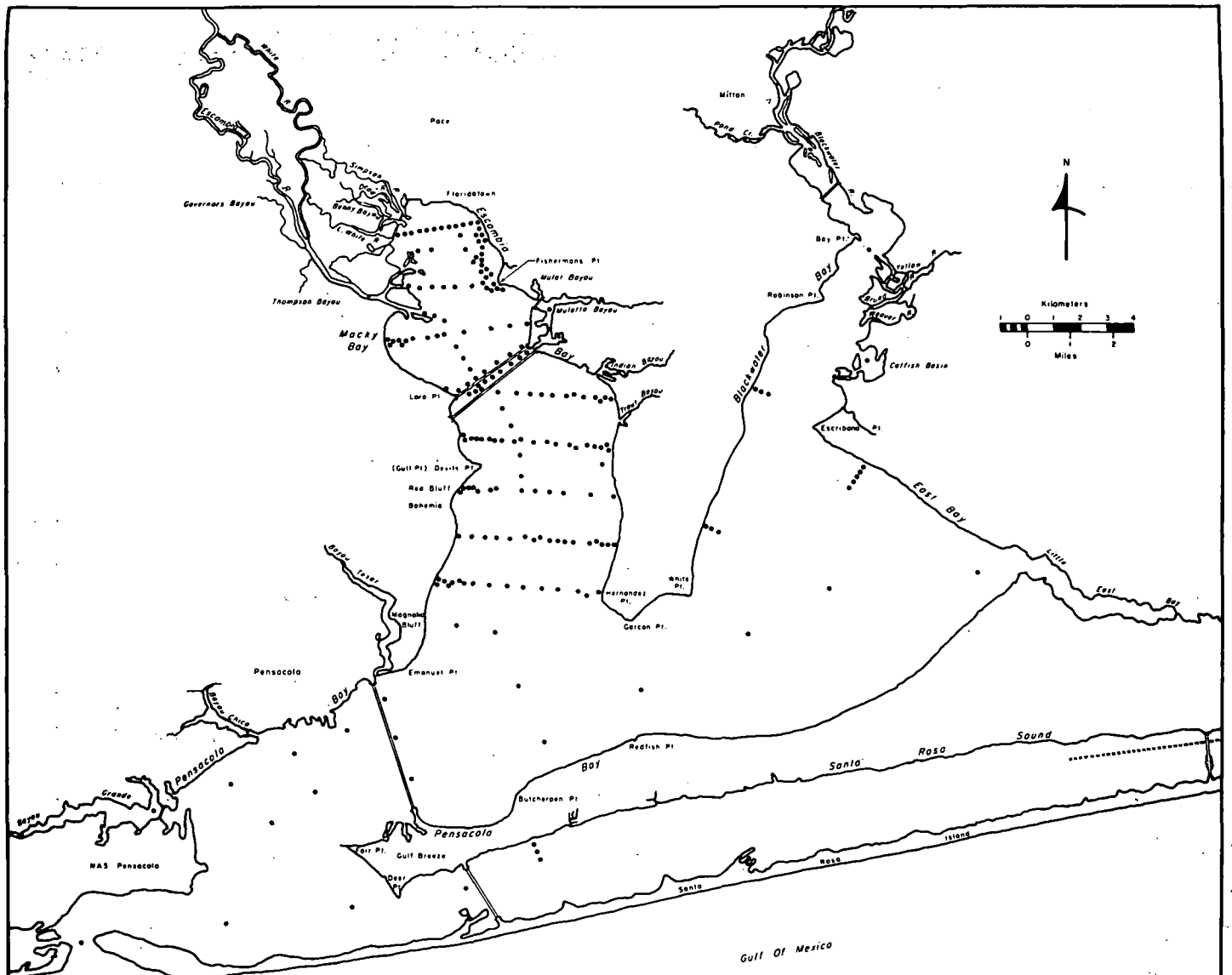
Appendix 6-7. Effluent dye concentrations during the Air Products dye study.



Appendix 7-1. Location of sediment sampling stations in the Pensacola Bay system during 1973-1974.



Appendix 7-1 (cont.) Location of sediment sampling stations in the Pensacola Bay system during 19731974.



Appendix 7-1 (cont.) Location of sediment sampling stations in the Pensacola Bay system during 1973-1974.

Appendix 7-2. Sediment sample stations and their habitat type in the Pensacola Bay system.

Sand Shelf	Transitation Zone	Mud Plain
ED	EC	EA
EE	GC	EB
GD	IC	GA
IE	ID	GB
KE	KC	IA
MC	KD	IB
MD	MB	KA
MMD	OB	KB
OD	OC	MA
QD	OB	OA
QE	OC	QA
SD	SC	QB
GC2	GB2	SA
OC2	OB2	SB
BWC	BWB	GA2
EBWC	EBWB	OA2
SRA	EBEB	BWA
SRC		SB
EBED		
EBEE		

Appendix 7 - 3. Physical and chemical data from core sampling stations in the Pensacola Bay system, Choctawhatchee Bay, and Panama City Bays.

Stations	Depth (m)	Total Phosphorus (mg/g)	Organic Nitrogen (mg/g)	Percent Organics (%)	Organic Carbon (mg/g)	Sediment Type	Percent Clay (%)	Percent Silt (%)	Percent Sand (%)	Percent Mud (%)	Mean Grain Size
E1	5.12	0.36	1.00	12.7	45.9	Sandy Silt	14.9	50.9	34.3	65.8	3.9
E2	5.82	-	-	14.5	-	Sandy Silt	18.7	47.0	38.3	61.7	4.2
E3	2.65	-	-	10.1	-	Silty Sand	7.4	29.4	63.2	36.8	3.3
E4	1.67	-	-	0.8	-	Sand	1.2	1.5	97.3	2.7	1.9
E5	0.67	-	-	0.8	-	Sand	1.2	1.8	97.0	3.0	2.1
E6	0.68	-	-	0.7	-	Sand	1.3	3.6	95.1	4.9	2.5
E7	2.16	-	-	5.0	-	Sand	8.5	15.3	76.8	23.2	3.3
E8	2.44	-	-	6.2	-	Silty Sand	10.1	32.1	57.8	42.2	3.7
E9	2.44	-	-	3.3	-	Silty Sand	10.3	26.4	63.3	36.7	3.5
E10	2.41	-	-	3.3	-	Silty Sand	9.0	30.4	60.6	39.4	3.5
E11	2.22	-	-	4.0	-	Silty Sand	8.5	23.7	67.8	32.2	3.3
E12	0.70	-	-	0.3	-	Sand	0.6	0.8	98.6	1.4	1.7
E1	1.74	-	-	5.6	-	Silty Sand	11.6	31.6	56.9	43.2	3.6
E2	2.01	0.21	1.31	6.5	24.5	Silty Sand	16.5	34.2	49.3	50.7	3.8
E6	2.32	0.14	0.52	6.0	19.0	Silty Sand	11.6	23.3	65.2	34.8	3.4
E7	1.65	0.04	0.24	1.6	6.7	Sand	3.7	8.7	87.5	12.5	2.5
E8	1.46	0.01	0.37	2.2	9.3	Sand	4.0	7.8	88.2	11.8	2.7
G1	0.85	-	-	1.3	-	Sand	2.5	6.3	91.1	8.9	2.4
G2	1.52	-	-	6.3	-	Sand	7.4	17.1	75.5	24.5	3.0
G3	1.34	-	-	0.8	-	Sand	1.0	3.0	96.1	4.0	1.9
G4	2.65	0.28	1.56	9.9	38.3	Silty Sand	15.9	30.9	53.2	46.8	3.8
G5	2.96	0.27	1.51	9.0	26.4	Silty Sand	15.8	29.3	54.9	45.1	3.7
G6	1.25	-	-	0.8	-	Sand	1.4	1.9	96.7	3.3	2.3
G7	1.22	-	-	1.2	-	Sand	2.0	4.4	93.6	6.4	2.5
G8	0.76	-	-	1.2	-	Sand	4.6	8.2	87.2	12.8	2.9
I1	0.76	-	-	0.7	-	Sand	1.5	3.7	94.8	5.2	1.9
I2	1.95	0.30	1.42	8.3	31.7	Silty Sand	15.3	42.1	42.7	57.4	-
I3	2.22	0.10	0.63	10.2	24.6	Sand-Silt-Clay	24.6	30.3	45.1	55.0	4.1
I4	-	-	-	12.7	-	Sandy Silt	18.0	41.3	40.8	59.2	4.1
I5	3.63	0.16	0.97	12.7	34.9	Sandy Silt	13.0	55.8	31.2	68.8	4.2
I6	2.68	0.24	1.50	11.6	29.8	Sand-Silt-Clay	21.6	35.9	42.5	57.5	4.1
I7	2.32	-	-	1.6	-	Sand	5.2	10.1	84.7	15.3	2.8
I8	1.71	-	-	0.9	-	Sand	1.5	2.8	95.8	4.3	2.3
K1	0.79	-	-	1.6	-	Sand	1.1	1.6	97.3	2.7	1.3
K2	1.25	-	-	0.5	-	Sand	0.8	1.8	97.4	2.6	1.0
K3	1.52	0.36	0.09	0.6	1.6	Sand	1.1	1.3	97.5	2.5	1.1
K4	3.02	0.12	1.39	13.2	42.1	Sandy Silt	14.8	61.2	24.0	76.0	4.3
K5	3.93	0.53	2.30	12.3	39.3	Sandy Silt	9.9	69.1	21.0	79.0	4.3
K6	2.62	0.42	1.59	10.4	33.8	Sand-Silt-Clay	27.6	43.5	28.8	71.2	4.5
K7	2.62	0.03	0.40	4.8	16.4	Silty Sand	10.9	21.4	67.7	32.4	3.4
K8	2.53	0.25	1.45	7.1	23.4	Silty Sand	16.3	29.4	45.3	45.7	3.8
K9	2.56	0.04	0.83	3.4	13.2	Silty Sand	7.4	18.3	74.4	25.7	3.0
K10	0.55	-	-	0.5	-	Sand	0.8	0.8	98.4	1.6	1.4
K11	0.33	-	-	0.6	-	Sand	1.6	1.9	96.6	3.4	1.7

Appendix 7 - 3 (cont). Physical and chemical data from core sampling stations in the Pensacola Bay system, Choctawhatchee Bay, and Panama City Bays.

Station	Depth (m)	Total Phosphorus (mg/g)	Organic Nitrogen (mg/g)	Percent Organics (%)	Organic Carbon (mg/g)	Sediment Type	Percent Clay (%)	Percent Silt (%)	Percent Sand (%)	Percent Mud (%)	Mean Grain Size
A1	0.79	0.19	0.11	0.4	2.1	Sand	0.8	0.9	98.3	1.7	1.9
A2	1.01	-	-	0.8	-	Sand	1.7	2.9	95.4	4.6	2.3
A3	2.83	-	-	3.3	-	Silty Sand	10.0	18.1	71.9	28.1	3.1
A4	2.77	0.31	2.60	17.6	30.4	Silty Sand	19.8	39.9	40.3	59.8	4.1
A5	2.77	0.25	1.39	8.1	24.9	Sandy Silt	16.9	61.4	21.7	78.3	4.4
A6	2.74	0.27	1.36	11.9	31.7	Sand-Silt-Clay	25.3	36.7	38.0	62.0	4.3
A7	2.74	6.29	1.65	13.4	33.2	Sand-Silt-Clay	20.5	41.4	38.1	61.9	4.3
A8	2.68	0.31	1.83	15.9	35.1	Silty Sand	19.1	36.6	44.4	55.7	4.0
A9	1.28	0.24	1.31	7.2	25.8	Silty Sand	12.5	30.9	56.6	43.4	3.6
A10	0.37	0.02	0.17	0.6	4.6	Sand	1.8	1.3	96.9	3.1	2.3
O1	0.61	-	-	0.1	-	Sand	1.3	1.1	97.6	2.4	2.2
O2	1.98	0.34	1.68	13.5	37.2	Sand-Silt-Clay	26.2	27.5	46.2	53.8	3.4
O3	2.71	0.29	1.51	14.9	36.8	Silty Sand	15.1	36.9	48.0	52.0	3.3
O4	2.99	0.15	1.13	13.1	28.8	Silty Sand	18.1	34.8	47.1	52.9	3.4
O5	-	-	-	14.4	-	Silty Sand	17.1	31.3	51.6	48.5	3.5
O6	3.26	0.33	1.63	14.4	35.7	Silty Sand	14.4	29.7	55.9	44.1	3.1
O7	3.08	0.19	0.69	10.7	29.9	Silty Sand	13.7	29.0	57.3	42.7	3.0
O8	-	-	-	-	-	Silty Sand	10.1	18.5	71.4	28.6	3.3
O9	1.07	-	-	0.5	-	Sand	1.6	1.9	96.5	3.5	2.4
O10	0.46	-	-	1.0	-	Sand	1.3	2.1	96.7	3.4	1.1
Q1	0.58	-	-	0.4	-	Sand	0.8	1.2	98.0	2.0	1.0
Q2	1.19	-	-	0.3	-	Sand	0.8	0.6	98.6	1.4	1.7
Q3	-	0.34	1.88	13.2	34.3	Sand-Silt-Clay	23.2	42.3	34.6	65.4	3.9
Q3A	-	-	-	-	-	-	23.2	42.2	34.6	65.4	3.9
Q4	-	0.36	1.83	11.7	36.3	Silty Sand	17.9	36.7	45.4	54.6	3.3
Q5	-	-	-	10.9	-	Sand-Silt-Clay	20.7	39.3	40.2	59.8	3.6
Q6	-	-	-	10.3	-	Silty Sand	18.6	34.3	47.1	52.9	3.6
Q7	-	0.28	1.54	9.2	27.9	Silty Sand	16.5	28.0	55.5	44.5	3.2
Q8	-	-	-	4.3	-	Silty Sand	10.8	17.2	72.0	28.0	3.0
Q9	-	-	-	0.7	-	Sand	2.2	1.4	96.4	3.6	2.3
Q10	-	-	-	1.5	-	Sand	0.6	1.1	98.3	1.7	1.7
S1	0.64	0.01	0.06	0.3	1.7	Sand	0.4	0.6	99.0	1.0	1.2
S2	0.94	-	-	0.3	-	Sand	0.3	0.3	99.4	0.6	1.7
S3	3.84	-	-	15.7	-	Clayey Silt	2.9	6.4	7.2	92.9	4.8
S4	4.45	0.35	1.81	14.2	34.7	Clayey Silt	34.5	57.2	8.3	91.7	4.8
S5	4.48	0.38	2.72	21.4	34.3	Clayey Silt	25.9	53.9	20.2	79.8	4.6
S6	4.18	0.36	2.01	13.5	35.9	Clayey Silt	28.7	16.7	9.6	90.4	4.8
S7	4.18	0.36	1.81	12.7	23.0	Clayey Silt	31.6	57.6	10.8	89.2	4.8
S8	3.90	0.24	1.37	7.7	20.9	Sand-Silt-Clay	22.4	38.4	39.2	60.9	4.1
S9	3.47	-	-	2.6	-	Sand	6.7	12.2	81.1	18.7	3.0
S10	1.07	-	-	0.4	-	Sand	0.6	0.8	98.6	1.4	2.0
S11	0.76	-	-	0.6	-	Sand	0.8	1.2	98.1	1.9	2.0
CH12	-	0.28	1.47	14.2	40.2	Clayey Silt	39.6	53.7	6.8	93.3	5.0
CH7	-	0.37	2.41	12.1	37.4	Silt	18.8	75.3	5.9	94.1	4.6
CH10	-	0.24	1.54	10.9	37.2	Clayey Silt	35.8	53.1	11.1	88.9	4.9
CH14	-	0.38	2.65	12.8	42.3	Sandy Silt	15.7	44.8	39.5	60.5	4.3
CH16	-	0.27	2.08	9.1	46.3	Sand-Silt-Clay	26.1	48.5	25.4	74.6	4.5
CH15	-	0.41	2.70	13.0	46.6	Sandy Silt	16.6	55.7	27.7	72.3	5.4

Appendix 7 - 3 (Cont). Physical and chemical data from core sampling stations in the Pensacola Bay system, Choctawhatchee Bay, and Panama City Bays.

Station	Depth (m)	Total Phosphorus (mg/g)	Organic Nitrogen (mg/g)	Percent Organics (%)	Organic Carbon (mg/g)	Sediment Type	Percent Clay (%)	Percent Silt (%)	Percent Sand (%)	Percent Mud (%)	Mean Grain Size
I10LN	-	0.40	2.62	12.7	44.3	Clayey Silt	26.1	61.6	12.4	87.7	4.7
I10	-	0.43	2.41	12.3	39.3	Clayey Silt	22.8	67.1	10.1	89.9	4.7
ERIV	-	-	-	-	-	-	0.5	1.4	98.1	1.9	1.8
ER24	-	0.02	0.06	0.1	-	Sand	0.1	0.0	99.9	0.1	0.9
IRW	-	-	-	-	-	-	0.6	1.3	98.2	1.8	1.0
ER20	-	-	-	-	-	-	0.0	0.7	99.3	0.7	1.1
ER20A	-	-	-	-	-	Not determined	0.1	0.0	99.9	0.1	1.2
MIDI	-	-	-	-	-	-	1.0	1.9	97.1	2.9	1.6
SERV	-	-	-	-	-	-	1.6	2.8	95.7	4.3	0.5
ER18	-	0.40	2.17	10.0	42.7	Silty Sand	8.6	36.8	54.7	45.3	3.6
ER19	-	-	-	-	-	Sand	0.1	0.1	99.8	0.3	2.0
BEN	-	-	-	0.7	-	(Grav) Mud Med S	7.5	4.6	87.5	12.1	1.7
EA	2.19	-	-	4.5	-	Sandy Mud	25.4	49.5	25.1	74.9	3.0
EB	2.13	-	-	4.7	-	Sandy Silt	20.7	48.0	31.3	68.3	2.6
EC	2.02	-	-	5.7	-	Sandy Mud(G, SH	28.7	56.7	14.6	85.3	2.8
ED	1.34	-	-	0.2	-	Fine Sand	1.7	1.5	96.8	3.2	2.4
EE	0.78	-	-	0.4	-	Fine Sand	0.7	0.6	98.7	1.3	2.3
ESC 1	-	-	-	0.1	-	Fine Sand(G,Q)	0.1	0.6	99.3	0.7	2.3
ESC 2	-	-	-	0.1	-	Fine Sand(G,Q)	0.1	0.4	96.8	0.5	2.4
GA	2.19	-	-	2.9	-	Sandy Mud(G,SH)	17.6	33.7	48.7	51.3	3.2
GB	1.77	-	-	1.9	-	Muddy V F Sand(	10.2	23.1	66.7	33.3	3.0
GC	1.35	-	-	0.7	-	Fine Sand(G,SH)	2.7	4.2	93.1	6.9	2.7
GD	1.08	-	-	1.6	-	Muddy F Sand(G,	8.9	15.7	75.4	24.5	2.9
IA	2.35	-	-	9.7	-	Sandy Mud	45.2	43.7	11.1	88.9	3.2
IB	1.19	-	-	8.0	-	Sandy Mud(G,SH)	41.2	41.4	15.2	82.7	3.0
IC	1.81	-	-	6.5	-	Sandy Mud	33.6	42.7	23.7	76.3	1.4
ID	1.08	-	-	1.8	-	Muddy F Sand	4.9	9.0	86.2	13.8	2.2
IE	0.91	-	-	0.6	-	Med Sand (G,SH.	1.3	1.2	97.2	2.5	1.8
KA	2.42	-	-	9.2	-	Sandy Mud	49.5	39.5	10.9	89.1	3.1
KB	2.11	-	-	6.6	-	Sandy Mud(G,SH)	35.0	40.2	24.1	75.1	2.9
KC	1.89	-	-	0.7	-	Muddy F Sand	3.8	7.1	89.1	10.9	2.3
KD	1.73	-	-	0.4	-	Fine Sand(G,SH)	2.1	3.5	94.3	5.6	2.3
KE	0.77	-	-	0.2	-	Fine Sand(G,Q)	0.3	0.3	99.3	0.6	2.2
HA	2.73	-	-	9.8	-	Mud(G,SH)	59.5	35.9	4.2	95.5	3.1
HB	2.08	-	-	6.6	-	Sandy Mud(G,SH)	32.3	36.9	30.7	69.2	2.9
HC	1.11	-	-	0.6	-	Fine Sand(G,SH)	1.8	1.1	97.1	2.8	2.4
HD	0.94	-	-	0.6	-	Fine Sand(G,SH)	1.3	0.4	98.2	1.7	2.3
HMA	2.81	-	-	9.0	-	Mud Sand Gravel	21.8	11.8	34.5	33.6	2.0
HB	2.15	-	-	3.6	-	Mud Sand Gravel	19.1	10.0	35.8	29.1	1.4
HBC	2.45	-	-	0.8	-	Fine Sand(G, SH	3.0	2.5	93.2	5.5	2.1
HMD	1.56	-	-	0.3	-	Fine Sand	0.7	0.6	98.7	1.3	2.4
OA	3.20	-	-	9.9	-	Mud	61.4	35.7	2.9	97.1	3.2
OB	2.02	-	-	5.6	-	Sandy Mud(G,SH)	20.9	45.3	30.4	66.1	3.0
OC	1.51	-	-	2.7	-	Muddy F Sand	8.1	10.9	81.0	19.0	2.5
OD	1.23	-	-	0.6	-	Fine Sand(G, SH	1.5	1.1	97.3	2.7	2.5

Appendix 7 - 3 (Cont). Physical and chemical data from core sampling stations in the Pensacola Bay system, Choctawhatchee Bay, and Panama City Bays.

Station	Depth (m)	Total Phosphorus (mg/g)	Organic Nitrogen (mg/g)	Percent Organics (%)	Organic Carbon (mg/g)	Sediment Type	Percent Clay (%)	Percent Silt (%)	Percent Sand (%)	Percent Mud (%)	Mean Grain Size
QA	3.20	-	-	4.0	-	Muddy Fine Sand	21.6	14.1	64.3	35.7	2.8
QB	2.95	-	-	3.7	-	Muddy Fine Sand	27.1	22.1	50.8	49.2	3.0
QC	2.25	-	-	0.5	-	Silty Fine Sand	2.2	15.2	82.6	17.4	2.5
QD	1.12	-	-	0.3	-	Silty Fine Sand	0.8	0.4	98.8	1.2	2.5
QE	1.25	-	-	0.2	-	Fine Sand(G,SH)	0.5	0.3	99.1	0.8	2.3
SA	4.82	-	-	11.9	-	Clay	67.5	30.0	2.5	97.5	2.5
SB	3.75	-	-	13.2	-	Clay	69.2	25.4	2.4	97.6	3.0
SC	3.31	-	-	8.7	-	Mud Med Sand(G,	22.0	12.1	45.2	34.1	1.9
SD	1.50	-	-	0.4	-	Fine Sand	0.5	0.2	99.3	0.7	2.0
SIM 1	2.44	-	-	0.5	-	Med Sand(G,Q)	1.4	1.3	97.6	2.8	1.6
SIM 2	5.18	-	-	0.3	-	Med Sand(G,Q)	0.5	0.4	98.8	0.8	1.2
TEXAR	2.44	-	-	8.5	-	Sand Mud(G, SH)	59.7	27.8	12.4	87.5	2.0
X	4.57	-	-	0.5	-	Medium Sand	3.7	2.3	94.0	6.0	1.7
GA(74	2.00	0.13	0.39	3.5	17.3	-	-	-	-	-	-
GB(74)	1.40	0.06	0.16	1.3	6.0	-	-	-	-	-	-
GC(74)	0.50	0.04	0.16	1.0	20.3	-	-	-	-	-	-
OA(74)	2.70	0.37	0.72	20.3	36.1	-	-	-	-	-	-
OB(74)	1.20	0.14	0.36	3.5	13.5	-	-	-	-	-	-
OC(74)	0.80	0.03	0.08	0.5	2.0	-	-	-	-	-	-
EWA	2.60	0.09	0.69	13.8	45.5	-	-	-	-	-	-
EWB	1.40	0.04	0.11	1.4	5.7	-	-	-	-	-	-
EWC	0.90	0.03	0.04	1.0	4.1	-	-	-	-	-	-
EBWA	2.30	0.28	0.47	5.0	21.8	-	-	-	-	-	-
EBWB	1.50	0.32	0.21	2.0	8.5	-	-	-	-	-	-
ESD	5.60	0.05	0.72	26.0	33.5	-	-	-	-	-	-
EBD	7.00	0.10	0.78	21.1	36.1	-	-	-	-	-	-
FBD	8.40	0.47	0.71	25.3	35.4	-	-	-	-	-	-
SBA	5.80	0.05	0.12	1.2	2.5	-	-	-	-	-	-
SBB	4.70	0.03	0.16	0.7	1.1	-	-	-	-	-	-
SBC	1.20	0.03	0.34	1.8	6.0	-	-	-	-	-	-
LNN-1	1.30	0.03	0.04	0.5	1.5	-	-	-	-	-	-
LNN-2	2.10	0.28	0.63	11.7	45.9	-	-	-	-	-	-
LNN-3	2.40	0.28	0.56	9.7	36.5	-	-	-	-	-	-
LNN-4	2.30	0.47	0.66	11.3	38.2	-	-	-	-	-	-
LNN-5	2.10	0.20	0.51	8.1	31.9	-	-	-	-	-	-
LNN-6	1.50	0.03	0.02	1.1	4.5	-	-	-	-	-	-
LNS-1	1.30	0.03	0.12	1.3	5.7	-	-	-	-	-	-
LNS-2	2.00	0.27	0.53	7.4	28.4	-	-	-	-	-	-
LNS-3	2.20	0.35	0.69	12.5	39.5	-	-	-	-	-	-
LNS-4	2.10	0.33	0.65	13.9	38.0	-	-	-	-	-	-
LNS-5	2.10	0.54	0.65	10.9	42.7	-	-	-	-	-	-
LNS-6	1.30	0.09	0.45	5.8	20.7	-	-	-	-	-	-

Appendix 7 - 3 (cont). Physical and chemical data from core sampling stations in the Pensacola Bay system, Choctawhatchee Bay, and Panama City Bays.

Station	Depth (m)	Total Phosphorus (mg/g)	Organic Nitrogen (mg/g)	Percent Organics (%)	Organic Carbon (mg/g)	Sediment Type	Percent Clay (%)	Percent Silt (%)	Percent Sand (%)	Percent Mud (%)	Mean Grain Size
A-1	-	0.01	0.01	0.1	0.1	-	-	-	-	-	-
A-3	-	0.01	0.01	0.1	0.1	-	-	-	-	-	-
A-5	-	0.01	0.04	0.2	0.5	-	-	-	-	-	-
A-7	2.30	0.18	0.68	6.8	19.2	-	-	-	-	-	-
A-10	2.00	0.09	0.44	2.3	10.9	-	-	-	-	-	-
A-12	2.40	0.42	0.63	19.3	39.7	-	-	-	-	-	-
A-13	1.40	0.23	0.53	9.5	36.1	-	-	-	-	-	-
A-14	2.60	0.37	0.53	16.5	33.6	-	-	-	-	-	-
A-15	2.40	0.35	0.45	13.8	33.1	-	-	-	-	-	-
E-1	-	0.08	0.39	0.8	20.0	-	-	-	-	-	-
E-5	-	0.29	0.70	17.1	44.0	-	-	-	-	-	-
E-6	-	0.27	0.60	27.7	43.9	-	-	-	-	-	-
E-7	-	0.28	0.43	10.3	28.1	-	-	-	-	-	-
E-9	-	0.03	0.22	0.3	3.9	-	-	-	-	-	-
E-11	3.70	0.32	0.45	12.7	33.0	-	-	-	-	-	-
E-11C	-	0.48	0.98	25.3	39.8	-	-	-	-	-	-
EWA	2.60	0.28	0.50	12.3	46.3	-	-	-	-	-	-
EWB	1.40	0.08	0.32	1.8	6.0	-	-	-	-	-	-
EWC	0.90	0.02	0.19	0.8	3.9	-	-	-	-	-	-
EYC	1.80	0.22	0.65	14.0	28.8	-	-	-	-	-	-
EYG	3.40	0.20	0.83	16.3	50.1	-	-	-	-	-	-
CAT	-	0.04	0.39	1.5	9.0	-	-	-	-	-	-
CB-1	2.40	0.48	1.33	19.8	81.9	-	-	-	-	-	-
CB-2	3.70	0.33	0.83	22.1	41.5	-	-	-	-	-	-
CB-2	1.00	0.80	0.68	11.6	58.8	-	-	-	-	-	-
CB-2	2.00	0.50	0.40	8.8	40.8	-	-	-	-	-	-
CB-3	2.10	0.30	2.53	22.7	97.1	-	-	-	-	-	-
CB-4	4.90	0.38	0.83	24.5	44.0	-	-	-	-	-	-
CB-5	7.80	0.34	1.58	17.3	62.4	-	-	-	-	-	-
CB-5	1.00	-	1.03	15.2	44.0	-	-	-	-	-	-
CB-5	2.00	-	0.88	13.9	70.7	-	-	-	-	-	-
CB-6	10.70	0.28	2.53	20.2	67.1	-	-	-	-	-	-
EBWA	2.30	0.08	0.43	8.0	16.4	-	-	-	-	-	-
EBWB	1.70	0.08	0.28	3.1	9.0	-	-	-	-	-	-
EBWC	0.90	0.02	0.31	3.8	2.6	-	-	-	-	-	-
ESD	5.60	0.40	0.83	18.9	36.7	-	-	-	-	-	-
GA	2.00	0.12	0.33	4.2	15.4	-	-	-	-	-	-
GB	1.40	0.06	0.32	1.8	9.8	-	-	-	-	-	-
GC	1.83	0.02	0.18	1.2	3.8	-	-	-	-	-	-
OA	3.90	0.31	0.53	23.8	36.6	-	-	-	-	-	-
OB	1.20	-	-	3.8	-	-	-	-	-	-	-
OC	0.80	0.04	0.37	9.3	7.8	-	-	-	-	-	-
PC-1	4.10	0.33	1.23	13.0	45.1	-	-	-	-	-	-
PC-2	8.20	0.48	1.10	11.9	40.9	-	-	-	-	-	-
PC-3	2.60	0.48	1.83	13.9	65.7	-	-	-	-	-	-
PC-4	4.30	0.48	1.60	16.1	58.9	-	-	-	-	-	-
PC-5	6.70	0.65	1.35	13.4	96.7	-	-	-	-	-	-
PC-6	9.10	0.38	0.50	4.8	15.7	-	-	-	-	-	-
PC-7	10.10	0.62	1.38	15.1	71.6	-	-	-	-	-	-
PC-8	8.20	0.63	1.43	25.7	155.9.	-	-	-	-	-	-
PC-9	6.20	0.18	0.60	4.9	17.2	-	-	-	-	-	-
PER	1.50	0.02	0.12	2.7	2.1	-	-	-	-	-	-
TEX	1.40	0.22	0.98	16.6	36.6	-	-	-	-	-	-
AC-1	2.30	0.16	0.48	5.8	21.8	-	-	-	-	-	-
AC-2	2.40	0.16	0.60	6.4	25.7	-	-	-	-	-	-
C-15	-	0.25	1.04	12.3	40.9	-	-	-	-	-	-
EBE-A	2.70	0.70	1.26	12.0	45.5	-	-	-	-	-	-
EBE-B	2.40	0.06	0.75	2.3	11.9	-	-	-	-	-	-
EBE-D	1.20	0.02	0.11	0.3	2.6	-	-	-	-	-	-
EBE-E	0.80	0.02	0.23	0.5	2.6	-	-	-	-	-	-
EBE-C	2.30	-	-	-	-	-	-	-	-	-	-

Appendix 7 - 3 (cont). Metal analysis results for all core samples in the Pensacola Bay system.

Station	Co µg/l	Va µg/l	Ti µg/l	Cr µg/l	Zn µg/l	Cu µg/l	Ni µg/l	Mn µg/l	Cd µg/l	Pb µg/l	Al µg/l	Fe µg/l
A-1	<2.0	<8.0	<10.0	5.5	3.0	<1.0	<8.0	50.0	<1.0	<5.0	130	865
A-3	<2.0	<8.0	<10.0	5.0	1.0	<1.0	<8.0	6.8	<1.0	<5.0	130	700
A-5	<2.0	<8.0	11.0	5.0	1.5	<1.0	<8.0	8.0	<1.0	<5.0	170	580
A-7	16.0	76.0	<80.0	39.0	43.0	8.0	9.0	120.0	<1.0	11.0	9,500	42,000
A-10	5.9	30.0	<78.0	12.0	16.0	3.9	2.0	37.0	<1.0	5.9	3,100	12,000
A-12	20.0	150.0	<78.0	63.0	71.0	15.0	16.0	380.0	1.0	37.0	18,000	53,000
A-13	11.0	72.0	<80.0	39.0	43.0	10.0	10.0	92.0	<1.0	25.0	12,000	40,000
A-14	19.0	110.0	<78.0	57.0	68.0	9.7	14.0	360.0	<1.0	28.0	18,000	48,000
A-15	20.0	110.0	<80.0	54.0	67.0	10.0	15.0	400.0	<1.0	28.0	18,000	51,000
B-1	<5.0	26.0	<80.0	7.0	13.0	2.0	3.0	20.0	<1.0	10.0	3,600	8,800
B-5	13.0	71.0	<79.0	50.0	62.0	5.9	14.0	350.0	<1.0	28.0	19,000	42,000
B-6	13.0	71.0	<79.0	52.0	61.0	7.9	15.0	410.0	<1.0	30.0	18,000	43,000
B-7	12.0	58.0	<80.0	44.0	53.0	6.0	13.0	320.0	<1.0	26.0	17,000	43,000
B-9	<5.0	<20.0	<80.0	<4.0	1.0	<1.0	<2.0	5.0	<1.0	<2.0	300	850
B-11	16.0	99.0	<80.0	47.0	62.0	8.0	12.0	330.0	1.0	27.0	15,000	40,000
B-11C	23.0	110.0	<80.0	67.0	85.0	16.0	16.0	500.0	1.0	38.0	19,000	50,000
BWA	10.0	55.0	24.0	42.0	53.0	7.0	<1.0	263.0	<1.0	29.0	15,000	37,000
BWB	<2.0	<8.0	28.0	5.0	7.0	1.5	<8.0	224.0	<1.0	5.0	2,200	8,400
BWC	<2.0	<8.0	26.0	6.5	4.0	1.0	<4.0	8.0	<1.0	<5.0	1,120	2,300
BYC	6.9	6.2	<79.0	54.0	1200.0	120.0	17.0	110.0	2.0	64.0	18,000	38,000
BYG	8.0	35.0	<80.0	58.0	52.0	8.0	14.0	170.0	2.0	28.0	18,000	42,000
CAT	<5.0	<20.0	<80.0	5.0	6.0	<1.0	<2.0	13.0	<1.0	2.0	1,500	5,100
CB-1	12.0	130.0	54.0	71.0	58.0	10.0	18.0	375.0	<1.0	30.0	21,000	60,000
CB-2	14.0	90.0	24.0	76.0	59.0	10.0	16.0	618.0	<1.0	34.0	20,000	53,000
CB-2-1	14.0	59.0	24.0	72.0	60.0	7.5	14.0	386.0	1.0	20.0	18,000	53,000
CB-2-2	13.0	57.0	26.0	80.0	56.0	8.0	1.0	672.0	1.0	27.0	15,000	48,000
CB-3	7.0	57.0	44.0	44.0	40.0	10.0	7.8	117.0	1.0	34.0	19,200	31,400
CB-4	14.0	151.0	41.0	80.0	58.0	12.0	18.0	643.0	1.0	34.0	28,000	57,000
CB-5	12.0	83.0	36.0	84.0	58.0	11.0	20.0	692.0	1.0	27.0	21,100	45,200
CB-5-1	9.0	50.0	50.0	53.0	30.0	12.0	18.0	170.0	1.0	22.0	8,800	18,800
CB-5-2	13.0	93.0	32.0	66.0	44.0	17.0	20.0	990.0	1.0	22.0	13,200	38,400
CB-6	13.0	86.0	80.0	72.0	47.0	15.0	18.0	1480.0	1.0	26.0	16,600	40,400
EBWA	5.0	<20.0	<79.0	22.0	21.0	3.0	6.8	87.0	<1.0	11.0	6,500	16,000
EBWB	<5.0	<20.0	<80.0	16.0	14.0	2.0	5.0	55.0	<1.0	8.0	3,900	12,000
EBWC	<5.0	<20.0	<80.0	4.0	1.0	<1.0	3.0	4.0	<1.0	<2.0	360	1,100
ESD	16.0	79.0	32.0	68.0	98.0	-	16.0	467.0	<1.0	43.0	19,900	46,800
GA	8.0	45.0	<80.0	26.0	29.0	6.0	8.0	91.0	<1.0	12.0	6,300	25,000
GB	<5.0	<20.0	<79.0	13.0	11.0	2.5	<2.0	29.0	<1.0	5.0	2,400	7,200
GC	<5.0	<20.0	<80.0	6.0	8.0	<1.0	<2.0	23.0	<1.0	4.0	890	2,800
OA	20.0	110.0	<80.0	68.0	71.0	13.0	19.0	390.0	<1.0	31.0	20,000	49,000
OB	7.0	35.0	<80.0	19.0	23.0	4.0	5.0	120.0	<1.0	12.0	6,600	14,000
OC	<5.0	<20.0	<79.0	4.0	6.9	1.0	<2.0	8.9	<1.0	2.0	630	1,500
PC-1	5.0	35.0	58.0	62.0	29.0	7.5	<1.0	128.0	<1.0	21.0	17,400	25,600
PC-2	5.0	38.0	70.0	57.0	28.0	6.5	12.0	125.0	<1.0	20.0	15,200	22,200
PC-3	5.0	38.0	56.0	68.0	34.0	7.8	12.0	99.0	<1.0	20.0	15,600	24,800
PC-4	5.8	42.0	66.0	75.0	40.0	9.0	14.0	110.0	<1.0	24.0	18,800	27,200
PC-5	6.2	38.0	70.0	70.0	44.0	10.0	14.0	133.0	1.0	26.0	18,800	26,200
PC-6	2.8	16.0	58.0	16.0	15.0	4.0	<8.0	65.0	<1.0	14.0	4,800	6,800
PC-7	5.9	42.0	100.0	54.0	48.0	15.0	12.0	270.0	1.0	30.0	13,300	25,000
PC-8	5.6	50.0	64.0	75.0	88.0	42.0	17.0	239.0	1.0	42.0	12,800	18,300
PC-9	<2.0	16.0	38.0	19.0	15.0	3.0	<8.0	50.0	<1.0	12.0	6,200	8,800
PER	<4.8	<19.0	<78.0	<3.9	6.8	<1.0	<3.9	23.0	<1.0	1.9	650	1,900
TEX	11.0	80.0	<80.0	55.0	150.0	16.0	13.0	82.0	1.0	58.0	21,700	40,000
AC-1	10.0	34.0	26.0	41.0	34.0	10.0	5.0	80.0	<1.0	13.0	7,000	19,800
AC-2	15.0	59.0	40.0	48.0	44.0	12.0	6.2	115.0	<1.0	14.0	9,600	29,600
C-15	32.0	84.0	36.0	70.0	78.0	26.0	12.0	215.0	1.0	30.0	15,600	45,900

Appendix 7 - 4. Pesticides concentrations in the sediments of the Pensacola Bay system during 1973 through 1974.

Pesticide	Approximate Minimum Detection Limit (µg/kg)
Aldrin	0.25
Lindane	0.10
Chlordane	2.50
Chlorobenzilate	25.00
DDD	0.50
DDE	0.50
DDT	1.00
Dieldrin	0.50
Endrin	1.00
Heptachlor Epoxide	0.50
Heptachlor	0.25
Methoxchlor	5.00
Toxaphene	15.00
Diazinon	10.00
Guthion	25.00
Methyl Parathion	1.00
Parathion	2.00
Malatnion	4.00
Ethion	4.00
Trithion	2.00
Mirex	1.00

Appendix 7 - 5. Nutrients (mg) present in the reactor water by day number in the sediment nutrient release study.

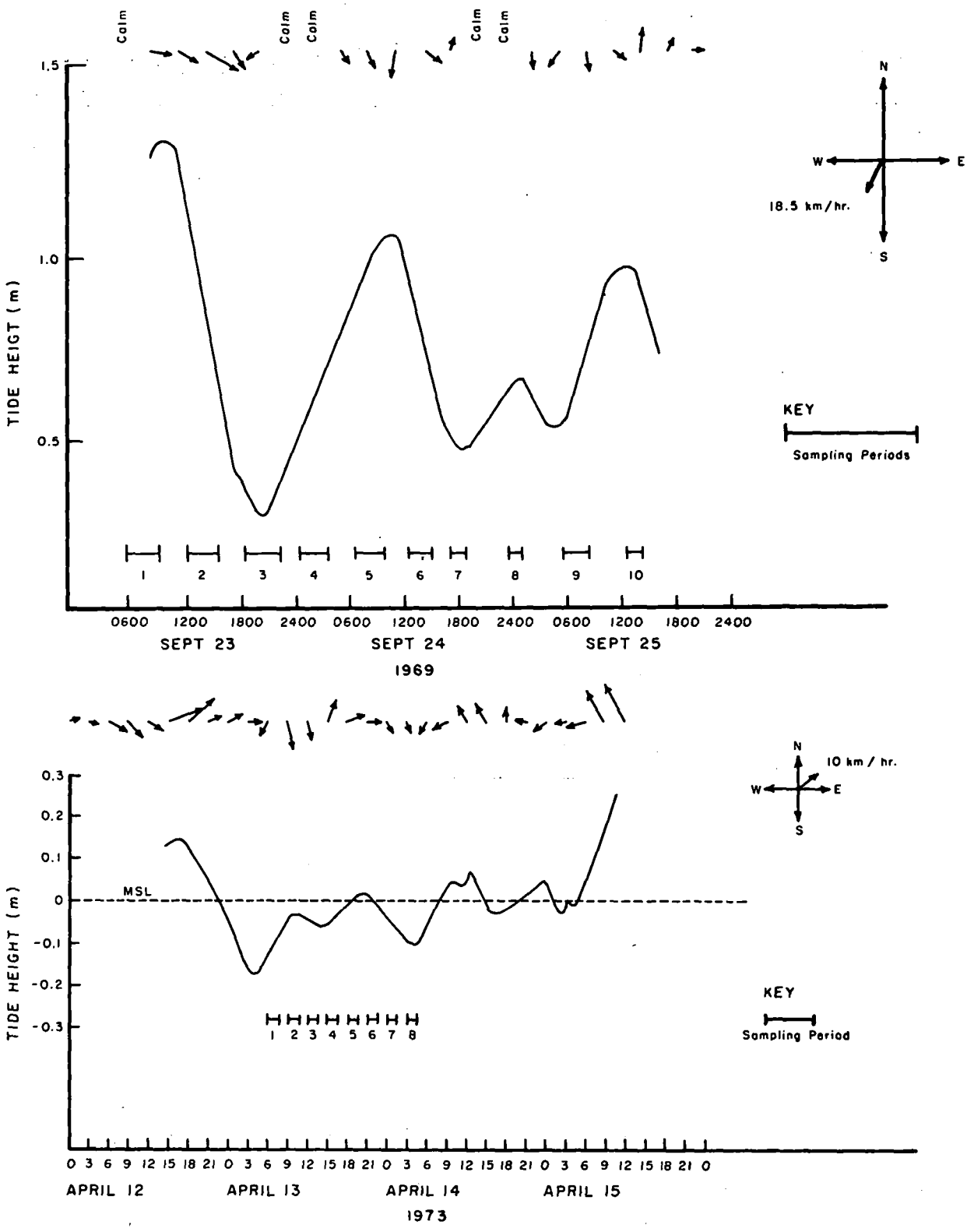
Station	Day Number	Total Phosphorus (mg)	Nitrate-Nitrite (mg)	TKN (mg)	Total Nitrogen (mg)	Dissolved Oxygen (mg/l)
EGLY	0	1.128	0.529	7.20	7.73	-
	3	0.674	0.529	12.99	13.52	7.7
	6	0.387	0.435	15.12	15.55	-
	9	0.293	0.529	22.88	23.41	8.1
	12	0.248	0.528	29.63	30.16	8.0
	16	0.247	0.468	29.08	29.56	8.6
	20	0.613	0.480	-	-	6.4
	24	0.613	0.480	166.44	166.92	9.9
	33	1.241	0.480	-	-	5.8
	41	0.490	0.360	140.18	140.55	-
	46	0.884	0.262	-	-	4.7
	54	0.344	0.262	61.95	62.21	-
	60	0.577	0.262	45.71	45.97	9.3
	65	0.704	0.262	48.73	48.99	-
	67	0.496	0.262	47.96	48.12	8.6
EEKV	0	0.230	0.230	4.14	4.37	7.5
	4	0.230	1.704	4.99	6.69	8.1
	6	0.230	1.415	2.79	4.21	7.4
	11	0.274	1.012	4.42	5.43	-
	17	0.230	0.654	-	-	8.8
	26	0.230	0.258	3.18	3.44	-
	32	0.231	0.434	3.02	3.45	-
	38	0.317	0.260	2.88	3.14	-
	40	-	-	-	-	8.2
	42	0.660	0.260	1.93	2.19	7.4
	45	0.330	0.261	1.30	1.56	7.8

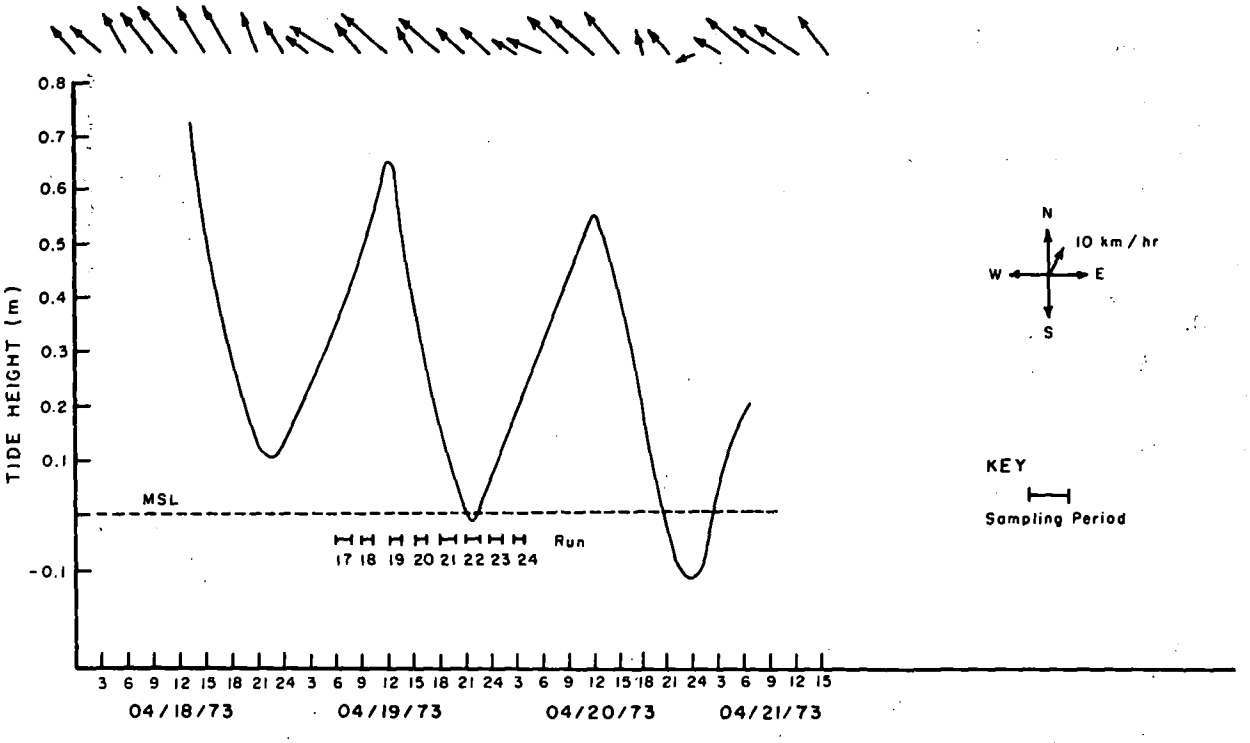
Appendix 7 - 5 (cont). Nutrients (mg) present in the reactor water by day number in the sediment nutrient release study.

Station	Day Number	Total Phosphorus (mg)	Nitrate-Nitrite (mg)	TKN (mg)	Total Nitrogen (mg)	Dissolved Oxygen (mg/l)
EIIL	0	0.338	0.312	8.58	8.89	-
	3	0.256	0.564	7.94	8.50	8.6
	6	0.256	1.657	8.96	10.62	-
	9	0.256	1.859	15.01	16.87	8.8
	12	0.256	2.034	12.25	14.28	8.6
	16	0.256	3.026	20.93	23.96	8.6
	20	0.782	4.256	24.62	28.88	7.6
	24	0.504	5.106	10.49	15.60	8.6
	33	0.866	8.122	18.21	26.33	7.2
	41	0.842	-	25.82	-	-
	46	0.732	-	22.77	-	7.1
	54	0.256	11.569	17.93	29.50	-
	60	1.082	12.368	-	-	8.7
	65	0.406	13.381	15.06	28.44	-
	67	0.362	13.375	4.39	17.76	8.7
EKMP	0	0.290	0.242	2.66	2.90	7.8
	4	0.293	0.886	6.72	7.61	7.3
	6	0.294	0.603	3.88	4.48	9.4
	11	0.294	0.508	4.28	4.79	-
	17	0.247	0.881	2.85	3.73	7.3
	26	0.247	0.788	10.01	10.80	-
	32	0.248	1.275	8.65	9.93	-
	38	0.568	1.411	7.34	8.75	-
	40	-	-	-	-	7.3
	42	0.340	-	-	-	7.7
	45	0.341	1.942	8.59	10.53	9.1

Appendix 7 - 5 (cont). Nutrients (mg) present in the reactor water by day number in the sediment nutrient release study.

Station	Day Number	Total Phosphorus (mg)	Nitrate-Nitrite (mg)	TKN (mg)	Total Nitrogen (mg)	Dissolved Oxygen (mg/l)
EPLP	0	0.812	0.232	6.26	6.49	-
	3	0.225	0.227	9.60	9.83	7.2
	6	0.477	0.225	16.56	16.79	-
	9	0.366	0.401	14.33	14.73	7.1
	12	0.232	0.401	23.36	23.76	8.0
	16	0.230	0.446	26.63	27.07	8.7
	20	0.450	0.552	23.83	24.38	7.8
	24	0.385	0.552	28.31	28.86	7.6
	33	1.301	0.445	30.19	30.63	6.4
	41	0.457	0.402	31.22	31.62	-
	46	0.333	2.234	31.77	34.00	5.2
	54	1.290	7.781	24.68	32.46	-
	60	0.903	11.014	15.99	27.00	8.5
	65	0.903	6.670	17.36	24.03	-
	67	0.766	4.860	17.53	22.39	9.1
EHPB	0	0.408	0.240	6.36	6.60	6.8
	4	0.455	0.832	4.10	4.93	-
	6	0.407	0.808	4.59	5.40	-
	11	0.489	0.763	15.04	16.80	-
	17	0.247	1.433	-	-	5.0
	26	0.246	1.835	16.27	18.11	-
	32	0.515	4.396	16.94	21.34	-
	38	0.626	8.103	9.17	17.27	-
	40	-	-	-	-	5.6
	42	0.341	11.402	6.11	17.51	7.9
	45	0.471	11.403	9.79	21.19	8.0


Calm
Calm
Calm
Calm
Calm
Calm
1.5
1.0
0.5
TIDE HEIGT (m)
N
W
E
S
18.5 km/hr.
KEY
Sampling Periods
1
2
3
4
5
6
7
8
9
10
0600
1200
1800
2400
0600
1200
1800
2400
0600
1200
1800
2400
SEPT 23
SEPT 24
SEPT 25
1969
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
MSL
TIDE HEIGHT (m)
N
10 km / hr.
W
E
S
KEY
Sampling Period
1 2 3 4 5 6 7 8
0 3 6 9 12 15 18 21 0 3 6 9 12 15 18 21 0 3 6 9 12 15 18 21 0 3 6 9 12 15 18 21 0
APRIL 12
APRIL 13
APRIL 14
APRIL 15
1973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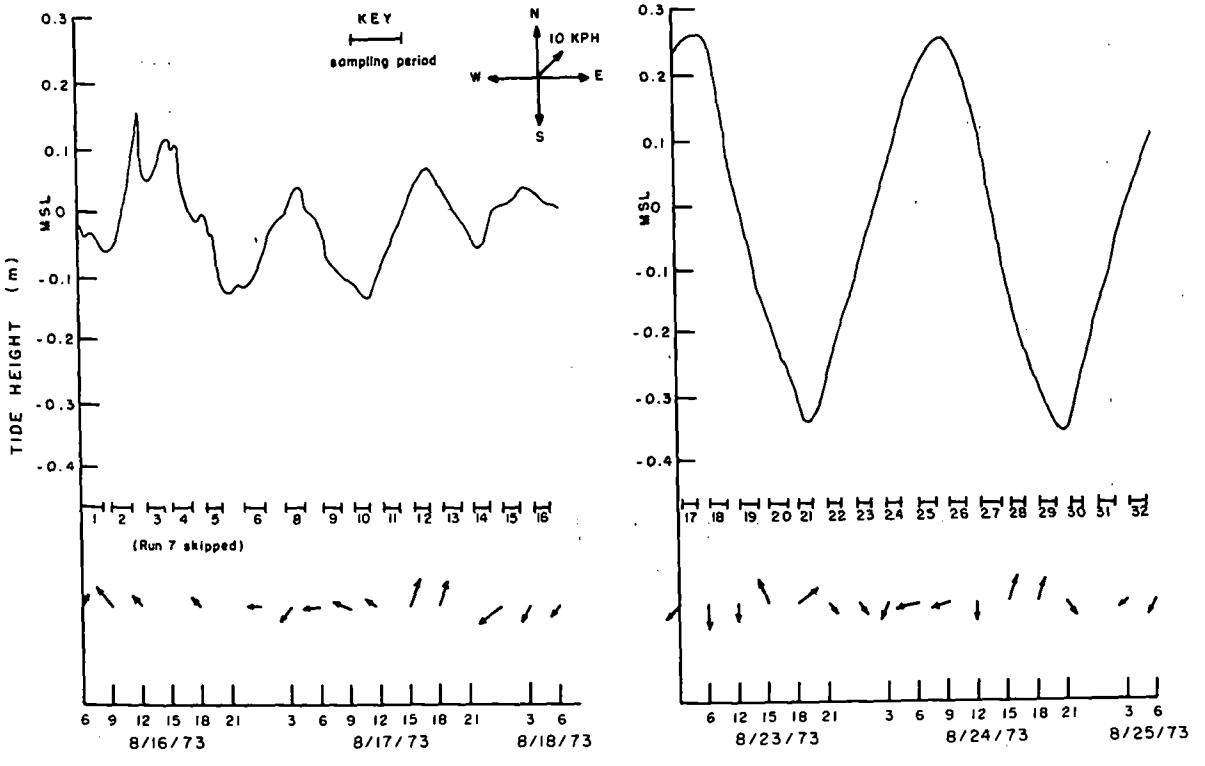
0.7
0.6
0.5
0.4
0.3
0.2
0.1
-0.1
MSL
Run
17 18 19 20 21 22 23 24
N
10 km / hr
W
E
S
KEY
Sampling Period
3 6 9 12 15 18 21 24 3 6 9 12 15 18 21 24 3 6 9 12 15 18 21 24 3 6 9 12 15
04/18/73
04/19/73
04/20/73
04/21/73


TIDE HEIGHT (m)
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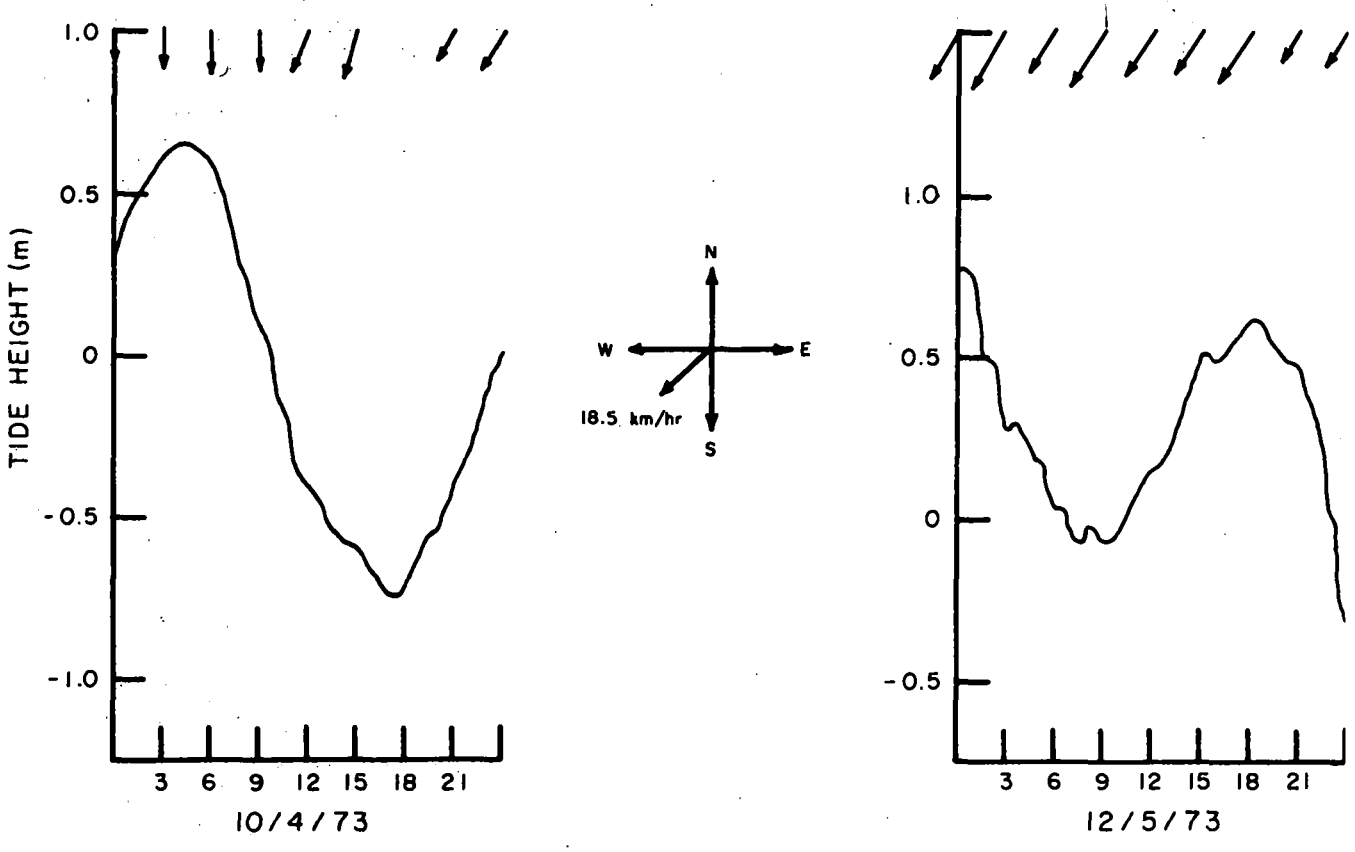
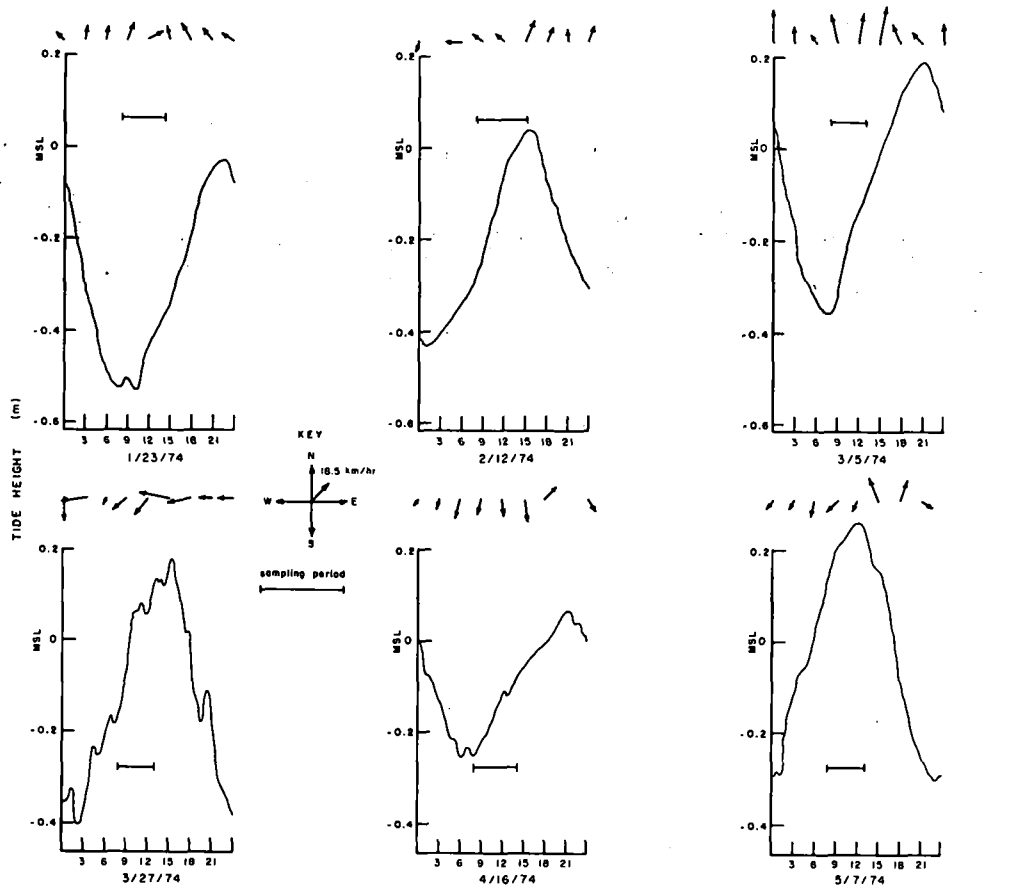
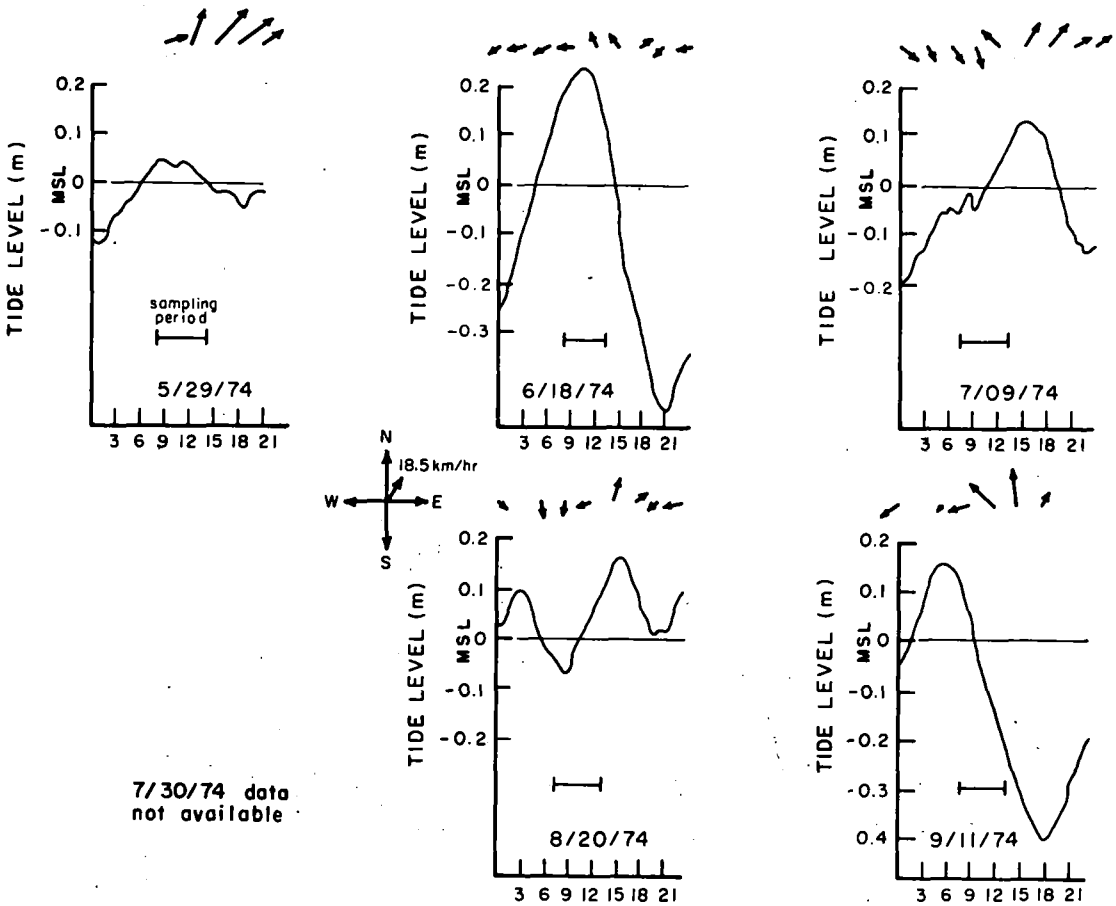
0.2
0.1
MSL
0
-0.1
-0.2
-0.3
-0.4
KEY
sampling period
N
10 KPH
W
E
S
1 2 3 4 5 6 8 9 10 11 12 13 14 15 16
(Run 7 skipped)
6 9 12 15 18 21 3 6 9 12 15 18 21 3 6
8/16/73
8/17/73
8/18/73
17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32
6 12 15 18 21 3 6 9 12 15 18 21 3 6
8/23/73
8/24/73
8/25/73


TIDE HEIGHT (m)
1.0
0.5
0
-0.5
-1.0
3 6 9 12 15 18 21
10/4/73
N
W
E
S
18.5 km/hr
1.0
0.5
0
-0.5
3 6 9 12 15 18 21
12/5/73





7/30/74 data not available

Appendix 8 - 2. Location, Storet retrieval information, and parameters sampled for all sampling stations occupied by US-EPA and University of West Florida during the Escambia Bay Recovery Study.

PAGE	PARAMETER	DESCRIPTION
1	00008	NUMBER USED IN SAMPLE ACCOUNTING PROCEDURE
1	00010	TEMPERATURE, WATER (DEGREES CENTIGRADE)
1	00070	TURBIDITY, (JACKSON CANDLE UNITS)
1	00077	TRANSPARENCY, SECCHI DISC (INCHES)
1	00300	OXYGEN, DISSOLVED (MG/L)
1	00301	OXYGEN, DISSOLVED (PERCENT OF SATURATION)
1	00343	OXYGEN DEMAND, TOTAL (MG/L)
1	00400	PH (STANDARD UNITS)
1	00480	SALINITY - PARTS PER THOUSAND
1	00600	NITROGEN, TOTAL (MG/L AS N)
1	00605	NITROGEN, ORGANIC, TOTAL (MG/L AS N)
1	00610	NITROGEN, AMMONIA, TOTAL (MG/L AS N)
1	00625	NITROGEN, KJELDAHL, TOTAL, (MG/L AS N)
1	00630	NITRITE PLUS NITRATE, TOTAL 1 DET. (MG/L AS N)
1	00665	PHOSPHORUS, TOTAL (MG/L AS P)
1	00671	PHOSPHORUS, DISSOLVED ORTHOPHOSPHATE (MG/L AS P)
1	00680	CARBON, TOTAL ORGANIC (MG/L AS C)
1	31505	COLIFORM,TOT,MPN,CONFIRMED TEST,35C (TUBE 31506)
1	31615	FECAL COLIFORM,MPN,EC MED,44.5C (TUBE 31614)
1	32230	CHLOROPHYLL A (MG/L)
1	32231	CHLOROPHYLL B (MG/L)
1	32232	CHLOROPHYLL C (MG/L)
1	70507	PHOSPHORUS,IN TOTAL ORTHOPHOSPHATE (MG/L AS P)
1	00003	DEPTH IN FEET
2	00530	RESIDUE, TOTAL NONFILTRABLE (MG/L)
28	00608	NITROGEN, AMMONIA, DISSOLVED (MG/L AS N)
28	00631	NITRITE PLUS NITRATE, DISS. 1 DET. (MG/L AS N)
28	00681	CARBON, DISSOLVED ORGANIC (MG/L AS C)
98	00094	SPECIFIC CONDUCTANCE,FIELD (UMHOS/CM @ 25C)
98	00690	CARBON, TOTAL (MG/L AS C)
98	70305	SALINITY BASED ON CONDUCTIVITY
105	70990	PHYTOPLANKTON PRODUCTION,C-14 METHOD (C-G/M3/HR)
142	00299	OXYGEN, DISSOLVED (ELECTRODE) (MG/L)

Appendix 8 - 2. (cont.).

AGENCY	PRIMARY STATION	SECONDARY	STATION LOCATION	STATE	MINOR BASIN
1113T070	120345	BJIV	CHANNEL MARKER 30	FLORIDA	BLACKWATER BAY
	120375	EPRF	NEAR OYSTER PLANTING S OF TROUTB	FLORIDA	ESCAMBIA BAY
	120860	A-011	1/2 MI 270 DEGREES W OF 021	FLORIDA	EAST BAY
	120865	A-012	3/5 MI 270 DEGREES W OF 022	FLORIDA	EAST BAY
	120870	A-013	2/3 MI 270 DEGREES W OF 023	FLORIDA	EAST BAY
	120855	A-021	CHANNEL MARKER R "16"	FLORIDA	EAST BAY
	120850	A-022	CHANNEL MARKER R "12"	FLORIDA	EAST BAY
	120845	A-023	CHANNEL MARKER R "8"	FLORIDA	EAST BAY
	120770	A-031	1 MI 91 DEGREES E OF 021	FLORIDA	EAST BAY
	120775	A-032	1/2 MI 180 DEGREES S OF 031	FLORIDA	EAST BAY
	120780	A-033	1/2 MI 180 DEGREES S OF 032	FLORIDA	EAST BAY
	120785	A-041	1/2 MI 180 DEGREES S OF 033	FLORIDA	EAST BAY
	120790	A-042	1/2 MI 180 DEGREES S OF 041	FLORIDA	EAST BAY
	120795	A-043	1/2 MI 180 DEGREES S OF 042	FLORIDA	EAST BAY
	120765	A-051	3/5 MI T N OF 052	FLORIDA	EAST BAY
	120760	A-052	3/5 MI T N OF 053	FLORIDA	EAST BAY
	120755	A-053	3/5 MI T N OF 091	FLORIDA	EAST BAY
	120725	A-061	4 MI 84 DEGREES E OF 023	FLORIDA	EAST BAY
	120730	A-062	1 MI 180 DEGREES S OF 061	FLORIDA	EAST BAY
	120720	A-063	4 3/4 MI 91 DEGREES E OF 023	FLORIDA	EAST BAY
	120880	A-071	1 1/4 MI 227 DEGREES SW OF 023	FLORIDA	EAST BAY
	120875	A-072	1 1/4 MI 206 DEGREES SW OF 023	FLORIDA	EAST BAY
	120840	A-073	1 1/3 MI 190 DEGREES SW OF 023	FLORIDA	EAST BAY
	120800	A-081	1/2 MI 180 DEGREES S OF 043	FLORIDA	EAST BAY
	120805	A-082	1/2 MI 180 DEGREES S OF 081	FLORIDA	EAST BAY
	120810	A-083	3/5 MI 180 DEGREES S OF 082	FLORIDA	EAST BAY
	120750	A-091	3/5 T N OF 092	FLORIDA	EAST BAY
	120745	A-092	3/5 MI T N OF 093	FLORIDA	EAST BAY
	120740	A-093	1/2 MI T N OF 123	FLORIDA	EAST BAY
	120885	A-101	2 MI 247 DEGREES SW OF 023	FLORIDA	EAST BAY
	120890	A-102	4/5 MI 192 DEGREES SW OF 101	FLORIDA	EAST BAY
	120895	A-103	3/4 MI 192 DEGREES SW OF 102	FLORIDA	EAST BAY
	120900	A-104	2/3 MI 192 DEGREES SW OF 103	FLORIDA	EAST BAY
	120835	A-111	1 4/5 MI 180 DEGREES S OF 023	FLORIDA	EAST BAY
	120830	A-112	2 1/2 MI 180 DEGREES S OF 023	FLORIDA	EAST BAY
	120825	A-113	3 1/5 MI 180 DEGREES S OF 023	FLORIDA	EAST BAY
	120815	A-121	3/5 MI 183 DEGREES S OF 083	FLORIDA	EAST BAY
	120820	A-122	3/5 MI 180 DEGREES S OF 121	FLORIDA	EAST BAY
	120735	A-123	3 1/2 MI 129 DEGREES SE OF 023	FLORIDA	EAST BAY
	120075	ADGV	EAST BAY	FLORIDA	EAST BAY CHANNEL AT BUOY 12
	120310	AFSX	MILLER PT WEST OF PWR CABELS	FLORIDA	EAST BAY
	120365	AGJI	CENTER OF EAST BAY	FLORIDA	EAST BAY
	120360	AGPH	3000 YDS WEST OF POWER LINES	FLORIDA	EAST BAY
	120305	AGTA	MILLER PT AT POWER CABLES	FLORIDA	EAST BAY
	120300	AGUF	MILLER PT. EAST OF PWR CABLES S	FLORIDA	EAST BAY
	120070	AJFD	EAST BAY	FLORIDA	EAST BAY CHANNEL AT BUOY 4
	120065	AKAA	EAST BAY	FLORIDA	EAST BAY AT BUOY 1, 1 MI S
	120370	ALEX	REDFISH COVE IN LINE WITH CHNL	FLORIDA	EAST BAY
	120385	BFEI	BUOY 40 IN BLACKWATER RIVER	FLORIDA	BLACKWATER RIVER
	120350	BNGA	CHANNEL MARKER 24	FLORIDA	BLACKWATER BAY
	120355	BREA	CHANNEL MARKER 18	FLORIDA	BLACKWATER BAY
	120700	E-011	1 MI 288 DEGREES NW OF 021	FLORIDA	ESCAMBIA BAY
	120705	E-012	1 1/3 MI 280 DEGREES NW OF 022	FLORIDA	ESCAMBIA BAY
	120710	E-013	5/8 MI EAST OF STATION 023	FLORIDA	ESCAMBIA BAY
	120695	E-021	2/3 MI NORTH OF STATION 022	FLORIDA	ESCAMBIA BAY

Appendix B - 2 (cont.).

AGENCY	PRIMARY STATION	SECONDARY	STATION LOCATION	STATE	MINOR BASIN
11137070	120690	E-022	2/3 MI NORTH OF STATION 023	FLORIDA	ESCAMBIA BAY
	120685	E-023	2 1/2 MI N OF SWING BRIDGE	FLORIDA	ESCAMBIA BAY
	120660	E-031	1 1/2 MI WNW OF N "14"	FLORIDA	ESCAMBIA BAY
	120655	E-032	1 MI WNW OF N "14"	FLORIDA	ESCAMBIA BAY
	120650	E-033	1/2 MI WNW OF N "14"	FLORIDA	ESCAMBIA BAY
	120715	E-041	RE RAF "18"	FLORIDA	ESCAMBIA BAY
	120665	E-042	C "15"	FLORIDA	ESCAMBIA BAY
	120645	E-043	N "14"	FLORIDA	ESCAMBIA BAY
	120680	E-051	1 1/2 MI FROM C15&ONLINE MULLATO	FLORIDA	ESCAMBIA BAY
	120675	E-052	1 MI FROM C15&ONLINE MULLATO BYU	FLORIDA	ESCAMBIA BAY
	120670	E-053	1/2 MI FROM C15&ONLINE W MULLATO	FLORIDA	ESCAMBIA BAY
	120640	E-061	1/2 MI FROM CHANNEL	FLORIDA	ESCAMBIA BAY
	120625	E-062	1/2 MI W OF N "12"	FLORIDA	ESCAMBIA BAY
	120620	E-063	1/2 MI W OF N "10"	FLORIDA	ESCAMBIA BAY
	120635	E-071	MID CHANNEL ONLINE BTWN 110 & RR	FLORIDA	ESCAMBIA BAY
	120630	E-072	N "12"	FLORIDA	ESCAMBIA BAY
	120615	E-073	N "10"	FLORIDA	ESCAMBIA BAY
	120605	E-081	100 YRDS OFF STAKES DUE SOUTH	FLORIDA	ESCAMBIA BAY
	120600	E-082	2 1/2 MI FROM C"7"&ONLINE INDN B	FLORIDA	ESCAMBIA BAY
	120610	E-083	1 MI FROM STAKES ONLINE RA REF 2	FLORIDA	ESCAMBIA BAY
	120595	E-084	2 MI FROM C"7"&ONLINE INDIAN BYU	FLORIDA	ESCAMBIA BAY
	120590	E-085	1 MI FROM C"7"&ONLINE INDIAN BYU	FLORIDA	ESCAMBIA BAY
	120580	E-091	1/4 MI E OF BR STK&ONLINE N"4"	FLORIDA	ESCAMBIA BAY
	120575	E-092	1 1/4 MI W OF N"4"&ONLINE BR STK	FLORIDA	ESCAMBIA BAY
	120570	E-093	3/4 MI W N"4"&ONLINE BRICK STACK	FLORIDA	ESCAMBIA BAY
	120585	E-101	C "7"	FLORIDA	ESCAMBIA BAY
	120565	E-102	N "4"	FLORIDA	ESCAMBIA BAY
	120545	E-103	N "12" RA REF	FLORIDA	ESCAMBIA BAY
	120560	E-111	3/4 MI E OF N "4"	FLORIDA	ESCAMBIA BAY
	120555	E-112	2 MI FROM C"7" ONLINE WITH IND B	FLORIDA	ESCAMBIA BAY
	120550	E-113	1 3/4 MI E N"4"&1/2 MI OFF E BNK	FLORIDA	ESCAMBIA BAY
	120540	E-121	2 MI OFF N "12"&ONLINE AERO BN	FLORIDA	ESCAMBIA BAY
	120535	E-122	1 1/2 MI OFF AERO BN&ONLINE N 12	FLORIDA	ESCAMBIA BAY
	120530	E-123	3/4 MI OFF AERO BN&ONLINE N "12"	FLORIDA	ESCAMBIA BAY
	120515	E-131	1 1/4 MI W OF 14181 MI SW OF N12	FLORIDA	ESCAMBIA BAY
	120520	E-132	3/4 MI S OF 13183 MI ENE AERO BN	FLORIDA	ESCAMBIA BAY
	120525	E-133	3/4 MI S OF 13283 MI E OF AEROBN	FLORIDA	ESCAMBIA BAY
	120510	E-141	3/4 MI N OF 142	FLORIDA	ESCAMBIA BAY
	120505	E-142	3/4 MI N OF 143	FLORIDA	ESCAMBIA BAY
	120500	E-143	4 MI E AREO BN/2 MI W GARCON PT	FLORIDA	ESCAMBIA BAY
	120125	EADQ	WHITE R. 3 MI ABOVE MOUTH	FLORIDA	ESCAMBIA BAY
	120200	EADT	WHITE RIV AT HEAD OF SIMPSON RIV	FLORIDA	ESCAMBIA BAY
	120195	E8FQ	SIMPSON RIV AT WOODBINE BAYOU	FLORIDA	ESCAMBIA BAY
	120205	ECEC	SIMPSON R LOWER BR. 1MI FM HEAD	FLORIDA	ESCAMBIA BAY
	120135	ECGN	SIMPSON R 1.3 MI ABOVE US-90 BR	FLORIDA	ESCAMBIA BAY
	120140	EDFE	BENNY BAYOU AND DEAD RIV.-CONFLU	FLORIDA	ESCAMBIA BAY
	120210	EDIP	SIMPSON RIV MOUTH ABV US-90 BR.	FLORIDA	ESCAMBIA BAY
	120130	EDIV	SIMPSON RIV. BELOW US-90 BRIDGE	FLORIDA	ESCAMBIA BAY
	120280	EDJL	UPPER BAY NEAR FLORIDATOWN	FLORIDA	ESCAMBIA BAY
	120285	EDKV	UPPER BAY NEAR FLORIDATOWN	FLORIDA	ESCAMBIA BAY
	120225	EDLU	ESC.BAY .6MI NW OF AIR PROD DSCG	FLORIDA	ESCAMBIA BAY
	120180	EEDG	ESC.RIV AT BUOY N32 CNTR CHAN.	FLORIDA	ESCAMBIA BAY
	120120	EEDR	ESCAMBIA R UPSTM S CNFLU WHITE R	FLORIDA	ESCAMBIA BAY
	120145	EEEM	LITTLE WHITE R 1.75 MI ABV MTH	FLORIDA	ESCAMBIA BAY
	120190	EEMF	LIT.WHITE R. .1MI FM BENNY BAYOU	FLORIDA	ESCAMBIA BAY

Appendix B - 2. (cont.).

AGENCY	PRIMARY STATION	SECONDARY	STATION LOCATION	STATE	MINOR BASIN
11137070	120020	EEIX	ESCAMBIA BAY	FLORIDA	ESCAMBIA BAY NEAR MOUTH OF
	120230	EEKD	ESC.BAY .7MI E. OF AIR PROD DSCG	FLORIDA	ESCAMBIA BAY
	120290	EEKE	UPPER BAY NEAR FLORIDATOWN	FLORIDA	ESCAMBIA BAY
	120160	EEKV	0.8M S. OF FLORIDATOWN	FLORIDA	ESCAMBIA BAY
	120215	EELI	ESC.BAY .2MI FM AIR PROD DSCHG	FLORIDA	ESCAMBIA BAY
	120220	EELL	ESC.BAY .5MI FM AIR PROD DSCHG	FLORIDA	ESCAMBIA BAY
	120260	EFKN	ESC.BAY .8MI NW OF AM.CYN. BOIL	FLORIDA	ESCAMBIA BAY
	120235	EFLI	ESC.BAY .5MI S. OF AIR PROD DSCG	FLORIDA	ESCAMBIA BAY
	120015	EFLU	ESCAMBIA BAY	FLORIDA	ESCAMBIA BAY ONE MI NW OF F
	120115	EGEC	ESC.RIV.DWNSTM GULF P DISCHARGE	FLORIDA	ESCAMBIA BAY
	120150	EGMI	EAST RIV 1 MI UPSTM FROM MOUTH	FLORIDA	ESCAMBIA BAY
	120255	EGLU	ESC.BAY .5MI WSW OF AM.CYN BOIL	FLORIDA	ESCAMBIA BAY
	120165	EGLY	0.4M S.W OF FISHERMANS POINT	FLORIDA	ESCAMBIA BAY
	120240	EGMK	ESC.BAY AT AM.CYN. OUTFALL BOIL	FLORIDA	ESCAMBIA BAY
	120155	EGMW	FISHERMANS PT. 200 YD OFFSHORE	FLORIDA	ESCAMBIA BAY
	120000	EHGD	ESCAMBIA RIVER	FLORIDA	ESCAMBIA RIVER AT HGWY 90
	120185	EHIR	ESC.RIV AT BUOY N22 CNTR. CHAN.	FLORIDA	ESCAMBIA BAY
	120250	EHLM	ESC.BAY .6MI SW OF AM.CYN. BOIL	FLORIDA	ESCAMBIA BAY
	120245	EHMH	ESC.BAY .5MI SSE OF AM.CYN. BOIL	FLORIDA	ESCAMBIA BAY
	120330	EHPK	500 YDS S.E. OF RR BRIDGE	FLORIDA	ESCAMBIA BAY,MULATTO BAYOU
	120040	EIIL		FLORIDA	ESCAM BAY HALF MI NE OF ELL
	120030	EIKC	ESCAMBIA BAY	FLORIDA	ESCAMBIA BAY CHANNEL AT BUO
	120035	EINE	ESCAMBIA BAY	FLORIDA	ESCAM BAY HALF MI SW OF MUL
	120335	EKLQ	0.3MI FM W SHORE JUST ABV RR BR.	FLORIDA	ESCAMBIA BAY
	120045	EKMP	ESCAMBIA BAY	FLORIDA	ESCAM B CHAN BETWEEN I-10 A
	120050	EMQC	ESCAMBIA BAY	FLORIDA	ESCAM B 0.75 MI W OF MOUTH
	120055	ENN8	ESCAMBIA BAY	FLORIDA	ESCAMBIA BAY CHANNEL AT BUO
	120175	EPLP	0.2M SE OF CHIMNEY STACK	FLORIDA	ESCAMBIA BAY
	120010	ER-10	ESCAMBIA RIVER	FLORIDA	ESCAMBIA R AT UPPER BLUFFS
	120025	ERPB	ESCAMBIA BAY	FLORIDA	ESCAMBIA BAY CHANNEL AT BUO
	120060	ETLQ	ESCAMBIA BAY	FLORIDA	ESCAM BAY ONE MI NE OF MAGN
	120170	ETQE	0.3 M WEST OF HERNANDEZ PT.	FLORIDA	ESCAMBIA BAY
	120005	GULF	GULF OF MEXICO	FLORIDA	PENS ENT CHAN AT BUOY 2 IN
	120380	PEUE	0.6MI ABV US-90 BR.CNTR OF BAYOU	FLORIDA	PENSACOLA BAY,BAYOU TEXAR
	120080	PHZM	PENSACOLA BAY	FLORIDA	PENSACOLA BAY 2.3 MI NO-EAS
	120085	PIVP	PENSACOLA BAY	FLORIDA	PENSACOLA BAY AT BAY BRIDGE
	120095	PJPD	PENSACOLA BAY	FLORIDA	PENSACOLA BAY AT ENTR TO B.
	120090	PJRT	PENSACOLA BAY	FLORIDA	PENSACOLA BAY CHANNEL AT BU
	120100	POOH	PENSACOLA BAY	FLORIDA	PENSACOLA BAY CHANNEL BTW B
	120105	PPJV	PENSACOLA BAY	FLORIDA	PENSACOLA BAY CHANNEL AT BU
	120110	PQJO		FLORIDA	PENSACOLA INLET AT BUOY 10
	120265	RSDE	MOUTH OF SOLDIERS CREEK	FLORIDA	PERDIDO BAY
	120275	RSDI	MOUTH OF SOLDIERS CREEK	FLORIDA	PERDIDO BAY
	120270	RSDJ	AT MOUTH OF SOLDIERS CREEK	FLORIDA	PERDIDO BAY
	120475	YINU	.5 MI S.E. OF BEN'S LAKE	FLORIDA	CHOCTAWHATCHEE BAY
	120455	YIVM	MDWY BTWN WHITE & BUCCAROO PT	FLORIDA	CHOCTAWHATCHEE BAY
	120460	YKRN	MDWY BTWN COBBS & BUCCAROO PT.	FLORIDA	CHOCTAWHATCHEE BAY
	120445	YK7U	I.C.W. MILE 237	FLORIDA	CHOCTAWHATCHEE BAY
	120485	YLGM	MOUTH OF GARNIER BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120470	YLNS	1.8 MI. EAST OF BLACK POINT	FLORIDA	CHOCTAWHATCHEE BAY
	120450	YLZ8	1.4 MI S.S.W. OF WHITE POINT	FLORIDA	CHOCTAWHATCHEE BAY
	120480	YNKF	1. MI SOUTH OF BLACK POINT	FLORIDA	CHOCTAWHATCHEE BAY
	120490	YOFY	MOUTH OF NARROWS. ICW MARKER 4	FLORIDA	CHOCTAWHATCHEE BAY
	120440	YQ9T	1.5 MI N.W. OF MORSESHOE BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120465	YPOO	.2 MI N. OF US-98 BR. AT DESTIN	FLORIDA	CHOCTAWHATCHEE BAY
	120420	ZHQH	1 MI S.W. MTH OF ALAQUA BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120425	ZIMY	.75 MI N. OF I.C.W. MARKER 47	FLORIDA	CHOCTAWHATCHEE BAY
	120435	ZJEJ	MDWY BTWN HAMMOCK & FOURMILE PT	FLORIDA	CHOCTAWHATCHEE BAY
	120410	ZJVW	1 MI S.W. OF MTH LA GRANGE BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120415	ZLQE	MARKER 1 IN LA GRANGE BYU CHNL	FLORIDA	CHOCTAWHATCHEE BAY
	120430	ZNMV	.7 MI N. OF HEWETT BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120315	ZOJO	HOGTOWN BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120320	ZOKH	HOGTOWN BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120405	ZOWL	.3MI N. CNTR SPAN OF 331 BRIDGE	FLORIDA	CHOCTAWHATCHEE BAY
	120395	ZO2L	MOUTH OF CHOCTAWHATCHEE RIVER	FLORIDA	CHOCTAWHATCHEE BAY
	120390	ZO6X	3.0 MI FM MOUTH OF CHOC. RIV	FLORIDA	CHOCTAWHATCHEE BAY
	120325	ZPKI	HOGTOWN BAYOU	FLORIDA	CHOCTAWHATCHEE BAY
	120400	ZR2J	BUOY 1 IN I.C.W. EAST SIDE	FLORIDA	CHOCTAWHATCHEE BAY

Appendix 8 - 3. Summary of bottom sampling depths (meters) for Study I (April 13 - 15, 1973) and Study II (April 19 to 21, 1973).

Station	Study I N	Mean	Low	High	C.V.%	Station	Study II N	Mean	Low	High	C.V.%
ADGV	7	2.7	2.4	2.7	4.3	ADGV	7	2.8	2.7	3.0	5.3
AJPD	7	3.0	2.7	3.0	5.0	AJPD	7	2.9	2.4	3.0	8.2
AKAA	7	3.2	2.7	3.4	7.4	AKAA	7	3.4	2.7	3.7	10.5
EEIX	8	1.0	0.6	1.2	21.8	EEIX	8	1.1	0.9	1.5	20.5
EFLU	8	2.0	1.8	2.1	8.2	EFLU	9	2.1	1.5	2.4	12.4
EIIL	8	1.7	1.5	1.8	9.7	EIIL	8	1.8	1.5	2.1	12.3
EIKC	8	3.3	2.7	4.3	18.0	EIKC	8	3.5	2.7	4.3	12.3
EIME	8	1.9	1.5	2.4	16.6	EIME	8	2.1	1.8	2.4	10.8
EKMP	8	2.1	1.5	3.4	28.6	EKMP	8	2.8	2.4	3.4	13.7
EMQC	8	1.7	1.5	1.8	9.2	EMQC	8	2.4	2.1	2.7	9.1
ENNB	8	1.9	1.5	2.4	18.4	ENNB	8	2.9	2.4	3.7	17.0
ERPB	8	2.6	1.5	3.0	18.0	ERPB	7	3.3	3.0	3.7	7.1
ER10	8	4.6	3.4	6.1	29.2	ER10	8	4.9	4.0	5.8	20.0
ETLQ	8	3.3	2.7	3.7	7.7	ETLQ	7	3.9	3.0	4.6	13.0
GULF	7	12.8	9.1	14.9	15.7	GULF	2	13.3	13.1	13.4	1.6
PHZH	7	4.9	4.6	5.5	6.6	PHZH	7	4.7	4.6	4.9	3.4
PIVP	7	8.1	7.6	8.8	5.3	PIVP	7	9.3	8.8	9.8	3.2
PJPD	7	4.5	3.0	3.0	24.1	PJPD	5	5.2	4.0	6.7	21.6
PJRT	7	10.9	9.1	13.4	14.8	PJRT	5	10.0	9.4	11.9	10.6
POOH	7	11.2	9.1	11.9	9.1	POOH	5	11.3	11.0	11.9	3.5
PPJV	7	11.6	9.1	13.4	13.8	PPJV	5	9.0	4.6	12.2	38.6
PQJQ	7	11.7	4.6	15.2	39.1	PQJQ	6	10.6	1.5	14.9	51.6

Appendix 8 - 3 (cont). Summary of bottom sampling depths (meters) for Study III (August 16 - 17, 1973), and Study IV (August 23 - 25, 1973).

Station	Study III N	Mean	Low	High	C.V.%	Station	Study IV N	Mean	Low	High	C.V.%
ADGV	8	2.9	2.7	3.0	5.4	ADGV	8	2.6	1.5	3.0	19.5
AJPD	8	3.2	3.0	3.4	5.0	AJPD	8	3.1	2.7	3.4	8.2
AKAA	8	3.6	3.2	4.3	11.4	AKAA	8	3.4	2.7	4.0	12.3
EEIX	7	0.9	0.6	1.2	19.2	EEIX	8	0.9	0.6	1.2	30.9
EEKV	7	1.4	1.2	1.8	17.2	EEKV	8	1.3	0.9	1.5	15.5
EGLY	7	2.1	2.1	2.1	0.0	EGLY	8	2.1	1.8	2.4	10.5
EIIL	7	1.6	1.5	1.8	9.2	EIIL	8	1.6	1.2	1.8	16.3
EIKC	7	3.7	3.4	4.0	8.3	EIKC	8	3.5	2.4	4.3	18.2
EIME	7	1.8	1.5	1.8	6.5	EIME	8	1.6	1.5	1.8	9.6
EKMP	7	3.1	2.1	4.3	24.3	EKMP	8	3.7	3.0	4.3	12.0
EMQC	7	2.1	1.8	2.4	10.1	EMQC	8	2.3	2.1	2.7	10.1
ENNB	7	3.2	2.7	3.7	10.9	ENNB	8	2.8	2.1	3.4	16.1
EPLP	7	2.2	2.1	2.4	6.7	EPLP	8	2.1	1.8	2.4	12.1
ERPB	7	3.3	3.0	3.7	6.4	ERPB	8	3.3	2.7	3.7	11.9
ER10	7	3.1	2.7	3.7	10.8	ER10	7	3.0	2.4	4.0	16.3
ETLQ	7	4.0	4.0	4.3	2.9	ETLQ	8	3.9	3.7	4.3	6.5
ETQE	7	1.7	1.5	1.8	9.8	ETQE	8	1.6	1.2	1.8	17.0
GULF	7	12.7	11.9	14.3	7.7	GULF	6	13.0	12.2	13.4	3.5
PHZH	8	5.0	4.6	5.5	5.6	PHZH	8	5.0	4.6	5.5	5.6
PIVP	8	8.1	7.9	8.8	4.0	PIVP	8	8.0	7.3	8.8	6.4
PJPD	8	4.9	4.6	6.4	12.6	PJPD	8	5.3	3.7	7.0	27.5
PJRT	8	9.9	8.8	11.3	11.2	PJRT	8	9.1	8.8	9.4	3.3
POOH	8	10.8	10.4	12.5	6.7	POOH	8	10.6	10.1	11.3	3.6
PQJQ	8	12.2	11.9	12.2	0.9	PQJQ	7	11.9	9.4	13.1	9.6

Appendix 8 - 4. Summary of depth (meters) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.3	0.3	0.3	0.0
ADGV	C	12	1.4	1.2	1.7	11.0
ADGV	E	12	2.6	2.3	2.9	7.1
AGJI	A	12	0.3	0.3	0.3	0.0
AGJI	B	12	0.9	0.8	1.1	11.3
AGJI	C	12	1.6	1.4	1.8	9.5
AGJI	D	12	2.3	2.0	2.7	8.7
AGJI	E	12	3.0	2.7	3.4	6.7
AGPH	A	12	0.3	0.3	0.3	0.0
AGPH	C	12	1.4	1.2	1.7	11.8
AGPH	E	12	2.7	2.4	3.0	7.8
AJFD	A	12	0.3	0.3	0.3	0.0
AJFD	C	12	1.6	1.4	1.8	10.8
AJFD	E	12	3.1	2.7	3.4	8.4
ALEX	A	12	0.3	0.3	0.3	0.0
ALEX	C	12	2.2	1.5	2.4	11.6
ALEX	E	12	4.2	3.0	4.6	9.9
EFEI	A	5	0.3	0.3	0.3	0.0
EFEI	C	5	1.7	1.7	2.0	7.8
EFEI	E	5	3.3	3.0	3.7	7.7
EJIV	A	12	0.3	0.3	0.3	0.0
EJIV	C	12	1.1	0.8	1.3	13.7
EJIV	E	12	2.1	1.7	2.4	11.8
ENGA	A	12	0.3	0.3	0.3	0.0
BNGA	C	12	1.1	0.9	1.4	16.7
BNGA	E	12	2.1	1.8	2.4	10.8
EREA	A	12	0.3	0.3	0.3	0.0
EREA	C	12	1.4	1.2	1.7	10.9
EREA	E	12	2.7	2.4	2.9	6.7
ECGM	A	12	0.3	0.3	0.3	0.0
ECGM	C	12	2.2	1.4	3.4	23.3
ECGM	E	12	4.1	2.1	6.4	25.1
EEDR	A	12	0.3	0.3	0.3	0.0
EEDR	C	12	2.1	1.8	2.6	12.0
EEDR	E	12	4.0	3.4	4.6	11.8
EEEM	A	12	0.3	0.3	0.3	0.0
EEEM	C	12	1.2	0.8	1.5	16.9
EEEM	E	12	2.1	1.5	2.4	15.2
EEIX	A	12	0.3	0.3	0.3	0.0
EEIX	C	8	0.6	0.5	0.8	16.9
EEIX	E	12	0.9	0.6	1.2	23.6
EEKV	A	12	0.3	0.3	0.3	0.0
EEKV	C	11	0.8	0.5	1.3	31.8
EEKV	E	12	1.4	0.9	2.3	32.3
EGLY	A	12	0.3	0.3	0.3	0.0
EGLY	B	12	0.7	0.5	0.8	14.5
EGLY	C	12	1.1	0.8	1.4	11.8
EGLY	D	12	1.6	1.4	1.9	8.6
EGLY	E	12	2.0	1.8	2.4	9.2
EHGD	A	12	0.3	0.3	0.3	0.0
EHGD	C	12	2.6	2.3	2.9	7.0
EHGD	E	12	5.0	4.6	5.5	6.2
EHPK	A	12	0.3	0.3	0.3	0.0
EHPK	C	11	0.8	0.6	1.9	15.7
EHPK	E	12	1.3	0.9	1.5	18.7
EIIL	A	12	0.3	0.3	0.3	0.0
EIIL	C	12	1.0	0.6	1.3	20.1
EIIL	E	12	1.6	1.2	2.0	14.8
EIKC	A	12	0.3	0.3	0.3	0.0
EIKC	C	12	1.2	0.9	1.8	24.9
EIKC	E	12	2.2	1.5	3.8	30.7
EKLQ	A	12	0.3	0.3	0.3	0.0
EKLQ	C	12	1.0	0.6	1.2	15.5
EKLQ	E	12	1.7	1.5	1.8	9.5
EKMP	A	12	0.3	0.3	0.3	0.0
EKMP	B	12	1.1	0.5	1.4	20.9
EKMP	C	12	1.9	1.1	2.4	18.0
EKMP	D	12	2.7	1.6	3.5	17.6
EKMP	E	12	3.5	2.1	4.6	17.6
EMQC	A	12	0.3	0.3	0.3	0.0
EMQC	C	12	1.3	1.1	1.4	9.1
EMQC	E	12	2.2	1.8	2.4	8.5
ENNB	A	12	0.3	0.3	0.3	0.0
ENNB	B	12	1.0	0.6	1.2	16.3
ENNB	C	12	1.8	1.2	2.1	13.6
ENNB	D	12	2.5	1.8	3.0	13.5
ENNB	E	12	3.3	2.4	4.0	13.0
EPLP	A	12	0.3	0.3	0.3	0.0
EPLP	C	12	1.2	1.1	1.2	5.8
EPLP	E	12	2.1	1.8	2.1	5.8
EPRF	A	12	0.3	0.3	0.3	0.0
EPRF	C	12	1.3	1.1	1.5	12.8
EPRF	E	12	2.3	2.0	2.6	8.4
ERPB	A	12	0.3	0.3	0.3	0.0
ERPB	B	12	1.0	0.8	1.1	12.1
ERPB	C	12	1.7	1.4	2.0	10.5
ERPB	D	12	2.5	2.1	2.7	8.2
ERPB	E	12	3.2	2.7	3.7	7.5
ER10	A	12	0.3	0.3	0.3	0.0
ER10	C	12	2.1	1.8	3.0	17.3
ER10	E	12	3.9	3.4	5.8	18.7
ETLQ	A	12	0.3	0.3	0.3	0.0
ETLQ	C	12	2.1	2.0	2.3	6.0
ETLQ	E	12	4.0	3.7	4.3	5.0
ETQE	A	12	0.3	0.3	0.3	0.0
ETQE	C	12	1.1	0.8	1.4	15.7
ETQE	E	12	2.1	1.5	2.4	13.5
PEUE	A	9	0.3	0.3	0.3	0.0
PEUE	C	9	1.1	0.9	1.2	9.8
PEUE	E	9	2.1	1.8	2.1	5.4
P01	A	12	0.4	0.3	0.9	49.5
P01	E	12	17.8	15.2	19.2	7.6
P02	A	12	0.4	0.3	0.9	49.5
P02	E	12	10.8	9.8	11.6	4.1
P03	A	12	0.3	0.3	0.6	26.6
P03	E	12	7.3	5.5	8.2	9.8
P04	A	12	0.3	0.3	0.6	26.6
P04	E	12	6.2	5.5	7.3	7.1
P05	A	12	0.4	0.3	1.2	59.3
P05	B	12	2.9	2.4	3.7	14.5
P05	C	12	5.5	4.6	7.6	18.8
P05	D	12	7.8	6.1	9.1	12.1
P05	E	12	10.2	7.6	11.6	9.8
P06	A	12	0.3	0.3	0.6	26.6
P06	E	12	6.4	6.1	7.0	5.7
P07	A	12	0.3	0.3	0.6	26.6
P07	E	12	5.5	4.6	6.1	9.7
P08	A	12	0.3	0.3	0.6	26.6
P08	E	12	10.1	6.1	11.6	14.1
P09	A	12	0.4	0.3	0.6	32.0
P09	E	12	3.7	3.0	4.6	15.6
P10	A	12	0.3	0.3	0.6	26.6
P10	E	12	8.4	7.0	9.8	8.3
P11	A	12	0.3	0.3	0.6	26.6
P11	E	12	5.3	4.3	6.1	8.6
P12	A	12	0.3	0.3	0.6	26.6
P12	E	12	5.1	4.6	5.8	7.5
P13	A	12	0.3	0.3	0.6	26.6
P13	B	12	1.7	1.5	1.8	9.5
P13	C	12	3.0	2.4	3.4	9.5
P13	D	12	4.3	3.7	4.9	9.0
P13	E	12	5.5	4.9	6.1	7.3
P14	A	12	0.3	0.3	0.6	26.6
P14	E	12	5.4	4.3	6.1	8.1
P15	A	12	0.3	0.3	0.6	26.6
P15	E	12	6.8	6.1	7.3	5.5

Appendix 8-5.--Water Quality Methods.

SAMPLE COLLECTION AND PRESERVATION

Surface samples for all water quality parameters except dissolved oxygen were collected by rapidly dipping the sample container one foot beneath the surface. Surface D.O. samples were collected using an APHA "dissolved oxygen dunker." All subsurface samples from depths less than 4.9 m (16 ft) were collected using a pump system. The pump system was thoroughly flushed with a diluted hydrochloric acid solution and tapwater before each study. In addition, the pump system was tested before each study to insure that it was not aerating the water samples. The pump was allowed to flush for one minute before the sample was collected. A Kemmerer-type sampler was used for samples from depths greater than 4.9 m (16 ft). Water samples for carbon, nitrogen, phosphorus, and turbidity were collected in 500 ml. nalgene bottles; samples for long-term BOD were collected in half-gallon plastic bottles; and samples for dissolved oxygen were collected in 300 ml BOD incubation bottles.

For preservation of dissolved oxygen samples, two ml of manganous sulfate and two ml of alkaline iodide-azide solution were added to each sample, and the sample was shaken. The D.O. samples were then kept at ambient temperature in the dark and analyzed within three hours after collection. Samples for all other parameters were kept on ice in coolers while being returned to the laboratory. In the laboratory, they were kept in a refrigerator at 5°C until they were analyzed. Any samples which could not be analyzed within one day of collection were preserved with sulfuric acid. This was only necessary with total organic carbon and total Kjeldahl nitrogen. Sufficient sulfuric acid was added to these samples to bring the pH below 2.

ANALYTICAL PROCEDURES

Dissolved Oxygen

Dissolved oxygen was analyzed by the modified Winkler with full-bottle technique (USEPA, 1974).

Nitrogen

Ammonia

Ammonia was analyzed by the Automated Colorimetric Phenate Method (USEPA, 1974).

Nitrate-Nitrite

Nitrate-Nitrite was analyzed by the Automated Cadmium Reduction Method (USEPA, 1974).

Total Kjeldahl Nitrogen (TKN)

Kjeldahl nitrogen was analyzed by a combination of a manual TKN digestion (USEPA, 1974), and analysis of the digestate by the Automated Colorimetric Phenate Method (USEPA, 1974).

Phosphorus

Total Phosphorus

For the analysis of total phosphorus, sulfuric acid and ammonium persulfate were added to an aliquot of each sample, which was autoclaved at 15 psi and 120°C for 30 minutes. The digested samples were analyzed by the Automated Colorimetric Ascorbic Acid Reduction Method (USEPA, 1974).

Total Orthophosphorus

Total orthophosphorus was analyzed by the Automated Colorimetric Ascorbic Acid Reduction Method (USEPA, 1974).

Dissolved Orthophosphorus

Dissolved orthophosphorus was determined by filtering an aliquot of each sample through a 0.45 μ membrane filter. The filtered samples were analyzed by the Automated Colorimetric Ascorbic Acid Reduction Method (USEPA, 1974).

Carbon

Total Organic Carbon (TOC)

Total organic carbon was determined by first purging the acidified samples with nitrogen gas to remove inorganic carbon, then analyzing the purged samples by the Total Organic Carbon Method (USEPA, 1974). The instrument used for analysis was a Beckman Model No. 915 TOC analyzer.

Turbidity

Turbidity was determined by the USEPA Turbidity Method. The instrument used was a Hach Model No. 2100 Turbidimeter.

Biochemical Oxygen Demand

Long-term BOD was determined with no dilution or seeding (USEPA, 1971). Duplicate BOD incubation bottles were set up for each sample. Initial D.O. concentration and D. O. concentrations at intervals of several days for a total of 50 days were read on a Y.S.I. Model 51-A Oxygen Meter.

Long-term BOD data were modeled using a computer program based on Marquardt's Compromise Method (Barnwell, 1970), which used non-linear techniques to estimate first order carbonaceous

and nitrogenous BOD parameters. The first order BOD model is represented by the following expressions:

when $t < t_n$

$$y = L_c \left(1 - e^{-k_c t} \right) \quad \text{.....8-1}$$

when $t > t_n$

$$y = L_c \left(1 - e^{-k_c t} \right) + L_n \left(1 - e^{-k_n (t+t_n)} \right) \quad \text{...8-2}$$

where

t = time in days

t_n = time that nitrogenous demand starts to be exerted (in days)

y = BOD (mg/l) exerted at time, t

L_c = ultimate carbonaceous BOD (mg/l)

L_n = ultimate nitrogenous BOD (mg/l)

k_c = carbonaceous rate constant (per day, base e)

k_n = nitrogenous rate constant (per day, base e)

Equation 8-1 represents just the carbonaceous demand, and Equation 8-2 represents the carbonaceous and nitrogenous demands. The computer program of the model provided values of the parameters t_n, L_c, L_n, k_c, and k_n that meet the statistic criteria of the computer program. As an additional check, calculated BOD values using Equations 8-1 and 8-2 were plotted against the actual values to examine the fit of the model by eye. Visually, the model provided an excellent fit of the actual data.

Total and Fecal Coliform Bacteria

Intensive water quality surveys were conducted during the months of April and August, 1973, and every three weeks beginning in January and ending in September, 1974. Sampling stations were located in Escambia River, Escambia Bay, Blackwater River, Blackwater Bay, East Bay, Bayou Texar, and Pensacola Bay (Figure 8-45).

Surface water samples were collected by grab technique at 0.3 m (1.0 ft) below the surface, and bottom samples were collected with a pump from 0.3 m (1.0 ft) above the bottom. The pump was submerged at bottom depth and allowed to pump for one minute before collecting the sample. Water samples were collected in sterile, wide mouth, glass bottles (250 ml) with ground glass stoppers. Samples were placed on ice until analysis. All samples were analyzed within four hours after collection.

Samples were analyzed by the Most Probable Number (MPN) multiple dilution tube fermentation test, using five tubes each for three dilutions, according to American Public Health Associaton (1971). Lauryl tryptose broth medium was used for the presumptive test. After 24 and 48 hours incubation at 35°C (±0.5°C) all positive tubes with gas production were transferred to brilliant green bile broth and EC Medium. Positive tubes with gas produced in brilliant green bile broth in 24 and 48 hours at 35°C (±0.5°C) were recorded as confirmed total coliforms. Fecal coliforms were determined by growth accompanied by gas production in 24 hours at 44.5°C (±0.5°C) in EC medium.

Appendix 8-6.--Florida Standards for Class II and Class III waters.

17-3.08 Criteria: Class II Waters - shellfish harvesting.

"The following criteria are for classification of waters in areas which either actually or potentially have the capability of supporting recreational or commercial shellfish propagation and harvesting. Harvesting may only occur in areas approved by the Division of Health, Florida Department of Health and Rehabilitative Services.

(1) Bacteriological Quality, Coliform Group - areas classified for shellfish harvesting, the median coliform MPN (Most Probable Number) of water cannot exceed seventy (70 per hundred (100) ml, and not more than ten (10) percent of the samples ordinarily exceed an MPN of two hundred and thirty (230) per one hundred (100) ml in those portions of areas most probably exposed to fecal contamination during most unfavorable hydrographic and pollutional conditions.

(2) Sewage, Industrial Wastes, or Other Wastes - any industrial wastes or other wastes shall be effectively treated by the latest modern technological advances as approved by the regulatory agency.

(3) pH - of receiving waters shall not be caused to vary more than one (1.0) unit above or below normal pH of the waters; and lower value shall be not less than six (6.0) and upper value not more than eight and one-half (8.5). In cases where pH may be, due to natural background or causes, outside limits stated above, approval of the regulatory agency shall be secured prior to introducing such material in waters of the state.

(4) Dissolved Oxygen - The concentration in all surface waters shall not average less than 5 mg/l in a 24-hour period and never less than 4 mg/l. Normal daily and seasonal fluctuations above these levels shall be maintained. Dissolved oxygen concentrations in estuaries and tidal tributaries shall not be less than 4.0 mg/l except in natural dystrophic waters. In those cases where background information indicates prior existence under unpolluted conditions of lower values than required above, lower limits may be utilized after approval by the regulatory authority. Sampling shall be performed according to the methods approved by the Florida Pollution Control Board.

(5) Toxic Substances - free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to humans, animal or aquatic life.

(6) Odor - threshold odor number not to exceed 24 at 60°C as a daily average."

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.101 FS. History-Formerly 28-5.08, Amended 6/10/72, 8/30/72, 7/3/73.

17-3.09 Criteria: Class III waters - recreation - propagation and management of fish and wildlife.

"The following criteria are for classification of waters to be used for recreational purposes, including such body contact activities as swimming and water skiing; and for the maintenance of a well-balanced fish and wildlife population. All surface waters within and coastal waters contiguous to these basins, including off-shore waters, not otherwise classified shall be classified as Class III; however, waters of the open ocean shall be maintained at a dissolved oxygen of not less than five (5.0) ml/l. Streams specifically listed in Section 17.3.21 by a separate listing designated as "Special Stream Classification" shall similarly be maintained at a minimum dissolved oxygen level of five (5.0) ml/l.

(1) Sewage, industrial wastes, or other wastes - any industrial waste or other wastes shall be effectively treated by the latest modern technological advances as approved by the regulatory agency.

(2) pH - of receiving waters shall not be caused to vary more than one (1.0) unit above or below normal pH of the waters; and lower value shall be not less than six (6.0), and upper value not more than eight and one-half (8.5). In cases where pH may be, due to natural background or causes outside limits stated above, approval of the regulatory agency shall be secured prior to introducing such material in waters of the state.

(3) Dissolved Oxygen - the concentration in all surface waters shall not average less than 5.0 mg/l in a 24-hour period and never less than 4.0 mg/l. Normal daily and seasonal fluctuations above these levels shall be maintained. Dissolved oxygen concentrations in estuaries and tidal tributaries shall not be less than 4.0 mg/l except in naturally dystrophic waters. In those cases where background information indicates prior existence under unpolluted conditions of lower values than required above, lower limits may be utilized after approval by the regulatory authority. Sampling shall be performed according to the methods approved by the Florida Pollution Control Board.

(4) Bacteriological - in those waters designated for body contact recreation, fecal coliform shall not exceed a monthly

average of 200 per 100 ml of sample, nor exceed 400 fecal coliform per 100 ml of sample in 10 percent of the samples, nor exceed 800 fecal coliform on any one day, nor exceed a total coliform count of 1,000 per 100 ml as a monthly average, nor exceed a total coliform count of 1,000 per 100 ml in more than 20 percent of the samples examined during any month; nor exceed 2,400 per 100 ml on any day. In those waters not normally used for body contact recreation, fecal coliform shall not exceed a monthly average of 500 per 100 ml of sample, nor exceed 750 fecal coliform per 100 ml of sample in 10 percent of the samples. Monthly averages shall be expressed as geometric means based on a minimum of 100 samples taken over a 30 day period. MPN or MF counts may be utilized.

(5) Toxic substances - free from substances attributable to municipal, industrial, agricultural or other discharges in concentrations or combinations which are toxic or harmful to humans, animal or aquatic life.

(6) Deleterious - free from material attributable to municipal, industrial, agricultural or other discharges producing color, odor or other conditions in such degree as to create a nuisance.

(7) Turbidity - shall not exceed fifty (50) Jackson units as related to standard candle turbidimeter above background."

General Authority 403.061 FS. Law Implemented 403.021, 403.031, 403.061, 403.101 FS. History-Formerly 28-5.09, Amended 6/10/72, 8/30/72, 7/3/73.

Appendix 8 - 7. Summary of total organic carbon (mg/l as C) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%	Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	4.8	1.0	11.0	56.3	ENNB	D	12	3.3	1.0	7.5	55.9
ADGV	E	12	3.8	1.0	7.0	51.3	ENNB	E	12	3.7	1.0	7.5	55.4
AGJI	A	12	4.2	1.0	10.0	56.4	EPLP	A	12	5.3	1.6	10.5	49.0
AGJI	B	12	3.7	1.0	7.0	48.0	EPLP	E	10	4.4	1.0	9.0	51.9
AGJI	C	12	4.2	2.0	6.1	35.4	EPRF	A	12	5.6	1.0	12.2	52.8
AGJI	D	12	4.1	1.0	8.5	51.1	EPRF	E	12	5.9	1.0	24.0	98.7
AGJI	E	11	3.7	1.0	7.5	55.9	ERPB	A	12	6.0	1.5	13.5	52.5
AGPH	A	12	4.3	1.0	11.7	65.6	ERPB	B	12	5.5	3.0	9.0	33.9
AGPH	E	12	3.6	1.0	6.5	43.0	ERPB	C	12	4.9	2.5	7.5	30.2
AJPD	A	12	3.9	1.0	8.0	52.8	ERPB	D	12	4.4	1.5	9.0	50.7
AJPD	E	12	3.6	1.0	9.2	67.6	ERPB	E	12	4.2	2.5	8.5	43.1
ALEX	A	12	3.9	1.0	5.7	37.6	ER10	A	12	6.5	1.0	11.0	46.6
ALEX	E	12	3.6	1.0	8.0	62.8	ER10	E	12	6.8	2.5	10.5	37.9
BPEI	A	5	6.1	1.0	14.4	81.1	ETLQ	A	12	4.9	2.5	9.5	44.6
BPEI	E	5	6.8	1.0	17.0	97.0	ETLQ	E	11	3.9	2.2	8.7	49.6
BJIV	A	12	4.6	1.0	15.2	84.6	ETQE	A	12	4.1	1.0	7.2	47.1
BJIV	E	12	4.7	1.0	14.3	79.8	ETQE	E	11	5.5	3.5	9.0	30.1
BNGA	A	12	5.4	1.0	15.8	75.2	PEUE	A	9	5.2	1.5	7.5	36.5
BNGA	E	12	4.1	1.0	9.5	64.6	PEUE	E	9	4.9	2.5	7.7	31.5
BREA	A	12	5.3	1.0	14.0	73.4	P01	A	10	3.2	1.0	7.5	60.4
BREA	E	12	5.0	1.0	10.5	54.8	P01	E	10	3.1	1.5	4.5	30.4
ECGM	A	12	6.7	1.0	20.0	89.8	P02	A	11	2.7	0.5	5.0	48.1
ECGM	E	12	5.9	3.0	12.5	45.0	P02	E	11	3.0	1.0	6.0	53.7
EEDR	A	12	5.6	2.5	11.0	49.4	P03	A	11	2.6	1.5	3.5	27.0
EEDR	E	12	5.6	1.0	12.0	62.4	P03	E	11	3.1	1.5	5.0	32.2
EEEM	A	12	5.7	1.0	14.9	68.4	P04	A	9	2.6	1.0	6.0	69.5
EEEM	E	12	6.4	1.0	16.3	58.7	P04	E	10	2.6	0.5	6.5	82.9
EEIX	A	12	5.9	4.0	13.0	43.0	P05	A	11	2.5	1.0	4.5	42.5
EEIX	E	12	5.6	2.5	10.7	46.5	P05	B	11	2.9	1.5	4.0	31.3
EEKV	A	12	6.7	3.2	17.2	62.7	P05	C	9	2.8	2.0	4.0	31.3
EEKV	E	12	5.4	2.5	10.5	40.8	P05	D	10	2.6	1.0	3.5	29.8
EGLY	A	12	5.7	1.0	9.0	37.8	P05	E	10	3.2	1.5	5.0	46.1
EGLY	B	12	5.4	1.0	10.6	43.2	P06	A	11	3.9	2.0	7.0	40.0
EGLY	C	12	5.6	1.0	12.1	57.0	P06	E	10	4.5	1.5	8.5	49.5
EGLY	D	11	5.6	2.5	14.0	57.6	P07	A	10	5.4	3.0	7.5	30.5
EGLY	E	12	5.5	1.7	9.5	53.8	P07	E	9	4.6	0.0	7.0	44.4
EHGD	A	12	5.5	1.0	13.4	66.3	P08	A	11	4.8	3.0	7.0	31.2
EHGD	E	11	5.5	1.0	15.1	74.9	P08	E	11	4.4	2.0	8.0	33.6
EHPK	A	12	6.6	3.5	10.5	28.0	P09	A	10	3.5	1.5	6.0	44.0
EHPK	E	12	6.2	1.0	13.0	46.4	P09	E	11	3.0	1.0	6.0	51.6
EIIL	A	12	5.3	1.0	11.0	51.7	P10	A	10	3.9	1.5	7.0	42.6
EIIL	E	12	5.1	1.0	10.0	55.8	P10	E	11	4.0	2.0	9.5	56.7
EIKC	A	12	5.3	1.0	12.5	61.0	P11	A	11	4.9	2.5	7.5	32.2
EIKC	E	12	5.1	1.0	14.0	68.7	P11	E	10	5.0	3.0	8.0	33.8
EKLQ	A	12	4.9	1.0	11.5	54.4	P12	A	11	4.0	1.0	8.0	64.6
EKLQ	E	12	4.2	1.0	9.3	52.4	P12	E	11	4.2	1.5	9.5	51.9
EKMP	A	12	5.2	2.0	11.5	50.1	P13	A	9	3.7	2.0	6.5	43.7
EKMP	B	12	4.9	1.0	9.3	44.3	P13	B	10	4.0	2.0	7.5	40.7
EKMP	C	11	4.0	1.6	5.5	33.4	P13	C	10	3.6	2.0	6.0	38.6
EKMP	D	11	3.9	1.0	9.0	54.9	P13	D	11	3.5	1.0	5.0	29.3
EKMP	E	12	4.0	1.0	7.5	46.5	P13	E	10	3.9	1.5	6.0	30.7
EMQC	A	12	4.4	1.8	6.5	34.6	P14	A	10	3.8	1.0	5.0	37.8
EMQC	E	12	3.6	1.0	6.2	43.4	P14	E	9	3.9	2.5	6.5	37.7
ENNB	A	12	5.5	1.6	10.0	49.1	P15	A	10	4.0	1.5	6.0	39.5
ENNB	B	12	5.4	1.6	9.0	45.0	P15	E	11	4.3	2.0	8.0	42.8
ENNB	C	11	4.2	2.0	9.0	44.3							

Appendix 8 - 8. Summary of ammonia (mg/l as N) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.027	0.010	0.080	87.486
ADGV	E	12	0.072	0.010	0.226	101.055
AGJI	A	12	0.028	0.010	0.116	109.957
AGJI	B	12	0.025	0.010	0.080	81.162
AGJI	C	12	0.024	0.010	0.075	82.219
AGJI	D	12	0.051	0.010	0.282	151.369
AGJI	E	12	0.077	0.010	0.262	103.691
AGPH	A	12	0.032	0.010	0.152	128.091
AGPH	E	12	0.053	0.010	0.170	94.092
AJFD	A	12	0.027	0.010	0.075	76.069
AJFD	E	12	0.062	0.010	0.177	86.121
ALEX	A	12	0.021	0.010	0.058	74.010
ALEX	E	12	0.087	0.010	0.197	72.637
BFEI	A	5	0.041	0.020	0.058	33.452
BFEI	E	4	0.099	0.050	0.225	85.466
BJIV	A	12	0.025	0.010	0.075	79.489
BJIV	E	12	0.044	0.010	0.105	84.608
BNGA	A	12	0.024	0.010	0.058	62.343
BNGA	E	12	0.064	0.010	0.170	92.483
BREA	A	12	0.024	0.010	0.075	82.112
BREA	E	12	0.092	0.010	0.282	97.271
ECGM	A	12	0.035	0.012	0.090	60.548
ECGM	E	12	0.105	0.012	0.312	92.102
EEDR	A	12	0.036	0.012	0.090	56.536
EEDR	E	12	0.073	0.012	0.275	103.116
EEEM	A	12	0.031	0.010	0.090	69.060
EEEM	E	12	0.066	0.015	0.259	121.436
EEIX	A	12	0.057	0.010	0.277	129.015
EEIX	E	12	0.039	0.010	0.090	67.998
EEKV	A	12	0.051	0.010	0.172	95.948
EEKV	E	12	0.091	0.010	0.530	160.734
EGLY	A	12	0.064	0.018	0.145	56.195
EGLY	B	12	0.097	0.012	0.308	99.753
EGLY	C	12	0.093	0.010	0.325	104.568
EGLY	D	12	0.083	0.010	0.278	102.824
EGLY	E	12	0.218	0.012	1.350	170.769
EHGD	A	12	0.038	0.012	0.090	52.801
EHGD	E	11	0.096	0.012	0.250	83.959
EHPK	A	12	0.066	0.010	0.182	95.059
EHPK	E	12	0.075	0.010	0.180	96.345
EIIL	A	12	0.037	0.010	0.103	69.991
EIIL	E	12	0.069	0.010	0.198	94.248
EIKC	A	12	0.046	0.012	0.111	55.769
EIKC	E	12	0.113	0.010	0.342	89.205
EKLQ	A	12	0.035	0.010	0.090	67.271
EKLQ	E	12	0.080	0.010	0.242	89.791
EKMP	A	12	0.038	0.010	0.098	68.477
EKMP	B	12	0.039	0.010	0.125	86.127
EKMP	C	12	0.079	0.010	0.270	118.630
EKMP	D	12	0.096	0.010	0.442	121.436
EKMP	E	12	0.114	0.022	0.442	99.454
EMQC	A	12	0.048	0.010	0.130	101.868
EMQC	E	12	0.067	0.010	0.276	120.305
ENNB	A	12	0.036	0.010	0.130	106.695
ENNB	B	12	0.038	0.010	0.130	103.205
ENNB	C	12	0.090	0.010	0.335	120.110
ENNB	D	12	0.079	0.010	0.272	95.221
ENNB	E	12	0.094	0.012	0.292	84.523
EPLP	A	12	0.034	0.010	0.130	103.886
EPLP	E	12	0.060	0.010	0.265	122.147
EPRF	A	12	0.039	0.010	0.111	95.939
EPRF	E	12	0.057	0.010	0.182	100.376
ERPB	A	12	0.042	0.010	0.170	115.946
ERPB	B	12	0.039	0.010	0.148	108.515
ERPB	C	12	0.043	0.010	0.170	113.302
ERPB	D	12	0.050	0.010	0.202	119.436
ERPB	E	12	0.084	0.010	0.230	86.127
ER10	A	12	0.034	0.010	0.080	55.072
ER10	E	12	0.031	0.010	0.080	63.548
ETLQ	A	12	0.034	0.010	0.148	117.421
ETLQ	E	12	0.093	0.015	0.180	57.539
ETQE	A	12	0.034	0.010	0.103	92.920
ETQE	E	12	0.058	0.010	0.145	90.363
PEUE	A	9	0.022	0.010	0.075	97.607
PEUE	E	9	0.037	0.010	0.215	179.549
P01	A	11	0.022	0.005	0.049	76.196
P01	E	11	0.017	0.005	0.041	81.843
P02	A	11	0.022	0.005	0.060	88.396
P02	E	11	0.028	0.005	0.069	88.775
P03	A	11	0.031	0.005	0.173	158.326
P03	E	11	0.037	0.005	0.114	101.037
P04	A	11	0.035	0.005	0.128	110.668
P04	E	11	0.039	0.005	0.113	89.474
P05	A	11	0.034	0.005	0.154	132.588
P05	B	11	0.022	0.005	0.080	111.177
P05	C	11	0.032	0.005	0.092	106.727
P05	D	10	0.036	0.006	0.121	105.356
P05	E	11	0.056	0.009	0.128	79.506
P06	A	11	0.033	0.005	0.111	97.463
P06	E	11	0.076	0.005	0.202	77.334
P07	A	11	0.035	0.005	0.105	94.806
P07	E	11	0.085	0.005	0.205	76.502
P08	A	11	0.034	0.005	0.084	89.603
P08	E	11	0.058	0.005	0.235	114.257
P09	A	11	0.029	0.005	0.076	86.716
P09	E	11	0.030	0.005	0.063	67.746
P10	A	11	0.026	0.005	0.088	108.049
P10	E	11	0.057	0.005	0.163	78.455
P11	A	11	0.036	0.006	0.114	100.630
P11	E	11	0.104	0.006	0.335	104.517
P12	A	11	0.038	0.005	0.147	111.683
P12	E	11	0.088	0.005	0.244	76.864
P13	A	11	0.032	0.005	0.071	90.639
P13	B	11	0.022	0.006	0.050	73.528
P13	C	11	0.034	0.006	0.077	77.915
P13	D	11	0.052	0.005	0.168	96.195
P13	E	11	0.078	0.005	0.238	90.686
P14	A	11	0.020	0.005	0.045	71.214
P14	E	11	0.070	0.005	0.199	98.323
P15	A	11	0.031	0.005	0.135	120.058
P15	E	11	0.096	0.005	0.275	93.549

Appendix 8 - 9. Summary of nitrate nitrite (mg/l - N) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.030	0.010	0.080	77.496
ADGV	B	12	0.029	0.010	0.070	72.957
AGJI	A	12	0.021	0.010	0.065	86.338
AGJI	B	12	0.020	0.010	0.060	88.126
AGJI	C	12	0.018	0.010	0.052	85.179
AGJI	D	12	0.020	0.010	0.052	80.507
AGJI	E	12	0.024	0.010	0.052	74.918
AGPH	A	12	0.020	0.010	0.060	84.227
AGPH	B	12	0.022	0.010	0.050	70.124
AJPD	A	12	0.023	0.010	0.055	73.807
AJPD	B	12	0.024	0.010	0.055	77.010
ALEX	A	12	0.021	0.010	0.055	72.087
ALEX	B	12	0.028	0.010	0.076	78.394
BFEI	A	5	0.093	0.030	0.124	39.248
BFEI	B	5	0.040	0.029	0.070	42.537
EJIV	A	12	0.065	0.022	0.095	34.020
EJIV	B	12	0.046	0.010	0.105	59.790
ENGA	A	12	0.055	0.021	0.100	40.977
ENGA	B	12	0.032	0.010	0.100	79.409
EREA	A	12	0.036	0.010	0.085	67.777
EREA	B	12	0.028	0.010	0.060	67.107
ECGM	A	12	0.132	0.050	0.210	34.463
ECGM	B	12	0.101	0.030	0.159	42.271
EEDR	A	12	0.149	0.052	0.237	38.663
EEDR	B	12	0.126	0.035	0.237	50.813
EEEM	A	12	0.136	0.054	0.225	35.677
EEEM	B	12	0.115	0.011	0.213	54.813
EEIX	A	12	0.103	0.053	0.159	31.311
EEIX	B	12	0.095	0.022	0.155	44.298
EEKV	A	12	0.089	0.010	0.140	48.643
EEKV	B	12	0.076	0.010	0.130	53.780
EGLY	A	12	0.086	0.010	0.210	67.340
EGLY	B	12	0.090	0.010	0.210	71.419
EGLY	C	12	0.092	0.010	0.225	81.171
EGLY	D	12	0.073	0.010	0.220	89.679
EGLY	E	12	0.080	0.010	0.335	123.666
EHGD	A	12	0.149	0.054	0.252	36.770
EHGD	B	12	0.068	0.020	0.140	58.217
EHPK	A	12	0.074	0.010	0.300	113.495
EHPK	B	12	0.075	0.010	0.345	129.254
EIIL	A	12	0.099	0.047	0.145	36.003
EIIL	B	12	0.070	0.016	0.135	57.658
EIKC	A	12	0.108	0.071	0.165	25.645
EIKC	B	12	0.061	0.019	0.135	59.754
EKLQ	A	12	0.088	0.010	0.140	42.485
EKLQ	B	12	0.067	0.022	0.135	53.303
EKMP	A	12	0.080	0.010	0.130	50.475
EKMP	B	12	0.068	0.010	0.130	69.534
EKMP	C	12	0.048	0.010	0.135	82.346
EKMP	D	12	0.040	0.010	0.135	95.234
EKMP	E	12	0.038	0.010	0.120	91.549
EMQC	A	12	0.063	0.010	0.182	87.724
EMQC	B	12	0.041	0.010	0.110	88.679
ENNB	A	12	0.059	0.010	0.130	71.877
ENNB	B	12	0.055	0.010	0.130	84.453
ENNB	C	12	0.049	0.010	0.130	88.261
ENNB	D	12	0.041	0.010	0.125	87.435
ENNB	E	12	0.043	0.010	0.125	83.086
EPLP	A	12	0.051	0.010	0.115	79.891
EPLP	B	12	0.048	0.010	0.115	82.329
EPRF	A	12	0.049	0.010	0.125	83.857
EPRF	B	12	0.038	0.010	0.095	81.440
ERPB	A	12	0.051	0.010	0.120	83.294
ERPB	B	11	0.050	0.010	0.125	89.666
ERPB	C	12	0.042	0.010	0.100	79.409
ERPB	D	12	0.031	0.010	0.087	85.053
ERPB	E	12	0.029	0.010	0.077	79.663
ER10	A	12	0.135	0.039	0.220	40.174
ER10	B	12	0.141	0.045	0.235	40.786
ETLQ	A	12	0.045	0.010	0.116	91.340
ETLQ	B	12	0.034	0.010	0.070	57.551
ETQB	A	12	0.058	0.010	0.242	113.828
ETQB	B	12	0.032	0.010	0.087	78.922
PEUE	A	9	0.029	0.010	0.080	100.511
PEUE	B	9	0.020	0.010	0.050	78.950
P01	A	11	0.033	0.009	0.156	126.680
P01	B	12	0.013	0.005	0.044	76.299
P02	A	12	0.015	0.005	0.060	108.926
P02	B	12	0.016	0.005	0.046	89.758
P03	A	12	0.012	0.005	0.053	109.192
P03	B	12	0.011	0.005	0.020	47.515
P04	A	12	0.014	0.005	0.049	97.662
P04	B	12	0.010	0.005	0.021	49.837
P05	A	12	0.013	0.005	0.063	122.226
P05	B	12	0.017	0.005	0.041	77.074
P05	C	12	0.013	0.005	0.034	62.639
P05	D	12	0.010	0.005	0.017	31.492
P05	E	12	0.014	0.005	0.029	50.782
P06	A	12	0.018	0.005	0.066	95.112
P06	B	12	0.031	0.010	0.092	73.688
P07	A	12	0.107	0.009	0.670	181.056
P07	B	12	0.042	0.005	0.210	129.283
P08	A	12	0.029	0.005	0.070	85.676
P08	B	12	0.018	0.005	0.058	76.693
P09	A	12	0.022	0.005	0.054	90.536
P09	B	12	0.015	0.005	0.050	85.714
P10	A	12	0.021	0.005	0.067	99.829
P10	B	12	0.024	0.005	0.086	98.077
P11	A	12	0.030	0.005	0.076	90.253
P11	B	12	0.032	0.005	0.091	86.208
P12	A	12	0.029	0.005	0.076	94.989
P12	B	12	0.035	0.005	0.110	89.252
P13	A	12	0.027	0.005	0.084	102.873
P13	B	12	0.025	0.005	0.104	125.421
P13	C	12	0.024	0.005	0.086	110.263
P13	D	12	0.017	0.005	0.048	69.646
P13	E	12	0.024	0.005	0.074	87.297
P14	A	12	0.021	0.005	0.059	84.389
P14	B	12	0.024	0.005	0.059	85.183
P15	A	12	0.022	0.005	0.060	93.446
P15	B	12	0.029	0.005	0.071	78.159

Appendix 8 - 10. Summary of organic nitrogen (mg/l as N) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.209	0.029	0.470	62.8
ADGV	E	12	0.238	0.025	0.488	50.7
AGJI	A	12	0.199	0.052	0.570	70.1
AGJI	B	12	0.206	0.040	0.550	63.3
AGJI	C	12	0.206	0.025	0.540	64.1
AGJI	D	12	0.189	0.025	0.320	35.6
AGJI	E	12	0.256	0.013	0.695	90.3
AGPH	A	12	0.196	0.020	0.700	92.0
AGPH	E	12	0.231	0.080	0.640	67.3
AJFD	A	12	0.237	0.062	0.610	58.3
AJFD	E	12	0.247	0.060	0.670	70.2
ALEX	A	12	0.283	0.120	0.640	49.6
ALEX	E	12	0.263	0.085	0.780	67.1
BPEI	A	5	0.311	0.003	1.138	151.1
BPEI	E	4	0.159	0.115	0.185	20.1
BJIV	A	12	0.153	0.029	0.350	73.1
BJIV	E	12	0.195	0.065	0.490	61.8
BNGA	A	12	0.148	0.035	0.310	67.2
BNGA	E	11	0.218	0.015	0.455	58.4
BREA	A	12	0.176	0.0	0.355	59.7
BREA	E	11	0.261	0.013	0.700	85.8
ECGM	A	12	0.240	0.007	0.449	57.7
ECGM	E	12	0.284	0.022	0.662	72.5
EEDR	A	12	0.358	0.027	1.375	97.1
EEDR	E	12	0.317	0.025	1.008	74.6
EEEM	A	12	0.202	0.010	0.360	52.5
EEEM	E	12	0.239	0.010	0.445	45.1
EEIX	A	12	0.222	0.036	0.460	55.7
EEIX	E	12	0.267	0.023	0.520	47.8
EEKV	A	12	0.336	0.130	0.648	50.8
EEKV	E	12	0.406	0.090	1.169	68.3
EGLY	A	12	0.360	0.055	0.668	45.7
EGLY	B	12	0.386	0.125	0.898	56.5
EGLY	C	12	0.467	0.075	1.058	66.5
EGLY	D	12	0.340	0.0	0.555	49.2
EGLY	E	11	0.393	0.083	0.728	51.6
EHGD	A	12	0.233	0.015	0.448	63.6
EHGD	E	11	0.300	0.070	0.428	36.4
EHPK	A	12	0.425	0.285	0.680	23.6
EHPK	E	12	0.366	0.147	0.518	35.6
EIIL	A	12	0.247	0.095	0.345	32.1
EIIL	E	12	0.295	0.085	0.540	43.9
EIKC	A	12	0.247	0.115	0.363	31.1
EIKC	E	12	0.316	0.010	0.628	52.0
EKLQ	A	12	0.282	0.065	0.403	39.4
EKLQ	E	12	0.314	0.004	0.598	48.1
EKMP	A	12	0.292	0.103	0.590	46.3
EKMP	B	12	0.317	0.052	0.440	32.0
EKMP	C	11	0.309	0.055	0.520	47.4
EKMP	D	12	0.313	0.012	0.640	53.3
EKMP	E	12	0.297	0.075	0.600	56.5
EMQC	A	12	0.308	0.060	0.475	37.1
EMQC	E	12	0.250	0.048	0.425	42.9
ENNB	A	12	0.260	0.063	0.370	38.9
ENNB	B	12	0.307	0.140	0.530	38.6
ENNB	C	12	0.359	0.175	0.645	43.3
ENNB	D	12	0.351	0.077	0.665	52.3
ENNB	E	12	0.301	0.022	0.565	54.3
EPLP	A	12	0.286	0.067	0.440	39.5
EPLP	E	10	0.297	0.158	0.450	34.6
EPRF	A	12	0.274	0.147	0.440	29.0
EPRF	E	12	0.229	0.040	0.418	53.4
ERPB	A	11	0.291	0.036	0.510	45.7
ERPB	B	12	0.301	0.063	0.510	40.7
ERPB	C	12	0.263	0.022	0.645	55.6
ERPB	D	12	0.232	0.022	0.448	54.8
ERPB	E	11	0.260	0.0	0.520	59.4
ER10	A	12	0.213	0.085	0.380	49.0
ER10	E	12	0.207	0.018	0.390	58.2
ETLQ	A	12	0.262	0.090	0.470	41.5
ETLQ	E	12	0.288	0.010	0.563	51.3
ETQE	A	12	0.257	0.097	0.440	36.3
ETQE	E	11	0.249	0.027	0.490	51.8
PEUE	A	9	0.357	0.085	0.690	56.2
PEUE	E	8	0.440	0.060	1.060	72.4
PC 1	A	12	0.158	0.030	0.396	67.1
PC 1	E	12	0.243	0.082	0.617	69.5
PC 2	A	12	0.208	0.078	0.385	51.7
PC 2	E	12	0.223	0.040	0.961	118.5
PC 3	A	12	0.206	0.013	0.485	73.5
PC 3	E	12	0.314	0.070	1.026	84.0
PC4	A	12	0.182	0.0	0.453	80.0
PC4	E	12	0.222	0.0	0.426	65.8
PC5	A	12	0.242	0.063	0.591	70.9
PC5	B	12	0.216	0.035	0.615	84.4
PC5	C	12	0.143	0.0	0.385	75.2
PC5	D	12	0.193	0.034	0.499	77.0
PC5	E	12	0.147	0.036	0.457	83.2
PC6	A	12	0.180	0.0	0.382	68.7
PC6	E	12	0.211	0.052	0.885	111.8
PC7	A	12	0.186	0.0	0.430	79.0
PC7	E	12	0.148	0.0	0.475	95.5
PC8	A	12	0.163	0.006	0.420	78.2
PC8	E	12	0.192	0.038	0.639	93.5
PC9	A	12	0.185	0.026	0.525	90.9
PC9	E	12	0.232	0.043	0.521	80.2
P10	A	12	0.154	0.0	0.433	88.0
P10	E	12	0.208	0.0	0.882	135.6
P11	A	12	0.218	0.0	0.800	101.8
P11	E	12	0.151	0.0	0.411	93.7
P12	A	12	0.174	0.0	0.379	70.0
P12	E	12	0.244	0.0	0.803	111.0
P13	A	12	0.201	0.013	0.422	60.7
P13	B	12	0.234	0.056	0.724	90.1
P13	C	12	0.253	0.0	0.493	65.7
P13	D	12	0.175	0.027	0.412	77.2
P13	E	12	0.258	0.0	0.492	55.8
P14	A	12	0.258	0.033	0.735	73.0
P14	E	12	0.256	0.0	0.736	97.1
P15	A	12	0.237	0.020	0.785	99.7
P15	E	12	0.265	0.0	0.703	95.1

Appendix 8 - 11. Summary of total nitrogen (mg/l as N) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.267	0.060	0.580	53.1
ADGV	B	12	0.339	0.060	0.510	34.7
AGJI	A	12	0.248	0.080	0.590	55.4
AGJI	B	12	0.251	0.060	0.570	52.8
AGJI	C	12	0.248	0.060	0.560	55.8
AGJI	D	12	0.259	0.060	0.500	43.1
AGJI	E	12	0.357	0.090	0.784	59.1
AGPH	A	12	0.248	0.060	0.720	71.7
AGPH	E	12	0.306	0.100	0.680	50.9
AJFD	A	12	0.287	0.100	0.630	49.3
AJFD	E	12	0.334	0.131	0.715	55.9
ALEX	A	12	0.325	0.140	0.660	44.6
ALEX	E	12	0.378	0.201	0.825	44.8
BFEI	A	5	0.445	0.157	1.304	108.7
BFEI	E	4	0.256	0.120	0.372	40.5
BJIV	A	12	0.243	0.100	0.487	47.5
BJIV	E	12	0.284	0.170	0.530	40.0
BNGA	A	12	0.226	0.071	0.367	47.0
BNGA	E	12	0.294	0.060	0.491	45.1
BREA	A	12	0.236	0.025	0.456	55.1
BREA	E	12	0.356	0.060	0.720	54.3
ECGM	A	12	0.407	0.245	0.630	31.1
ECGM	E	12	0.490	0.289	0.773	32.9
EEDR	A	12	0.544	0.275	1.585	64.4
EEDR	E	12	0.517	0.295	1.150	40.8
EEEM	A	12	0.370	0.200	0.485	24.7
EEEM	E	12	0.429	0.257	0.555	20.4
EEIX	A	12	0.361	0.192	0.588	31.1
EEIX	E	12	0.401	0.245	0.562	23.5
EEKV	A	12	0.476	0.268	0.960	39.3
EEKV	E	12	0.573	0.258	1.281	48.0
EGLY	A	12	0.510	0.115	0.880	42.1
EGLY	B	12	0.573	0.175	1.262	46.5
EGLY	C	12	0.652	0.128	1.510	66.1
EGLY	D	12	0.493	0.102	0.940	50.9
EGLY	E	11	0.565	0.147	1.055	46.9
EHGD	A	12	0.420	0.202	0.642	33.5
EHGD	E	11	0.465	0.320	0.603	19.7
EHPK	A	12	0.564	0.330	0.890	26.9
EHPK	E	12	0.516	0.215	0.995	37.1
EIIL	A	12	0.383	0.220	0.491	21.4
EIIL	E	12	0.434	0.197	0.657	29.3
EIKC	A	12	0.401	0.238	0.595	21.3
EIKC	E	12	0.491	0.218	0.917	40.9
EKLQ	A	12	0.405	0.161	0.561	27.2
EKLQ	E	12	0.461	0.220	0.742	28.3
EKMP	A	12	0.410	0.130	0.730	39.0
EKMP	B	12	0.424	0.090	0.602	30.7
EKMP	C	11	0.430	0.100	0.857	49.2
EKMP	D	12	0.449	0.080	0.942	47.6
EKMP	E	12	0.449	0.195	0.797	39.8
EMQC	A	12	0.419	0.100	0.672	38.1
EMQC	E	12	0.358	0.105	0.516	36.2
ENNB	A	12	0.356	0.148	0.562	29.5
ENNB	B	12	0.401	0.180	0.677	36.6
ENNB	C	12	0.499	0.290	1.088	43.7
ENNB	D	12	0.472	0.157	0.778	37.8
ENNB	E	12	0.439	0.110	0.674	32.1
EPLP	A	12	0.371	0.107	0.598	39.0
EPLP	E	10	0.380	0.218	0.540	23.1
EPRF	A	12	0.363	0.175	0.585	34.1
EPRF	E	12	0.325	0.062	0.475	43.2
ERPB	A	12	0.358	0.060	0.630	50.0
ERPB	B	12	0.385	0.095	0.662	43.5
ERPB	C	12	0.348	0.069	0.717	47.4
ERPB	D	12	0.313	0.060	0.505	50.9
ERPB	E	12	0.351	0.120	0.567	44.4
ER10	A	12	0.382	0.225	0.502	23.1
ER10	E	12	0.379	0.227	0.500	25.7
ETLQ	A	12	0.341	0.125	0.522	39.7
ETLQ	E	12	0.415	0.120	0.655	34.4
ETQE	A	12	0.350	0.125	0.545	33.7
ETQE	E	12	0.318	0.065	0.587	47.7
PEUE	A	9	0.407	0.135	0.710	46.3
PEUE	E	9	0.447	0.105	1.080	69.0
P01	A	12	0.209	0.089	0.420	50.2
P01	E	12	0.271	0.095	0.640	61.7
P02	A	12	0.243	0.090	0.430	49.8
P02	E	12	0.264	0.059	1.040	103.4
P03	A	12	0.247	0.090	0.512	58.9
P03	E	12	0.359	0.089	1.140	81.1
P04	A	12	0.225	0.010	0.536	69.2
P04	E	12	0.265	0.095	0.469	54.3
P05	A	12	0.286	0.075	0.693	64.7
P05	B	12	0.252	0.090	0.675	73.5
P05	C	12	0.179	0.031	0.400	61.7
P05	D	12	0.233	0.069	0.530	61.5
P05	E	12	0.212	0.080	0.604	72.8
P06	A	12	0.228	0.089	0.439	49.0
P06	E	12	0.312	0.096	1.102	91.2
P07	A	12	0.323	0.085	0.760	62.1
P07	E	12	0.258	0.070	0.770	79.7
P08	A	12	0.222	0.090	0.464	56.8
P08	E	12	0.264	0.072	0.709	72.2
P09	A	12	0.234	0.095	0.537	65.9
P09	E	12	0.275	0.092	0.580	65.1
P10	A	12	0.197	0.080	0.445	62.1
P10	E	12	0.282	0.067	0.969	106.5
P11	A	12	0.279	0.080	0.826	77.2
P11	E	12	0.275	0.110	0.487	53.9
P12	A	12	0.232	0.080	0.506	55.7
P12	E	12	0.354	0.070	0.972	78.4
P13	A	12	0.257	0.103	0.435	44.1
P13	B	12	0.279	0.089	0.781	76.5
P13	C	12	0.308	0.089	0.560	54.3
P13	D	12	0.239	0.069	0.475	61.3
P13	E	12	0.351	0.110	0.687	51.5
P14	A	12	0.298	0.095	0.827	66.4
P14	E	12	0.342	0.084	0.909	77.1
P15	A	12	0.288	0.096	0.980	92.7
P15	E	12	0.377	0.085	0.855	70.9

Appendix 8 - 12. Summary of total phosphorus (mg/l as P) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%	Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.014	0.010	0.030	42.9	ENNB	D	12	0.042	0.016	0.118	67.9
ADGV	E	12	0.022	0.010	0.054	63.4	ENNB	E	12	0.039	0.014	0.088	53.0
AGJI	A	12	0.013	0.010	0.027	39.3	EPLP	A	12	0.027	0.013	0.049	44.5
AGJI	B	12	0.013	0.010	0.030	43.6	EPLP	E	12	0.030	0.010	0.054	52.9
AGJI	C	11	0.012	0.010	0.023	32.7	EPRP	A	12	0.018	0.010	0.031	39.6
AGJI	D	12	0.014	0.010	0.031	44.4	EPRP	E	12	0.021	0.010	0.037	44.6
AGJI	E	12	0.019	0.010	0.040	41.8	ERPB	A	12	0.019	0.010	0.045	51.9
AGPH	A	12	0.013	0.010	0.021	26.3	ERPB	B	12	0.021	0.010	0.037	54.2
AGPH	E	12	0.018	0.010	0.036	40.6	ERPB	C	12	0.018	0.010	0.027	36.4
AJFD	A	12	0.013	0.010	0.019	24.2	ERPB	D	12	0.018	0.010	0.029	35.7
AJFD	E	12	0.021	0.010	0.031	35.1	ERPB	E	12	0.028	0.010	0.048	48.1
ALEX	A	12	0.018	0.010	0.083	114.2	ER10	A	12	0.040	0.024	0.055	22.4
ALEX	E	12	0.021	0.010	0.042	39.6	ER10	E	12	0.040	0.027	0.070	30.5
BPEI	A	5	0.018	0.010	0.026	36.5	ETLQ	A	12	0.023	0.010	0.067	70.0
BPEI	E	5	0.024	0.019	0.029	18.2	ETLQ	E	12	0.039	0.010	0.139	90.6
BJIV	A	12	0.019	0.011	0.030	27.4	ETQE	A	12	0.016	0.010	0.028	40.5
BJIV	E	12	0.026	0.010	0.065	53.7	ETQE	E	12	0.018	0.012	0.040	43.8
BNGA	A	12	0.017	0.010	0.024	29.9	PEUE	A	9	0.026	0.016	0.037	28.8
BNGA	E	11	0.020	0.011	0.027	25.4	PEUE	E	9	0.030	0.021	0.052	33.4
BREA	A	12	0.016	0.010	0.032	49.1	P01	A	12	0.047	0.010	0.260	146.4
BREA	E	12	0.022	0.013	0.052	49.0	P01	E	12	0.021	0.006	0.041	52.4
ECGM	A	12	0.033	0.019	0.072	42.5	P02	A	12	0.022	0.007	0.063	72.9
ECGM	E	12	0.035	0.017	0.056	40.2	P02	E	12	0.020	0.010	0.058	67.8
EEDR	A	12	0.040	0.020	0.068	37.6	P03	A	12	0.020	0.006	0.080	104.3
EEDR	E	12	0.038	0.023	0.075	34.9	P03	E	12	0.040	0.005	0.230	151.8
EEEM	A	12	0.033	0.022	0.070	39.3	P04	A	12	0.022	0.005	0.056	74.0
EEEM	E	12	0.041	0.025	0.120	63.1	P04	E	12	0.028	0.006	0.045	47.4
EEIX	A	12	0.033	0.018	0.060	35.8	P05	A	12	0.021	0.007	0.071	88.0
EEIX	E	12	0.036	0.022	0.057	27.4	P05	B	12	0.017	0.007	0.031	52.4
EEKV	A	12	0.030	0.018	0.055	35.0	P05	C	12	0.017	0.006	0.037	73.1
EEKV	E	12	0.033	0.020	0.053	31.5	P05	D	12	0.018	0.005	0.045	67.4
EGLY	A	12	0.027	0.015	0.048	36.8	P05	E	12	0.029	0.007	0.059	64.0
EGLY	B	12	0.031	0.017	0.055	39.8	P06	A	12	0.022	0.007	0.081	91.0
EGLY	C	12	0.034	0.016	0.066	45.9	P06	E	12	0.027	0.006	0.060	61.4
EGLY	D	12	0.034	0.014	0.062	48.4	P07	A	12	0.077	0.006	0.600	215.7
EGLY	E	12	0.033	0.014	0.060	46.6	P07	E	12	0.037	0.010	0.085	54.9
EHGD	A	12	0.037	0.020	0.070	38.1	P08	A	12	0.021	0.006	0.037	54.8
EHGD	E	12	0.043	0.025	0.142	72.7	P08	E	12	0.036	0.005	0.080	59.0
EHPK	A	12	0.034	0.010	0.059	45.2	P09	A	12	0.018	0.005	0.039	62.6
EHPK	E	12	0.034	0.014	0.066	40.1	P09	E	12	0.018	0.005	0.034	55.3
EIIL	A	12	0.031	0.019	0.064	39.8	P10	A	12	0.016	0.007	0.026	41.1
EIIL	E	12	0.030	0.011	0.047	38.9	P10	E	12	0.031	0.005	0.075	65.9
EIKC	A	12	0.028	0.014	0.055	40.9	P11	A	12	0.025	0.005	0.047	52.3
EIKC	E	11	0.046	0.014	0.160	88.3	P11	E	12	0.030	0.005	0.056	53.0
EKLQ	A	12	0.025	0.014	0.055	46.5	P12	A	12	0.021	0.005	0.066	79.1
EKLQ	E	12	0.031	0.016	0.060	38.4	P12	E	12	0.032	0.005	0.071	69.0
EKMP	A	12	0.028	0.013	0.052	50.3	P13	A	12	0.016	0.006	0.035	51.8
EKMP	B	12	0.028	0.011	0.050	44.5	P13	B	12	0.016	0.005	0.032	61.9
EKMP	C	12	0.027	0.013	0.044	41.0	P13	C	12	0.017	0.005	0.039	62.4
EKMP	D	12	0.033	0.016	0.070	48.1	P13	D	12	0.020	0.005	0.042	65.1
EKMP	E	12	0.034	0.019	0.055	32.2	P13	E	12	0.036	0.006	0.146	105.5
EMQC	A	12	0.022	0.010	0.051	50.1	P14	A	12	0.016	0.006	0.032	58.4
EMQC	E	12	0.022	0.010	0.037	38.7	P14	E	12	0.030	0.005	0.084	79.5
ENNB	A	12	0.023	0.013	0.051	54.7	P15	A	12	0.020	0.005	0.075	98.2
ENNB	B	11	0.028	0.011	0.070	67.9	P15	E	11	0.026	0.005	0.047	50.3

Appendix 8 - 13. Summary of dissolved orthophosphorus (mg/l as P) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.010	0.010	0.010	0.0
ADGV	E	12	0.010	0.010	0.010	0.0
AGJI	A	12	0.010	0.010	0.010	0.0
AGJI	B	12	0.010	0.010	0.010	0.0
AGJI	C	12	0.010	0.010	0.010	0.0
AGJI	D	12	0.010	0.010	0.010	0.0
AGJI	E	12	0.010	0.010	0.012	5.7
AGPH	A	12	0.010	0.010	0.010	0.0
AGPH	E	12	0.010	0.010	0.010	0.0
AJPD	A	12	0.010	0.010	0.010	0.0
AJPD	E	12	0.010	0.010	0.010	0.0
ALEX	A	12	0.010	0.010	0.012	5.7
ALEX	E	12	0.010	0.010	0.010	0.0
BPEI	A	5	0.010	0.010	0.010	0.0
BPEI	E	5	0.010	0.010	0.010	0.0
BJIV	A	12	0.010	0.010	0.010	0.0
BJIV	E	12	0.010	0.010	0.010	0.0
BNGA	A	12	0.010	0.010	0.010	0.0
BNGA	E	12	0.010	0.010	0.010	0.0
BREA	A	12	0.010	0.010	0.010	0.0
BREA	E	12	0.010	0.010	0.012	5.7
ECGM	A	12	0.010	0.010	0.010	0.0
ECGM	E	12	0.010	0.010	0.010	0.0
EEDR	A	12	0.011	0.010	0.015	14.2
EEDR	E	12	0.010	0.010	0.012	7.5
EEEM	A	12	0.011	0.010	0.023	33.3
EEEM	E	12	0.010	0.010	0.010	0.0
EEIX	A	12	0.010	0.010	0.010	0.0
EEIX	E	12	0.010	0.010	0.010	0.0
EEKV	A	12	0.010	0.010	0.010	0.0
EEKV	E	12	0.010	0.010	0.010	0.0
EGLY	A	12	0.010	0.010	0.010	0.0
EGLY	B	12	0.010	0.010	0.010	0.0
EGLY	C	12	0.010	0.010	0.010	0.0
EGLY	D	12	0.010	0.010	0.010	0.0
EGLY	E	12	0.010	0.010	0.010	0.0
EHGD	A	12	0.010	0.010	0.015	13.9
EHGD	E	12	0.010	0.010	0.012	5.7
EHPK	A	12	0.010	0.010	0.010	0.0
EHPK	E	12	0.010	0.010	0.010	0.0
EIIL	A	12	0.010	0.010	0.010	0.0
EIIL	E	12	0.010	0.010	0.011	2.9
EIKC	A	12	0.010	0.010	0.010	0.0
EIKC	E	12	0.010	0.010	0.010	0.0
EKLQ	A	12	0.010	0.010	0.011	2.9
EKLQ	E	12	0.010	0.010	0.010	0.0
EKMP	A	12	0.010	0.010	0.010	0.0
EKMP	B	12	0.010	0.010	0.010	0.0
EKMP	C	12	0.010	0.010	0.010	0.0
EKMP	D	12	0.010	0.010	0.010	0.0
EKMP	E	12	0.010	0.010	0.010	0.0
EMQC	A	12	0.010	0.010	0.010	0.0
EMQC	E	12	0.010	0.010	0.010	0.0
ENNB	A	12	0.010	0.010	0.010	0.0
ENNB	B	12	0.010	0.010	0.010	0.0
ENNB	C	12	0.010	0.010	0.012	5.7
ENNB	D	12	0.010	0.010	0.010	0.0
ENNB	E	12	0.010	0.010	0.010	0.0
EPLP	A	12	0.010	0.010	0.010	0.0
EPLP	E	12	0.010	0.010	0.010	0.0
EPRF	A	12	0.010	0.010	0.010	0.0
EPRF	E	12	0.010	0.010	0.010	0.0
ERPB	A	12	0.010	0.010	0.010	0.0
ERPB	B	12	0.010	0.010	0.010	0.0
ERPB	C	12	0.010	0.010	0.010	0.0
ERPB	D	12	0.010	0.010	0.014	11.2
ERPB	E	12	0.010	0.010	0.010	0.0
ER10	A	12	0.011	0.010	0.016	19.7
ER10	E	12	0.011	0.010	0.018	23.5
ETLQ	A	12	0.010	0.010	0.010	0.0
ETLQ	E	12	0.010	0.010	0.010	0.0
ETQE	A	12	0.010	0.010	0.010	0.0
ETQE	E	12	0.010	0.010	0.010	0.0
PEUE	A	9	0.010	0.010	0.010	0.0
PEUE	E	9	0.010	0.010	0.010	0.0
P01	A	12	0.005	0.005	0.005	0.0
P01	E	12	0.005	0.005	0.005	0.0
P02	A	12	0.005	0.005	0.005	0.0
P02	E	12	0.005	0.005	0.005	0.0
P03	A	12	0.005	0.005	0.005	0.0
P03	E	12	0.005	0.005	0.005	0.0
P04	A	12	0.005	0.005	0.005	0.0
P04	E	12	0.005	0.005	0.005	0.0
P05	A	12	0.005	0.005	0.005	0.0
P05	B	12	0.005	0.005	0.005	0.0
P05	C	12	0.005	0.005	0.005	0.0
P05	D	12	0.005	0.005	0.005	0.0
P05	E	12	0.005	0.005	0.005	0.0
P06	A	12	0.005	0.005	0.005	0.0
P06	E	12	0.005	0.005	0.005	0.0
P07	A	12	0.007	0.005	0.030	101.9
P07	E	12	0.009	0.005	0.041	118.7
P08	A	12	0.005	0.005	0.005	0.0
P08	E	12	0.005	0.005	0.005	0.0
P09	A	12	0.005	0.005	0.005	0.0
P09	E	12	0.005	0.005	0.005	0.0
P10	A	12	0.005	0.005	0.005	0.0
P10	E	12	0.005	0.005	0.005	0.0
P11	A	12	0.005	0.005	0.005	0.0
P11	E	12	0.005	0.005	0.005	0.0
P12	A	12	0.005	0.005	0.005	0.0
P12	E	12	0.005	0.005	0.005	0.0
P13	A	12	0.005	0.005	0.005	0.0
P13	B	12	0.005	0.005	0.005	0.0
P13	C	12	0.005	0.005	0.005	0.0
P13	D	12	0.005	0.005	0.005	0.0
P13	E	12	0.005	0.005	0.005	0.0
P14	A	12	0.005	0.005	0.005	0.0
P14	E	12	0.005	0.005	0.005	0.0
P15	A	12	0.005	0.005	0.005	0.0
P15	E	12	0.005	0.005	0.005	0.0

Appendix 8 - 14. Summary of orthophosphorus (mg/l as P) data for the Pensacola Bay system January through September, 1974.

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.012	0.010	0.021	31.6
ADGV	E	12	0.014	0.010	0.042	63.1
AGJI	A	12	0.011	0.010	0.026	40.8
AGJI	B	12	0.011	0.010	0.026	40.8
AGJI	C	12	0.011	0.010	0.017	19.1
AGJI	D	12	0.010	0.010	0.010	0.0
AGJI	E	12	0.014	0.010	0.033	49.9
AGPH	A	12	0.011	0.010	0.015	17.8
AGPH	E	12	0.012	0.010	0.019	23.8
AJFD	A	12	0.011	0.010	0.015	14.2
AJFD	E	12	0.012	0.010	0.019	22.8
ALEX	A	12	0.010	0.010	0.010	0.0
ALEX	E	12	0.012	0.010	0.019	24.5
BFEI	A	5	0.011	0.010	0.013	12.9
BFEI	E	5	0.012	0.010	0.016	23.6
BJIV	A	12	0.015	0.010	0.029	46.6
BJIV	E	12	0.013	0.010	0.021	27.0
BNGA	A	12	0.014	0.010	0.030	49.2
BNGA	E	12	0.014	0.010	0.033	49.0
BREA	A	12	0.013	0.010	0.026	39.0
BREA	E	12	0.015	0.010	0.039	53.6
ECGM	A	12	0.027	0.015	0.052	47.3
ECGM	E	12	0.027	0.011	0.054	49.2
EEDR	A	12	0.028	0.013	0.052	44.3
EEDR	E	12	0.032	0.015	0.072	53.8
EEEM	A	12	0.029	0.015	0.059	52.0
EEEM	E	12	0.032	0.014	0.080	59.4
EEIX	A	12	0.025	0.012	0.056	53.4
EEIX	E	12	0.027	0.013	0.054	45.6
EEKV	A	12	0.028	0.010	0.117	102.0
EEKV	E	12	0.022	0.010	0.053	51.3
EGLY	A	12	0.021	0.010	0.056	60.4
EGLY	B	12	0.024	0.010	0.056	51.6
EGLY	C	12	0.023	0.010	0.050	55.6
EGLY	D	12	0.021	0.010	0.053	47.9
EGLY	E	12	0.021	0.012	0.047	52.2
EHGD	A	12	0.029	0.012	0.054	48.2
EHGD	E	12	0.029	0.010	0.080	66.7
EHPK	A	12	0.022	0.010	0.049	49.5
EHPK	E	12	0.024	0.010	0.045	43.1
EIIL	A	12	0.021	0.011	0.057	57.8
EIIL	E	12	0.020	0.011	0.042	44.1
EIKC	A	12	0.022	0.012	0.047	58.6
EIKC	E	11	0.023	0.010	0.042	38.0
EKLQ	A	12	0.021	0.010	0.053	70.3
EKLQ	E	12	0.020	0.010	0.041	43.3
EKMP	A	12	0.021	0.010	0.047	58.0
EKMP	B	12	0.021	0.010	0.050	60.2
EKMP	C	12	0.016	0.010	0.042	56.3
EKMP	D	12	0.019	0.010	0.042	48.4
EKMP	E	12	0.020	0.010	0.047	49.9
EMQC	A	12	0.016	0.010	0.030	39.8
EMQC	E	12	0.014	0.010	0.030	41.5
ENNB	A	12	0.020	0.010	0.041	47.7
ENNB	B	11	0.016	0.010	0.039	55.6
ENNB	C	12	0.019	0.010	0.047	61.9
ENNB	D	12	0.022	0.013	0.035	37.6
ENNB	E	12	0.020	0.010	0.032	39.1
EPLP	A	12	0.017	0.010	0.037	44.9
EPLP	E	12	0.017	0.010	0.037	52.3
EPRF	A	12	0.012	0.010	0.024	36.1
EPRF	E	12	0.012	0.010	0.016	21.6
ERPB	A	12	0.014	0.010	0.032	45.4
ERPB	B	12	0.014	0.010	0.037	55.4
ERPB	C	12	0.012	0.010	0.022	30.4
ERPB	D	12	0.011	0.010	0.016	18.2
ERPB	E	12	0.014	0.010	0.021	32.1
ER10	A	12	0.034	0.018	0.054	34.2
ER10	E	12	0.034	0.017	0.059	40.2
ETLQ	A	12	0.011	0.010	0.022	31.5
ETLQ	E	12	0.018	0.010	0.042	63.9
ETQE	A	12	0.011	0.010	0.015	15.1
ETQE	E	12	0.011	0.010	0.017	22.9

Appendix 8 - 15. Data base for calculation of initial PNI values.

Description	Date	Agency Code	Station Numbers	Remarks
All data collected by the Escambia Bay Recovery Study	1973 to 1974	1113T070	120000 - 120490	Primary station number
Univ. of West Fla. Sea Grant data for Escambia and East Bays	1973	1113T070	120500 - 120900	Primary station number
Univ. of West Fla. Sea Grant data for Pensacola BAY	1974	-	P01 - P15	Unpublished data (not in STORET)
Data from FWPCA Study of Escambia Bay	1969	-	E01 - E27	Not in STORET after USDI, 1970
Data from USEPA study of Perdido Bay	1972	1113S000	017000 - 017012 640075 - 640111	After USEPA, 1972
Data from USEPA study of Mississippi Gulf coast	1972	-	WQ-01 - WQ-05 WQ-20,WQ-21,WQ-55,WQ-56	Unpublished data
Data from USEPA study of Escambia River	1971	-	R1 - R14	Unpublished data

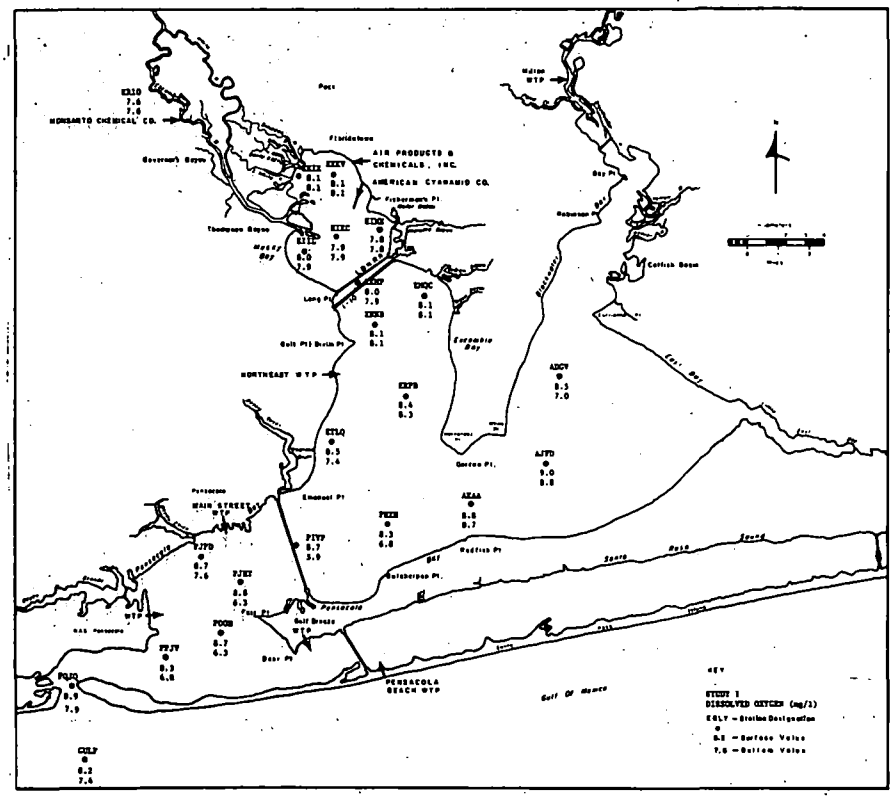
Appendix 8 - 16. Summary of dissolved oxygen (mg/l) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

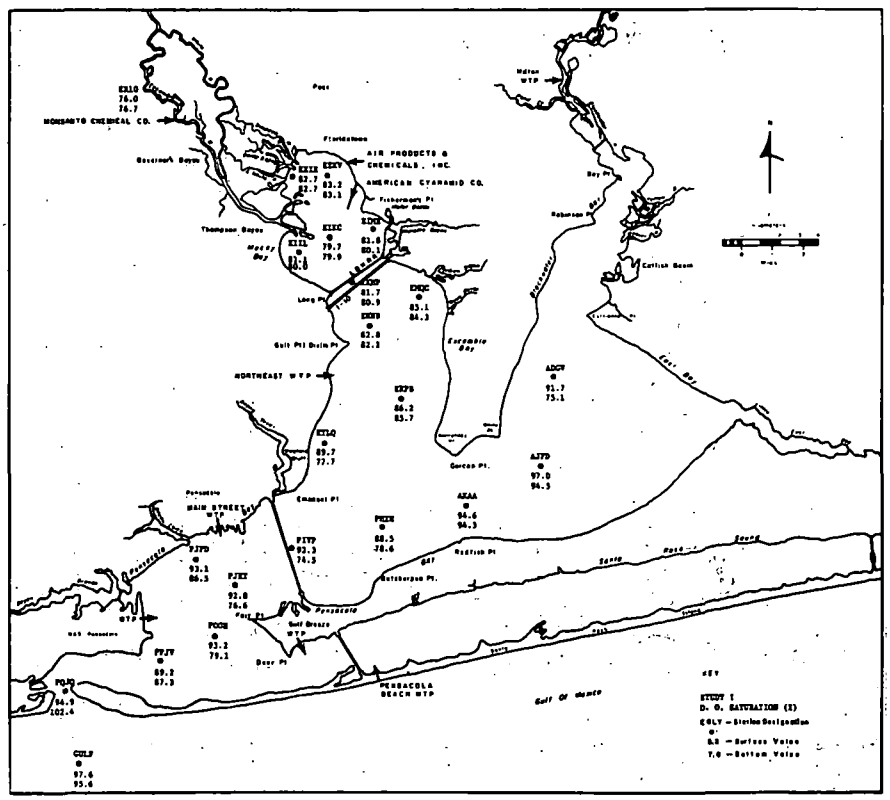
Sta.	Dep.	No.	Mean	Min.	Max.	CV%	Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	7.9	6.2	9.6	14.4	ENNB	D	11	4.2	0.0	9.5	67.0
ADGV	B	12	5.2	2.4	9.0	43.9	ENNB	E	12	4.0	0.6	8.7	54.3
AGJI	A	12	8.1	6.2	10.1	13.9	EPLP	A	12	8.3	6.3	9.3	10.9
AGJI	B	12	8.0	5.7	10.1	15.5	EPLP	E	12	6.1	1.5	9.5	46.7
AGJI	C	12	8.0	6.0	10.5	17.8	EPRP	A	12	8.4	7.2	10.1	12.0
AGJI	D	12	7.9	6.1	9.7	14.8	EPRP	B	12	6.2	1.0	9.5	44.1
AGJI	E	11	4.7	1.0	9.8	56.1	ERPB	A	12	8.1	6.7	9.7	12.2
AGPH	A	12	7.8	5.7	10.0	16.6	ERPB	B	12	8.0	6.2	9.4	13.0
AGPH	E	12	5.3	2.1	9.9	40.3	ERPB	C	12	7.4	3.8	9.7	24.3
AJPD	A	12	8.0	6.8	9.7	12.5	ERPB	D	12	6.3	3.9	10.0	36.9
AJPD	E	12	5.4	3.3	9.6	32.2	ERPB	E	12	4.3	1.5	9.2	46.9
ALEX	A	12	8.1	7.0	10.0	11.9	ER10	A	11	6.9	5.4	9.2	15.7
ALEX	E	12	4.4	0.7	6.7	33.5	ER10	E	12	6.9	5.2	8.8	16.4
EFEI	A	5	5.9	4.9	6.5	10.5	ETLQ	A	11	8.2	7.0	9.9	11.6
EFEI	E	4	2.2	0.0	4.7	89.9	ETLQ	E	12	3.4	1.1	5.3	35.5
EJIV	A	12	7.5	4.5	9.1	16.1	ETQE	A	12	8.3	7.0	10.8	13.8
EJIV	E	11	5.5	4.0	8.7	28.8	ETQE	E	12	7.0	3.8	9.9	24.8
ENGA	A	12	7.5	4.5	9.1	18.1	FBUE	A	9	9.0	8.1	11.1	10.8
ENGA	E	11	5.7	2.9	9.4	36.3	FBUE	E	9	6.5	3.5	10.7	33.9
EREA	A	12	7.5	5.0	8.9	15.8	P01	A	12	6.7	2.1	10.7	40.4
EREA	E	11	4.9	2.0	8.4	37.9	P01	E	12	6.8	2.1	10.8	38.9
FCGM	A	12	6.8	4.7	9.3	22.6	P02	A	12	7.6	2.2	11.8	37.2
FCGM	E	12	5.2	0.6	9.1	56.7	P02	E	12	6.0	2.2	9.4	38.2
FEDR	A	12	6.9	5.4	9.0	17.4	P03	A	12	7.1	2.4	12.6	41.0
FEDR	E	12	6.1	0.2	9.2	45.1	P03	E	12	5.9	2.3	11.3	41.2
FEEM	A	12	7.1	5.3	9.1	19.4	P04	A	12	7.1	2.2	12.1	41.6
FEEM	E	12	6.0	0.4	9.3	47.2	P04	E	12	5.5	2.0	9.3	42.2
FEIX	A	12	7.1	5.1	9.2	17.8	P05	A	12	7.2	2.3	12.7	40.9
FEIX	E	12	7.0	5.2	9.2	17.8	P05	B	12	6.7	2.5	10.5	41.5
FEKV	A	12	8.0	5.8	9.1	11.5	P05	C	12	5.9	2.4	8.8	40.1
FEKV	E	12	5.7	0.8	8.9	47.7	P05	D	12	5.4	2.1	8.1	44.5
FGLY	A	12	7.9	5.4	9.1	12.7	P05	E	12	5.2	2.4	8.1	39.7
FGLY	B	10	8.2	6.7	9.8	10.4	P06	A	12	7.3	2.4	12.8	41.7
FGLY	C	12	7.6	5.6	9.1	13.2	P06	E	12	4.9	2.1	7.1	35.2
FGLY	D	12	6.2	3.3	9.0	33.7	P07	A	12	7.1	2.3	11.0	41.9
FGLY	E	11	4.3	2.1	8.9	56.7	P07	E	12	4.0	1.7	6.1	40.5
FHGD	A	12	6.8	5.3	9.3	20.5	P08	A	12	7.1	2.3	11.6	41.1
FHGD	E	11	4.6	0.0	9.3	71.8	P08	E	12	5.0	2.0	7.8	37.4
FHPK	A	12	7.9	5.8	10.0	12.6	P09	A	12	7.2	2.0	12.1	42.6
FHPK	E	12	6.9	3.6	10.1	27.0	P09	E	12	6.2	1.8	9.7	40.4
FIIL	A	11	7.5	4.8	9.1	17.5	P10	A	12	7.3	1.8	11.9	42.2
FIIL	E	12	6.1	2.2	9.2	42.9	P10	E	12	4.7	1.7	7.0	38.8
FIKC	A	11	7.3	4.8	8.9	17.9	P11	A	12	7.1	1.9	11.4	42.9
FIKC	E	12	4.7	0.0	8.5	51.9	P11	E	12	3.7	1.4	5.3	40.3
FKLQ	A	12	7.9	4.9	9.2	13.8	P12	A	12	7.0	1.9	10.3	39.9
FKLQ	E	11	5.6	0.6	9.3	52.9	P12	E	12	3.5	1.3	5.3	41.0
FKMP	A	12	8.1	5.4	9.6	14.4	P13	A	12	7.0	1.9	11.5	43.2
FKMP	B	12	8.0	4.8	9.5	15.1	P13	B	12	7.0	1.8	11.2	44.5
FKMP	C	12	5.9	2.3	9.6	42.7	P13	C	12	6.6	1.8	11.2	43.7
FKMP	D	12	4.4	0.0	9.1	60.1	P13	D	12	5.1	1.2	8.4	47.6
FKMP	E	11	3.9	0.0	7.9	62.4	P13	E	12	3.5	1.5	5.1	36.3
FMQC	A	12	8.0	5.9	9.6	13.8	P14	A	12	7.0	1.7	11.6	45.1
FMQC	E	12	5.7	2.5	9.0	38.0	P14	E	12	4.1	1.5	6.4	41.4
FNNB	A	12	8.2	5.3	9.3	12.7	P15	A	12	7.3	1.8	11.7	44.6
FNNB	B	12	8.2	4.9	9.2	14.0	P15	E	12	3.8	0.8	8.1	56.2
FNNB	C	12	6.1	1.5	9.4	41.3							
FNNB	D	11	4.2	0.0	9.5	67.0							

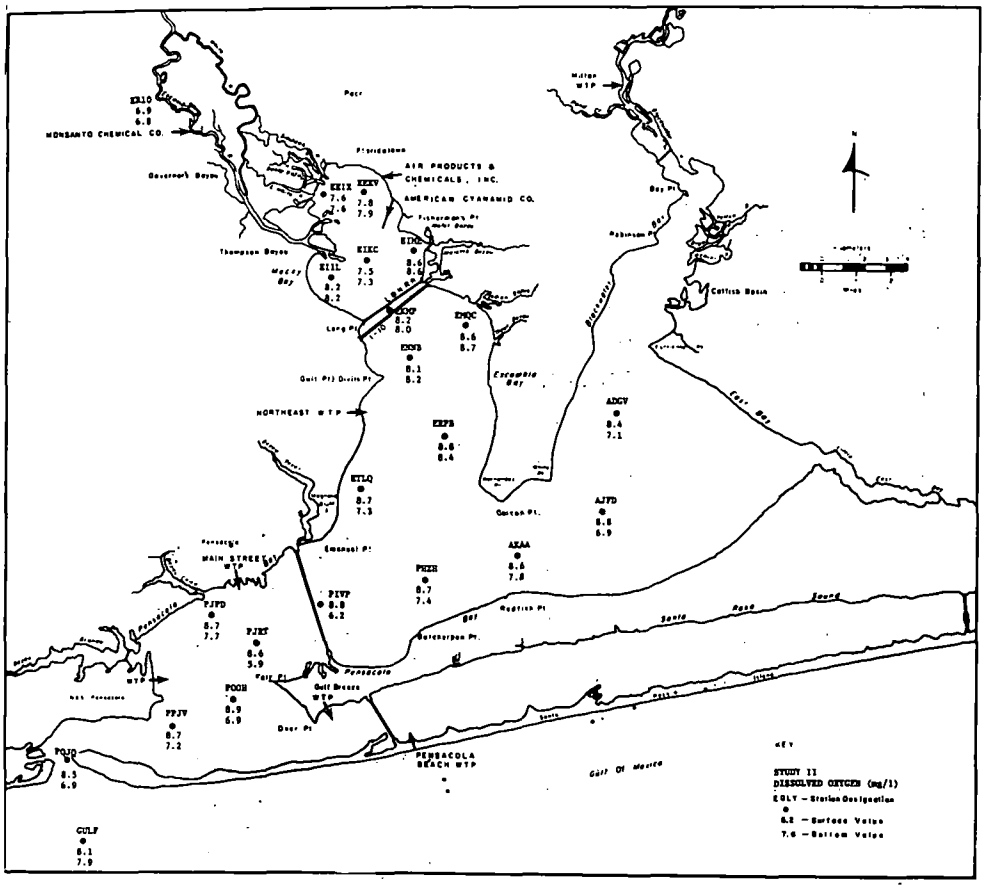
Appendix 8 - 17. Summary of dissolved oxygen percent saturation (%) data for the Pensacola Bay system during January through September, 1974 (Pensacola Bay data from the University of West Florida).

Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	95.3	80.1	106.7	7.8
ADGV	E	12	67.1	30.3	106.5	38.4
AGJI	A	12	101.9	91.7	124.2	7.9
AGJI	B	12	100.1	84.3	114.0	8.2
AGJI	C	12	100.9	88.8	115.4	8.6
AGJI	D	12	102.1	67.8	129.7	14.3
AGJI	E	11	63.0	15.1	105.2	52.0
AGPH	A	12	96.9	80.9	106.3	6.6
AGPH	E	12	68.7	26.8	99.2	36.3
AJFD	A	12	100.9	89.7	112.2	5.8
AJFD	E	12	71.1	41.8	103.7	25.3
ALEX	A	12	102.9	96.1	115.5	5.2
ALEX	E	12	60.5	10.6	103.2	37.2
EFEI	A	5	74.3	58.1	81.3	12.6
EFEI	E	4	28.7	0.0	55.9	83.1
EJIV	A	12	87.3	54.3	108.7	16.6
EJIV	E	11	67.4	43.3	91.2	20.4
ENGA	A	12	87.2	54.7	108.3	14.8
ENGA	E	11	70.9	33.1	98.5	29.2
EREA	A	12	89.6	62.4	108.2	12.2
EREA	E	11	65.0	27.5	90.8	33.8
ECGM	A	12	76.0	55.5	96.2	14.1
ECGM	E	12	57.4	8.6	90.0	49.3
EEDR	A	12	77.3	63.5	85.9	7.7
EEDR	E	12	66.8	3.0	88.8	40.2
EEEM	A	12	79.3	62.5	101.2	12.3
EEEM	E	12	65.9	5.9	86.7	42.7
EEIX	A	12	81.3	62.0	103.0	13.4
EEIX	E	12	81.6	63.2	101.3	13.0
EEKV	A	12	95.3	72.8	123.5	17.9
EEKV	E	12	68.6	10.8	109.5	44.8
EGLY	A	12	96.1	67.5	123.5	16.9
EGLY	B	10	99.0	83.2	123.3	14.2
EGLY	C	12	92.9	68.3	108.0	11.8
EGLY	D	12	76.1	48.4	107.8	27.6
EGLY	E	11	52.4	31.0	95.7	42.2
EHGD	A	12	77.7	62.5	87.7	9.8
EHGD	E	11	46.7	0.0	86.2	58.2
EHPK	A	12	98.2	76.7	112.9	12.2
EHPK	E	12	85.6	46.7	109.4	23.2
EIIL	A	11	87.8	57.5	99.6	13.6
EIIL	E	12	72.0	32.9	111.3	38.3
EIKC	A	11	85.0	58.0	107.9	16.4
EIKC	E	12	57.5	0.0	88.5	48.0
EKLQ	A	12	94.7	63.8	107.3	13.4
EKLQ	E	11	65.6	9.0	105.5	50.0
EKMP	A	12	98.1	66.8	126.4	18.0
EKMP	B	12	97.1	59.5	117.8	17.1
EKMP	C	12	73.4	34.4	133.9	38.2
EKMP	D	12	54.5	0.0	89.2	49.7
EKMP	E	11	47.5	0.0	83.5	50.6
EMQC	A	12	100.6	77.4	115.1	10.7
EMQC	E	12	73.4	35.9	110.8	31.6
ENNB	A	12	101.9	68.4	119.4	14.8
ENNB	B	12	100.6	61.6	118.9	16.3
ENNB	C	12	76.7	22.8	113.8	36.9
ENNB	D	11	53.1	0.0	103.1	54.4
ENNB	E	12	50.1	9.2	96.1	42.3
EPLP	A	12	103.1	84.7	118.0	9.7
EPLP	E	12	74.7	22.7	108.9	38.1
EPRF	A	12	104.8	94.9	123.7	7.3
EPRF	E	12	78.3	15.1	121.6	38.8
ERPB	A	12	100.7	84.2	111.9	8.0
ERPB	B	12	99.5	85.2	110.5	9.2
ERPB	C	12	93.6	52.6	118.9	19.2
ERPB	D	12	82.2	54.0	143.7	30.3
ERPB	E	12	57.4	21.9	94.4	40.7
ER10	A	11	78.1	67.8	85.8	7.5
ER10	E	12	77.3	61.1	87.2	9.3
ETLQ	A	11	103.1	93.0	110.2	6.1
ETLQ	E	12	47.2	17.0	71.8	34.1
ETQE	A	12	103.6	93.0	109.5	4.4
ETQE	E	12	90.3	44.5	119.9	21.4
PEUE	A	9	120.3	104.6	131.2	6.6
PEUE	E	9	85.5	48.8	124.8	25.1
P01	A	12	86.9	32.0	123.9	31.5
P01	E	12	93.8	31.4	169.6	39.0
P02	A	12	94.9	32.0	134.9	31.7
P02	E	12	83.2	33.2	130.8	34.9
P03	A	12	90.3	34.6	147.9	32.9
P03	E	12	78.3	35.9	126.3	32.0
P04	A	12	89.1	32.5	142.9	33.0
P04	E	12	72.1	29.7	97.6	32.6
P05	A	12	90.1	32.2	149.1	33.4
P05	B	12	85.4	38.3	124.0	33.7
P05	C	12	78.8	37.1	113.5	33.1
P05	D	12	73.9	31.9	109.8	39.4
P05	E	12	70.9	35.6	101.7	34.0
P06	A	12	89.9	33.4	146.2	33.7
P06	E	12	67.1	31.9	96.7	31.2
P07	A	12	87.1	32.1	129.1	33.8
P07	E	12	53.9	26.9	85.1	34.9
P08	A	12	87.7	31.9	132.8	33.2
P08	E	12	69.1	29.4	97.9	32.4
P09	A	12	88.1	28.7	137.7	34.3
P09	E	12	80.5	27.2	118.9	33.3
P10	A	12	89.1	25.7	136.6	35.0
P10	E	12	64.4	25.8	97.2	34.5
P11	A	12	86.8	27.0	128.7	33.9
P11	E	12	50.4	21.7	71.9	36.7
P12	A	12	85.2	23.3	114.6	32.8
P12	E	12	47.8	20.9	71.4	38.2
P13	A	12	85.9	25.7	130.6	34.2
P13	B	12	86.0	25.7	126.2	35.8
P13	C	12	82.6	25.8	115.0	33.1
P13	D	12	65.8	18.5	93.9	39.6
P13	E	12	47.8	21.9	71.4	34.1
P14	A	12	86.2	24.3	134.7	36.4
P14	E	12	55.6	23.9	90.0	38.8
P15	A	12	89.4	25.7	135.5	36.5
P15	E	12	50.1	11.9	93.7	51.4

Appendix 8-18. Mean dissolved oxygen concentrations and percent dissolved oxygen saturation during the 1973 diel water quality surveys.



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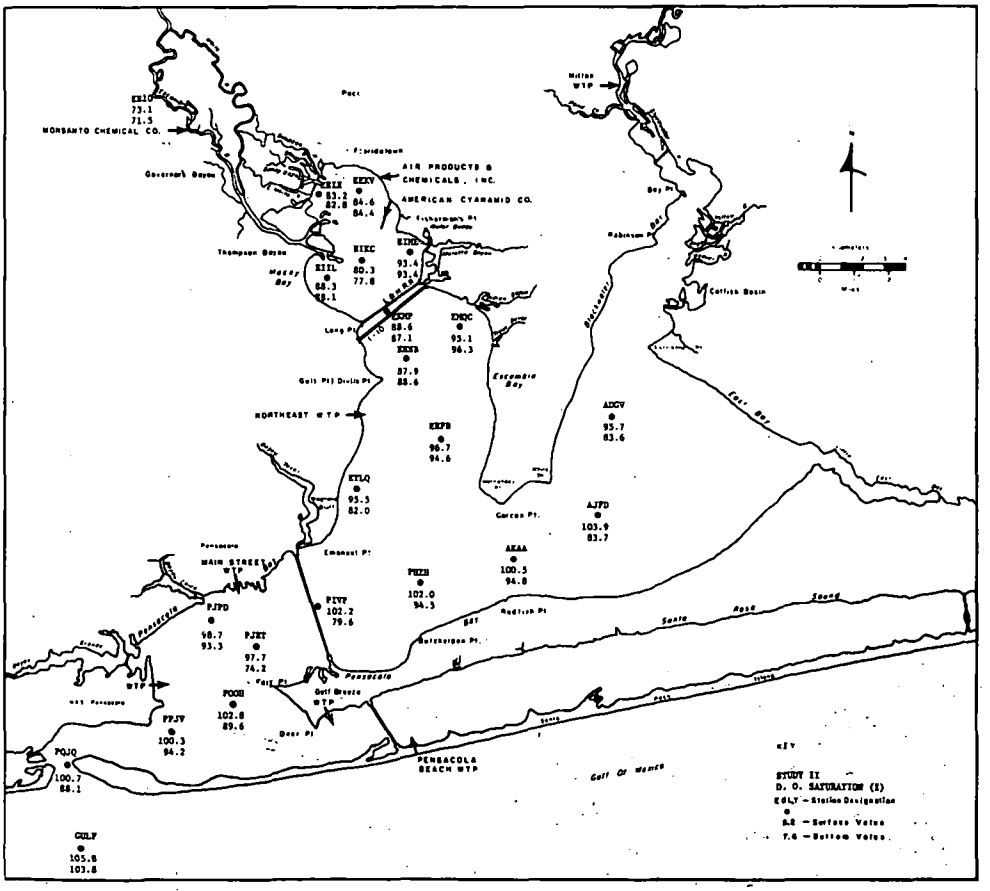
AIR PRODUCTS & CHEMICALS, INC.
AMERICAN CYANAMID CO.
NORTHEAST WTP
MAIN STREET WTP
GULF BREEZE WTP
PENSACOLA BEACH WTP
Escambia Bay
Santa Rosa Sound
Gulf Of Mexico
STUDY II
DISSOLVED OXYGEN (mg/l)
EGLY - Station Designation
8.2 - Surface Value
7.6 - Bottom Value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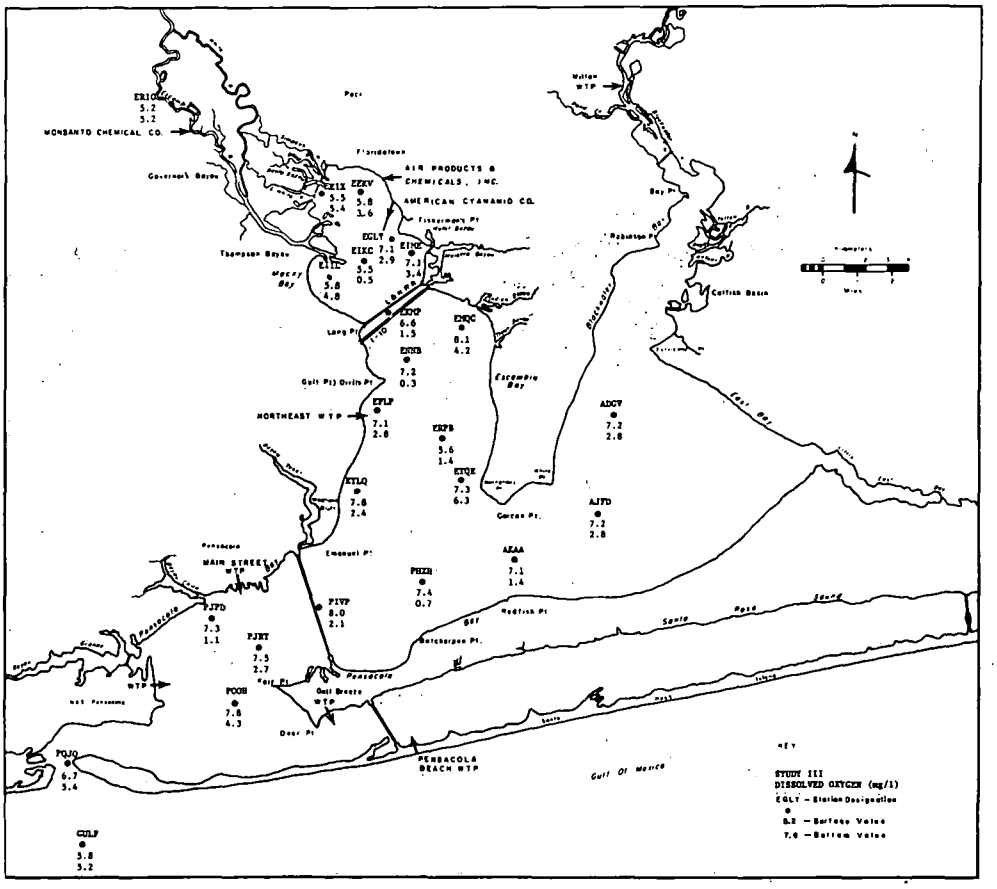
AIR PRODUCTS & CHEMICALS, INC.
AMERICAN CYANAMID CO.
NORTHEAST WTP
MAIN STREET WTP
GULF BREEZE WTP
PENSACOLA BEACH WTP
Escambia Bay
Santa Rosa Sound
Gulf Of Mexico
STUDY II
D. O. SATURATION (%)
EGLY - Station Designation
83.2 - Surface Value
84.4 - Bottom Value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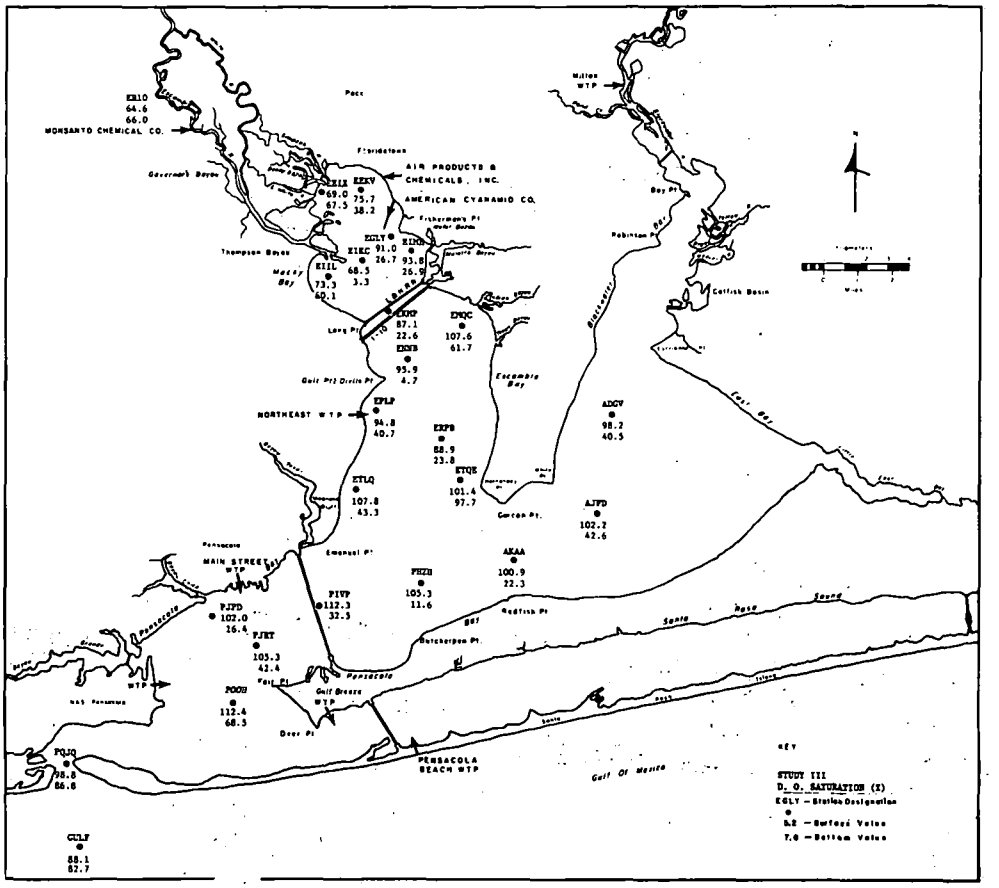
AIR PRODUCTS & CHEMICALS, INC.
AMERICAN CYANAMID CO.
NORTHEAST W.T.P.
MAIN STREET W.T.P.
GULF BREEZE W.T.P.
PENSACOLA BEACH W.T.P.
Milton W.T.P.
Gulf Of Mexico
STUDY III
DISSOLVED OXYGEN (mg/l)
EGLY - Station Designation
S.S - Surface Value
T.B - Bottom Value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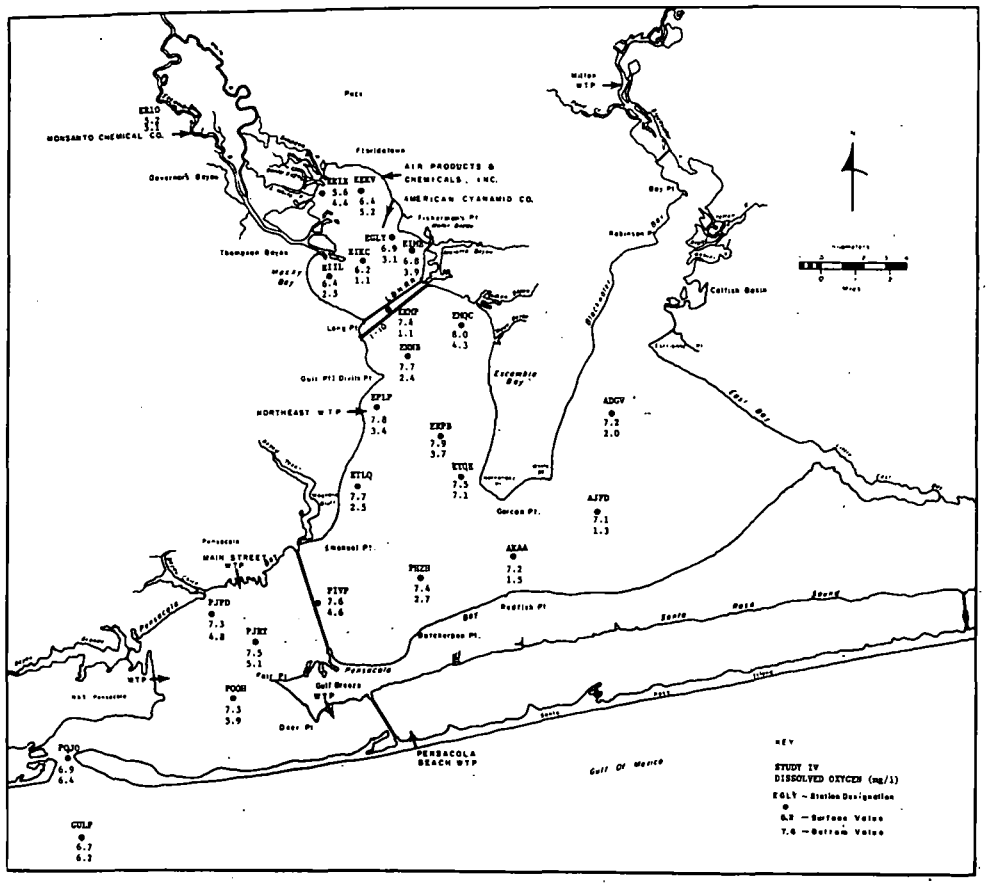
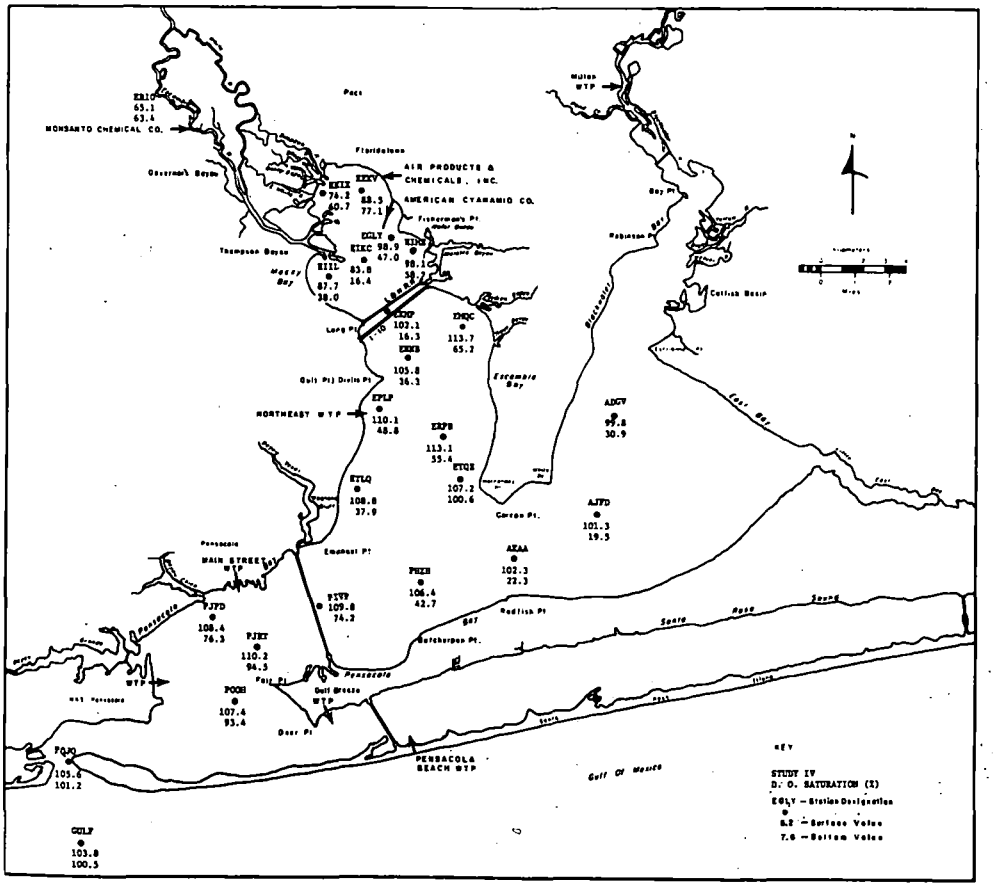
AIR PRODUCTS & CHEMICALS, INC.
AMERICAN CYANAMID CO.
NORTHEAST W.T.P.
MAIN STREET W.T.P.
GULF BREEZE W.T.P.
PENSACOLA BEACH W.T.P.
Milton W.T.P.
Gulf Of Mexico
STUDY III
D. O. SATURATION (%)
EGLY - Station Designation
S.S - Surface Value
T.B - Bottom Value


MONSANTO CHEMICAL CO.
AIR PRODUCTS & CHEMICALS, INC.
AMERICAN CYANAMID CO.
NORTHEAST WTP
MAIN STREET WTP
GULF BREEZE WTP
PENSACOLA BEACH WTP
Gulf Of Mexico
KEY
STUDY IV
DISSOLVED OXYGEN (mg/l)
EGLY - Station Designation
6.2 - Surface Value
7.6 - Bottom Value


MONSANTO CHEMICAL CO.
AIR PRODUCTS & CHEMICALS, INC.
AMERICAN CYANAMID CO.
NORTHEAST WTP
MAIN STREET WTP
GULF BREEZE WTP
PENSACOLA BEACH WTP
Gulf Of Mexico
KEY
STUDY IV
D. O. SATURATION (%)
EGLY - Station Designation
6.2 - Surface Value
7.6 - Bottom Value

Appendix 8 - 19. Ultimate biochemical oxygen demand data for Station ER10 surface and bottom by date.

DATE	ER10 - S						ER10 - B					
	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	5.9	4.3	1.6	30.4	0.097	0.117	5.1	3.5	1.6	29.1	0.093	0.089
2/12/74	5.7	3.7	2.0	28.7	0.042	0.034	7.1	2.3	4.8	20.5	0.089	0.017
3/05/74	4.2	2.4	1.8	19.9	0.056	0.025	4.2	2.6	1.6	19.0	0.044	0.017
3/27/74	4.9	1.3	3.6	7.1	0.757	0.037	5.7	1.4	4.3	6.6	0.715	0.029
4/16/74	3.8	3.1	0.7	36.5	0.060	0.389	16.1	2.2	13.9	15.0	0.122	0.004
5/07/74	3.3	1.0	2.3	8.0	0.300	0.040	3.8	2.9	0.9	43.2	0.050	0.030
5/29/74	3.9	2.4	1.5	17.1	0.324	0.123	4.1	2.7	1.4	18.4	0.195	0.082
6/18/74	14.6	2.1	12.5	27.1	0.100	0.004	7.7	2.6	5.1	29.0	0.090	0.013
7/09/74	3.3	2.4	0.9	27.0	0.051	0.035	3.3	3.3	-	-	0.028	-
7/30/74	3.1	3.1	-	-	0.030	-	2.7	2.7	-	-	0.038	-
8/20/74	3.2	0.8	2.4	18.5	1.890	0.088	3.8	1.0	2.8	14.7	2.250	0.050
9/11/74	10.9	10.9	-	-	0.015	-	7.0	4.7	2.3	24.0	0.042	0.022
average	5.6	3.1	2.9	24.0	0.310	0.090	5.9	2.7	3.9	22.0	0.313	0.040

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station EGLY surface and bottom by date.

Date	EGLY - S						EGLY - B					
	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	5.8	2.0	3.8	16.0	0.183	0.019	23.6	10.1	13.5	32.2	0.101	0.062
2/12/74	11.9	1.7	10.2	10.0	0.457	0.009	7.0	3.2	3.8	16.7	0.158	0.049
3/05/74	9.8	7.2	2.6	34.3	0.056	0.001	8.0	7.3	0.7	31.0	0.035	0.069
3/27/74	5.9	1.5	4.4	9.2	0.501	0.039	4.5	1.2	3.3	9.2	0.345	0.056
4/16/74	5.5	5.2	0.3	36.9	0.047	0.439	4.2	3.5	0.7	15.0	0.056	0.136
5/07/74	5.5	2.5	3.0	14.2	0.170	0.060	6.7	2.5	4.2	12.0	0.150	0.040
5/29/74	8.5	5.4	3.1	17.6	0.205	0.112	6.3	4.4	1.9	17.8	0.163	0.164
6/18/74	8.8	5.5	3.3	26.0	0.120	0.094	8.9	5.9	3.0	25.6	0.110	0.069
7/09/74	9.7	9.3	0.4	27.0	0.047	0.097	7.4	4.4	3.0	24.1	0.113	0.090
7/30/74	8.7	6.8	1.9	38.5	0.117	0.350	8.4	3.4	5.0	25.0	0.103	0.033
8/20/74	5.5	2.2	3.3	18.0	0.707	0.141	8.3	3.6	4.7	15.8	0.225	0.091
9/11/74	10.9	3.8	7.1	24.5	0.085	0.024	44.7	44.7	-	-	0.006	-
average	8.0	4.4	3.6	22.6	0.225	0.115	11.5	7.9	4.0	20.4	0.130	0.078

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station EKMP surface and bottom by date.

Date	EKMP - S						EKMP - B					
	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	5.0	2.5	2.5	27.0	0.163	0.048	4.0	2.6	1.4	30.0	0.154	0.196
2/12/74	8.4	2.6	5.8	20.0	0.181	0.016	6.1	2.3	3.8	19.2	0.201	0.030
3/05/74	6.2	3.2	3.0	20.0	0.081	0.015	5.8	5.8	-	-	0.026	-
3/27/74	6.7	1.5	5.2	9.8	0.283	0.023	3.9	1.4	2.5	10.0	0.228	0.067
4/16/74	51.7	2.4	49.3	21.0	0.058	0.001	3.7	2.3	1.4	15.0	0.102	0.061
5/07/74	5.3	4.8	0.5	38.1	0.050	0.150	15.7	4.4	11.3	34.9	0.060	0.002
5/29/74	5.6	3.7	1.9	18.3	0.241	0.184	6.4	4.5	1.9	18.2	0.138	0.181
6/18/74	8.0	5.3	2.7	26.9	0.100	0.092	8.7	5.6	3.1	20.0	0.110	0.058
7/09/74	4.4	3.4	1.0	26.5	0.098	0.268	-	-	-	-	-	-
7/30/74	8.8	4.9	3.9	29.3	0.122	0.049	6.0	4.5	1.5	38.6	0.040	0.261
8/20/74	5.1	1.7	3.4	16.9	0.630	0.057	6.4	1.6	4.8	15.3	0.576	0.058
9/11/74	5.6	3.4	2.2	30.1	0.070	0.071	22.3	19.7	2.6	20.6	0.006	0.143
average	10.1	3.3	6.8	23.7	0.173	0.081	6.5	5.0	3.1	20.1	0.158	0.089

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station ENNB surface and bottom by date.

Date	ENNB - S						ENNB - B					
	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	5.6	4.1	1.5	30.5	0.117	0.135	9.5	2.8	6.7	18.7	0.200	0.008
2/12/74	4.2	2.1	2.1	19.1	0.134	0.040	11.7	1.9	9.8	16.8	0.200	0.010
3/05/74	12.4	4.5	7.9	20.0	0.064	0.003	5.3	5.3	-	-	0.021	-
3/27/74	17.3	2.9	14.4	21.7	0.142	0.003	4.0	1.5	2.5	10.4	0.287	0.069
4/16/74	16.1	16.1	-	-	0.008	-	4.6	4.6	-	-	0.043	-
5/07/74	5.3	5.2	0.1	44.9	0.050	0.110	5.3	4.9	0.4	38.0	0.060	0.090
5/29/74	6.5	3.6	2.9	16.2	0.237	0.061	7.3	4.1	3.2	16.9	0.197	0.100
6/18/74	6.1	4.2	1.9	26.5	0.120	0.142	7.1	5.5	1.6	32.9	0.080	0.073
7/09/74	8.4	6.8	1.6	27.0	0.038	0.113	4.4	3.5	0.9	35.6	0.065	-
7/30/74	-	-	-	-	-	-	7.8	6.6	1.2	17.0	0.039	0.058
8/20/74	6.4	2.3	4.1	15.4	0.514	0.052	7.3	7.3	-	-	0.031	-
9/11/74	44.6	3.3	41.2	23.1	0.070	0.002	7.3	1.2	6.1	13.6	0.116	0.030
average	12.1	5.0	7.1	24.4	0.147	0.072	6.7	4.1	3.5	22.2	0.118	0.055

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station ERPB surface and bottom by date.

	ERPB - S						ERPB - B					
Date	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	5.2	3.8	1.4	28.8	0.122	0.095	-	-	-	-	-	-
2/12/74	6.7	1.9	4.8	11.3	0.315	0.032	6.2	1.6	4.6	20.5	0.173	0.015
3/05/74	5.1	4.2	0.9	43.4	0.068	0.257	4.8	4.8	-	-	0.033	-
3/27/74	3.5	2.7	0.8	34.8	0.010	0.430	5.0	2.0	3.0	25.7	0.065	0.018
4/16/74	9.8	9.8	-	-	0.017	-	3.9	2.4	1.5	18.9	0.099	0.108
5/07/74	6.3	2.3	4.0	10.0	0.210	0.032	4.2	4.2	-	-	0.040	-
5/29/74	5.9	4.0	1.9	27.4	0.283	0.166	6.0	4.4	1.6	18.4	0.144	0.161
6/18/74	9.4	4.4	5.0	30.3	0.120	0.037	6.0	3.4	2.6	27.1	0.130	0.086
7/09/74	4.5	3.2	1.3	27.0	0.079	0.156	35.1	3.3	31.8	25.4	0.064	0.003
7/30/74	16.5	7.2	9.3	13.0	0.022	-	13.0	13.0	-	-	0.008	-
8/20/74	5.2	2.3	2.9	18.0	0.361	0.095	5.0	1.4	3.6	17.3	0.241	0.066
9/11/74	5.1	2.5	2.6	19.2	0.131	0.065	6.4	6.4	-	-	0.028	-
average	4.4	4.0	3.2	23.9	0.153	0.137	8.5	4.3	7.0	21.9	0.108	0.065

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station AGJI surface and bottom by date.

	AGJI - S						AGJI - B					
Date	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	3.3	2.3	1.0	40.0	0.191	0.317	7.0	3.0	4.0	21.5	0.188	0.021
2/12/74	5.6	1.6	4.0	21.2	0.130	0.020	3.6	2.3	1.3	34.1	0.059	0.084
3/05/74	3.8	2.1	1.7	19.0	0.127	0.065	3.8	1.9	1.9	28.3	0.093	0.234
3/27/74	4.7	3.3	1.4	34.1	0.118	0.120	3.3	2.5	0.8	34.5	0.079	0.293
4/16/74	4.6	4.6	-	-	0.039	-	6.9	6.9	-	-	0.029	-
5/07/74	9.6	4.6	5.0	33.7	0.060	0.004	3.7	3.7	-	-	0.050	-
5/29/74	4.3	2.6	1.7	27.1	0.278	0.116	-	-	-	-	-	-
6/18/74	4.3	3.1	1.2	29.0	0.140	0.093	5.6	3.7	1.9	28.3	0.110	0.113
7/09/74	4.0	2.8	1.2	27.0	0.058	0.128	19.3	2.6	16.7	23.7	0.064	0.003
7/30/74	5.5	4.6	0.9	37.1	0.032	0.109	19.8	19.8	-	-	0.007	-
8/20/74	7.4	2.3	5.1	13.5	0.329	0.019	6.6	1.9	4.7	17.8	0.253	0.086
9/11/74	5.3	2.8	2.5	27.8	0.141	0.044	3.3	2.0	1.3	29.8	0.098	0.112
average	5.4	3.1	2.3	28.2	0.147	0.086	7.5	4.6	4.1	27.2	0.093	0.119

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station BPEI surface and bottom by date.

Date	BPEI - S						BPEI - B					
	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	-	-	-	-	-	-	-	-	-	-	-	-
2/12/74	-	-	-	-	-	-	-	-	-	-	-	-
3/05/74	-	-	-	-	-	-	-	-	-	-	-	-
3/27/74	-	-	-	-	-	-	-	-	-	-	-	-
4/16/74	-	-	-	-	-	-	-	-	-	-	-	-
5/07/74	-	-	-	-	-	-	-	-	-	-	-	-
5/29/74	-	-	-	-	-	-	-	-	-	-	-	-
6/18/74	-	-	-	-	-	-	3.4	2.4	1.0	29.0	0.080	0.424
7/09/74	2.4	1.9	0.5	27.0	0.062	0.940	6.9	2.6	4.3	26.1	0.083	0.023
7/30/74	-	-	-	-	-	-	-	-	-	-	-	-
8/20/74	3.8	1.1	2.7	22.0	0.215	0.022	4.3	1.1	3.2	18.4	0.189	0.093
9/11/74	8.0	7.2	0.8	44.5	0.027	0.054	6.3	4.9	1.4	29.8	0.048	0.070
average	4.7	3.4	1.3	31.2	0.101	0.338	6.5	2.8	2.5	25.8	0.082	0.152

Appendix 8 - 19 (cont). Ultimate biochemical oxygen demand data for Station PEUE surface and bottom by date.

Date	PEUE - S						PEUE - B					
	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})	Lu (mg/l)	Lc (mg/l)	Ln (mg/l)	tn (days)	kc (day^{-1})	kn (day^{-1})
1/23/74	-	-	-	-	-	-	-	-	-	-	-	-
2/12/74	-	-	-	-	-	-	-	-	-	-	-	-
3/05/74	-	-	-	-	-	-	-	-	-	-	-	-
3/27/74	-	-	-	-	-	-	-	-	-	-	-	-
4/16/74	-	-	-	-	-	-	-	-	-	-	-	-
5/07/74	-	-	-	-	-	-	-	-	-	-	-	-
5/29/74	-	-	-	-	-	-	-	-	-	-	-	-
6/18/74	9.7	7.4	2.3	32.3	0.106	0.141	8.3	6.0	2.3	26.2	0.090	0.054
7/09/74	9.3	6.5	2.8	25.8	0.094	0.079	8.5	7.8	0.7	27.0	0.037	3.700
7/30/74	11.1	11.1	-	-	0.044	-	5.5	4.1	1.4	37.4	0.055	0.155
8/20/74	9.8	6.5	3.3	21.8	0.084	0.052	11.2	6.0	5.2	20.0	0.111	0.063
9/11/74	10.4	5.4	5.0	24.6	0.104	0.099	7.2	3.0	4.2	14.3	0.146	0.049
average	10.1	7.4	3.4	26.1	0.086	0.093	8.2	5.4	2.8	25.0	0.087	0.804

Appendix 8 - 20. Summary of turbidity (JTU) data for the Pensacola Bay system January through September, 1974.

Sta.	Dep.	No.	Mean	Min.	Max.	CV%	Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	4.6	1.1	15.0	95.3	EHPK	A	12	9.1	2.8	22.0	58.8
ADGV	E	12	6.4	1.4	10.0	82.7	EHPK	E	12	9.9	3.5	24.5	58.0
AGJI	A	12	2.9	0.5	15.0	138.2	EIIL	A	12	13.6	3.5	36.0	75.1
AGJI	B	12	2.8	0.7	14.0	131.5	EIIL	E	12	11.4	3.8	28.5	66.3
AGJI	C	12	2.6	0.6	8.0	94.0	EIKC	A	12	14.5	3.2	37.0	71.6
AGJI	D	12	2.5	0.5	7.7	84.8	EIKC	E	12	17.0	3.2	49.0	84.7
AGJI	E	12	5.7	0.9	9.8	47.5	EKLQ	A	12	12.8	3.2	33.0	73.9
AGPH	A	12	3.0	0.9	7.5	79.0	ETLQ	E	12	10.8	2.1	27.0	70.4
AGPH	E	12	4.8	1.6	9.1	50.1	EKMP	A	12	12.9	2.3	34.0	86.9
AJPD	A	12	3.2	0.7	10.0	86.3	EKMP	B	12	12.0	2.8	30.0	87.3
AJPD	E	12	5.3	0.5	10.0	55.7	EKMP	C	12	10.0	2.7	30.5	86.5
ALEX	A	12	2.1	0.5	4.8	63.0	EKMP	D	12	11.0	3.7	29.0	70.9
ALEX	E	12	4.7	2.0	10.0	50.2	EKMP	E	12	14.7	4.1	34.0	66.9
BPEI	A	5	4.4	2.3	8.9	61.0	EMQC	A	12	7.5	1.6	21.5	98.3
BPEI	E	5	5.5	2.3	15.0	97.0	EMQC	E	12	7.5	1.9	15.0	50.6
BJIV	A	12	5.9	1.2	16.0	74.9	ENNB	A	12	11.2	1.8	33.0	101.5
BJIV	E	12	6.1	2.3	14.0	65.1	ENNB	B	12	10.8	1.5	30.0	99.3
BNGA	A	12	7.0	1.9	20.5	78.8	ENNB	C	12	12.3	1.0	33.0	87.9
BNGA	E	12	6.3	1.7	21.5	89.7	ENNB	D	12	13.2	5.3	22.5	48.1
BREA	A	12	5.2	1.2	21.0	106.6	ENNB	E	12	14.1	6.6	29.0	58.1
BREA	E	12	9.1	1.9	39.0	110.7	EPLP	A	12	8.9	1.5	26.0	90.9
ECGM	A	12	16.7	4.9	37.0	56.2	EPLP	E	12	8.5	2.1	23.0	80.8
ECGM	E	12	15.6	5.1	44.0	73.6	EPRP	A	12	5.4	1.3	16.0	87.1
EEDR	A	12	17.8	5.4	43.0	57.4	EPRP	E	12	5.3	1.2	10.0	49.8
EEDR	E	12	18.9	4.5	45.0	60.1	ERPB	A	12	7.2	1.0	22.5	103.3
EEEM	A	12	18.5	5.5	44.0	61.9	ERPB	B	12	6.3	1.0	24.0	112.4
EEEM	E	12	20.2	6.6	52.0	63.6	ERPB	C	12	6.8	0.6	27.0	113.6
EEIX	A	12	15.1	4.7	34.0	63.9	ERPB	D	12	4.6	1.4	10.0	63.7
EEIX	E	12	14.8	3.8	34.0	65.1	ERPB	E	12	7.4	2.8	18.0	59.5
EEKV	A	12	12.3	3.2	30.0	69.6	ER10	A	12	19.7	8.1	39.0	43.4
EEKV	E	12	10.2	3.5	30.5	83.0	ER10	E	12	20.8	12.0	39.0	38.1
EGLY	A	12	11.6	3.3	34.0	85.6	ETLQ	A	12	6.4	0.6	20.5	107.3
EGLY	B	12	11.2	3.3	31.0	84.9	ETLQ	E	12	10.7	2.4	26.0	71.1
EGLY	C	12	10.9	2.6	30.0	89.9	ETQE	A	12	4.2	0.9	13.0	93.5
EGLY	D	12	10.5	2.3	27.5	74.0	ETQE	E	12	4.1	0.7	12.5	90.5
EGLY	E	12	10.6	3.2	27.5	67.8	PEUE	A	9	6.2	2.0	16.0	77.0
EHGD	A	12	17.6	5.9	43.0	61.5	PEUE	E	9	5.8	2.9	8.9	38.1
EHGD	E	12	15.9	3.3	57.0	99.3							

Appendix 8 - 21. Locations of sampling stations during August 15 and November 20, 1974 turbidity studies.

Station	Road	River	Location
E-1	U.S.-90	Escambia River	6 km. south of Pace, Florida
E-2	Fl.-184	Escambia River	8 km. northeast of Cantonment, Florida
E-3	Fl.-4	Escambia River	5 km. east of Century, Florida
E-4	U.S.-29	Big Escambia Creek	2 km. north of Flomaton, Alabama
E-5	Fl.-41	Conecuh River	3 km. south of East Brewton
E-6	Fl.-41	Murder Creek	2 km. east of Brewton,Alabama
E-7	U.S.-29	Conecuh River	27 km. east of Brewton,Alabama
E-8	U.S.-84	Conecuh River	3 km. west of Andalusia, Alabama
E-9	U.S.-29	Conecuh River	8 km. north of Andalusia, Alabama
E-10	(dirt)	Patsaliga Creek	6 km. west of Gantt, Alabama
E-11	U.S.-84	Pigeon Creek	19 km. west of Andalusia. Alabama
B-1	U.S.-90	Blackwater River	1 km. west of Milton, Florida
B-2	(dirt)	Blackwater River	2 km. northwest of Harold, Florida
B-3	Fl.-4	Blackwater River	6 km. northwest of Baker, Florida
B-4	Fl.-191	Coldwater Creek	11 km. northeast of Milton, Florida
B-5	Fl.-4	Coldwater Creek	10 km. west of Munson, Florida
B-6	Fl.-4	Coldwater Creek	5 km. east of Jay, Florida
Y-1	Fl.-87	Yellow River	16 km. north of Holley, Florida
Y-2	U.S.-90	Yellow River	5 km. west of Crestview, Florida
Y-3	Fl.-2	Yellow River	8 km. east of Blackman, Florida
Y-4	Fl.-85	Shoal River	8 km. south of Crestview, Florida
Y-5	Fl.-285	Shoal River	8 km. north of Mossy Head, Florida

Appendix 8 - 22. Turbidities in the Escambia, Blackwater and Yellow Rivers during August 15, 1974 and November 20, 1974.

Station	Turbidity (JTU) August 15	November 20	Station	Turbidity (JTU) August 15	November 20
B1	11.0	2.2	E1	10.0	5.0
	10.0	2.3		10.0	5.0
	11.0	2.8		10.0	4.8
B4	3.1	1.8	E2	15.0	6.3
	3.7	1.5		15.0	8.0
	4.0	1.7		15.0	8.5
B5	2.8	1.0	E3	36.0	15.0
	3.2	1.5		34.0	13.0
	2.0	1.5		38.0	13.0
B6	5.3	2.8	E4	21.0	7.0
	5.3	2.8		22.0	7.5
	4.7	2.5		23.0	6.3
B3	3.7	2.3	E6	10.0	58.0
	3.3	2.3		10.0	70.0
	4.2	2.5		10.0	60.0
Y2	12.0	4.2	E5	42.0	10.0
	12.0	4.5		39.0	10.0
	6.8	4.0		40.0	12.0
Y3	19.0	6.0	E7	28.0	10.2
	22.0	5.3		29.0	10.0
	21.0	5.3		30.0	9.2
Y5	4.2	6.0	E9	13.0	5.8
	4.2	5.8		12.0	5.2
	4.3	7.0		12.0	5.5
Y4	6.4	5.0	E10	42.0	33.0
	6.3	5.0		40.0	32.0
	6.0	5.5		43.0	35.0
B2	5.0	4.5	E8	24.0	9.8
	5.4	4.5		24.0	8.8
	4.6	4.5		25.0	9.8
Y1	5.7	6.5	E11	20.0	25.0
	5.8	6.0		18.0	27.0
	5.4	6.0		20.0	25.0
			E12	33.0	18.0
				37.0	18.0
				33.0	20.0

Appendix 9 - 1. Summary of chlorophyll a (mg/l) data for the Pensacola Bay system January through September, 1974.

Sta.	Dep.	No.	Mean	Min.	Max.	CV%	Sta.	Dep.	No.	Mean	Min.	Max.	CV%
ADGV	A	12	0.0039	0.0022	0.0100	54.4	EPLP	A	12	0.0073	0.0039	0.0143	50.6
AGJI	A	12	0.0034	0.0017	0.0082	54.3	EPRF	A	12	0.0056	0.0028	0.0107	41.8
AGPH	A	12	0.0035	0.0014	0.0086	53.4	ERPB	A	12	0.0058	0.0028	0.0113	52.5
AJFD	A	11	0.0038	0.0011	0.0110	69.4	ER10	A	11	0.0053	0.0013	0.0096	56.9
ALEX	A	12	0.0032	0.0016	0.0065	40.5	ETLQ	A	12	0.0048	0.0020	0.0118	53.5
EFEI	A	5	0.0036	0.0003	0.0062	67.6	ETQE	A	12	0.0043	0.0013	0.0067	42.9
BJIV	A	12	0.0045	0.0017	0.0111	66.7	PEUE	A	8	0.0121	0.0061	0.0239	52.6
BNGA	A	12	0.0046	0.0017	0.0093	51.0	P01	A	12	0.0026	0.0004	0.0126	135.1
BREA	A	12	0.0044	0.0012	0.0160	90.8	P02	A	12	0.0042	0.0010	0.0138	99.3
ECGM	A	12	0.0041	0.0016	0.0073	46.2	P03	A	12	0.0035	0.0011	0.0096	86.6
EEDR	A	12	0.0049	0.0019	0.0121	59.1	P04	A	12	0.0035	0.0010	0.0094	67.6
EEEM	A	12	0.0051	0.0016	0.0086	44.6	P05	A	12	0.0033	0.0010	0.0100	84.2
EEIX	A	12	0.0056	0.0015	0.0108	55.3	P06	A	12	0.0044	0.0015	0.0111	73.8
EEKV	A	12	0.0084	0.0007	0.0170	65.0	P07	A	12	0.0040	0.0022	0.0095	53.5
EGLY	A	12	0.0081	0.0027	0.0137	48.5	P08	A	12	0.0033	0.0012	0.0116	85.7
EHGD	A	12	0.0038	0.0014	0.0088	59.6	P09	A	12	0.0033	0.0011	0.0090	71.9
EHPK	A	12	0.0161	0.0066	0.0410	68.1	P10	A	12	0.0032	0.0013	0.0047	37.4
EIIL	A	12	0.0056	0.0023	0.0100	43.2	P11	A	12	0.0065	0.0013	0.0376	155.8
EIKC	A	12	0.0051	0.0006	0.0131	73.0	P12	A	12	0.0033	0.0017	0.0051	34.6
EKLQ	A	12	0.0068	0.0019	0.0102	33.1	P13	A	12	0.0032	0.0012	0.0092	68.8
EKMP	A	12	0.0071	0.0033	0.0179	54.0	P14	A	12	0.0032	0.0012	0.0095	65.7
EMQC	A	12	0.0057	0.0028	0.0087	29.7	P15	A	11	0.0038	0.0013	0.0080	64.4
ENNB	A	12	0.0066	0.0026	0.0106	39.5							

Appendix 10 - 1. Bimonthly distribution of otter trawl samples by area and by station.

Area	Station	Number of trawl samples						
		Oct.	Dec.	Feb.	Apr.	June	Aug.	Total
1	II	2	2	2	2	2	2	12
	III	2	2	2	2	2	2	12
2	V	2	2	2	2	2	2	12
	VI	2	2	2	2	2	2	12
3	VII	2	2	2	2	2	2	12
	VIII	2	2	2	2	2	2	12
4	I	0	1	2	2	2	2	9
	IV	1	2	2	2	2	2	11
	IX	2	0	1	2	2	2	9
5	X	2	2	2	2	2	2	12
	XI	0	2	2	2	2	2	10
Total		17	19	21	22	22	22	123

Appendix 10 - 2. Spatial distribution of fishes collected by otter trawl in Escambia Bay, during 1973 through 1974. Areas are illustrated in Figure 10 - 1.

Species	Area 1	Area 2	Area 3	Area 4	Area 5	Total catch
	Number of trawl samples					
	24	24	24	29	22	
Dasyatis sabina	0	0	0	1	1	2
Dasyatis sayi	0	0	1	0	1	2
Lepisosteus osseus	24	1	0	0	4	29
Elops saurus	2	1	0	5	0	8
Brevoortia patronus	1,570	270	255	6,724	486	9,305
Harengula pensacolae	0	1	13	0	241	255
Dorosoma petenese	10	0	0	5	0	15
Anchoa hepsetus	173	1,273	1,670	101	1,975	4,693
Anchoa mitchilli	5,522	5,690	3,601	10,190	5,563	30,565
Synodus foetens	0	5	2	1	2	11
Ictalurus punctatus	0	0	0	5	0	5
Arius felis	3	30	27	21	42	123
Bagre marinus	0	1	0	0	0	1
Opsanus beta	0	1	0	0	0	1
Menidia beryllina	1	0	0	5	0	6
Syngnathus louisianae	0	0	1	0	0	1
Syngnathus scovelli	0	0	0	0	1	1
Caranx hippos	10	1	0	10	2	23
Chloroscombrus chrysurus	9	181	45	0	383	625
Oligoplites saurus	2	0	0	1	0	3
Selene vomer	0	0	1	1	2	4
Eucinostomus argenteus	1	0	0	112	0	113
Archosargus probatocephalus	0	7	2	0	2	11
Lagodon rhomboides	0	0	0	25	0	25
Bairdiella chrysura	2	16	7	52	7	84
Cynoscion arenarius	172	157	162	885	211	1,587
Cynoscion nebulosus	0	2	0	7	2	11
Leiostomus xanthurus	2,828	2,387	767	6,515	1,329	13,826
Menticirrhus americanus	0	2	5	0	5	12
Menticirrhus litteralis	0	0	0	0	5	5
Micropogon undulatus	1,493	1,363	1,166	1,986	1,907	7,915
Chaetodipterus faber	0	1	0	0	0	1
Mugil cephalus	0	0	0	23	1	24
Polydactylus octonemus	131	145	70	84	37	467
Gobioides broussonneti	0	0	0	1	0	1
Gobionellus hastatus	0	0	0	17	0	17
Gobionellus shufeldti	1	0	0	0	0	1
Trichiurus lepturus	3	3	10	0	9	25
Scomberomorus maculatus	0	3	0	0	0	3
Peprilus alepidotus	4	5	1	0	10	20
Prionotus tribulus	0	0	1	0	1	2
Citharichthys spilopterus	1	2	4	3	2	12
Etropus crossotus	0	3	4	0	3	10
Paralichthys lethostigma	0	0	0	4	2	6
Trinectes maculatus	1	0	1	5	1	8
Symphurus plagfusa	0	0	0	0	1	1
Sphoeroides parvus	0	0	4	2	3	9
Chilomycterus schoepfi	0	0	1	0	0	1
Total	11,963	11,551	7,821	26,791	11,750	69,876

Appendix 10 - 3. Bimonthly distribution of fishes collected by otter trawl in Escambia Bay, 1973-74.

Species	Oct.	Dec.	Feb.	Apr.	June	Aug.	Total catch
	Number of trawl samples						
	17	19	21	22	22	22	
Dasyatis sabina	0	1	1	0	0	0	2
Dasyatis sayi	0	0	0	0	2	0	2
Lepisosteus osseus	16	2	1	6	1	3	29
Elops saurus	0	0	0	7	0	1	8
Brevoortia patronus	3	5	5,305	2,319	1,640	33	9,305
Harengula pensacolae	1	0	0	0	0	254	255
Dorosoma petenese	0	8	7	0	0	0	15
Anchoa hepsetus	1,517	2,435	0	0	24	717	4,693
Anchoa mitchilli	7,092	11,591	3,532	979	2,938	4,434	30,566
Synodus foetens	0	5	0	1	0	5	11
Ictalurus punctatus	0	0	2	0	3	0	5
Arius felis	17	0	0	18	40	48	123
Bagre marinus	0	0	0	1	0	0	1
Opsanus beta	0	0	0	1	0	0	1
Menidia beryllina	0	0	6	0	0	0	6
Syngnathus louisianae	0	1	0	0	0	0	1
Syngnathus scovelli	0	0	1	0	0	0	1
Caranx hippos	1	9	0	0	5	8	23
Chloroscombrus chrysurus	254	2	2	0	0	367	625
Oligoplites saurus	0	3	0	0	0	0	3
Selene vomer	2	0	0	0	0	2	4
Eucinostomus argenteus	0	111	2	0	0	0	113
Archosargus probatocephalus	2	2	1	4	0	2	11
Lagodon rhomboides	2	0	1	0	10	12	25
Bairdiella chrysura	0	9	14	1	37	23	84
Cynoscion arenarius	20	55	6	116	1,104	286	1,587
Cynoscion nebulosus	0	8	1	0	2	0	11
Leiostomus xanthurus	1,593	411	1,821	2,911	6,151	939	13,826
Menticirrhus americanus	1	7	4	0	0	0	12
Menticirrhus litteralis	0	4	0	1	0	0	5
Micropogon undulatus	181	79	398	2,171	4,183	903	7,915
Chaetodipterus faber	0	1	0	0	0	0	1
Mugil cephalus	0	3	12	6	3	0	24
Polydactylus octonemus	10	0	0	13	379	65	467
Gobioides broussonneti	1	0	0	0	0	0	1
Gobionellus hastatus	0	0	3	13	1	0	17
Gobionellus shufeldti	0	0	1	0	0	0	1
Trichiurus lepturus	0	0	0	6	19	0	25
Scomberomorus maculatus	3	0	0	0	0	0	3
Peprilus alepidotus	5	0	0	1	1	13	20
Prionotus tribulus	0	2	0	0	0	0	2
Citharichthys spilopterus	0	0	1	3	2	6	12
Etropus crossotus	0	10	0	0	0	0	10
Paralichthys lethostigma	0	0	0	2	3	1	6
Trinectes maculatus	0	0	1	3	2	2	8
Symphurus plagfusa	0	1	0	0	0	0	1
Sphoeroides parvus	1	1	0	3	2	2	9
Chilomycterus schoepfi	0	1	0	0	0	0	1
Total	10,722	14,767	11,123	8,586	16,552	8,126	69,876

Appendix 10 - 4. Bimonthly distribution of fishes collected by seine in Escambia Bay, 1973-74.

Species	Oct.	Dec.	Feb.	Apr.	June	Aug.	Total catch
	Number of seine hauls						
	4	4	4	4	4	4	
Elops saurus	0	0	0	2	0	0	2
Brevoortia patronus	2669	12	8	2807	3	0	5499
Harengula pensacolae	5	0	0	0	0	15	20
Anchoa hepsetus	0	0	0	0	2	0	2
Anchoa mitchilli	155	33	0	22	1231	7	1448
Synodus foetens	0	0	0	4	0	0	4
Arius felis	0	0	0	0	1	1	2
Strongylura marina	0	0	0	0	3	0	3
Cyprinodon variegatus	0	5	0	1	0	0	6
Fundulus grandis	0	0	0	21	49	0	70
Fundulus similis	5	1	0	0	4	0	10
Lucania parva	2	0	0	0	0	0	2
Menidia beryllina	384	6	18	48	403	83	942
Micropterus salmoides	0	0	0	0	2	0	2
Chloroscombrus chrysurus	0	0	0	0	1	298	299
Oligoplites saurus	3	0	0	0	0	2	5
Lutjanus griseus	1	1	0	0	0	0	2
Eucinostomus argenteus	38	5	0	4	0	14	61
Lagodon rhomboides	1	0	1	20	35	7	64
Cynoscion arenarius	1	8	0	22	2	0	33
Cynoscion nebulosus	1	1	0	0	0	0	2
Leiostomus xanthurus	7	4	33	28	97	2	171
Menticirrhus americanus	0	0	0	0	1	0	1
Micropogon undulates	4	3	0	109	251	121	488
Mugil cephalus	0	13	57	237	10	0	317
Polydactylus octonemus	0	0	0	0	10	0	10
Gobiosoma bosci	1	0	0	0	0	0	1
Gobiosoma robustum	0	0	1	0	0	0	1
Gobionellus shufeldti	0	0	1	0	0	0	1
Citharichthys spilopterus	0	0	0	0	1	0	1
Etropus crossotus	1	0	0	0	0	0	1
Trinectes maculatus	0	0	0	0	1	0	1
Sphoeroides parvus	0	0	0	0	3	22	25
Total	3,278	92	119	3,325	2,110	572	9,496

Appendix 10 - 5. Spatial distribution of fishes collected by seine in Escambia Bay during 1973 through 1974.

Species	Area 1	Area 2	Area 3	Area 4	Total catch
	Number of seine hauls				
	6	6	6	6	
Elops saurus	1	1	0	0	2
Brevoortia patronus	4706	760	8	25	5499
Harengula pensacolae	0	0	20	0	20
Anchoa hepsetus	1	0	0	1	2
Anchoa mitchilli	329	17	1046	56	1448
Synodus foetens	0	4	0	0	4
Arius felis	2	0	0	0	2
Strongylura marina	1	0	1	1	3
Cyprindon variegatus	0	0	0	6	6
Fundulus grandis	0	1	0	69	70
Fundulus similis	0	0	1	9	10
Lucania parva	0	0	0	2	2
Menidia beryllina	138	336	73	395	942
Micropterus salmoides	0	0	0	2	2
Chloroscombrus chrysurus	0	5	294	0	299
Oligoplites saurus	2	2	1	0	5
Lutjanus griseus	0	0	0	2	2
Eucinostomus argenteus	33	0	12	16	61
Lagodon rhomboides	18	0	4	42	64
Cynoscion arenarius	7	2	24	0	33
Cynoscion nebulosus	0	0	2	0	2
Leiostomus xanthurus	56	7	34	74	171
Menticirrhus americanus	0	1	0	0	1
Micropogon undulates	371	8	15	94	488
Mugil cephalus	2	13	57	245	317
Polydactylus octonemus	0	0	0	10	10
Gobiosoma bosci	0	0	0	1	1
Gobiosoma robustum	0	0	0	1	1
Gobionellus shufeldti	0	0	0	1	1
Citharicthys spilopterus	0	0	0	1	1
Etropus crossotus	0	0	1	0	1
Trinectes maculatus	1	0	0	0	1
Sphoeroides parvus	0	3	22	0	25
Total	5,668	1,160	1,615	1,053	9,496

Appendix 10 - 6. Spatial distribution of shrimps (Penaeus spp.) collected by otter trawl in Escambia Bay during 1973 and 1974. Areas are illustrated in Figure 10 - 1.

Species	Area 1	Area 2	Area 3	Area 4	Area 5	Total catch
	Number of trawl samples					
	24	24	24	29	22	
Penaeus setiferus	4	11	4	50	14	83
Penaeus aztecus	59	51	42	153	57	362
Penaeus duorarum	0	7	26	0	4	37
Total	63	69	72	203	**75**	**482**

Appendix 10 - 7. Bimonthly distribution of shrimps (Penaeus spp.) collected by otter trawl in Escambia Bay during 1973 and 1974.

Species	Oct.	Dec.	Feb.	Apr.	June	Aug.	Total
	Number of trawl samples						
	17	19	21	22	22	22	
Penaeus setiferus	8	19	4	1	1	50	83
Penaeus aztecus	25	25	27	49	226	10	362
Penaeus duorarum	2	0	35	0	0	0	37
Total	35	44	66	50	**227**	60	482

Appendix 10 - 8. Commercial landings of shrimp (Penaeus spp.) from Escambia Bay from 1964 to 1973.

Year	Number of trips	Catch (lbs)			Total catch (lbs)	Dollar value	Average catch/trip (lbs)
		Brown	Pink	White			
1964	182	0	0	29,374	29,374	13,763	161.4
1965	241	16,701	501	18,587	35,789	15,894	148.5
1966	63	0	0	3,563	3,563	2,623	56.6
1967	415	59,214	833	5,818	65,865	30,181	158.7
1968	410	53,093	1,160	7,740	61,993	35,561	151.2
1969	429	1,955	14,999	8,180	25,134	18,327	58.6
1970	59	73	853	1,700	2,626	1,663	44.5
1971	2	110	20	0	130	151	65.0
1972	0	0	0	0	0	0	0.0
1973	2	0	98	0	98	96	49.0
Annual average	180	13,115	1,847	7,496	22,457	11,826	124.6
Five-year average (1964-1968)	262	25,802	499	13,016	39,317	19,604	150.0
Five-year average (1969-1973)	98	428	3,194	1,976	5,598	4,047	56.9

Appendix 10 - 9. Commercial landings of shrimp (Penaeus spp.) from East Bay from 1964 to 1973.

Year	Number of trips	Catch (lbs)			Total catch (lbs)	Dollar value	Average catch/trip (lbs)
		Brown	Pink	White			
1964	84	0	0	6,796	6,796	3,519	80.9
1965	468	100,406	0	20,675	121,081	49,315	258.7
1966	58	4	64	4,744	4,814	3,638	83.0
1967	60	8,613	632	0	9,245	4,325	154.1
1968	493	41,876	3,170	12,274	57,320	37,113	116.3
1969	103	8,278	1,102	371	9,751	4,901	94.7
1970	0	0	0	0	0	0	0.0
1971	0	0	0	0	0	0	0.0
1972	0	0	0	0	0	0	0.0
1973	69	0	2,341	0	2,341	2,605	33.9
Annual average	133	15,917	731	4,449	22,749	10,542	170.4
Five-year average (1964-1968)	233	30,180	773	8,898	39,451	19,582	169.6
Five-year average (1969-1973)	34	1,655	689	74	2,418	1,501	70.2

Appendix 10 - 10. Commercial landings of shrimp (Penaeus spp.) from Pensacola Bay from 1964 to 1973.

Year	Number of trips	Catch (lbs)			Total catch (lbs)	Dollar value	Average catch/trip (lbs)
		Brown	Pink	White			
1964	2,224	182,152	67,403	44,208	293,763	113,285	132.1
1965	2,646	365,802	98,436	72,058	536,296	242,874	202.7
1966	3,950	448,716	135,581	10,124	594,421	344,255	150.5
1967	3,816	337,903	168,856	16,334	523,093	325,610	137.1
1968	4,207	702,030	166,757	33,534	902,321	490,044	214.5
1969	2,417	120,022	83,730	32,020	235,772	162,503	97.5
1970	924	6,484	34,497	11,043	52,024	41,552	56.3
1971	545	15,356	1,609	186	17,151	15,968	31.5
1972	766	1,320	55,372	2,042	58,734	48,662	76.7
1973	1,524	117	121,584	542	122,243	150,334	80.2
Annual average	2,302	217,990	93,383	25,734	333,582	193,509	144.9
Five-year average (1964-1968)	3,368	407,321	127,407	35,251	569,979	303,213	169.2
Five-year average (1969-1973)	1,235	28,660	59,358	16,217	97,185	83,804	78.7

Appendix 10 - 11. Commercial landings of shrimp (Penaeus spp.) from Choctawhatchee Bay from 1964 to 1973.

Year	Number of trips	Catch (lbs)			Total catch (lbs)	Dollar value	Average catch/trip (lbs)
		Brown	Pink	White			
1964	247	10,843	1,434	6,521	18,798	9,205	76.1
1965	267	35,537	1,082	20,789	57,408	31,917	215.0
1966	795	49,739	21,226	28,921	99,886	83,761	125.6
1967	807	30,966	31,449	14,571	76,986	63,247	95.4
1968	611	33,302	24,334	8,823	66,459	60,261	108.8
1969	315	452	17,387	8,440	26,279	21,156	83.4
1970	298	5,072	24,493	16,610	46,175	32,994	154.9
1971	259	11,084	9,418	10,395	30,897	27,950	119.3
1972	525	61,451	13,600	1,647	76,698	106,874	146.1
1973	419	0	31,834	0	31,834	43,256	76.0
Annual average	454	23,844	17,626	11,671	53,142	48,062	117.1
Five-year average (1964-1968)	543	32,077	15,905	15,925	63,907	49,678	117.7
Five-year average (1969-1973)	363	15,612	19,346	7,418	42,377	46,446	116.7

Appendix 10 - 12. Monthly distribution of fish kills in the Pensacola Bay system from 1970 through 1974.

Month	1970	1971	1972	1973	1974	Total
January	0	0	1	0	0	1
February	0	0	0	0	0	0
March	0	0	2	1	0	3
April	1	0	2	0	4	7
May	0	0	4	1	3	8
June	3	2	2	1	3	11
July	15	6	4	2	0	27
August	13	8	6	8	0	35
September	19	20	5	4	4	52
October	5	6	8	2	0	21
November	0	0	0	0	0	0
December	0	0	1	0	0	1
Total	56	42	35	19	14	166

Appendix 10 -13. Listing of the time, place and estimated size of the fish kills in the Pensacola Bay system during 1970.

Date	Location	Estimated number of individuals
April 21	Bayou Chico	3,500
June 21	Mulat Bayou	250,000
June 29	Mulatto Bayou	750,000
June 29	Trout Bayou	1,000,000+
July 1	Mulat Bayou	2,000
July 1	Bayou Grande	50
July 3	Bass Hole Cove	11,000,000+
July 3	Trout Bayou	1,000,000+
July 5-7	Mulat Bayou	11,000,000+
July 8	Bayou Chico	8,000
July 9	Dead River	10,000,000+
July 12-13	Mulat Bayou	10,000+
July 13	Bayou Chico	20,000
July 25,27	Trout Bayou	1,000,000+
July 27	Bass Hole Cove	750,000
July 27	Mulat Bayou	1,000,000
July 27	Racoon Bayou	millions
July 29	Bayou Chico	1,000+
July 30	Trout Bayou	10,000
August 5	Escambia Bay	hundreds
August 6	Indian Bayou	5,000
August 7	Racoon Bayou	15,000
August 17	Bayou Chico	1,000+
August 18-25	Bayou Texar	4,000+
August 24	Trout Bayou	500
August 25	Bayou Chico	5,000+
August 25	Bayou Texar	3,000+
August 25	Mullatto Bayou	700

Appendix 10 -13(cont). Listing of the time, place and estimated size of the fish kills in the Pensacola Bay system during 1970.

Date	Location	Estimated number of individuals
August 26-31	Escambia Bay	10,000,000
August 27	Woodland Bayou	5
August 27	Indian Bayou	10,000,000
August 31	Trout Bayou	3,000
September 1	Hoffman Bayou	100
September 2-3	Bayou Texar	300
September 2	Escambia Bay	millions
September 2	Racoon Bayou	thousands
September 2-4	Bayou Grande	150+
September 3	Woodland Bayou	100
September 3	Gilmore Bayou	50
September 4	Thompson Bayou	no estimate
September 4	Mulatto Bayou	no estimate
September 8	Trout Bayou	500
September 10-22	Bayou Texar	200+
September 18	Bayou Chico	20,000
September 18	Escambia Bay	4,000
September 18	Woodland Bayou	300
September 23	Escambia Bay	45
September 24	Bayou Grande	25+
September 24-25	Escambia Bay	2,000+
September 24	Hoffman Bayou	200
September 28	Mulatto Bayou	1,000,000
October 12	Mulat Bayou	200,000
October 12	Escambia Bay	3,000
October 26-27	Bayou Chico	10,000
October 27	Escambia Bay	3,000
October 27	Judge's Bayou	300,000

Appendix 10 - 15. Total - length frequency of Atlantic bumper, Chloroscombrus chrysurus, from Escambia Bay during 1973-1974.

Midclass (mm)	Oct.	Dec.	Feb.	Apr.	June	Aug.
17						
22	1				1	2
27	54					2
32	68					3
37	8		1			8
42	4	1				23
47	4	1				31
52	3		1			19
57	8					6
62	1					5
67						13
72	1					24
77						31
82						45
87						22
92						11
97						4
Total	152	2	2	0	1	249

Appendix 10 - 14. Total - length frequency of Gulf menhaden, Brevoortia patronus, from Escambia Bay from 1973-1974.

Midclass (mm)	Oct.	Dec.	Feb.	Apr.	June	Aug.
22		3	4	3		
27		9	43	81		
32			106	77		
37			21	32		
42			1	16	14	2
47				12	26	1
52				5	29	3
57				9	36	
62				6	21	1
67				3	9	
72					17	1
77				1	21	1
82				5	12	6
87				14	14	8
92	1			10	14	9
97				3	5	1
102				7	1	
107	6			7		
112	22			3		
117	53	2		2	1	
122	62					
127	38					
132	10	2				
137	7	1				
Total	199	17	175	296	192	33

Appendix 10 - 16. Total-length frequency of sand seatrout, Cynosian arenarius, from Escambia Bay during 1973 - 1974.

Midclass (mm)	Oct.	Dec.	Feb.	Apr.	June	Aug.
27				7		
32				15		1
37	2			23	2	
42	4			17	3	1
47	3			9	17	
52	1			1	27	1
57				5	52	3
62	1			2	45	6
67	1	1		1	35	3
72					19	21
77		1			24	14
82		5			6	21
87		8			6	19
92		6	1		5	21
97		10	1		5	18
102		8			11	29
107		7	2		9	34
112	1	4	2		6	11
117		2			6	11
122					9	4
127	1				5	3
132	2				2	2
137					2	2
142	1					2
147	2					2
152	2					2
157					1	3
162				3		1
167						3
172		1				2
177						
182						2
187						2
192					1	6
197					1	2
202					1	2
207					3	2
212					5	
217					2	
222						
227					3	
232					1	
237					2	1
242					2	
247						
257						1
282						1
292						1
297						1
327						1
332						1
337						1
Total	21	53	6	82	318	263

Appendix 10 - 17. Total - length frequency of spot, Leiostomus xanthurus, from Escambia Bay during 1973 - 1974.

Midclass (mm)	Oct.	Dec.	Feb.	Apr.	June	Aug.
17		5	21	2		
22		3	82	25		
27		2	205	43		
32			165	15		
37			64	11		
42			8	29	9	
47			3	48	16	
52			1	33	17	
57				20	18	8
62				9	27	19
67	1			5	47	42
72	3			2	30	39
77	9			2	33	46
82	21				39	50
87	47			1	26	40
92	29	7			14	31
97	10	23			11	18
102	11	43			8	16
107	4	48		3	1	6
112	1	54	2	5	2	6
117	4	39	6	5		4
122	1	30	13	6	4	2
127	1	23	10	5	1	3
132		18	8	4	1	3
137		18	13	7	1	4
142	1	6	11	4	3	6
147		15	9	2	5	10
152		5	3	5	4	7
157	1	2	4	3	4	4
162	1	3			1	1
167		4		1	1	2
172				1	2	
177			1		2	1
182				2		2
187		1			1	1
192		2	1	1		
197		1			1	1
202				1		2
207			1			2
212		1	3		1	4
217			2	1	5	4
222		1			2	2
227					5	1
232					5	1
237		1			1	2
242	2		2	1	3	3
247		1	1		1	1
252					3	3
257			1			
262					3	
267						
272	1				1	2
Total	148	356	640	302	359	399

Appendix 10 - 18. Total - length frequency of Atlantic croker, Micropogon undulatus, from Escambia Bay during 1973 - 1974.

Midclass (mm)	Oct.	Dec.	Feb.	Apr.	June	Aug.
12			1			
17		2	6			
22			19	1		
27		1	47	7		
32			42	14		
37		1	42	29		
42		3	34	12		
47		1	25	14	1	
52		3	23	16	9	
57		2	17	22	9	
62		1	5	22	14	
67		2	3	23	27	
72			4	20	31	
77		1	8	18	34	4
82			7	11	24	10
87			5	12	25	14
92			2	4	12	27
97			2	2	17	28
102					19	38
107	1			1	10	34
112	1				10	49
117	1		1		5	31
122	1				6	28
127	7				4	24
132	4	1			2	23
137	10	2				16
142	14	4				17
147	14	6				13
152	15	7	1			13
157	10	9	2	1		8
162	7	5	4			13
167	5	7	4			11
172	3	1	6	1		6
177		3	2	1		5

Appendix 10 - 18(cont). Total - length frequency of Atlantic croker, Micropogon undulatus, from Escambia Bay during 1973 - 1974.

Midclass (mm)	Oct.	Dec.	Feb.	Apr.	June	Aug.
182	2	1	2	1	3	3
187		2	2	5	3	3
192		2	1	1	5	2
197		3	4	5	6	1
202	2	2	8	6	13	3
207			7	5	10	8
212	2		4	1	11	9
217	2	2	4	4	15	5
222		1	4	1	6	6
227		2	2	3	9	6
232		1		1	6	7
237	2	2	2	1	4	7
242		1	2	1	1	5
247						4
252			1			5
257						2
262			1		6	3
267			1			5
272					1	6
282			1	2	1	7
287				1		1
292				1		2
297				2		2
302					1	1
307						1
312						
317						
322						1
327						1
347					1	
352						2
402					1	
Total	103	83	362	272	362	520

Appendix 11 - 1. Benthic macroinvertebrate sampling dates and stations in the Pensacola Bay system.

July - August, 1973	EA, EB, EC, ED, EE, GA, GB, GC, GD, IA, IB, IC, ID, IE, KA, KB, KC, KD, KE, MA, MB, MC, MD, MMA, MMB, MMC, MMD, OA, OB, OC, OD, QA, QB, QC, QE, SA, SB, SC, SD
January, 1974	GA, GB, GD, OA, OB, OD, BWA, BWB, BWC, EBWA, EBWB, EBWC, ESD, EBD, PBD, SRA, SRB, SRC
April, 1974	EBEA, EBEB, EBEC, EBED, EBEE
August, 1974	ACY, APD, APDN, BWG, ESG, NES

Appendix 11-2.--Benthic Macro-fauna from the Pensacola Estuary. (E = Escambia Bay; A = East and Blackwater Bays; S = Santa Rosa Sound)

Arthropoda	
Insecta	
Chironomid (Midge)	E
Crustacea	
Amphipoda	
Ampelisca vadorum	EAS
Ampelisca sp. (nr. verrilli)	S
Ampelisca abida	S
Monoculodes edwardsi	EAS
Monoculodes sp. B.	EA
Haustorius sp.	EAS
Photis pugnator	ES
Listriella sp. (nr. barnardi)	AS
Rudilemboides nageli	S
Grandidierella bonnieroides	EAS
Gammarus mucronatus	EA
Elasmopus levis	S
Melita nitida	EA
Batea catharinensis	S
Cymadusa compta	S
Corophium sp. (nr. acutum)	EA
Paracaprella pusilla	S
Isopoda	
Edotea sp.	EAS
Cyathura sp.	AS
Erichsonella filiformis	AS
Tanaidacea	
Leptochelia sp.	A
Apseudes sp.	S
Cumacea	
Oxyurostylis smithi	EAS
Mysidacea	
Mysidopsis bigelowi	EAS
Praunus sp.	EA
Decapoda	
Penaeus setiferus	EA
Penaeus aztecus	EA
Trachypeneus constricta	S
Palaemonetes pugio	EA
Palaemonetes sp.	EA
Hippolyte pleuracantha	S
Periclimenes longicaudatus	S
Family: Processidae	S
Sicyonia brevirostris	S
Shrimp sp. A.	E
Pinnixa sayana	EAS
Pinnixa chaetopterana	S

Callianassa jamaicense louisianensis	EA
Pagurus longicarpus	S
Micropanope sp.	A
Eurypanopeus depressus	EA
Neopanope texana texana	EAS
Callinectes sapidus	EA
Callinectes ornatus	EA
Zanthid juveniles	ES
Portunid juveniles	E
Unidentified larval crustacean	ES

Mollusca

Pelecypoda

Mysella planulata	EA
Nuculana acuta	S
Mercenaria campechiensis	EAS
Tellina versicolor	ES
Tellina sp. B.	S
Cyclinella tenuis	EAS
Macoma mitchelli	EA
Ensis minor	EAS
Mactra fragilis	EAS
Mulinia lateralis	EA
Polymesoda caroliniana	EAS
Rangia cuneata	E
Amygdalum papyria	EA
Tagelus plebeius	EAS
Anomalocardia cuneimeris	E
Brachidontes recurvus	EA
Crassostrea virginica	EAS
Brachidontes exustus	EAS
Abra aequalis	S
Lyonsia hyalina floridana	S
Crassinella lunata	S
Anadara transversa	S
Martesia cuneiformis	A
Martesia smithi	A
Lucina multilineata	S
Lucina amiantus	S
Laevicardium mortoni	S
Dinocardium robustrum	S
Macoma tenta	S
Cumingia antillarum	S
Musculus lateralis	S

Gastropoda

Nassarius vibex	ES
Crepidula maculosa	S
Crepidula fornicata	S
Crepidula plana	EA
Retusa canaliculata	EAS
Olivella pusilla	S
Kurtziella limonitella	S
Natica pusilla	S
Anachis simplicata	S

Mitrella lunata	S
Granulina (Bullata) ovuliformis	S
Thais haemastoma	S
Thais sp. B.	S
Mangelia stellata	S
Urosalpinx cinera	S
Eupleura sulcidentata	S
Nudibranchs	EAS
Prunum apicinum	S
Turbonilla conradi	S
Odostomia sp. A.	EA
Odostomia sp. B.	EA
Bulla occidentalis	ES
Epitonium rupicola	ES
Polinices duplicata	EA
Neritina reclivata	EA
Polychaetes	
Polynoidae	
Antinoella sarsi	S
Eunoe nodosa	S
Harmothoe lunulata	S
Sigalionidae	
Sthenelais boa	EAS
Amphinomidae	
Amphinome rostrata	S
Phyllodocidae	
Anaitides maculata	ES
Eteone heteropoda	ES
Nereiphyla fragilis	S
Phyllodoce (Genetyllis) castanea	S
Pilargidae	
Ancistrosyllis hamata	EA
Cabira incerta	S
Parandalia fauveli	EA
Sigambra bassi	EA
Hesionidae	
Gyptis capensis	EAS
Podarke obscura	E
Nereidae	
Laeonereis culveri	EA
Leptonereis laevis	S
Neanthes succinea	EAS
Nereis pelagica occidentalis	S
Platynereis dumerili	S
Nephtyidae	
Aglaophamus inermis	S
Glyceridae	
Glycera oxycephala	AS
Goniadidae	
Glycinde solitaria	EA
Eunicidae	
Marphysa sanguinea	E
Onuphidae	

Diopatra c. cuprea	EAS
Lumbrineridae	
Ninoe nigripes gracilis	E
Lumbrineris pallida	S
Arabellidae	
Drilonereis cylindrica	EA
Spionidae	
Microspio pigmentata	S
Paraprionospio pinnata	EAS
Polydora caeca	EAS
Polydora socialis	S
Polydora websteri	EA
Prionospio pygmaea	S
Scolelepis squamata	EAS
Spiophanes bombyx	S
Spio pettiboneae	S
Magelonidae	
Magelona alleni	S
Poecilochaetidae	
Poecilochaetus johnsoni	S
Cirratulidae	
Cirratulus cirratus	S
Cossura longocirrata	S
Orbiniidae	
Haploscoloplos fragilis	EAS
Paraonidae	
Aricidea suecica	S
Opheliidae	
Polyophthalmus pictus	S
Trayisia forbesii	S
Capitellidae	
Heteromastus filiformis	EAS
Maldanidae	
Axiothella mucosa	S
Gravierella sp.	A
Isocirrus longiceps	A
Sternaspidae	
Sternaspis fossor	S
Pectinariidae	
Pectenaria gouldii	EAS
Ampharetidae	
Amphicteis gunneri floridus	EA
Melinna maculata	S
Terebellidae	
Lanice conchilega	S
Pista cristata	S
Terebellides stroemi	S
Sabellidae	
Chone duneri	S
Potamilla reniformis	S
Serpulidae	
Hydroides uncinata	S

Hirudinia

Species	E
Hemichordate	
Species	EA
Nemertean	
Species *Cerebratulus lacteus* (Leidy)	EAS
Phoronida	
Phoronis architecta	S
Platyhelminthes	
Species	EAS
Echinoderms	
Ophiuroids	
Amphioplus coniortodes	S
Amphiodia atru	S
Holothuroids	
Synaptula hydriformis	EAS
Pentamera pulcherrima	S
Echinoid	
Lythecinus variegatus	S
Coelenterates	
Hydroid forms	S
Medusoid forms	S
Anemones	S
Chordates	
Branchiostoma caribaeum	S
Vertebrates	
Gobiosoma sp.	A
Trinectes maculatus	ES
Microdesmus longipinnis	E
Microgobius gulosus	E
Gobioides sp.	E
Myrophis punctatus	E
Gobiosoma bosci	E
Pipefish	S
Priapulida	
Species	S

Appendix 11 - 3. Shannon - Weaver (H') diversity index values for all benthic macro-fauna stations in the Pensacola Bay system.

Station	Total Species/Station	Total Individuals/m^2	Diversity (H')	Biomass (gr./m^2)
ACY	11	239.8	1.634	0.48
APD	9	167.7	1.732	0.19
APDN	7	340.6	0.831	0.18
EWA	18	286.2	2.439	0.92
EWB	21	348.7	2.483	0.25
EWC	21	412.9	2.111	0.10
EWG	24	704.8	1.813	5.16
EA	2	5.2	0.562	0.01
EB	4	11.7	1.149	0.03
EBD	10	82.0	1.787	0.06
EBEA	10	55.9	1.748	0.19
EBEB	13	150.6	1.722	0.02
EBEC	25	4271.7	0.955	4.64
EBED	8	1595.7	0.219	0.17
EBEE	26	1527.0	1.316	0.28
EBWA	19	239.4	2.452	1.17
EBWB	23	244.3	2.516	0.13
EBEC	12	788.7	0.504	0.12
EC	9	144.4	1.390	0.16
ED	12	314.9	1.486	0.30
EE	12	593.5	1.275	0.34
ESD	8	52.0	1.724	0.03
ESG	23	924.2	1.933	5.45
GA	7	160.0	0.779	0.04
GA2	13	264.1	2.056	0.23
GB	6	83.3	1.260	0.12
GB2	22	822.3	1.858	0.60
GC	8	140.5	1.233	0.25
GC2	16	1916.2	1.206	0.34
GD	11	90.3	1.871	1.62
IA	4	10.4	1.255	0.04
IB	2	3.9	0.637	0.01
IC	3	9.1	0.796	0.11
ID	11	239.4	1.303	1.84
IE	13	1553.2	1.507	3.05
KA	5	36.4	1.251	0.02
KB	3	42.9	1.680	0.27
KC	17	85.9	2.250	0.12
KD	19	171.7	2.269	0.25
KE	13	203.2	1.931	0.09
MA	5	20.8	1.160	0.02
MB	2	9.1	0.410	0.02
MC	11	571.2	1.259	0.46
MD	13	1114.5	1.075	0.85
MMA	19	361.7	1.879	228.11
MMB	21	651.9	1.969	107.10
MMC	18	135.3	2.404	2.40
MMD	22	193.6	2.357	0.09
NES	23	774.2	1.347	0.43
OA	4	63.8	1.134	0.36
OAD2	13	200.3	2.013	1.47
OA2	16	197.8	2.147	0.38
OB	9	37.7	1.868	0.07
OB2	17	264.1	2.196	0.26
OC	12	104.1	1.788	0.31
OC2	21	211.3	2.357	0.08
OD	15	583.9	1.604	0.25
PBD	12	154.8	1.760	0.12
QA	5	54.6	0.833	0.07
QB	3	62.5	0.830	0.03
QC	18	257.6	2.020	0.98
QE	11	67.7	2.120	0.03
SA	4	9.1	1.277	0.05
SB	3	9.1	0.956	0.01
SC	9	61.3	1.731	0.14
SD	10	61.1	1.600	0.05
SDP	15	145.7	2.089	0.15
NES	25	778.1	1.376	0.43
SRA	67	1781.4	3.005	1.85
SRB	68	1937.5	2.892	2.94
SRC	83	1525.0	3.012	0.61

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