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Canaveral National Seashore Water Quality and Aquatic Resource Inventory

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Summary

Mosquito Lagoon is a shallow bar built estuary located on the east central Florida Coast. The lagoon and associated watershed cover approximately 327 km^2 (79422 acres). The lagoon occupies 159 km^2 (37853 acres). Water depths average approximately 1 m. This gives the lagoon an estimated volume of approximately $1.6x10^8 m^3$. A large portion of the relatively undisturbed watershed is owned and managed by the federal government as Canaveral National Seashore, the Merritt Island National Wildlife Refuge, and the NASA Kennedy Space Center. This report contains results of a water resources inventory that included water and sediment chemistry, underwater light attenuation, distribution and composition of submerged aquatic vegetation beds, demersal fish sampling, and meteorological data summaries for the region.

Generally, water quality of Mosquito Lagoon is considered good. In part this is a result of the low level of watershed development in the region. Three major forces, gravity, wind, and radiation control water movement influencing the mass balance or concentrations of chemicals in the various components of the system at any given instance. Influences of tidal action and the Atlantic Ocean through Ponce de Leon Inlet are limited primarily to the northern reaches of the Lagoon and the northern section of Canaveral National Seashore. Water quality in the southern region of the lagoon is affected by evapotransporation, rainfall, discharges from mosquito control impoundments, and exchange with the Indian River Lagoon through Haulover Canal. Groundwater seepage into and out of the lagoon also influences water quality along with biological processes.

Salinity data collected for the lagoon typically range between 20 ppt and 35 ppt. The lowest value recorded was 4.5 ppt and the highest value was 37 ppt. Lower values are associated with areas of fresh water discharge while higher values can be observed during periods of low rainfall and high evapotransporation. A slight gradient of 2-3 ppt was observed between the northern and southern reaches of the lagoon. Stations 1 and 2 in the south averaged 25 ppt while northern stations averaged 28 ppt. This gradient most probably represents influences of Ponce de Leon Inlet. Salinity values are positively correlated with total dissolved solids, conductivity, and specific compounds as expected.

Lagoon water temperatures fluctuate 2-3°C over a 24 h period. Summer temperatures typically range between 27 and 31°C and winter temperatures range between 15 and 23°C. Cold front passage in late fall and winter can rapidly alter water temperature by 5-10°C or more in a short period of time. The highest temperature recorded was 33.4°C and the lowest temperature was 8.8°C following passage of a winter storm.

Dissolved oxygen concentrations displayed a high degree of variability when monitored continuously at the Canaveral National Seashore boat dock. Values ranged from a low of 0.4 mg/l to a high of 15.3 mg/l. Extended periods of readings below the Florida Department of Environmental Protection criteria of 4.0 mg/l were observed in fall and spring months suggesting high system respiration and oxygen demand. In contrast, results of daytime dissolved oxygen sampling at the six water and sediment chemistry stations found values always above 5.0 mg/l. Without continuous monitoring the periods of low dissolved oxygen would not have been documented.

Results of metals analyses suggest the need for additional evaluation to understand chemical dynamics and processes that control water concentrations and chemistry within the lagoon. Several metals such as antimony, arsenic, molybdenum and mercury were reported as below detection limits for all samples. In contrast, metals of concern such as cadmium, copper,

chromium, silver, and zinc were found to be periodically above the Florida Department of Environmental Protection criteria for Class II and Class III surface waters. Specific sources for these metals are not readily identifiable and little is known about their partitioning within different components of the lagoon system. Chemical analyses for pesticides and herbicides in water and sediments were consistently reported as below detection.

The ability of light to penetrate the water column and reach the bottom is important to overall system primary production. Light drives the photosynthetic process occurring in phytoplankton, benthic algae, and submerged aquatic vegetation. Results of the light attenuation study showed a high degree of variability between different regions of the lagoon. The minimum attenuation value was 0.3 m^{-1} at Station 3A. Maximum attenuation of 1.69 m^{-1} was measured at Station 4A. The high attenuation at Transect 4 is the result of tidal influences, turbulent mixing, and the resulting increased turbidity. The average scalar attenuation for all stations and seasons was 0.92 m^{-1}. Primary factors influencing the underwater light field include sun angle, water color, bottom color, and total suspended sediments or turbidity. Stormwater runoff with its nutrient and particulate load is recognized as a potential source for these parameters. Daily rainfall amounts for the study period ranged between 0 and 2.95 inches. The mean rainfall volume for the 207 recorded rainfall days was 0.44 in. Rainfall pH ranged between 3.85 and 7.06 pH units.

Results of submerged aquatic vegetation sampling at select transects found the system dominated by two species, shoal grass (*Halodule wrightii*) and manatee grass *(Syringodium filiforme)*. Seagrass beds were less dense and reduced in distribution in the northern regions of Canaveral National Seashore where tidal fluctuations and high turbidity are most evident. Submerged aquatic vegetation was most abundant in the shallow southern regions of the lagoon with shoal grass most abundant in shallow areas and manatee grass increasing in importance in deeper areas. The central basin of the lagoon was found to be devoid of seagrass. Drift algae were present in deeper areas.

Fish community sampling at five stations produced 49 species. The fish fauna consisted of a few specimens that were numerically dominate and a larger number of increasingly rare species. The bay anchovy often composed over 90% of the catch. Although a small species, the bay anchovy often predominates in biomass because of sheer abundance. Other numerically common species were silver perch, pinfish, pigfish, spot, croaker, Gulf pipefish, silver jenny, and code goby. Large specimens are relatively rare in trawl collections. When they are caught, however, they may dominate in biomass due to their large size. Typical examples were the butterfly ray, blunt-nose stingray, and hardhead catfish. Community composition varied from station to station and between sampling periods. Although this variation was often of large magnitude, most of it proved to be statistically random and insignificant. The patterns of variation that appeared to be consistent and statistically significant over the two year period were: 1) Stations 1 and 2 were highly correlated and were very similar in community composition. (2) Station 4 was consistently uncorrelated with any other station and had a different community composition. (3) The silver jenny was more abundant in 1991 than in 1992. (4) The spot was more abundant in 1992 than 1991. (5) Rare species were encountered more often at the northern stations than at the southern stations. Important environmental considerations that appear to influence community composition are habitat diversity and proximity to ocean access (Stations 1 and 2) and drift algae density (Station 4).

The following recommendations are provided based on results of this project.

1) Continue to develop information necessary to quantify the water budget for Mosquito Lagoon. This should be accomplished at a level of detail that will allow for creation of a simple mass balance model that can be used to support management decisions. One area needing immediate attention is the rate and quality of groundwater leakage into and or out of Mosquito lagoon.
2) Develop information on the relationship between sediment chemistry and the chemistry of the overlying water column with emphasis on the exchange rates and controlling factors for metals and other ions. Define sources of metals in the environment and develop management strategies if possible..
3) Work closely with the St Johns River Water Management District and Volusia County staff to develop and participate in a joint interagency monitoring program that includes Canaveral National Seashore. Participate in the St Johns River Water Management Districts Pollution Load Reduction Program.
4) Develop a working adaptive water resources management strategy that defines the goals of the CNS with regard to water quality issues. Set specific objectives and priorities.
5) Continue monitoring the species composition and abundance of submerged aquatic vegetation by use of transect sampling and aerial photography or other remote sensing methods.
6) Work with State and federal programs to continue monitoring fish communities in Mosquito Lagoon with emphasis on critical periods in the early life history.
7) Establish a protocol for monitoring tissue concentrations of metals in shellfish and their relationships to concentrations in sediments and the water column.
8) Support development of a multi-agency program to monitor seaturtle use of Mosquito Lagoon with emphasis on species composition, health and abundance.

Canaveral National Seashore
Water Quality and Aquatic Resource Inventory

1.0 Introduction

This report covers Phase II of an Interagency Agreement IA 5000-0-9504 between the National Park Service at Canaveral National Seashore and the National Aeronautics and Space Administration at the John F. Kennedy Space Center. The study design was based on results of a comprehensive literature review and information search reported in the "Mosquito Lagoon Environmental Resources Inventory" (Provancha et al. 1992), which represented Phase I of the project. Phase II covered two years of data collection based on information needs identified through literature review.

Mosquito Lagoon is a shallow, bar built, barrier island estuary located on the east coast of central Florida north of Cape Canaveral. Figure 1 shows the study area with the southern boundary at 28 42.44 N and the northern boundary in the vicinity of Turtle Mound at 28 57.30 N. Our objective was to provide a more comprehensive baseline database for water quality and select biological resources that exist in Mosquito Lagoon with emphasis on the Canaveral National Seashore. This baseline characterization program developed information on the following topics:

- meteorology (rainfall, air temperature, wind speed and wind direction);
- water and sediment chemistry, temperature, salinity, and light attenuation;
- seagrasses (species composition, relative abundance, distribution maps)
- fish community data (species composition, relative abundance with comparisons to historical data).

Information derived in Phase II was used to recommend monitoring programs for implementation by the National Park Service personnel at Canaveral National Seashore (CNS).

2.0 Water and Sediment Quality

2.1 Introduction

Review of existing information on Mosquito Lagoon and Canaveral National Seashore revealed several issues. There is a lack of long-term (greater than 10 years) data with consistent variables and analytical procedures. Implementation of a monitoring program, coordinated by the St. Johns River Water Management District, in 1989 for 135 sites in the Indian River Lagoon continues to address this problem. However, several site-specific questions remain unanswered. The majority of existing and historic sample stations are concentrated around the communities of Edgewater and New Smyrna and do not provide adequate descriptions of water quality conditions inside the CNS boundary.

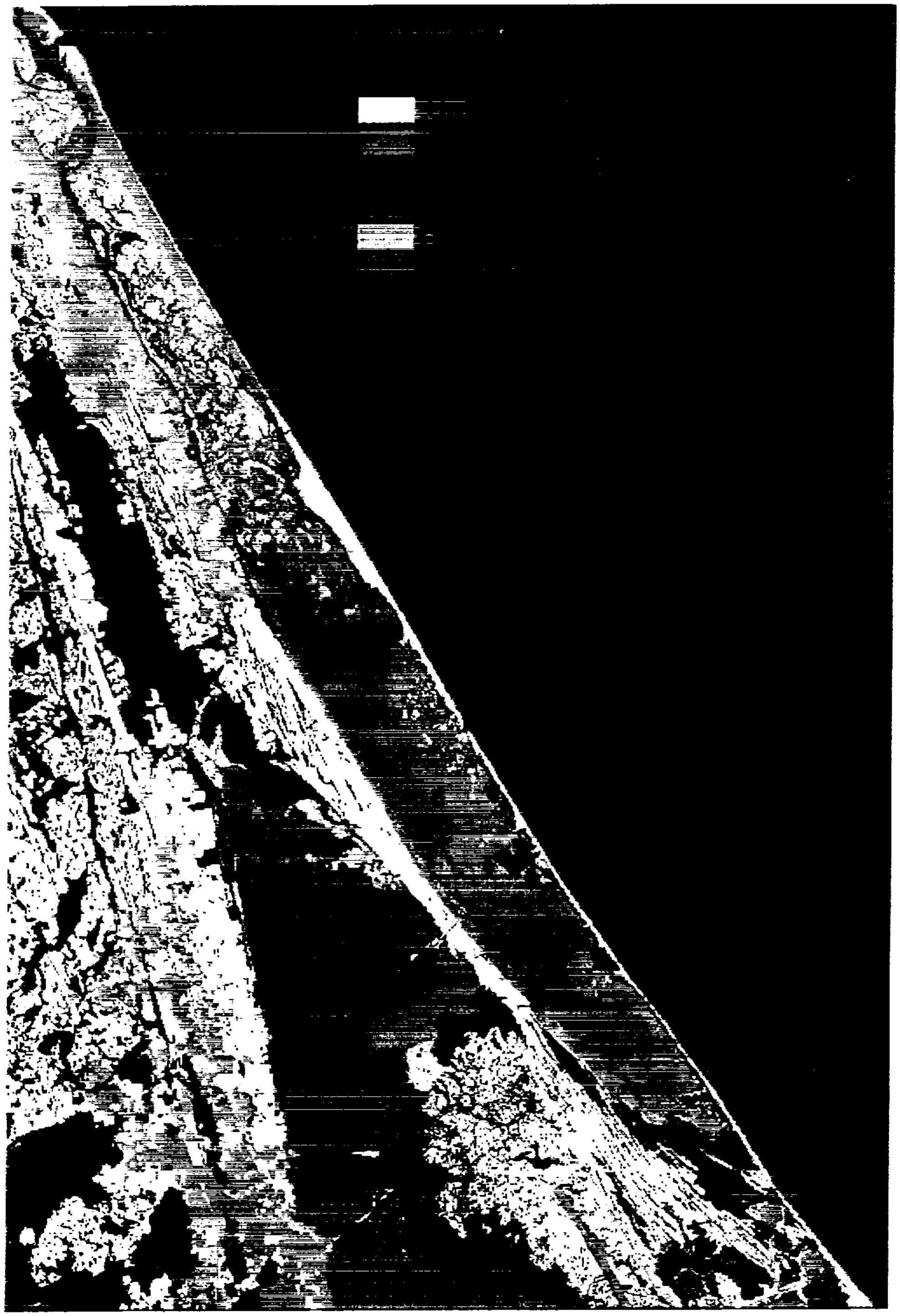


Figure 1. Canaveral National Seashore, Mosquito Lagoon and the north Indian River estuarine systems in east central Florida. The region has high biodiversity and an abundance of wetlands and seagrass beds supporting high primary production.

This study focused on development of baseline characterization data for water quality in and around CNS.

Interpretation of water quality data requires an understanding of the water budget and basic hydrodynamic processes that influence the mass balance, distribution and concentration of chemicals within Mosquito Lagoon. Factors controlling water quality operate across a variety of spatial and temporal scales each of which must be considered during sampling, analyses, and interpretation. These factors are summarized in Provancha et al. (1992) and Woodward Clyde (1994) and generally are represented by the water budget of the system.

Components of a basic water balance or water budget equation for Mosquito Lagoon can be developed as shown in equation 1:

$$V = P + R \pm G - E \pm T \pm H \qquad (1)$$

Where:

V = instantaneous total lagoon volume
P = precipitation on the lagoon surface
R = watershed surface runoff and discharges to the lagoon (all sources)
G = groundwater seepage to/or from the lagoon
E = evapotranspiration from lagoon
T = tidal exchange between the ocean and lagoon through Ponce de Leon Inlet
H = water exchange with the Indian River Lagoon through Haulover Canal

In its simplest form, the equation states that the lagoon volume, V, is controlled by direct precipitation on its surface plus runoff and surface input from point and non-point source discharges, plus or minus groundwater seepage, minus evapotranspiration, plus or minus flow through Haulover Canal, and plus or minus tidal exchange with the Atlantic Ocean. This conceptual model is presented graphically in Figure 2. The major unknown in the equation is the volume of groundwater movement into or out of the system. Basic order of magnitude estimates for the other components of the water budget are available in the literature (Provancha et al. 1992, Woodward Clyde 1994).

Three forcing functions, gravity, radiation, and wind, serve as major controlling factors affecting water movement and the mass balance or concentrations of chemicals in the system. Gravity drives the major contributions or fluxes such as rainfall, stormwater runoff, and groundwater seepage, tidal exchange and density stratifications. Wind serves as a source of energy for advective mixing and movement, influencing several aspects of the mass balance equation such as transport through Haulover Canal and Ponce de Leon inlet. Radiation (light and heat) drives density dependent mixing events, evapotranspiration rates and biological processes such as photosynthesis, respiration, and microbial decomposition. Water levels within south Mosquito Lagoon average about 0.2 m above mean sea level, rising and falling in an annual cyclic pattern in response to the annual rise and fall of sea level (Provancha et al. 1992).

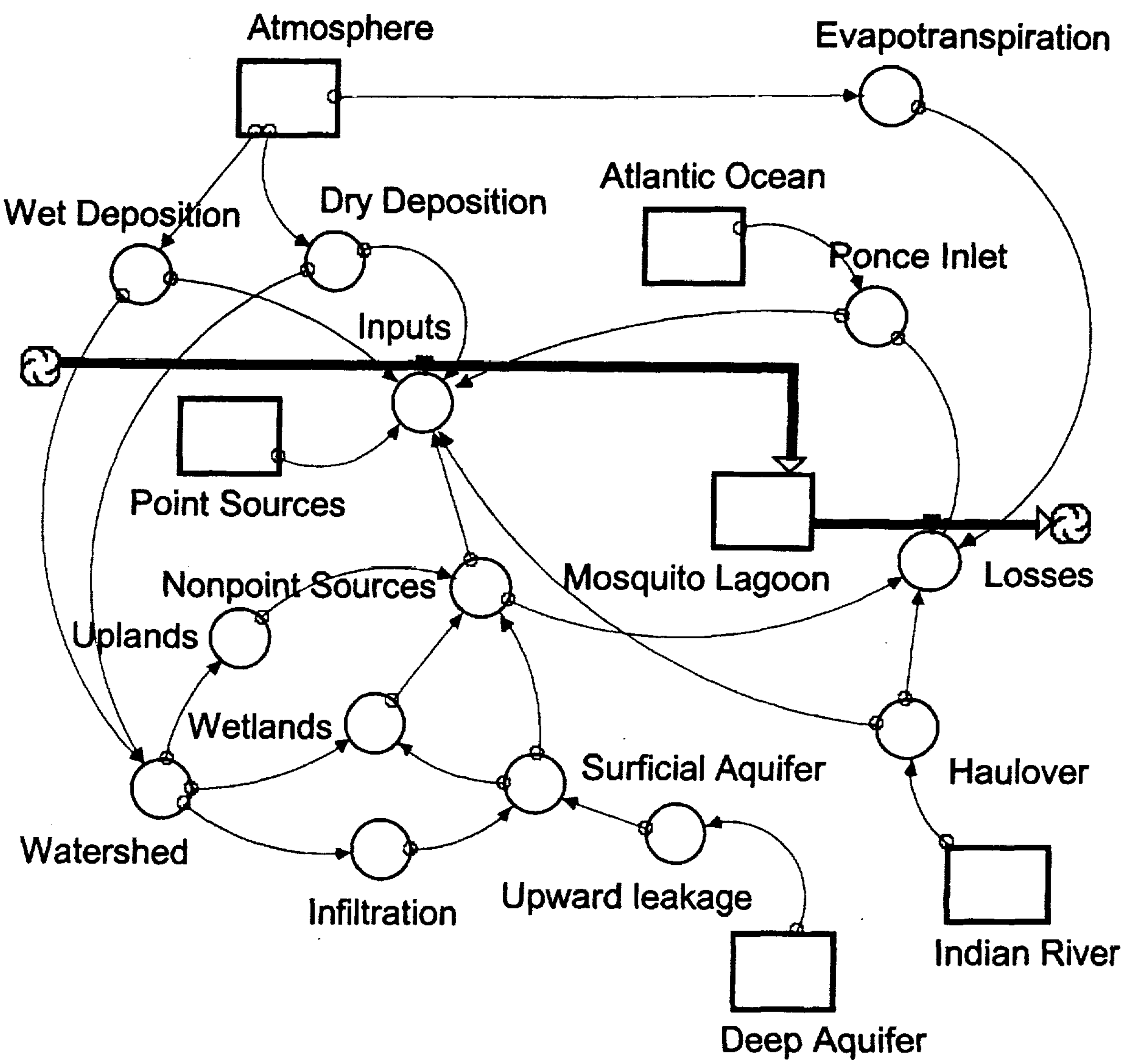


Figure 2. Conceptual model of hydrologic pathways and processes influencing the mass balances of water and chemicals in Mosquito Lagoon. Inputs include atmospheric deposition, runoff, surficial aquifer leakage, deep aquifer leakage, and transport through Haulover Canal and Ponce de Leon Inlet.

Water levels in Mosquito Lagoon reach highs in October and November, and lows in April and May. The estimated average 0.2 m difference in hydraulic head between south Mosquito Lagoon and the Atlantic Ocean generates a net long-term flux of water out of the lagoon through Ponce de Leon inlet onto the near-shore continental shelf (Provancha et al. 1992; Woodward Clyde 1994). Influences of the tidal connection at Ponce de Leon Inlet are significant when considering system hydrodynamics on a time scale of hours or days, especially in the vicinity of the pass. Daily tidal cycles serve as water and energy exchange mechanisms resulting in mixing of estuarine and oceanic waters as well as suspension of sediments and other low-density materials. At the inlet, mean tidal range is 0.7 m with tidal influences extending approximately 10-15 km into Mosquito Lagoon (Provancha et al. 1992). Tidal fluctuations in the Canaveral National Seashore area range from 50 cm at the north end to less than 2 cm at the south end (Grizzle 1988). Daily tidal influences have not been measured at the south end of Mosquito Lagoon.

On a long-term basis there is a net seaward flow of water and materials through Ponce de Leon Inlet to the Atlantic Ocean (Woodward Clyde 1994). However, during high temperature periods, high evaporation from the lagoon surface can result in lowering of water levels producing a prolonged (days to weeks) net inward flux of seawater to replace estuarine water losses. Near the inlet, water quality appears oceanic during these periods. In south Mosquito Lagoon hyper-saline conditions may develop with salinities approaching and exceeding 40 ppt.

Superimposed on the daily tidal cycle near the inlet and the annual cycle in sea level that influences the entire system are effects of wind driven circulation processes. Wind forcing on the water surface tends to push water in the direction of the wind causing it to set up or set down. For example, southeasterly breezes tend to push water in the Indian River and Mosquito Lagoon to the north. This produces a difference in elevations between the two lagoons with water in the Indian River being "set up" in its north basin and water in the south end of Mosquito Lagoon being "set down" by the wind. This difference in water surface elevations generates a net flux through Haulover Canal from the Indian River Lagoon to Mosquito Lagoon. In contrast, large volumes of oceanic water may be transported into Mosquito Lagoon during extreme high tide periods associated with storms in the Atlantic. These wind driven circulation processes are of great importance when assessing results of water quality sampling in the Indian River and Mosquito Lagoon (Woodward Clyde 1994).

Influences of storms on estuarine water quality and ecosystem productivity are poorly documented in the scientific literature. Flint (1985) suggests that extreme weather events may be responsible for controlling long-term productivity of estuarine and near-shore ecosystems by producing major perturbations in biogeochemical processes and disrupting nutrient sinks, analogous to fire or floods in terrestrial ecosystems. During March 1993, east central Florida experienced westerly winds in excess of 40 knots for more than 24 hours in what was termed by the media as the storm of the century. These winds lowered regional water levels and exposed large areas of seagrass beds and sediments to the atmosphere and low air temperatures. This exposure to the atmosphere alters the oxidation-reduction potential in surface sediments and can cause a die off and detachment of large areas of seagrass blades and macroalgae. This resulting pulse of organic matter and nutrients impacts the detritus base of the food chain in the lagoon and near shore continental shelf. Quantitative assessments of the significance of these types of events on system dynamics have not been conducted and the role in overall system productivity and water quality is poorly understood.

2.2 Methods

Water and sediment chemistry, microbiological samples, and basic field parameters were collected at six stations in Mosquito Lagoon (Figure 3). Station 1, near Gallinipper Point, has been sampled as part of Kennedy Space Center (KSC) long-term monitoring since 1984. Station 2, located south of Eldora, represents the southeastern section of the park. Station 3 was located in the Brickhouse Cove area of the west central region of the park. Station 4 was located in the northeast section of the park near Turtle Mound and the associated urbanized region of the barrier island. Station 5 was located in the southwest section of the park near Oak Hill, an area of possible contamination sources. Station 6 was located at the northwest end of the park. Coordinates for these stations are presented in Table 1.

Table 1. Global Positioning System (GPS) coordinates for the Canaveral National Seashore sampling stations. Water and sediment chemistry station designations include a W. Light attenuation sampling stations include the letter A, B, or C designating location along a transect.

Location	*Latitude*	*Longitude*
CNS1A	28 42 27.00618	80 42 52.3016
CNS1B	28 42 27.90976	80 42 23.08577
CNS1C	28 42 29.59069	80 41 48.84447
CNS1W	28 41 13.9033	80 40 29.1598
CNS2A	28 44 9.79526	8 0 44 33.65264
CNS2B	28 44 16.81208	80 44 5.09409
CNS2C	28 44 18.04776	80 43 32.6989
CNS3A	28 51 14.08643	80 49 13.56059
CNS3B	28 51 17.34338	80 49 2.09203
CNS3C	28 51 24.81714	80 48 35.25331
CNS3W	28 55 4.83162	80 51 39.1558
CNS4A/CNS2W	28 54 9.65259	80 49 7.46075
CNS4B	28 54 37.3500	80 49 20.4960
CNS4C	28 55 24.9636	80 49 34.2408
CNS4W	28 56 43.95463	80 50 17.33822
CNS5A/CNS5W	28 52 01.1000	80 50 4.22331
CNS5B	28 52 24.4455	80 50 4.32287
CNS5C	28 52 45.0815	80 50 16.13092
CNS6W	28 56 33.51459	80 52 9.79602

Water and sediment samples were collected and analyzed according to procedures outlined and approved by the State of Florida as part of their State Laboratory Certification Program. These methods generally followed procedures from the EPA Methods for Chemical

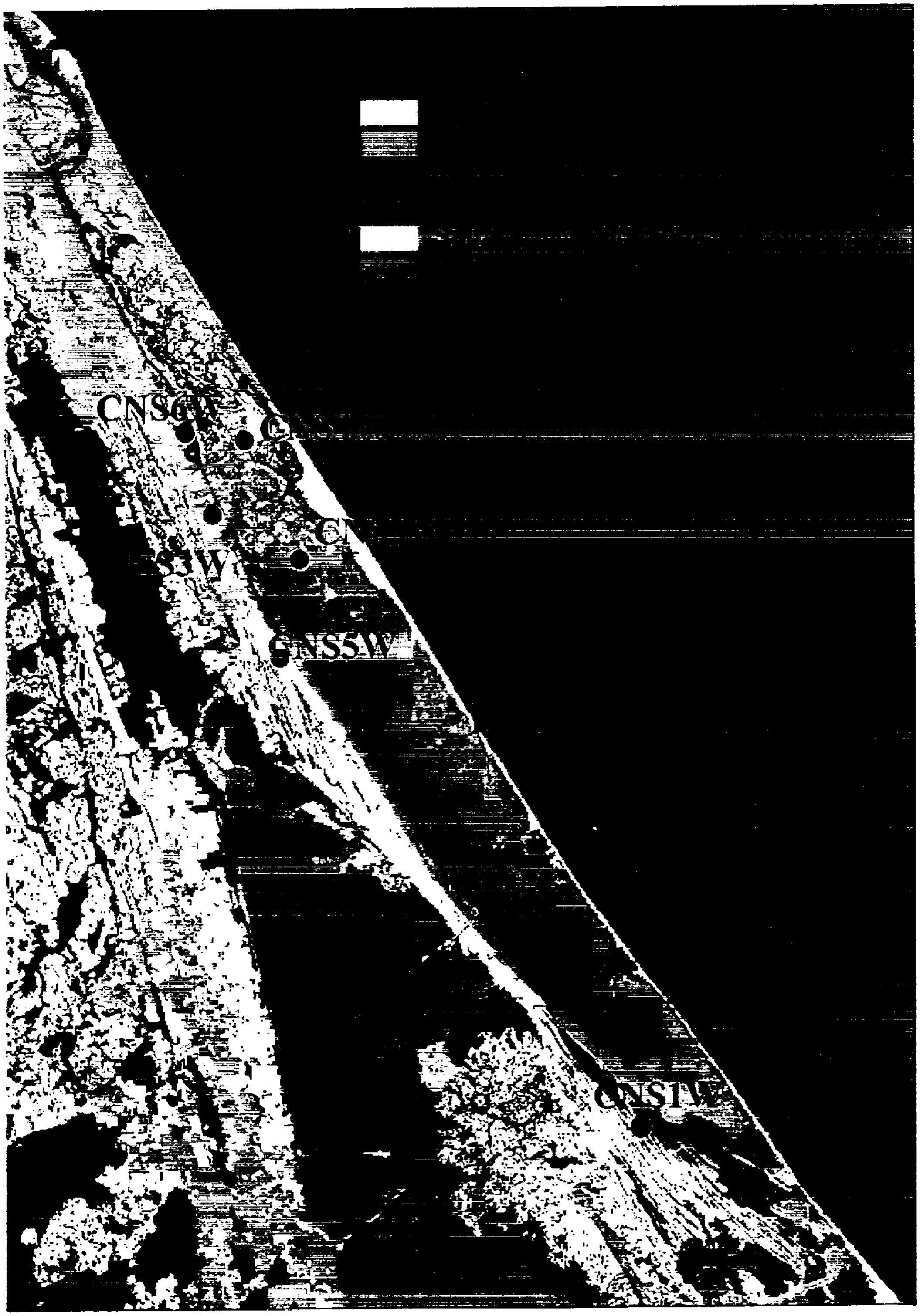


Figure 3. Locations of surface water sampling stations utilized during the water and sediment chemistry characterization program for Mosquito Lagoon.

Analysis of Water and Waste (EPA-600/4-79-020, revised March 1983). All samples, except the 1993 sediment samples, were processed through the State Certified chemical laboratory of Post, Buckley, Schuh and Jernigan Inc., Orlando, Florida. The NASA Biomedical Office Environmental Chemistry Laboratory at John F. Kennedy Space Center processed all sediment samples collected in 1993. Microbiological samples were processed by the NASA Biomedical Office Environmental Microbiology Laboratory using Florida DHRS Certified procedures. Parameters monitored during the characterization program are listed in Table 2.

Table 2. Parameters measured for water and sediment samples collected in Mosquito Lagoon between 1991 and 1993.

Basic Physical/Chemical	*Inorganics*	*Organics*	*Metals*
Conductivity (CON)	OrthoPhosphate (PO_4)	Phenols (PHE)	Arsenic (As)
Total Suspended Solids (TSS)	Total Phosphorus (TP)	Total Organic Carbon (TOC)	Mercury (Hg)
Total Dissolved Solids (TDS)	Magnesium (Mg)	Grease and Oil	Silver (Ag)
Chlorophyll A (CPA)	Total Kjeldahl Nitrogen (TKN)	Herbicides	Cadmium (Cd)
Total Alkalinity (TAK)	Nitrate (NO_3)	Pesticides	Zinc (Zn)
Salinity (SAL)	Nitrite (NO_2)		Iron (Fe)
Turbidity (TB)	Ionized Ammonia (NH_4)		Aluminum (Al)
Color (COL)	Calcium (Ca)		Boron (B)
pH	Potassium (K)		Beryllium (Be)
Chemical Oxygen Demand (COD)	Sulfate (SO_4)		Copper (Cu)
Biological Oxygen Demand (BOD)			Molybdenum (Mo)
			Nickel (Ni)
			Lead (Pb)
			Silicon (Si)
			Chromium (Cr)
			Manganese (Mn)
			Antimony (Sb)

The six surface water stations were sampled on 12 occasions beginning in July 1991, following a bimonthly schedule. Sediment sampling also followed the bimonthly schedule but began in September 1991. Pesticide samples were collected three times during a six month period from September 1991 to February 1992. Total and fecal coliform samples were also collected bimonthly, beginning in September 1991 with one collection missed in March 1993 as a result of equipment failure. Parameters measured in the field included temperature, DO, pH, CON, oxidation-reduction potential (ORP), and SAL, using a Hydrolab Datasonde 3. At one fixed station, data on CON, SAL, DO, pH, and temperature were collected every two hours. The site was located approximately ten miles south of Ponce de Leon Inlet at the CNS boat dock in Mosquito Lagoon. Sampling began on 8 October 1991 and continued for 608 days yielding

6,252 bi-hourly records. Probes were mounted approximately 35 cm above the bottom in an area approximately 1.2 m deep. Datasondes were typically in the field for fourteen days before being replaced with a calibrated unit. Instruments were returned to the laboratory for data downloading, cleaning, and calibration.

Data analyses were conducted following an approach that included development of basic descriptive statistics and bivariate correlations. Basic descriptive statistics were calculated to characterize the statistical nature of the parameters. In this phase of the analysis the variability of the data was defined and the need for data transformations, parameter deletions or the use of nonparametric procedures were determined. The second phase of the analysis involved determination of bivariate measures of association between parameters to define interdependency and covariance. The ultimate goal of the analysis procedure was definition of the statistical nature of the data for use as a baseline with future goal specific monitoring or research activities.

2.3 Results and Discussion

Results of chemical analyses and field monitoring are presented in tabular and graphical form in Appendix A. Tables A-1 to A-9 list results for surface water chemical analyses in summary form sorted by sample date and station. Tables A-10 to A-14 present statistical summaries for sediment analyses sorted by sample date and station. Tables A-15 and A-16 contain results of the nonparametric Spearman Rank Correlation analyses. Figures A-1 to A-10 display results of DO and SAL data collected on five transects as part of a light attenuation study. Figures A-11 to A 71 show the temporal pattern of SAL, DO and temperature for the bi-hourly data collected at the CNS boat dock. Figures A-72 to A-84 present frequency distributions of sediment chemical analyses. All analyses for herbicides, pesticides, Hg and Mo were below the analytical procedure detection limits utilized by the chemistry laboratory or had too few readings to analyze. These parameters are not discussed further.

2.3.1 Basic Physical and Chemical Parameters

2.3.1.1 Dissolved Oxygen (DO)

Dissolved oxygen is a critical and essential constituent for maintenance of biological resources in aquatic systems. The Florida Department of Environmental Protection (DEP) Quality Criteria for Surface Water Quality (FAC 62-302.530) state, that for Class II Waters used for propagation or harvesting of shellfish DO levels shall not average less than 5.0 mg/l in a 24 hour period and shall never be less than 4.0 mg/l. Normal daily and seasonal fluctuations above these levels shall be maintained. Factors that directly control DO levels include temperature, SAL, photosynthesis, BOD and COD. Gas exchange accompanies metabolic processes when organic substances are synthesized or decomposed. The rate at which oxygen is consumed in the water column is a function of mineralization of organic matter by bacteria as well as respiration of aquatic plants and animals. Increases in dissolved carbon dioxide typically follow decreases in oxygen levels. This in turn may alter the pH of water by formation of carbonic acid. Conversely, photosynthetic activity in benthic algae, seagrass, macroalgae and phytoplankton can liberate large quantities of oxygen into the water column, under proper growth conditions, reversing the cycle.

Results of bi-hourly data collection at the CNS boat dock are presented in Appendix A, Figures A-51 to A-71. Three trends are present in the data. A short term, 24 hour daily fluctuation is present that corresponds to the daily cycle of photosynthesis and respiration. A general longer term trend of higher values during cool months and lower values during warm months is present that is directly related to the inverse relationship between temperature and dissolved gases in water. Year to year differences are present, especially when comparing winter/ spring 1991-1992, to winter/spring 1992-1993.

Also important in the data set are the large number of readings and the extended periods of measured values below the 5 mg/l 24-hour average and the 4 mg/l minimum DEP criteria. Readings were consistently below the criteria between October 9, 1991 and November 24, 1991, March 9 to March 18,1992, April 1 to April 27, 1992 and May 1 to July 8, 1992. In contrast, extended periods of relatively high DO occurred in July 1992, October 1992, and November 1992 and between January and March 1993. During these periods values were consistently above 8 mg/l. The sudden increase in DO in July from about 1 mg/l to 11 mg/l was associated with an influx of oceanic water through Ponce de Leon inlet. Salinity at the site increased from 18 ppt to almost 30 ppt in a two-hour period. Dissolved oxygen readings reached super saturation levels of 197.2% with the highest recorded reading of 15.3 mg/l on March 2, 1993. The lowest value was recorded on August 25, 1992 at only 5.7% saturation or 0.37 mg/l.

Results of DO sampling at 15 stations associated with the underwater light attenuation study are presented in Appendix A, Figures A-1 to A-5. These results display little deviation between stations for the mid-day samples where all data were collected between 1000 h and 1500 h. All values in this data set are in compliance with the DEP criteria for DO of no values below 4 mg/l. All transects and stations followed a general trend of maximum temperatures in fall 1991 and relatively constant readings for the rest of the sampling with minimum values in summer 1992.

2.3.1.2 Temperature

Results of water temperature measurements are presented in Appendix A, Figures A-11 to A-30. Two major temporal cycles are present in the data. On a daily basis, water temperatures fluctuate about 2-3°C. Summer temperatures, June through August, generally range between 27 and 31 degrees while winter temperatures, December through February, typically range between 15 and 23°C. Spring and fall are transitional periods. The passage of high-pressure cold fronts during fall and winter can have dramatic influences over water temperature. Figure 4 displays effects of the passage of distinct frontal systems showing rapid cooling of the water by typically 5-10°C and the gradual return to more average conditions over the next 5 to 6 days. The influences of frontal system passage appear most commonly in data

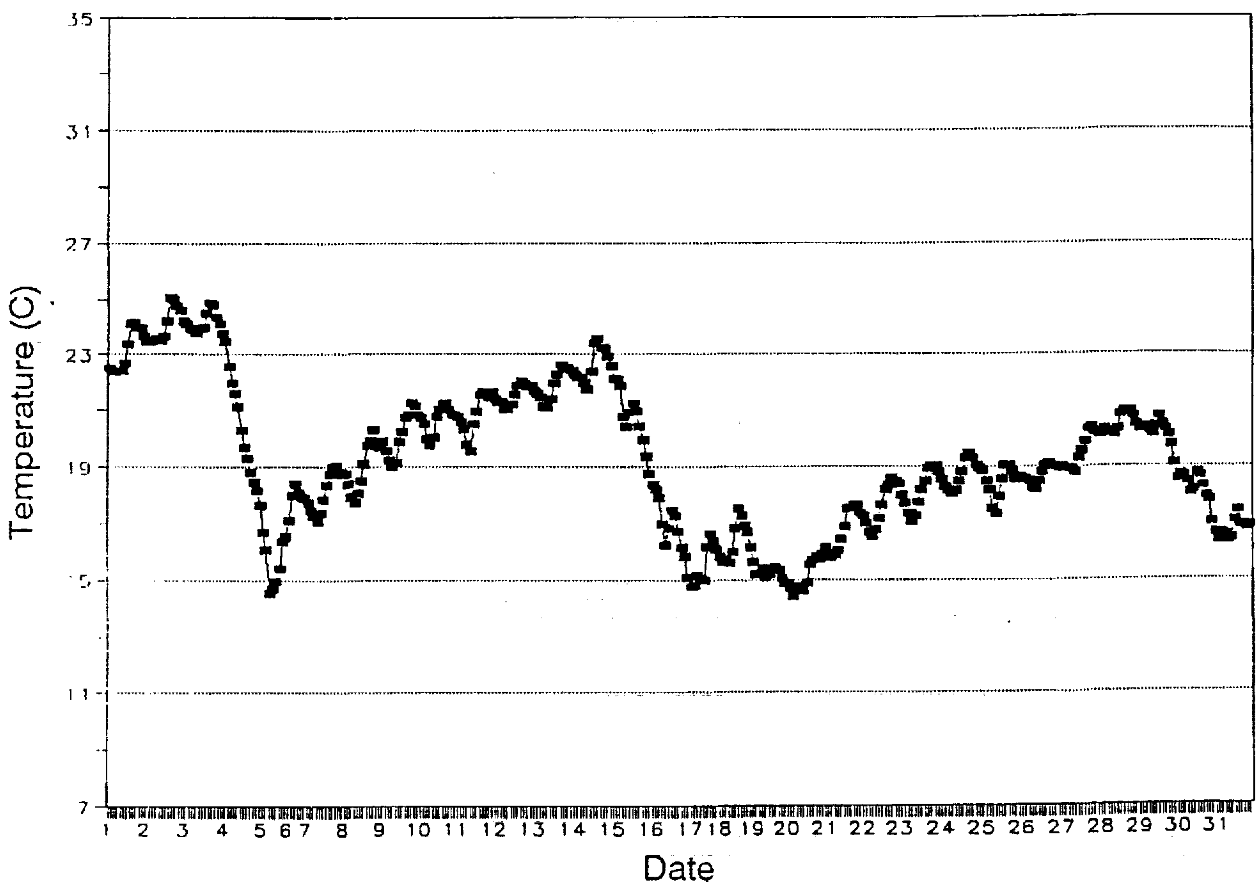


Figure 4. Bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock in December, 1991. Data were collected utilizing a programmable Hydrolab data logger set at a two-hour sampling interval. Probes were located 30 - 40 cm above the bottom in 1.2 m of water.

collected between November and April. Passage of the storm of the century in March 1993 produced a 14°C decline in water temperature during a 48-hour period with values falling from about 23°C to 9°C. The highest temperature recorded during the project was on July 27, 1992 reaching 33.4°C, while the lowest recorded temperature was on March 15, 1993 at only 8.8 °C.

2.3.1.3 Salinity (SAL), Conductivity (CON), and Total Dissolved Solids (TDS)

Virtually all naturally occurring elements of the earth's crust can be found in some concentration dissolved in seawater. Concentrations of dissolved substances in fresh and estuarine ecosystems are a function of relationships that exist between the body of water and its watershed characteristics. Inland waters, rivers and streams are generally high in CO_3, SO_4, Ca, and Mg with lesser amounts of Na and Cl (Reid 1961). Relative concentrations of these ions depend primarily on soil characteristics and geology of the watershed. Oceanic constituents are virtually constant and include primarily Na (30.4%) and Cl (55.2%) and to a much lesser degree Mg (3.7%) and SO_4 (7.7%). The chemical composition and distribution of ions in Mosquito Lagoon are the end result of mixing of normally dissimilar waters including rainfall, watershed runoff, industrial discharges, groundwater leakage, transport from the Indian River through the Haulover Canal and the tidal influence of the Atlantic Ocean.

Three related measures of dissolved constituents in Mosquito Lagoon are SAL, CON, and (TDS). Total Dissolved Solids are measured by evaporating a filtered quantity of water at low temperature. The dried residue contains both the inorganic and organic materials dissolved in the sample. Ignition of the residue at high temperature eliminates the volatile organics, and decomposes bicarbonates with the loss of carbon dioxide. Only the inorganic salts expressed as mg/l TDS remain. The total weight of the ionic component expressed as a proportion of the original sample in terms of parts per thousand (ppt) is the salinity. The salinity of the open ocean generally ranges between 33 ppt and 38 ppt with an average value of 35 ppt. The average salinity of soft fresh water is 0.065 ppt and of hard fresh water is 0.3 ppt. From this it is apparent that high estuarine salinities are derived almost entirely from seawater while low salinities represent areas of high fresh water influence.

A third and simple method to measure the amount of dissolved ionized materials is through the determination of electrical conductance. This parameter closely approximates the residue in solution and generally is highly correlated with TDS and salinity. By definition conductance is the reciprocal of the resistance measured between two electrodes. Measurements are generally expressed in micro-mhos per centimeter (umhos/cm) at 25°C and are called specific conductance.

Salinity values, collected with the Hydrolab Datasonde 3, at the CNS boat dock, are presented in Appendix A, Figures A-31 to A-50. The highest measurement was recorded on May 8, 1993 reaching 40 ppt, and the lowest measurement of 18.3 ppt was recorded on July 7, 1992. Salinity readings higher than oceanic values generally result from low rainfall and high evaporation in the lagoon during warm dry periods of late spring.

Early in the study (October - November 1991), SAL at the CNS boat dock site increased from about 25 ppt to about 32-35 ppt and remained in this range for most of the following six months. During the period between June and September 1992, in what is commonly referred to as the wet season, salinities at the boat dock were noticeably lower with most values between 20 and 30 ppt. In the following months values varied more than in the previous year.

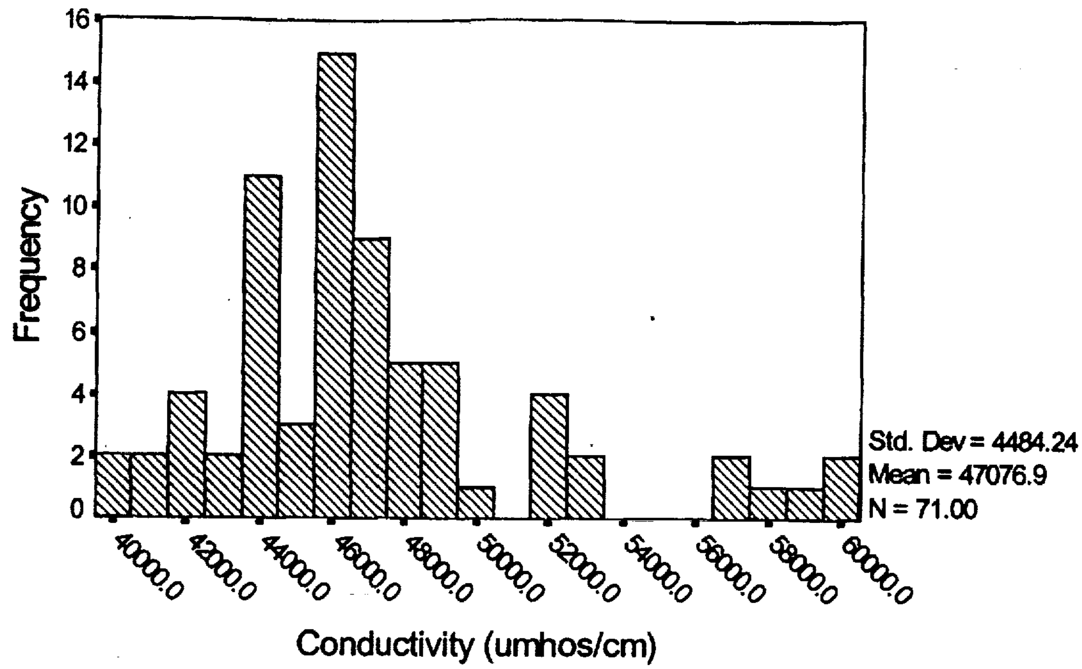
Salinity data, collected during the light attenuation study are shown graphically in Figures A-6 through A-10. As with the DO data, SAL variation along transects was small. Transects 1 and 2 appear similar with Transect 2 having slightly lower values possibly as a function of lower salinity waters moving from the Indian River Lagoon through Haulover Canal to Mosquito Lagoon. In summer 1991 data on Transect 2 were almost 4 ppt lower than Transect 1 in south Mosquito Lagoon and 2-3 ppt lower than Transects 3, 4 and 5 north of Haulover Canal.

Results of SAL measurements from the six bimonthly monitoring stations are presented in Tables A-1 to A-3, providing additional spatial and temporal information about the lagoon. Salinity measurements were variable across all seasons and stations ranging from a reported low of 4.5 ppt at Station 2 in July 1992 to a high of 37 ppt at Stations 2 and 4 in June 1993. The low value of 4.5 ppt appears to be an outlier, however the possibility of sampling a freshwater lens does exist and the data were retained in the dataset. The majority of SAL measurements ranged between 20 and 35 ppt with an overall average of 27 ppt and a standard deviation of 6.8 ppt or about 24% of the mean value. Figure 5 shows the sampling distribution of the SAL data. Average salinities at Station 1 and Station 2 were 25 ppt while Stations 3 through 6 averaged 27 to 28 ppt. Salinities at the southern two sites were generally 2-3 ppt less than the northern stations, similar to results observed in the underwater light attenuation study. This salinity gradient may be partially attributed to station locations relative to Haulover Canal and Ponce de Leon Inlet with associated oceanic tidal influences.

A summary of CON and SAL measurements is presented in Figure 5. The average CON measurement for the bimonthly water quality stations was 47,077 umhos/cm with a standard deviation of 4,484 umhos/cm or only about 10 % of the mean, a value that is similar to the estimate for TDS. The minimum CON value of 39,900 umho/cm was observed at Station 5 on September 22, 1992. The maximum value of 59,900 umho/cm occurred at Station 2 in conjunction with the elevated TDS measurement of June 16, 1993. As with TDS and SAL the average CON value at Station 1 in south Mosquito Lagoon was lower than observed at the northern sites.

Across all stations and sample periods TDS averaged 32,612 mg/l with a standard deviation of 2,966 mg/l. The minimum value of 25,960 mg/l was collected at Station 1 in November 1991, corresponding to a period of low salinity (16 ppt) and low conductance (40,230 umho/cm). The maximum TDS value of 40,500 mg/l was collected at Station 4 on June 16, 1993. Results of TDS measurements for each station and sample period are summarized in Table A-1 to A-3 and are presented graphically in Figure 6.

The relationships between CON, SAL and TDS are apparent since each is a measurement that involves the total ionic concentration in the sample. Results of non-parametric Spearman Rank Correlation analysis (Table A-15) indicated significant positive correlations between CON and TDS ($r = 0.7228$, $p < 0.001$), CON and SAL ($r = 0.3808$, $p = 0.001$), and TDS and SAL ($r = 0.2935$, $p = 0.013$). The correlations between CON and SAL, and TDS and SAL, although significant, were not as strong as expected based on the chemical relationships that exist between the parameters.



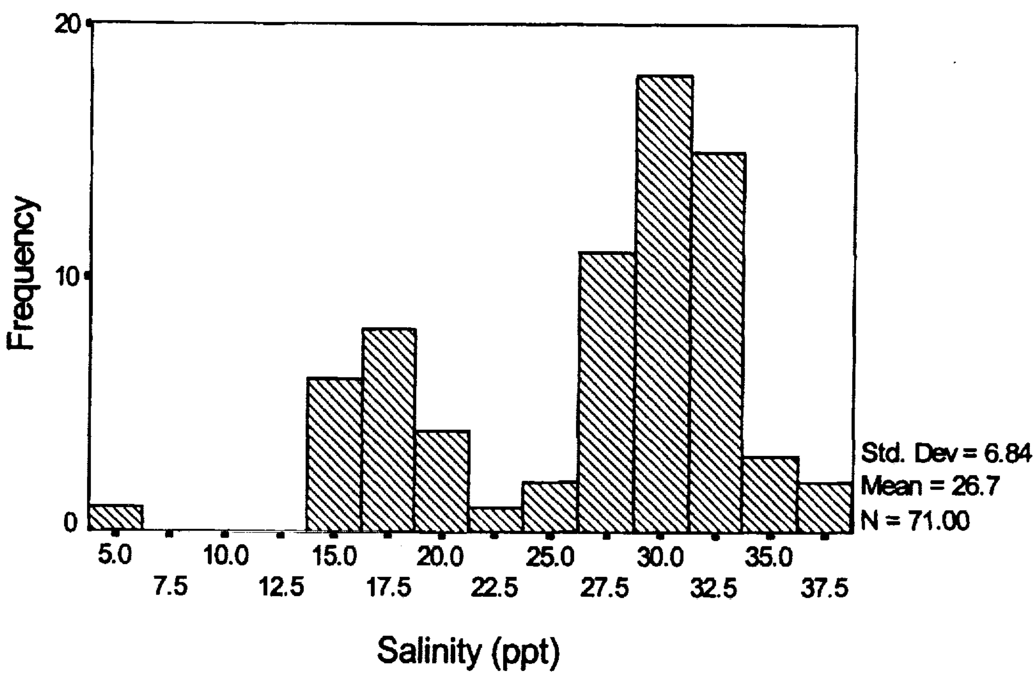
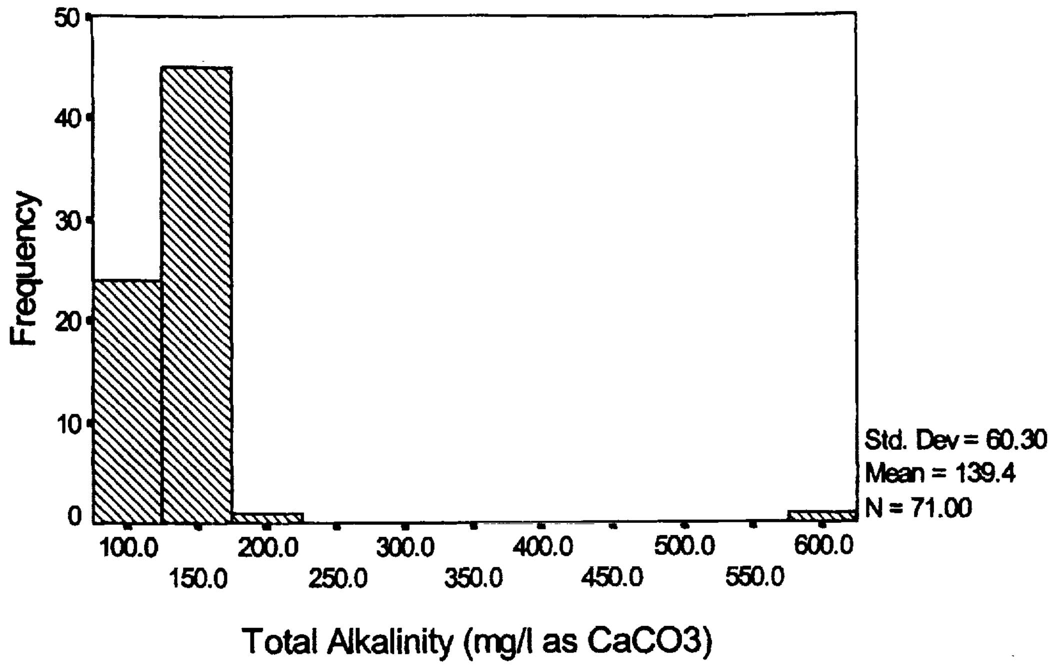


Figure 5. Water quality sample frequency distributions for conductivity and salinity. There are no Class II criteria for conductivity or salinity.



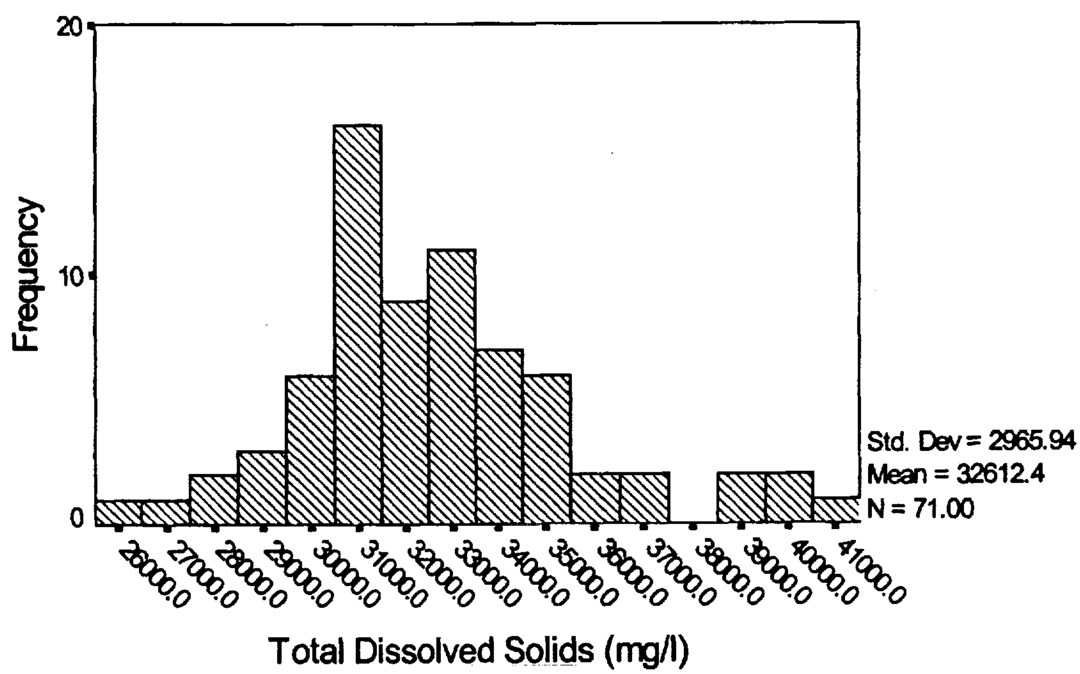


Figure 6. Water quality sample frequency distributions for total alkalinity and total dissolved solids. There are no Class II criteria for alkalinity or dissolved solids.

2.3.1.4 Total Alkalinity (TAK) and pH

The chemistry of marine waters is different from fresh water because of the large volume of dissolved minerals present. Total alkalinity (TAK) is the sum total of components dissolved in water that tend to elevate pH above a value of about 4.5 units. It is a measure of water's capacity to neutralize strong acids through the hydroxide, carbonate and bicarbonate ion system.

The average pH value for water quality samples collected at the six sample stations combined was 8.41 units with a standard deviation of 0.28 units. The minimum value observed was 7.98 units from Station 4 and the maximum value was 9.04 units at Station 1. The average for each station ranged between 8.3 and 8.6 units. The pH levels exceeded the 8.5 unit State of Florida criteria at all six stations in July 1991, March 1992 and May 1992. Stations 1, 2, and 5 also had values higher than the limit in July 1992. The high value observed at Station 1, which is located in a shallow seagrass bed, is subject to high photosynthetic and respiration rates.

Results from the Spearman Rank Correlation analysis indicated pH was significantly correlated with several parameters. There were weak negative correlations with Al ($r = -0.3016$, $p = 0.020$), color ($r = -0.3406$, $p = 0.004$), and BOD ($r = -0.3170$, $p = 0.011$). Significant positive correlations were found between pH and Cu ($r = 0.8815$, $p < 0.001$), TAK ($r = 0.2952$, $p = 0.012$), and TOC ($r = 0.4836$, $p < 0.001$). Sediment pH values ranged between 6.82 at Station 1 on March 2, 1992 and 8.58 at Station 4 on May 5, 1992. The average sediment pH was 7.75. Sediment pH was significantly correlated with Ag ($r = .9355$, $p < .001$), Al ($r = .2525$, $p = .042$), Fe ($r = .1809$, $p = .0149$), NH_4 ($r = .3846$, $p = .002$), NO_3 ($r = -.3723$, $p = .043$), and TSS ($r = .4065$, $p = .001$).

2.3.1.5 Total Suspended Solids (TSS) and Turbidity (TB)

Suspended solids are the organic and inorganic particles in suspension in the water column. Turbidity is a term that is applied to waters containing suspended matter that interferes with the passage of light through the water or in which the depth of light penetration or photic zone is reduced. Turbidity may be caused by a variety of materials including colloidal particles, eroded soil, organic flocculants, and microscopic organisms. Suspended solids and TB can interfere with commercial and recreational use of waters through alteration of aesthetics and productivity. Impacts of TB and suspended solids can occur in the water column and in areas of sedimentation. Effects include reduced primary production, smothering of fish and shellfish spawning sites, increased mortality of eggs and juvenile fish, disruption of feeding success, and reduction of secondary production. Often, suspended solids contribute to the BOD of waters and may serve as adsorption sites for metals and other pollutants, concentrating them in areas of sedimentation. The State of Florida has not issued criteria for total suspended solids but historically set a limit on TB of no increase above background levels in excess of 29 NTU (62-302.530 F.A.C.).

Results of total suspended solids (TSS) measurements are presented in Table A-1 to A-3.

Total suspended solids averaged 61.49 mg/l with a standard deviation of 67.02 mg/l. The minimum value of 16.0 mg/l was observed at Station 1 on March 31, 1993. The maximum value of 350 mg/l occurred at Station 3 on November 16, 1992. Station averages ranged between 32.8 and 74.3 mg/l with the lowest average being at Station 1 in south Mosquito Lagoon. Highest average values of 74.3, 71.6, and 70.4 mg/l occurred at Stations 6, 4, and 3 respectively. These northern stations are believed to experience the largest tidal influences.

Mean TB, averaged across all sites and sample periods, was 6.15 NTU with a standard deviation of 4.34 NTU or 76% of the mean value. The minimum value of 0.928 NTU occurred at Station 5 on January 19, 1993. The maximum value of 22.6 NTU occurred at Station 4 on September 22, 1992. The high value is below the "not to be elevated more than 29 NTU" criteria once used by the state in regulating TB. As with TSS, Station 1 in south Mosquito Lagoon displayed the lowest average value of 3.14 NTU. Station 4 had the highest average of 8.79 NTU when all samples periods are combined. Based on all samples, TB and TSS were significantly positively correlated ($r = 0.4536$, $p < 0.001$) as expected.

Examination of the correlation table (Table A-15) showing bivariate relationships between TSS and other parameters suggests several trends. TSS is positively correlated with SAL, CON and total dissolved solids. These parameters are in general higher at the northern stations and are directly influenced by tidal exchange at Ponce de Leon Inlet. TSS is positively correlated with Al, Si, Ca, Fe and SO_4. These are common components of the lagoon sediment that may be suspended in the water column by tidal action, wind driven turbulent mixing, and man's activities. TSS was positively correlated with nutrients (nitrite, total phosphorous and total Kjeldahl nitrogen), color, and CPA.

2.3.1.6 Chlorophyll A (CPA)

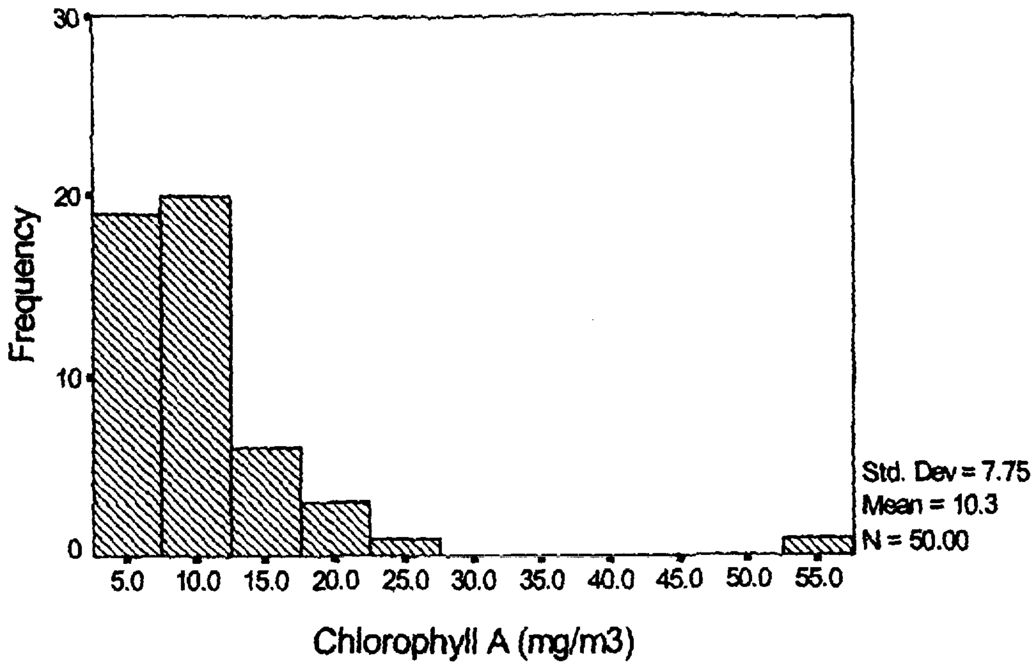
Chlorophyll A measurements from the water column can provide a good indication of the overall biological status of an aquatic system. Chlorophyll based primary production links the inorganic world to the organic world through photosynthesis (Gross 1972). Extreme low chlorophyll values (low phytoplankton production) may indicate nutrient limitations while extreme high values can be indicative of eutrophication. Results of chlorophyll analysis are shown in Figure 7 and Tables A-1 to A-3. The Florida DEP does not provide criteria for chlorophyll concentrations. During this sampling the minimum value of 2.70 mg m^{-3} was recorded for Station 4 on March 1992 while the maximum of 53.40 mg m^{-3} was recorded for Station 5 in July 1992. For all stations and all sample periods the average value was 10.34 mg/m^3. These results are similar to previously reported values (Woodward-Clyde 1994). Chlorophyll concentrations were positively correlated with Al ($r = 0.5178$, $p = 0.001$), BOD ($r = 0.4577$, $p = 0.002$), Ca ($r = 0.4165$, $p = 0.003$), COD ($r = 0.2327$, $p = 0.104$), COL ($r = 0.5384$, $p < 0.001$), Si ($r = 0.6703$, $p < 0.001$), TB ($r = 0.6598$, $p < 0.001$), TKN ($r = 0.5038$, $p < 0.001$), TSS ($r = 0.4391$, $p = 0.001$). These relatively strong correlations with color, TB, and total suspended solids are expected responses to phytoplankton abundance in the water column. Similarly, increasing phytoplankton abundance would result in increases in Si and TKN in the water column. Significant negative correlations were observed with Cu ($r = -0.6524$, $p = 0.021$), GO ($r = -0.3446$, $p = 0.037$), pH ($r = -0.2737$, $p = 0.054$), PHE ($r = -0.3256$, $p = 0.029$), and SO_4 ($r = -0.2940$, $p = 0.038$).

2.3.1.7 Color (COL)

The Florida DEP does not provide criteria for color in Class II or Class III waters. Color is a measure of the optical property of a water sample based on wavelength dependent absorption and scattering by materials in solution or suspension. As such it is sensitive to the presence of compounds that absorb and scatter photons in the visible 400 to 700 nm wavelength region that corresponds to the region of photosynthetic activity. Examples of materials that influence color include natural metallic ions (Fe and Mn), suspended sediments, phytoplankton, and humic acids. The ability of light of select wavelengths to penetrate the water column is critical to the production of healthy communities of submerged aquatic vegetation, phytoplankton and benthic algae. Results are summarized in Figure. 7. The minimum value recorded was 5.00 pt co units occurring on February 3, 1992, March 2 1992, January 19, 1993, and March 31, 1993 at Stations 1, 2, 3, and 6. The maximum value of 50.00 pt co units occurred on September 18, 1991 at Station 4. The mean for the two-year period was 21.59 pt co units with a standard deviation of 11.26 pt co units. Station 4, influenced most by tidal activity, displayed the highest average value of 28.75 pt co units while Station 5 at the southwest end of the park had the lowest average value of 10.47 pt co units. Station 1, at the south end of Mosquito Lagoon, averaged 16.11 pt co units. Results of bivariate correlation analyses are presented in Table A-16. Color was significantly positively correlated with Al ($r = 0.3531$, $p = 0.007$), BOD ($r = 0.3033$, $p = 0.016$), Con ($r = 0.2445$, $p = 0.043$), CPA ($r = 0.5384$, $p < 0.001$), NH_4-N ($r = 0.3184$, $p = 0.013$), Si ($r = 0.6314$, $p < 0.001$), TB ($r = 0.7757$, $p < 0.001$), TKN ($r = 0.3297$, $p = 0.006$), TP ($r = 0.3747$, $p = 0.002$), TSS ($r = 0.4626$, $p < 0.001$), and Zn ($r = 0.5397$, $p = 0.003$). Color was significantly negatively correlated with Cd ($r = -0.3996$, $p = 0.008$), NI ($r = -0.4436$, $p = 0.044$), pH ($r = -0.3406$, $p = 0.004$), and TOC ($r = -0.4091$, $p < 0.001$).

2.3.1.8 Biological Oxygen Demand (BOD)

Biological oxygen demand is an indication of the biological activity present in the water column. The test is analogous to a wet oxidation bioassay in which living organisms (primarily bacteria) serve as the medium for oxidation of organic matter. Florida DEP criteria state that the BOD shall not be increased to exceed values that would cause oxygen to be depressed below limits established for the subject class. In no case shall BOD be great enough to produce nuisance conditions. Measured BOD values ranged between 1.0 mg/l and 7.0 mg/l with an average of 2.48 mg/l (Figure 8). Maximum values were reported at Stations 4 and 5. BOD was significantly correlated with COL ($r = 0.3033$, $p = 0.016$), CPA ($r = 0.4577$, $p = 0.002$), K ($r = -0.2588$, $p = 0.039$), Ni ($r = -0.5095$, $p = 0.022$), NO_2 ($r = 0.4562$, $p = 0.002$), pH ($r = -0.3170$, $p = 0.011$), PO_4 ($r = -.4924$, $p = 0.007$), Si ($r = 0.3384$, $p = 0.017$), TB ($r = 0.4605$, $p < 0.001$), TKN ($r = 0.3747$, $p = 0.002$), and TSS ($r = 0.3361$, $p = 0.007$). Biological oxygen demand was not measured in sediments.



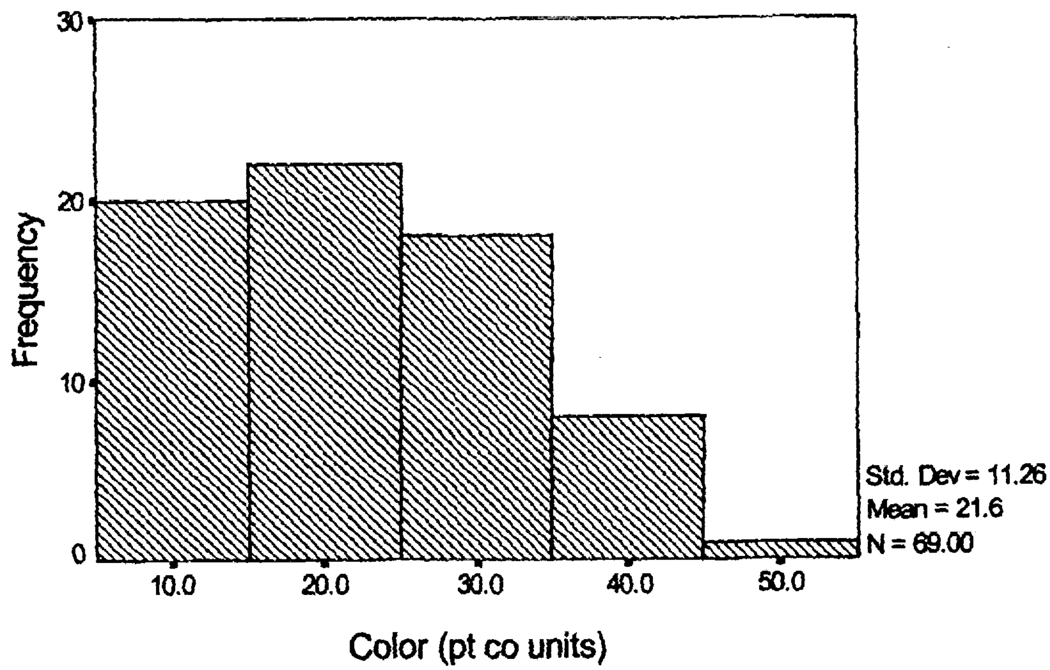


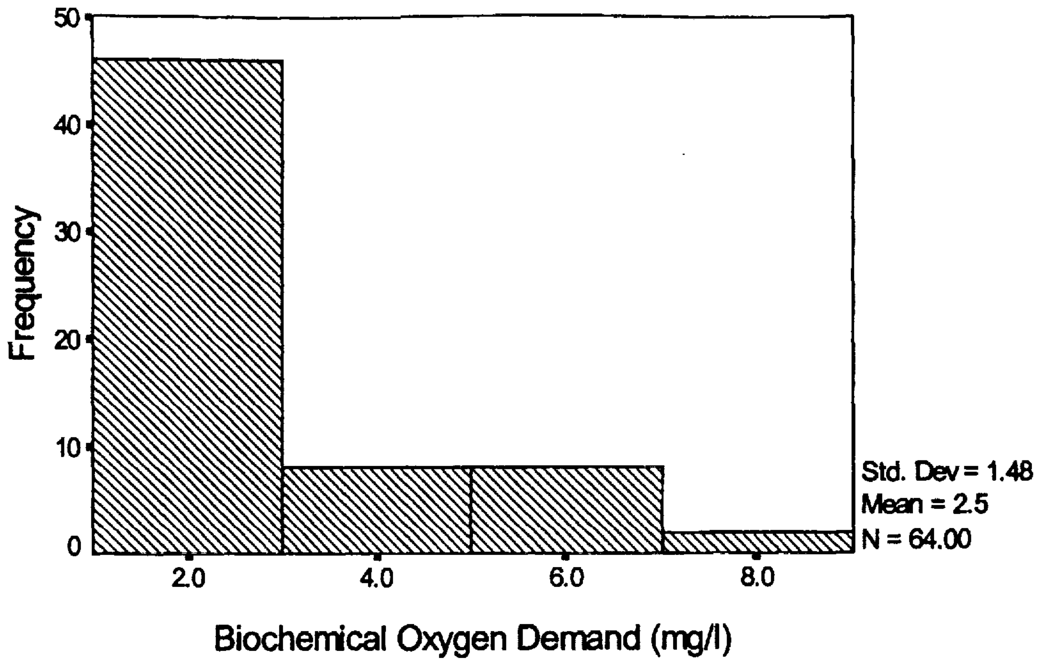
Figure 7. Water quality sample frequency distributions for chlorophyll A and color. There are no State criteria for these compounds.

2.3.1.9 Chemical Oxygen Demand (COD)

Chemical oxygen demand is a measure of the oxygen required to oxidize all compounds present in the water column within the constraints of the test procedure. This measure includes many chemicals that are resistant to biological oxidation and in general is typically larger than BOD. The Florida DEP does not provide criteria for COD. Chemical oxygen demand values ranged between 355.0 mg/l and 9300.0 mg/l with a mean value of 1141.96 mg/l. The minimum and maximum values were both recorded from Station 1. Chemical oxygen demand was significantly correlated with Ca ($r = 0.3370$, $p = 0.004$), CON ($r = 0.2887$, $p = 0.015$), Cr ($r = 0.3719$, $p = 0.006$), Mg ($r = 0.2982$, $p = 0.012$), NH_4-N ($r = 0.4948$, $p < 0.001$), TB ($r = 0.2324$, $p = 0.051$), and Zn ($r = 0.4361$, $p = 0.020$). Chemical oxygen demand was not measured in sediment samples.

2.3.2 Total Metals

Metals are naturally occurring elements that may be beneficial, troublesome or toxic depending on their form or concentration. Concentrations in estuarine surface waters and sediments are related to watershed soil characteristics, seawater concentrations, atmospheric inputs, and anthropogenic inputs from point and non-point source discharges. Metals in estuarine and coastal environments are known to react strongly with particulates and organics in the water column and at the water sediment interface. These reactions include adsorption, desorption, complexation, and chelation processes. Factors that control partitioning of metals between the bottom environment and overlying water column include pH, SAL, oxidation and reduction potentials, amount and type of organic matter present, particle grain size distributions, biological activity, temperature, and physical mixing (Manahan1991). Effects of exposure to metals can include altered metabolic and physiologic rates, reduced fecundity, increased risk of cancer formation, reduced survival of larvae, juveniles and adults, and altered mental capacity. In an effort to minimize human and ecosystem risks the Florida Department of Environmental Protection has established concentration criteria for different surface water quality classifications or uses. For this assessment we have utilized the Class II: Shellfish Propagation and Harvesting criteria and Class III Recreation, Propagation and Maintenance of a Healthy, Well Balanced Population of Fish and Wildlife. Results are summarized in Appendix A, Tables A-1, A-4, A-5, A-10, A-11, and A-12.



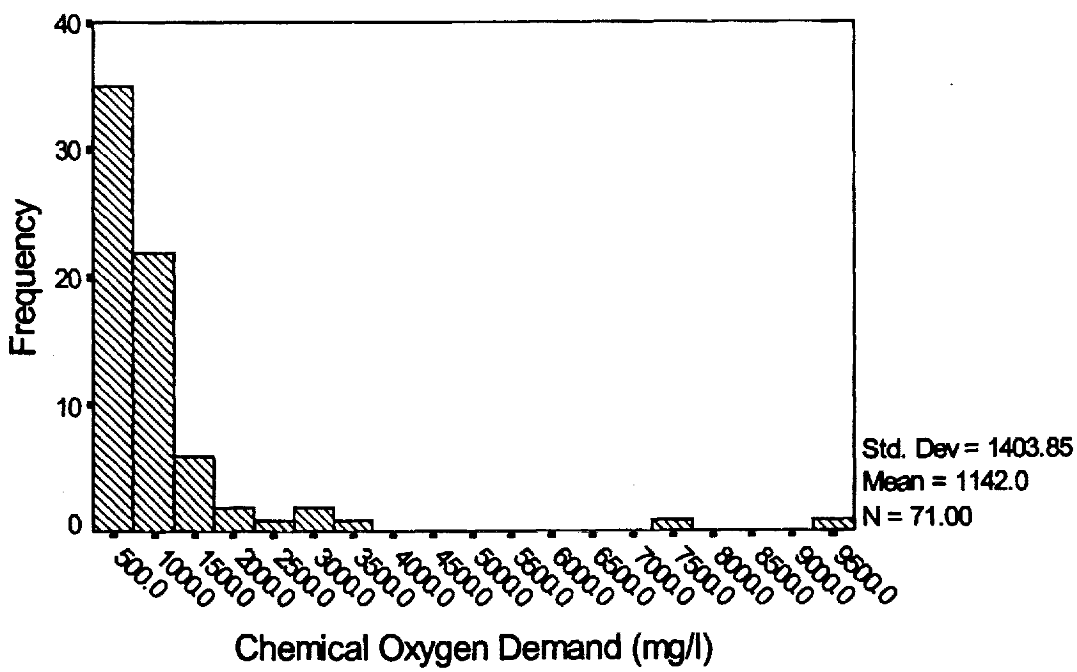


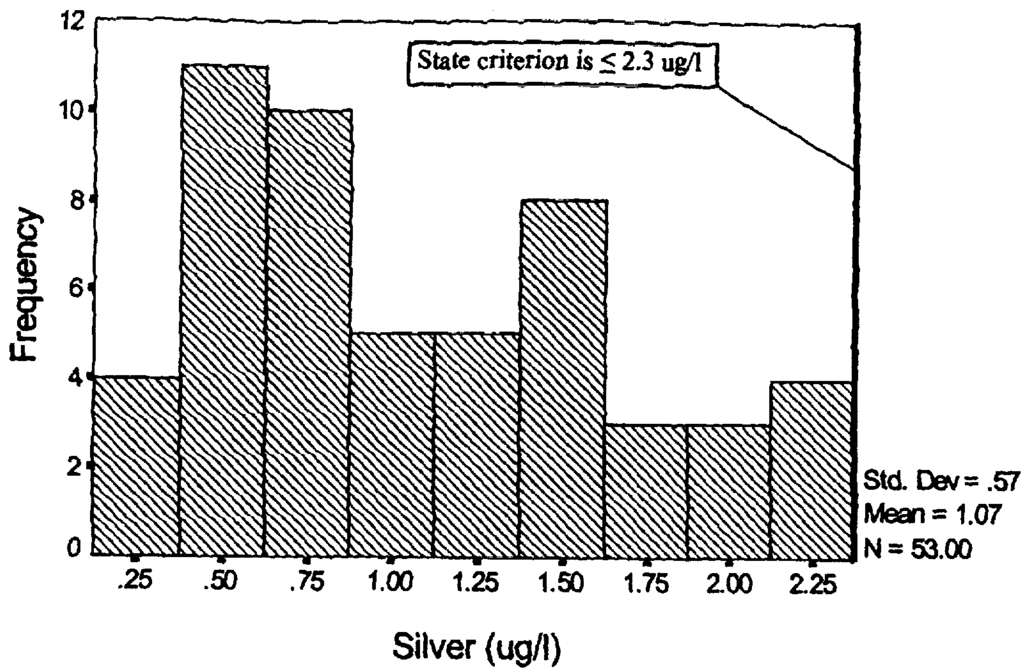
Figure 8. Water quality sample frequency distributions for biological oxygen demand (BOD) and chemical oxygen demand (COD). The Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.) state that BOD should not exceed values that depress dissolved oxygen below established limits, or produce nuisance conditions. There is no criterion for COD.

2.3.2.1 Silver (Ag)

The Florida DEP criteria for Class II water used for shellfish propagation and harvest is 0.05 ug/l. Provancha et al. (1992) report that total Ag concentrations in excess of the 0.05 ug/l criteria have been reported in all water bodies sampled at KSC and MINWR. Background values for Ag in soils typically range between 0.03 and 3.2 mg/kg (Kabata-Pendias and Pendias 1984). In addition, seawater is reported to contain Ag concentrations between 0.055 and 1.5 ug/l (Friberg et al. 1986). The minimum observed value of 0.15 ug/l was reported from Station 1 on September 22, 1992, and the maximum observed value of 2.20 ug/l occurred on July 23, 1991 at Station 4 (Table A-5). The average of observed values was 1.07 ug/l. Eighteen of the 71 possible samples were reported as below detection. The frequency distribution of reported sample values is presented in Figure 9. Silver concentrations displayed significant positive correlations with pH ($r = 0.4277$, $p = 0.001$), TDS ($r = 0.3315$, $p = 0.015$), and TOC ($r = 0.3506$, $p = 0.010$). Negative bivariate correlations were observed with Al ($r = -0.4028$, $p = 0.007$), Fe ($r = -0.4090$, $p = 0.007$), and NH_4-N ($r = -0.3148$, $p = 0.033$). Silver concentrations in sediments ranged between 0.05 mg/kg at Station 3 in 1993 and 10.13 mg/kg at Station 4 in 1992 with an average across all station and sample periods of 1.78 mg/kg. Sediment concentrations of Ag were negatively correlated with Pb ($r = -.8108$, $p = .027$), and positively correlated with sediment pH ($r = .9355$, $p < .001$). Long and Morgan (1990) report sediment concentrations below 1.0 mg/kg pose little risk to biota. Concentrations in excess of 2.2 mg/kg pose a greater risk.

2.3.2.2 Aluminum (Al)

Aluminum is a major constituent of the earth's crust and common to soils in coastal Florida. Alumino-silicates are produced by weathering and are a major constituent of many soils. The State criterion for Class II and III water is 1.5 mg/l. Aluminum is an abundant component of coastal soils in Florida and is frequently reported at concentrations near or above the State criteria (Provancha et al. 1992). The toxicity of Al depends on a variety of factors including form, complex, and pH. For example, organically bound forms of Al are generally less toxic than inorganic forms. Aluminum is generally more toxic at low pH than high pH. Because of the many species of Al found in water, the precise relationships of Al concentrations to toxicity are still not well understood (see Flora et al. 1984). Aluminum was reported as above detection in 59 of 71 samples.



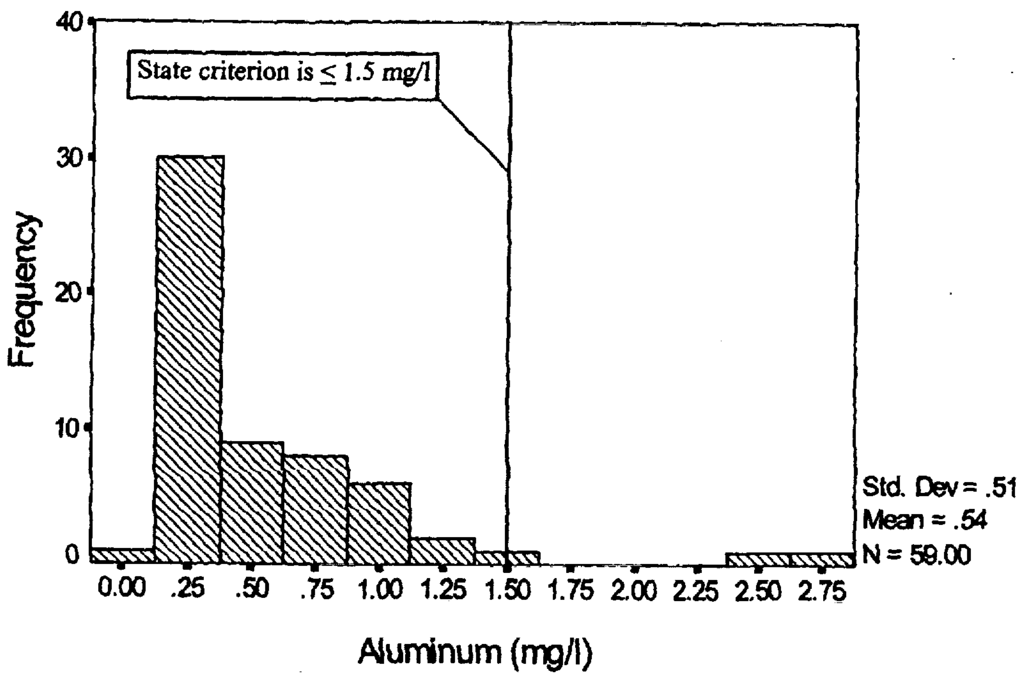


Figure 9. Water quality sample frequency distributions for Ag and Al compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line.

The minimum reported value of 0.11 mg/l value occurred on March 2, 1992 at Station 5. The maximum value of 2.64 mg/l occurred on September 22, 1992 at Station 4. A value of 2.60 mg/l was reported for Station 1 on May 5, 1992. The sample distribution and state criteria are shown in Figure 9. Three of 71 samples were at or above the criteria of 1.5 mg/l. The overall average reported concentration of Al during this study was 0.54 mg/l with a standard deviation of 0.51 mg/l. Aluminum was positively correlated with B ($r = 0.2976$, $p = 0.022$), Ca ($r = 0.2826$, $p = 0.030$), COL ($r = 0.3531$, $p = 0.007$), CPA ($r = 0.5178$, $p = 0.001$), Fe ($r = 0.5249$, $p = 0.001$), SAL ($r = 0.3549$, $p = 0.006$), Si ($r = 0.5906$, $p < 0.001$), TB ($r = 0.4469$, $p < 0.001$), TKN ($r = 0.2764$, $p = 0.037$), and TSS ($r = 0.4882$, $p < 0.001$). Aluminum was negatively correlated with Ag ($r = -0.4028$, $p = 0.007$), pH ($r = -0.3016$, $p = 0.020$), and SO_4 ($r = -0.2745$, $p = 0.035$).

Results of sediment analyses are presented in Tables A-1, A-4 and A-5. The average value was 4528 mg/kg. The minimum Al concentration of 325 mg/kg was recorded at Station 5. The maximum value of 21166 mg/kg was recorded at Station 2. Aluminum was highly correlated with many parameters. Significant Spearman Rank Correlations were observed with Be ($r = 0.7218$, $p < 0.001$), Cd ($r = 0.4318$, $p = 0.002$), Cr ($r = 0.8093$, $p < 0.001$), Cu ($r = 0.4570$, $p = 0.006$), Fe ($r = 0.8440$, $p < .001$), K ($r = 0.6767$, $p < 0.001$), Mg ($r = 0.6227$, $p < 0.001$), Mn ($r = .8656$, $p < 0.001$), Ni ($r = 0.3221$, $p = 0.029$), Pb ($r = 0.8812$, $p < 0.001$), pH ($r = 0.2525$, $p = 0.042$), TKN ($r = 0.3721$, $p = 0.002$), TOC ($r = 0.4626$, $p < 0.001$), TP ($r = 0.3366$, $p = 0.021$), and Zn ($r = 0.4729$, $p < 0.001$).

2.3.2.3 Beryllium (Be)

Beryllium is recognized as being widely distributed in low concentrations in soils and is known to be toxic to plants (Kabata-Pendias and Pendias 1984). Sources of Be in the environment include smelters and coal combustion. Soil Be samples at KSC are consistently reported as below detection levels. Results for analyses of Be in water are presented in Figure 10 and Tables A-1, A-4 and A-5. Beryllium was reported in 30 of 71 possible samples. Forty-one analyses were below detection. All reported values are above the Florida DEP criteria of 0.13 ug/l annual average. The minimum value of 0.20 ug/l was reported for Station 5 on July 23, 1991 and September 22, 1992. The maximum value of 2.2 ug/l was reported for Station 1 on February 3, 1992. Beryllium was positively correlated with CON ($r = 0.4150$, $p = 0.023$), Cr ($r = 0.3567$, $p = 0.053$), and SO_4 ($r = 0.3826$, $p = 0.037$), and negatively correlated with grease and oil (GO) ($r = -0.5121$, $p = 0.015$).

Analyses of Be concentrations in sediments are summarized in Table A-10. The minimum value of 0.03 mg/kg was observed at Station 5 on September 18, 1991. The maximum value of 2.04 occurred at Station 4 on March 31, 1993. The average value for all stations and sample periods was 0.32 mg/kg. Total Be was significantly correlated with Al ($r = .7218$, $p < .001$), Cd ($r = .4894$, $p < .001$), Cr ($r = .5787$, $p < .001$), Fe ($r = .7050$, $p < .001$), K ($r = .4781$, $p < .001$), Mg ($r = .4058$, $p = .001$), Mn ($r = .6948$, $p < .001$), Pb ($r = .7228$, $p < .001$), PO_4 ($r = .6378$, $p = .035$), SO_4 ($r = .3808$, $p = .008$), TKN ($r = .4271$, $p < .001$), TP ($r = -.3830$, $p = .008$), and Zn ($r = .4898$, $p < 0.001$).

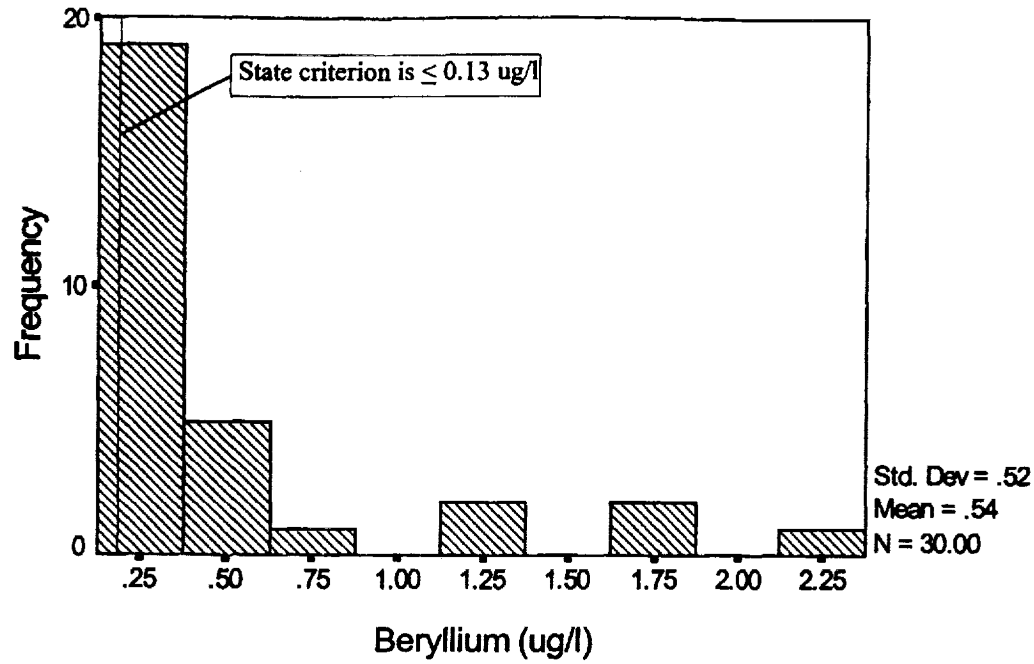
2.3.2.4 Boron (B)

Figure 10 displays results for the chemical analysis of total B in Mosquito Lagoon surface water samples. Concentrations of B in seawater typically average 4.6 ppm. (Gross 1972). There are no Florida DEP criteria for this element in Class II or Class III waters. Boron displayed significant but weak positive correlations with Al ($r = 0.2976$, $p = 0.022$), Ca ($r = 0.6302$, $p < 0.001$), CON ($r = 0.3751$, $p = 0.001$), Fe ($r = 0.3054$, $p = 0.044$), Mg ($r = 0.3071$, $p = 0.009$), Ni ($r = 0.4367$, $p = 0.030$), SAL ($r = 0.6149$, $p < 0.001$), and TDS ($r = 0.4264$, $p < 0.001$). Boron displayed no negative bivariate correlations. The minimum value of 0.24 mg/l occurred on November 20, 1991 at Station 2 (Table A-4). The maximum value of 5.98 mg/l occurred on June 16, 1993 at Station 1. The mean of reported concentrations was 2.96 mg/l with a standard deviation of 0.99 mg/l.

In sediments the minimum B value reported was 6.15 mg/kg from Station 1 on January 19, 1993. The maximum measured sediment concentration was 66.18 mg/kg for Station 3 on September 2, 1992. Sediment B concentrations were significantly correlated with Cu ($r = .6606$, $p = .038$), and K ($r = .6393$, $p = .010$).

2.3.2.5 Calcium (Ca)

The Florida DEP does not recommend criteria for Ca, a common and abundant constituent of coastal soils and seawater. Results of Ca analyses for surface waters are presented in Figure 11. The mean reported value was 297.7 mg/l with a range of 80.0 to 453.0 mg/l. The minimum value was reported from Station 4 on March 13, 1993 and the maximum value was recorded for Station 5 on May 5, 1992. Calcium was significantly positively correlated to Al ($r = 0.2826$, $p = 0.030$), B ($r = 0.6302$, $p < 0.001$), Cd ($r = 0.2977$, $p = 0.050$), COD ($r = 0.3370$, $p = 0.004$), CON ($r = 0.4399$, $p < 0.001$), CPA ($r = 0.4165$, $p = 0.003$), Mg ($r = 0.6394$, $p < 0.001$), Ni ($r = 0.4458$, $p = 0.038$), pH ($r = 0.2409$, $p = 0.043$), SAL ($r = 0.3908$, $p = 0.001$), TDS ($r = 0.4575$, $p < 0.001$), and TSS ($r = 0.2413$, $p = 0.043$). Calcium was negatively correlated with Cu ($r = -0.6124$, $p = 0.020$), and NH_4-N ($r = -0.2743$, $p = 0.032$). Total Ca concentrations in sediments are directly related to the presence of shell materials and other Ca bearing particulates. The minimum value reported was 1460 mg/kg from Station 6. The maximum value was 134,000 mg/kg from Station 1. The average concentration was 24,732 mg/kg. Sediment Ca was significantly but weakly correlated with Cr ($r = -.2516$, $p = .043$).



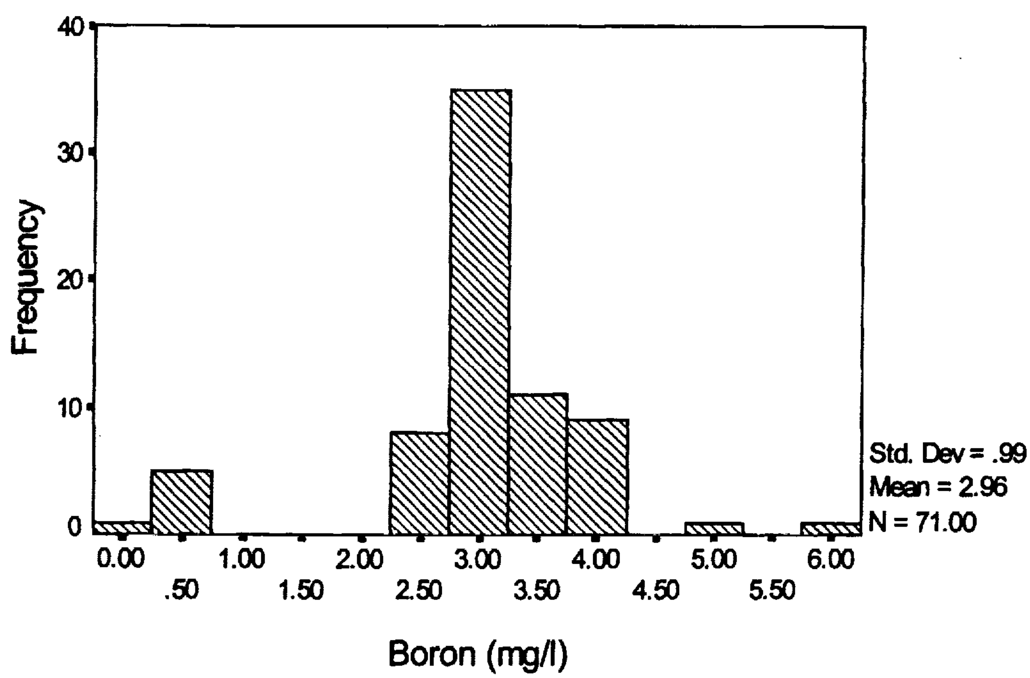
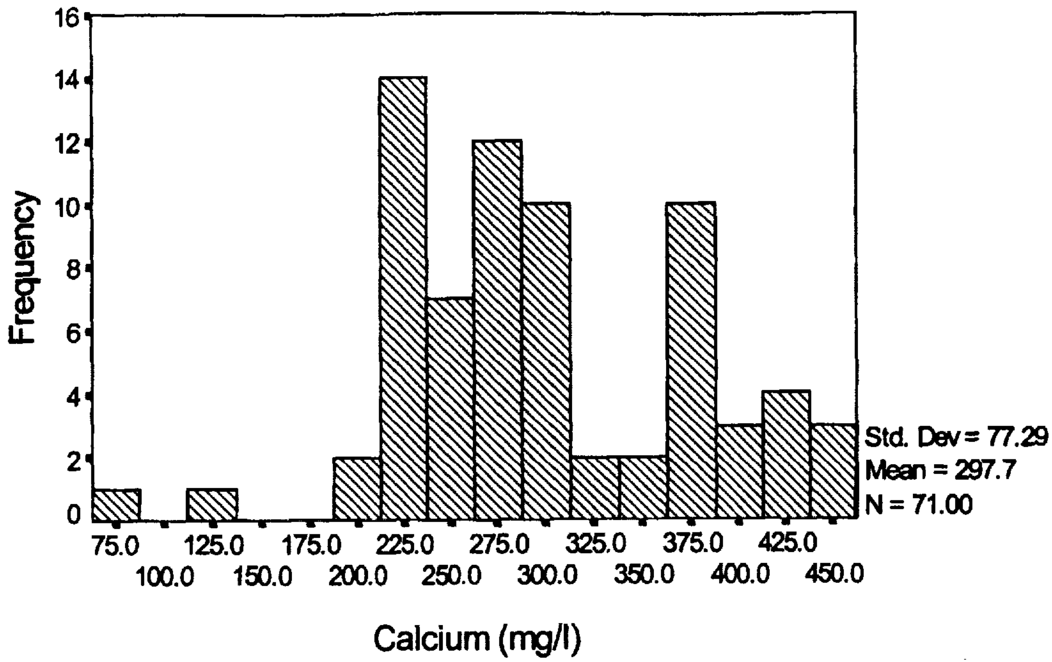


Figure 10. Water quality sample frequency distributions for beryllium and boron compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line. There is no Class II criterion for boron.



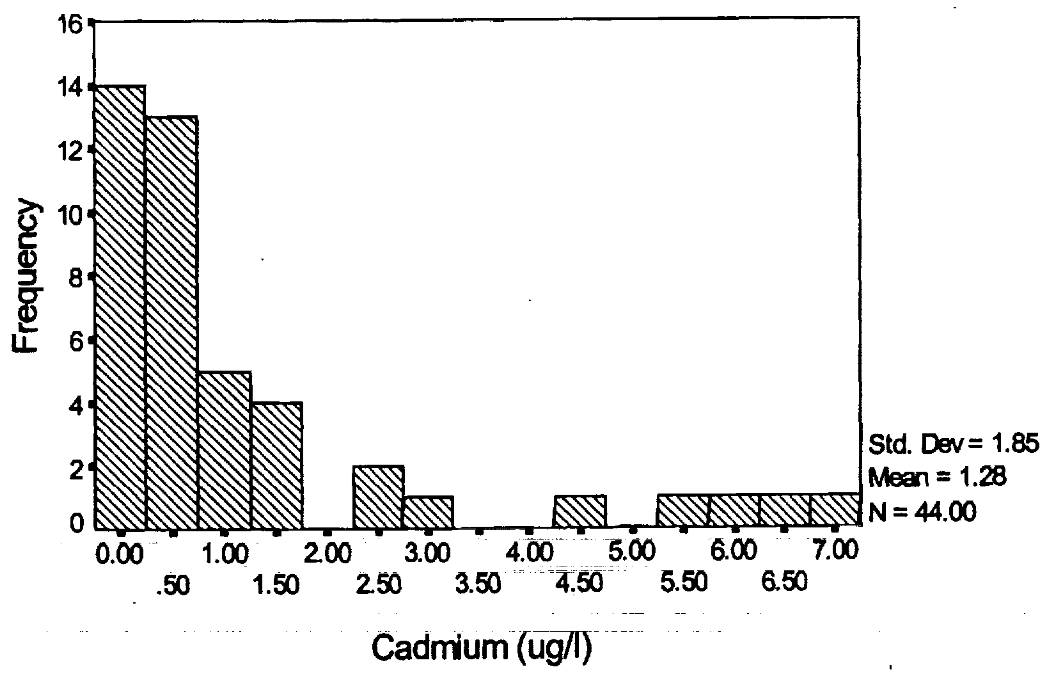


Figure 11. Water quality sample frequency distributions for calcium and cadmium. The Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.) criterion for cadmium is $\leq$ 9.3 ug/l. There is no criterion for calcium.

2.3.2.6 Cadmium (Cd)

Cadmium is recognized as a highly toxic metal causing growth, behavioral and physiological problems in fish and other aquatic organisms. It is known to bioaccumulate in fish and invertebrates. Results of Cd analyses are presented in Figure 11 and Tables A-1, A-4 and A-5. The Florida DEP criterion for Cd in Class II and Class III waters is 9.3 ug/l. All 44 reported values for this study were below the criterion. The average concentration was 1.28 ug/l with a range of reported values between 0.01 and 7.10 ug/l. The minimum reported values were from Stations 5 and 6 on November 20, 1991 and June 16, 1993 respectively. The maximum value occurred on May 5, 1992 at Station 2 near Haulover Canal. Cd displayed positive correlations with Ca ($r = 0.2977$, $p = 0.050$), COD ($r = 0.572$, $p < 0.001$), Cr ($r = 0.6208$, $p < 0.001$), Mg ($r = 0.4888$, $p = 0.001$), Ni ($r = 0.571$, $p = 0.013$), pH ($r = 0.4352$, $p = 0.003$), SO_4 ($r = 0.3617$, $p = 0.016$), TDS ($r = 0.3592$, $p = 0.017$), TOC ($r = 0.6473$, $p < 0.0010$). Negative correlations were found between Cd and COL ($r = -0.3996$, $p = 0.008$), and GO ($r = -0.3525$, $p = 0.052$).

Cadmium is known to form complexes with SO_4, a common component of estuarine sediments, and it may become sequestered in the benthic environment. The minimum reported sediment concentration was 0.01 mg/kg. The maximum concentration of total Cd in sediments was 0.80 mg/kg. The average reported Cd concentration for sediments was 0.10 mg/kg. Cd was significantly correlated with Al ($r = .4318$, $p = .002$), Be ($r = .4984$, $p < .001$), Cr ($r = .3044$, $p = .030$), Fe ($r = .3447$, $p = .013$), GO ($r = -.3525$, $p = .019$), Mn ($r = .4293$, $p = .002$), Pb ($r = .3827$, $p = .006$), SO_4 ($r = .3960$, $p = .008$), TKN ($r = .3610$, $p = .009$), TSS ($r = -.6374$, $p < .001$), and Zn ($r = .4830$, $p = .001$).

2.3.2.7 Chromium (Cr)

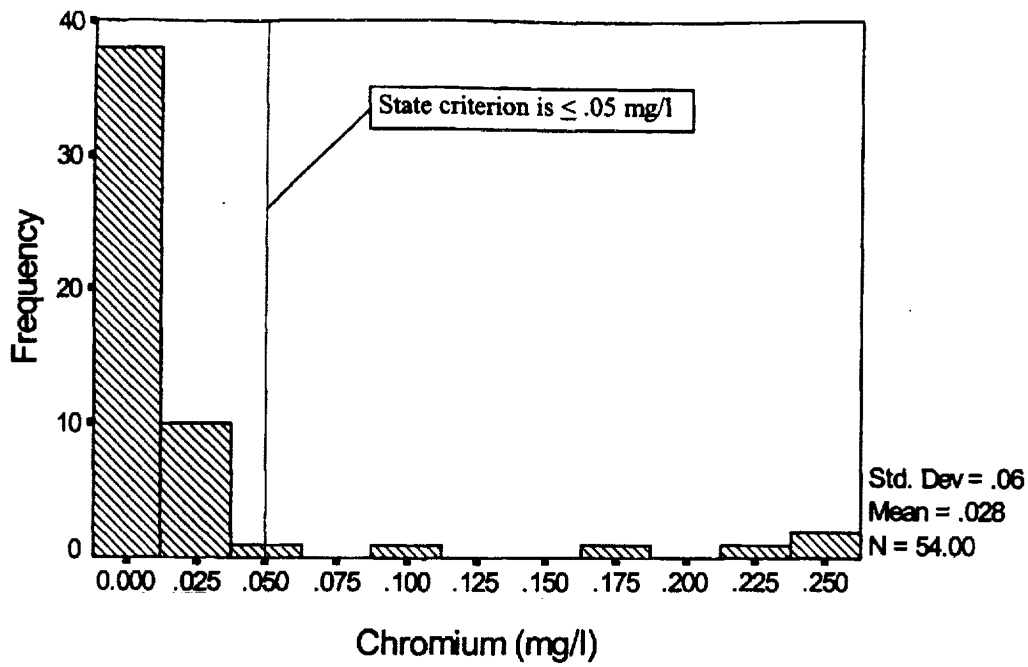
Chromium behavior and potential toxicity in estuarine environments is a complex issue because Cr may be present in a variety of forms (Manahan 1991). Depending on the chemical state the same elemental concentration may have a wide range of mobility and reactivity. Most Cr in surface waters is typically in a particulate trivalent form associated with suspended matter and sediments. Ingestion of these particulates by organisms is a common form of exposure. The hexavalent form of Cr is highly soluble and may enter organisms by sorption through the gills and other membranes. The Florida DEP has set a Class II and Class III criterion of 50 ug/l for hexavalent Cr but provides no guidance for total Cr or trivalent Cr in Class II or Class III waters. Results of chemical analyses for total Cr are presented in Figure 12. Fifty-four of 71 samples were reported to have total Cr levels above the detection limits of the laboratory procedure. Minimum values of 0.002 mg/l (2 ug/l) occurred at Stations 5 and 6 on July 23, 1991 and September 22, 1992. A maximum value of 0.258 mg/l (258 ug/l) occurred on March 31, 1993 at Station 4. The mean value was 0.03 mg/l. Chromium was positively correlated with Be ($r = 0.3567$, $p = 0.053$), Cd ($r = 0.6208$, $p < 0.001$), COD ($r = 0.3719$, $p = 0.006$), pH ($r = 0.2905$, $p = 0.033$), PHE ($r = 0.2172$, $p = 0.047$), SO_4 ($r = 0.3992$, $p = 0.003$), TDS ($r = 0.3705$, $p = 0.006$), and TOC ($r = 0.3158$, $p = 0.020$). Chromium was negatively correlated with COL ($r = -0.4411$, $p = 0.001$), and TB ($r = -0.3373$, $p = 0.013$).

The minimum total Cr sediment value was 0.17 mg/kg collected from Station 5 on September 18, 1991. The maximum was 251.00 mg/kg collected from Station 4. The average sediment value was 18.53 mg/kg. Sediment Cr was significantly positively correlated with Al ($r = .8093$, $p < .001$), Be ($r = .5787$, $p < .001$), Cd ($r = .3044$, $p = .030$), Cu ($r = .3709$, $p = .028$), Fe ($r = .7418$. $p < .001$). K ($r = .7668$, $p < .001$), Mg ($r = .4284$, $p < .001$), Mn ($r = .8344$, $p < .001$), Pb ($r = .7495$, $p < .001$), PO_4 ($r = .7091$, $p = .015$), SO_4 ($r = .3328$, $p = .022$), TKN ($r = .2705$, $p = .029$), and Zn ($r = .4629$, $p < .001$). Negative correlations were found with Ca ($r = -.2516$, $p = .043$), GO ($r = -.4100$, $p = .004$) and TP ($r = -.4614$, $p = .001$). Sources of potential Cr contamination include industrial waste, mining and metal processing, wood preservatives and sewage sludge (Kabata-Pendias and Pendias 1984).

2.3.2.8 Copper (Cu)

The Florida DEP has set a Class II and Class III criteria of 2.9 ug/l for Cu. Copper is an essential element for life but in high concentrations it can become toxic. In water, Cu acts synergistically with other contaminants such as Cd, Hg, and Zn to produce an increased toxic effect on fish. Results of reported analyses are presented in Figure 12. Only 14 samples were reported to contain concentrations in excess of laboratory detection limits for this compound. Reported detection limits ranged from 1 ug/l to 30 mg/l depending on method of analysis. This inconsistency makes interpretation of these results problematic. The minimum reported value was 0.02 mg/l from all stations on January 19, 1993. The maximum reported value was collected at Station 2 on March 2, 1992. The average for the 14 reported values was 0.05 mg/l. Even though the reported values were few in number Cu displayed a positive correlation with NH_4-N ($r = 0.5774$, $p = 0.049$), pH ($r = 0.8815$, $p < 0.001$), SO_4 ($r = 0.5595$, $p = .037$), TAK ($r = 0.6956$, $p = 0.006$), and TDS ($r = 0.6014$, $p = .023$). Copper was negatively correlated with Ca ($r = -0.6124$, $p = 0.020$), CON ($r = -0.6232$, $p = 0.017$), CPA ($r = -0.6524$, $p = 0.021$), SAL ($r = -0.8261$, $p < 0.001$), and TOC ($r = -0.6787$, $p = 0.008$).

Sediment Cu values were above the detection limits in 35 samples. Values ranged between a low of 0.26 mg/kg at Station 5 and a high of 59.0 mg/kg at Station 3. The average was 5.95 mg/kg. Sediment Cu was significantly correlated with Al ($r = .4570$, $p = .006$), B ($r = .6606$, $p = .038$), Cr ($r = .3709$, $p = .028$), Fe ($r = .3621$, $p = .033$), K ($r = .5407$, $p = .001$), Pb ($r = .4383$, $p = .014$), and TOC ($r = .3743$, $p = .027$). Kabata-Pendias and Pendias (1984) report that Cu concentration in soils typically range between 6-60 mg/kg and it is relatively immobile. Agriculture chemicals such as fungicides and fertilizers may contribute to non-point source discharges of Cu. Other possible sources include industrial processes, municipal waste, and coal combustion.



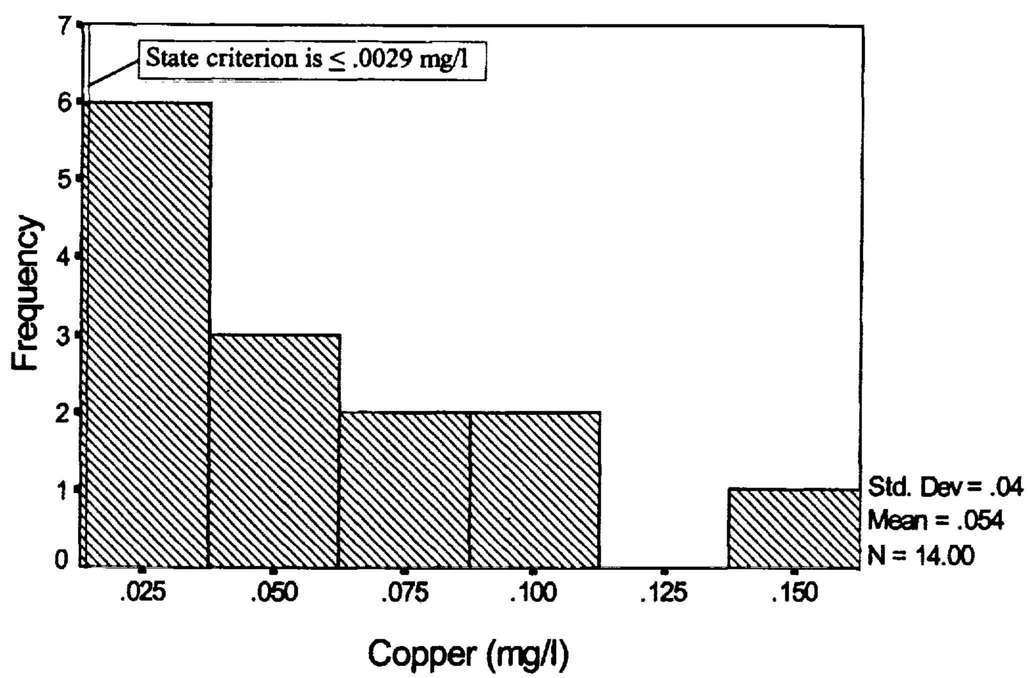


Figure 12. Water quality sample frequency distributions for chromium and copper compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line.

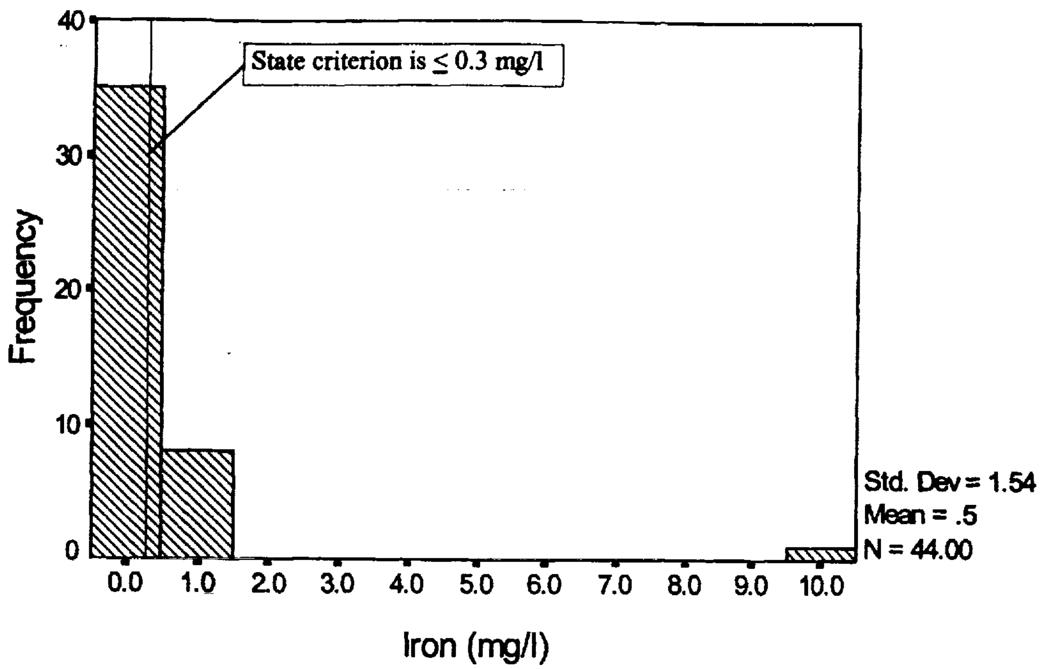
2.3.2.9 Iron (Fe)

Iron is the fourth most abundant element in the earth's crust making up about 4.7 % of the total mass. It is present in hundreds of minerals including many silicates, sulfides and carbonates where it exists mainly as insoluble ferric oxide. In reducing or anaerobic conditions ferric iron is reduced to the much more soluble ferrous state. Iron in high concentrations produces a distinct reddish color that can serve as a pollution indicator. In the presence of oxygen Fe can form hydroxide or oxide precipitates that can flocculate and settle to the bottom. This flocculent can be detrimental to benthic filter feeding organisms and eggs and larvae of fish and shellfish. The Florida DEP criterion for Fe in Class II and Class III water is 0.3 and 1.0 mg/l respectively. Results are presented in Figure 13. Iron was reported above detection limits in 44 of 71 possible samples. The minimum reported value was 0.05 mg/l that occurred at Station 1 on May 5, 1992 (Table A-1). The maximum reported value was 10.40 mg/l for Station 4 on March 3, 1993. The average concentration of Fe in seawater is reported by Gross (1972) as 0.01 mg/l. The mean value across all stations and time periods was 0.50 mg/l (Table A-1), which is slightly higher than the State criteria of 0.3 mg/l. Iron displayed significant positive correlations with Al ($r = .0.5249$, $p = 0.001$), B ($r = 0.3054$, $p = 0.044$), K ($r = 0.3106$, $p = 0.040$), NH_4-N ($r = 0.3500$, $p = 0.027$), TB ($r = 0.3414$, $p = .023$), and TSS ($r = 0.3119$, $p = 0.039$). Negative correlations were found between Fe and Ag ($r = -0.4090$, $p = 0.007$).

In sediment samples the minimum value for total Fe was 349 mg/kg. This was observed at Station 5 on September 18, 1991. The maximum value of 253401 mg/kg was collected at Station 3 on May 5, 1992. Results of bivariate correlations analyses are presented in Table A-16. Total Fe was significantly correlated with Al ($r = .8440$, $p < .001$), Be ($r = .7050$, $p < .001$), Cd ($r = .3447$, $p = .013$), Cr ($r = .7418$, $p < .001$), Cu ($r = .3621$, $p = .033$), K ($r = .5205$, $p < .001$), Mg ($r = .5682$, $p < .001$), Mn ($r = .8184$, $p < .001$), Pb ($r = .7837$, $p < .001$), pH ($r = .1809$, $p = .0149$), PO_4 ($r = .6545$, $p = .029$), SO_4 ($r = .5324$, $p < .001$), TKN ($r = .4377$, $p < .001$), TOC ($r = .2648$, $p = .033$), TP ($r = -.3681$, $p = .011$), TSS ($r = -.3600$, $p = .003$), and Zn ($r = .6023$, $p < .001$).

2.3.2.10 Magnesium (Mg)

Magnesium is a major constituent of seawater typically representing 3.7 % of the total dissolved salts. In estuaries the concentration of Mg, like Na, Cl, and Ca is greatly influenced by the degree of mixing between seawater and fresh water inflows. There are no Florida DEP criteria for Mg and it is generally of no toxicological concern. The average value for all sites and sample periods was 972.94 mg/l. The minimum value recorded was 41.60 mg/l on March 13, 1993 and the maximum value was 1370.00 mg/l on May 5, 1992. Both samples were collected



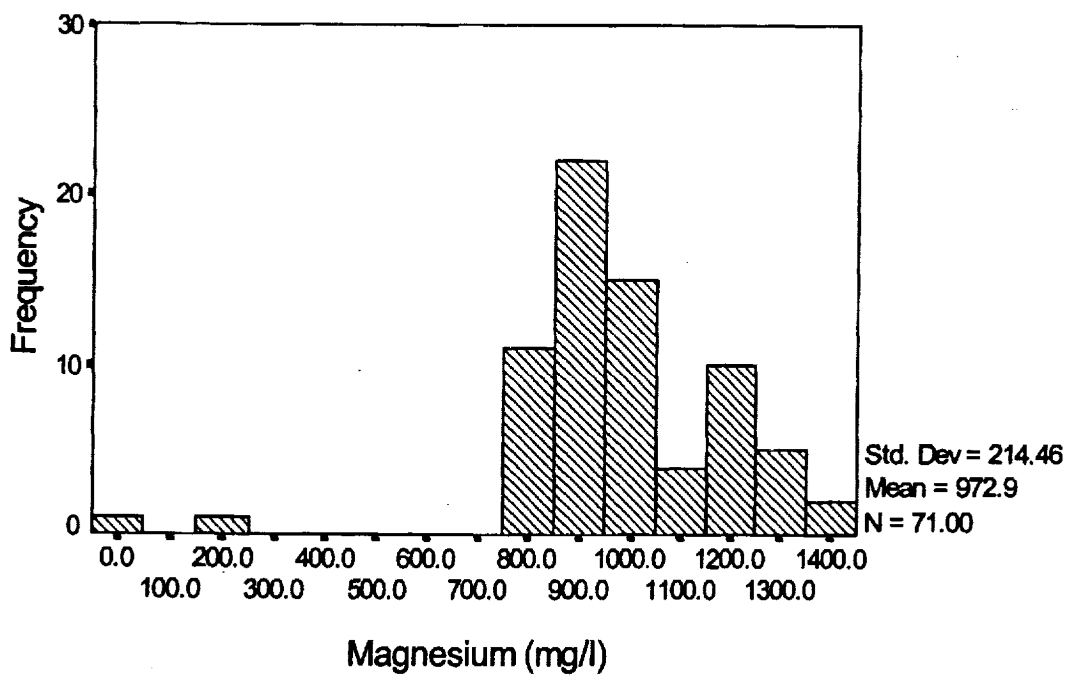


Figure 13. Water quality sample frequency distributions for iron and magnesium compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line. There is no criterion for magnesium.

at Station 4. Gross (1972) reports an average concentration of Mg in seawater of 1350 mg/l suggesting Station 4 was experiencing tidal influence from Ponce de Leon Inlet. Magnesium was significantly positively correlated with B ($r = 0.3071$, $p = 0.009$), Ca ($r = 0.6394$, $p < .001$), Cd ($r = 0.4888$, $p = 0.001$), COD ($r = 0.2982$, $p = 0.012$), CON ($r = 0.6209$, $p < 0.001$), K ($r = 0.2698$, $p = 0.023$), Ni ($r = 0.5867$, $p = 0.004$), pH ($r = 0.2805$, $p = 0.018$), and TDS ($r = 0.6011$, $p < 0.001$). Note that positive correlations existed with CON, TDS, and Ca, each of which are related to the concentration of seawater in the lagoon. Magnesium was negatively correlated with Zn ($r = -0.3904$, $p = 0.040$).

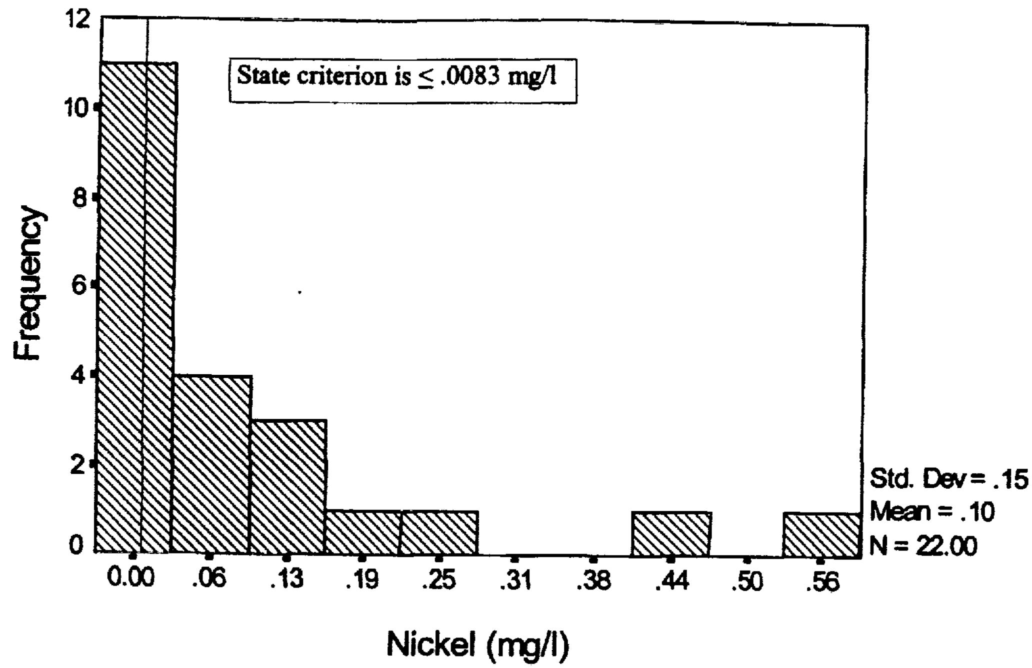
Sediment Mg levels ranged between a low of 245 mg/kg collected at Station 5 on January 19, 1993 and a high of 5838 mg/kg collected at Station 3 on July 27, 1992. Mg was significantly correlated with Al ($r = .6227$, $p < .001$), Be ($r = .4058$, $p = .001$), Cr ($r = .4284$, $p < .001$), Fe ($r = .5682$, $p < .001$), K ($r = .3900$, $p = .002$), Mn ($r = .5553$, $p < .001$), Pb ($r = .5799$, $p < .001$), SO_4 ($r = .4702$, $p = .001$), TKN ($r = .4696$, $p < .001$), TOC ($r = .5773$, $p < .001$), TSS ($r = -.3908$, $p = .001$), and Zn ($r = .4796$, $p < .001$).

2.3.2.11 Manganese (Mn)

Manganese is an abundant trace element (Kabata-Pendias and Pendias 1984) with generally low concentrations in sandy soils. All surface water samples for Mn were reported as below detection limit which was 0.02 mg/l. Gross (1972) reports average concentrations in seawater of 0.002 mg/l. The Florida DEP criterion for Class II waters is 0.1 mg/l. Sediment samples for total Mn ranged from a low 4.17 mg/kg at Station 5 on September 18, 1991 to a high concentration of 97.90 mg/kg at Station 3 on July 27, 1992. The average value was 21.78 mg/kg. Sediment Mn was significantly correlated with other metals such as Al ($r = .8656$, $p < .001$), Be ($r = .6948$, $p < .001$), Mg ($r = .5553$, $p < .001$), Pb ($r = .7806$, $p < .001$) and Zn ($r = .5831$, $p < .001$). Weaker correlations were observed with SO_4 ($r = .4431$, $p = .002$), TKN ($r = .4402$, $p < .001$), TOC ($r = .3106$, $p = .012$),TP ($r = -.2842$, $p = .053$), and TSS ($r = -.3105$, $p = .012$). Sources of Mn in the environment include sewage sludge and fertilizers (Kabata-Pendias and Pendias 1984).

2.3.2.12 Nickel (Ni)

The Florida DEP criterion for Ni in Class II and Class III marine water is 0.0083 mg/l. Nickel is potentially toxic to marine organisms however its toxicity may be reduced in the presence of Mg (Manahan 1991). Ni concentrations in seawater average about 0.0055 mg/l (Gross 1972). Results of analyses are presented graphically in Figure 14. Twenty-two of 71 samples were reported as having concentrations above the laboratory detection limits. The minimum



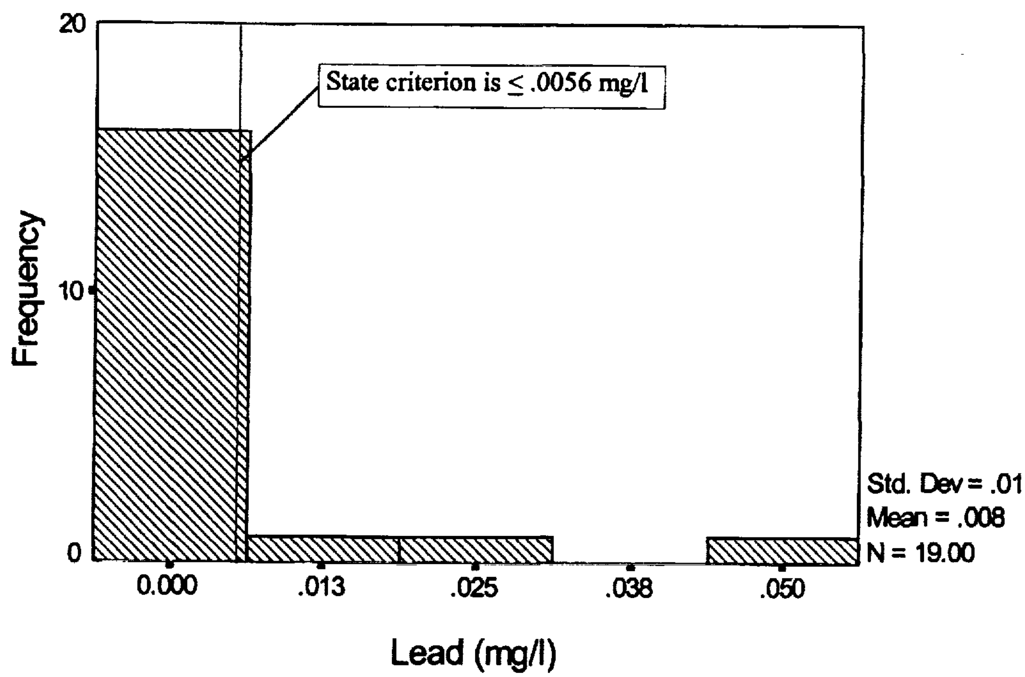


Figure 14. Water quality sample frequency distributions for nickel and lead compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for SurfaceWater Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line.

observed value of 0.004 mg/l was reported for Stations 3 and 4 on September 18, 1991 and November 16, 1992, respectively. The maximum value of 0.580 mg/l was observed on May 5, 1992 at Station 6. The overall mean of reported values was 0.10 mg/l. Nickel was significantly positively correlated with B ($r = 0.4367$, $p = 0.030$), Ca ($r = 0.4458$, $p = 0.038$), Cd ($r = 0.571$, $p = 0.013$), CON ($r = 0.5379$, $p = 0.010$), K ($r = 0.6167$, $p = 0002$), Mg ($r = 0.5867$, $p = 0.004$), pH ($r = 0.5330$, $p = 0.011$), TDS ($r = 0.6665$, $p = 0.001$), and TOC ($r = 04826$, $p = 0.023$). Negative correlations were observed between Ni and BOD ($r = -0.5095$, $p = 0.022$), COL ($r = -0.4436$, $p = 0.044$), Si ($r = -0.5449$, $p = 0.029$), TB ($r = -0.4662$, $p = 0029$), and TP ($r = -0.5665$, $p = 0.007$). Nickel is typically found at low concentrations in sandy coastal soils. Possible sources include industrial activities such as metal plating operations, municipal sewage discharges, and fossil fuel (coal) combustion (Manahan 1991).

Sediment concentrations of Ni were reported above detection in 46 of the possible 65 samples. The minimum value of 0.16 mg/kg and the maximum value of 12.26 mg/kg were observed at Station 3 on June 16, 1993 and July 27, 1992 respectively. Sediment concentrations were positively correlated with Al ($r = .3221$, $p = .029$), SO_4 ($r = .4013$, $p = .021$), and TOC ($r = .4421$, $p = .002$).

2.3.2.13 Lead (Pb)

Results for the analysis of Pb in lagoon water are presented graphically in Figure 14. Nineteen of 71 samples produced detectable results. The Florida DEP criterion for Pb is 0.0056 mg/l in both Class II and Class III waters. Lead is known to be toxic to fish and shellfish impacting such traits as survival, growth, reproduction, learning, and metabolic processes. Lead in estuarine environments may become tightly associated with sediment particulates with the amount absorbed being dependent on the availability of ligands, pH, redox conditions, Fe concentrations, salinity and other polar particulates (Manahan 1991). Cycling of Pb in estuaries involves a complex interaction between dissolved and particulate phases. Lead is known to have synergistic toxicity when present with Cd, Hg, Cu, and Zn. The average concentration of the reported Pb values was 0.01 mg/l. The minimum value reported was 0.003 mg/l from Stations 2 and 5. The maximum observed value of 0.044 mg/l was collected from Station 1 on July 27, 1992. Lead was significantly correlated with K ($r = -0.6490$, $p = 0.003$), pH ($r = 0.4706$, $p = 0.042$), and TAK ($r = 0.4646$, $p = 0.045$).

Sediment concentrations of Pb ranged from a minimum value of 0.11 mg/kg at Station 5 to a maximum value of 11.24 mg/kg at Station 3. The average reported value was 3.58 mg/kg. Pb sediment concentrations were significantly correlated with Ag ($r = -.8108$, $p < .001$), Al ($r = .8812$, $p < .001$), Be ($r = .7228$, $p < .001$), Cd ($r = .3827$, $p = .006$), Cr ($r = .7495$, $p < .001$), Cu ($r = .4383$, $p = .014$), Fe ($r = .7837$, $p < .001$), K ($r = .6190$, $p < .001$), PO_4 ($r = .6455$, $p = .032$), SO_4 ($r = .4653$, $p = .001$), TKN ($r = .5515$, $p < .001$), TOC ($r = .4380$, $p < .001$), TSS ($r = -.3474$, $p = .006$), and Zn ($r = .5956$, $p < .001$). Sources of Pb in the environment include industrial processes, municipal sewage, and burning of fossil fuels.

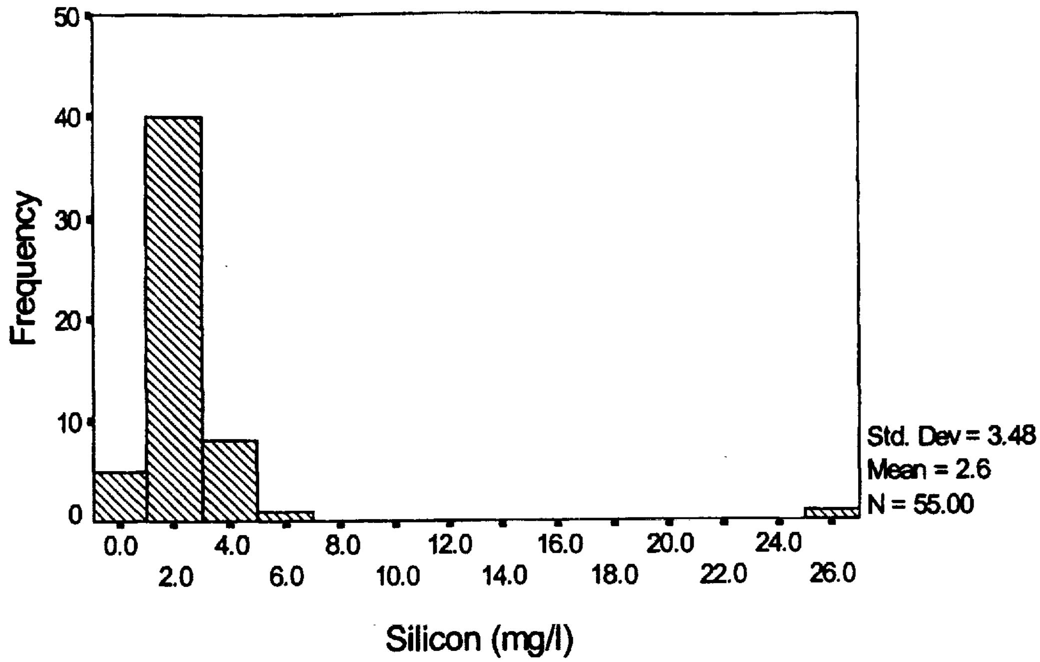
2.3.2.14 Silicon (Si)

Silicon, like Al, is a primary constituent of the sandy soils along the east Florida coast and the Florida DEP does not provide a criterion. Silicon is basically an inert compound with very low toxicity. The presence of Si in the water column is most often associated with suspended sediments or other particulates such as diatoms. Results of silicon (Si) analyses are presented in Figure 15. The average concentration across all stations and time periods was 2.57 mg/l. The minimum value was 0.80 mg/l reported for Station 2 on February 3, 1992 and the maximum value of 26.6 mg/l was reported from Station 4 on March 3, 1993. Silicon was positively correlated with Al ($r = 0.5906$, $p < 0.001$), BOD ($r = 0.3384$, $p = 0.017$), COL ($r = 0.6314$, $p < 0.001$), CPA ($r = 0.6703$, $p < 0.001$), TB ($r = 0.7080$, $p < 0.001$), and TKN ($r = 0.3656$, $p = 0.007$). Negative bivariate associations were observed with Ni ($r = -0.5449$, $p=0.029$), PHE ($r = -0.2817$, $p = 0050$), SO_4 ($r = -0.2913$, $p = 0.031$), and TOC ($r = -0.3042$, $p = 0.024$). Sediment samples were not analyzed for total Si because of the known high content associated with local sandy soils.

2.3.2.15 Zinc (Zn)

Zinc is a trace metal that is considered an essential element at desired concentrations. At high levels it is known to cause growth retardation, histopathological changes, physiological stress, reduced fecundity, altered behavior and mortality in fishes (Furness and Rainbow 1990). Gross (1972) reports average concentrations in seawater of 0.01 mg/l. The Florida DEP has established a Class II and Class III criteria of 0.086 mg/l for marine waters. Results of chemical analyses are presented in Figure 15. For the 71 possible samples 43 were reported as below detection and 28 were reported above detection. The minimum value recorded was 0.01 mg/l on May 5, 1992, July 27, 1992, November 16, 1992, March 31, 1992, and June 16, 1993 at Stations 1,2,3,5,and 6, respectively. One sample was above the DEP criteria and this maximum value came from Station 4 on March 31, 1993. Zinc displayed significant positive bivariate correlations with COD ($r = 0.4361$, $p = 0.020$), COL ($r = 0.5397$, $p = 0.003$), NH_4-N ($r = 0.4653$, $p = 0.017$), Si ($r = 0.5122$, $p = 0.009$), and TB ($r = 0.4940$, $p = 0.008$). Zinc was negatively correlated with CON ($r = -0.4855$, $p = 0.009$), Mg ($r = -0.3904$, $p = 0.040$), PHE ($r = -0.4508$, $p = 0.021$), and SAL ($r = -0.3865$, $p = 0.042$). The negative correlations with CON and other indicators of seawater suggest Zn may be derived from freshwater inputs.

Sediment concentrations of Zn ranged between a minimum value of 2.15 mg/kg at Station 6 and maximum value of 74.20 mg/kg from Station 4. The average Zn value for sediments was 14.07 mg/kg. Zinc sediment concentrations were correlated with Al ($r = .4729$, $p < .001$), Be ($r = .4898$, $p < .001$), Cd ($r = .4830$, $p = .001$), Cr ($r = .4629$, $p < .001$), Fe ($r = .6023$, $p < .001$), GO ($r = -.3362$, $p = .028$), Mg ($r = .4796$, $p < .001$), Mn ($r = .5831$, $p < .001$), Pb ($r = .5956$, $p < .001$), SO_4 ($r = .4573$, $p = .002$), and TKN ($r = .5341$, $p < .001$). Possible sources of Zn in the environment include industrial and municipal discharges, and corrosion control coatings.



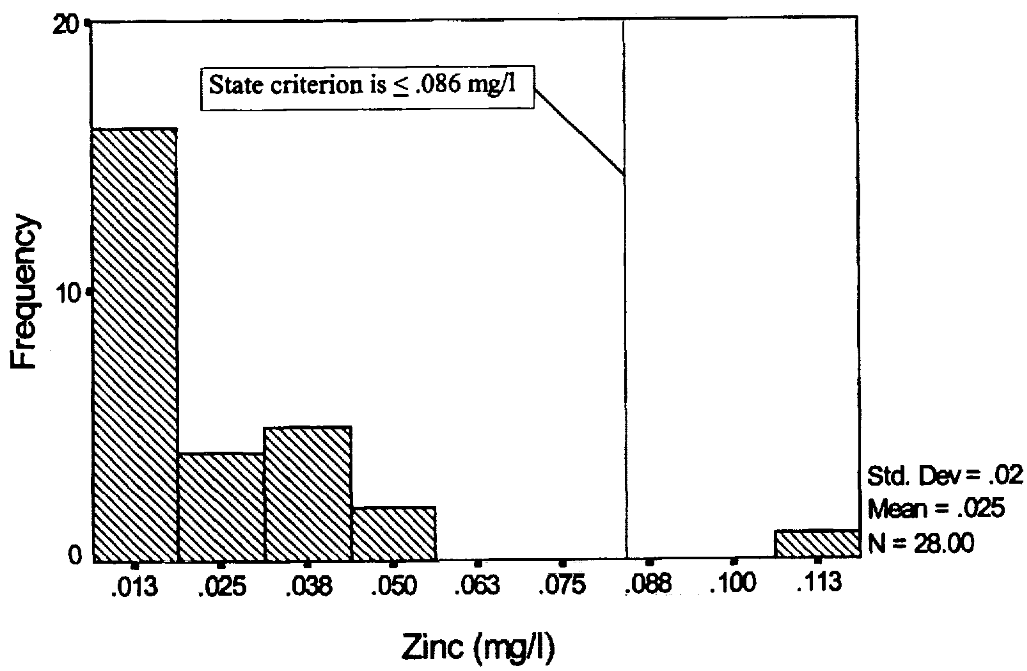


Figure 15. Water quality sample frequency distributions for silicon and zinc compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line. There is no criterion for silicon.

2.3.3 Inorganic Chemistry

2.3.3.1 Ammonia (NH_3), Nitrite (NO_2), and Nitrate (NO_3)

The importance of nitrogen in Mosquito Lagoon rests upon its role in the synthesis and maintenance of protein, a major component of all organisms. Derived originally from the atmosphere, nitrogen is involved in a complex cycle that involves plants, animals and a variety of chemical forms. Nitrogenous compounds in Mosquito Lagoon may be derived from external (allochthonous) or internal (autochthonous) sources. External sources include precipitation and atmospheric deposition, surface water runoff, tidal transport, and groundwater seepage. Autochthonous sources include nitrogen fixing bacteria and algae. Once in the ecosystem a great proportion is involved in a cycle of biological assimilation and decomposition along with other inorganic processes (Reid 1960).

An important feature of shallow estuarine systems is the interaction or coupling between benthic and pelagic communities. Pelagic primary production and sedimentation of detritus is often a major source of organic material for benthic community metabolism. The rate of benthic nutrient regeneration affects the nutrient availability in the overlying water column (Nowicki and Nixon 1985). In Mosquito Lagoon, light reaches the bottom in sufficient quantity in many areas to support the growth of seagrasses and benthic algae. In these communities the system supports both heterotrophic remineralization as well as the production of organic forms of nitrogen. Eventually, certain quantities are lost from the system through sedimentation and burial, transport through Ponce de Leon Inlet and Haulover Canal, and biological harvesting and migrations (Provancha et al. 1992).

The synthesis of inorganic nitrogen into plant and animal tissue produces various organic nitrogen compounds such as proteins, and metabolic wastes such as urea or uric acid (Reid 1960). Blue-green algae and bacteria may secrete nitrogenous compounds such as polypeptides, amides, and amino acids. The measure of organic nitrogen is a valuable indication of the productivity of a body of water because most will ultimately be transformed into material that can be used in the production of living matter.

In addition to its occurrence in the organic state, nitrogen is also present in inorganic form such as ammonia (NH_3), nitrite (NO_3) and nitrate (NO_2). In most natural systems concentrations of these forms are low. These compounds are used by plants in photosynthesis. Once locked up by the plant in organic compounds, nitrogen is returned to the environment by decomposition. The first stage of oxidative degradation of animal and plant protein results primarily in release of free NH_3 with lesser amounts of ammonium hydroxide and ammonium carbonate. Decomposition is the result of microbiologically mediated processes. In an intermediate phase of the oxidation process, NH_3 is attacked by nitrifying bacteria such as Nitrosomonas that absorb NH_3 and release NO_2 ions. This process releases energy that is utilized by the bacteria for growth. Nitrite nitrogen generally occurs in very small quantities, if at all, in unpolluted waters. In the final phase of the de-nitrification process nitrites are oxidized by bacteria (Nitrobacter) to (NO_3) nitrate nitrogen. Nitrate nitrogen is an extremely important inorganic nutrient. It is generally found in low concentrations because it is rapidly assimilated by plants, including algae and submerged aquatic vegetation (SAV).

The average ammonia nitrogen (NH_4-N) concentration across all stations and sample periods was 0.12 mg/l with a standard deviation of 0.09 mg/l or about 75% of the mean (Tables A-1, A-6 and A-7, and Figure 16). The minimum value was 0.02 mg/l, which was at the detection limit of the analytical method. The maximum values recorded were 0.46 mg/l from

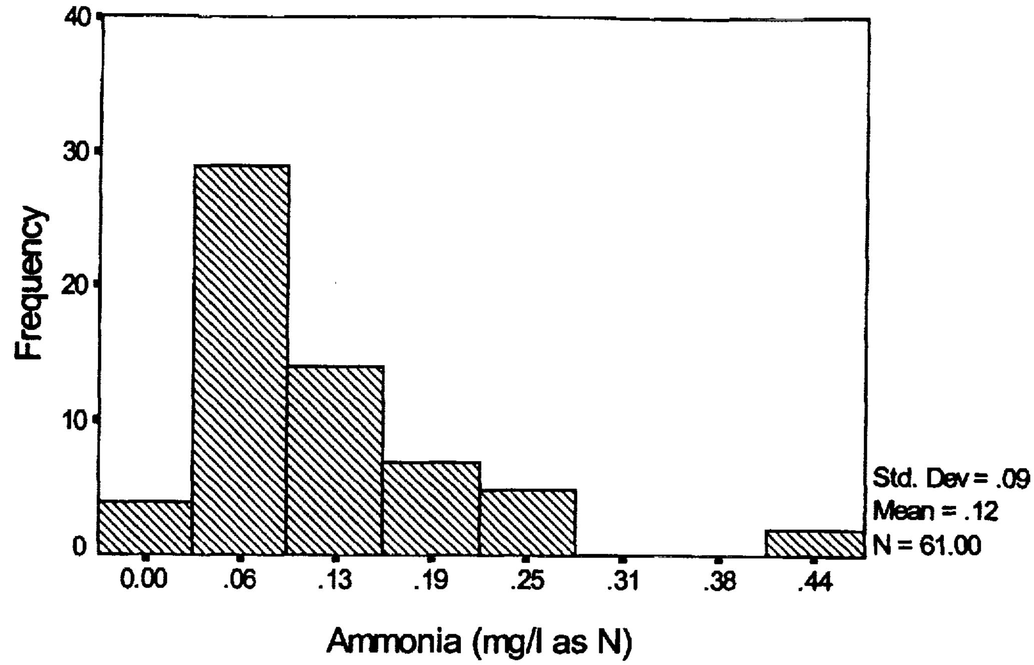
Station 4 on September 22, 1992 and 0.45 mg/l from Station 2 on March 2, 1992. A total of 61 samples had values above the detection limit. The Florida DEP does not set specific criteria for ammonia. Ammonia nitrogen was only weakly correlated with COL ($r = .318$, $p = .013$), K ($r = .256$, $p = .046$), PO_4 ($r = .489$, $p = .010$), and TAK ($r = .369$, $p = .003$). Results of analyses for ammonia in sediments are presented in Tables A-10, A-11 and A-12. The minimum value was 0.73 mg/kg N observed on September 22, 1992 at Station 3. The maximum value of 47.79 mg/kg N was also collected at Station 3 on July 27, 1992. The average value for sediments was 11.03 mg/kg. Sediment ammonia concentrations were significantly correlated with NO_3 ($r = .7143$, $p < .001$), Pb ($r = .3335$, $p = .009$), pH ($r = .3846$, $p = .002$), PHE ($r = .5597$, $p = .001$), and TSS ($r = .2472$, $p = .047$).

Results of NO_2 and NO_3 analyses are presented in Tables A-1, A-4 and A-5. There are no Florida DEP criteria for NO_2 and NO_3. Samples for NO_2 in Mosquito Lagoon were consistently below the detection limit of 0.01 mg/l, consistent with areas having low organic pollutant loading. Nitrite in natural situations is converted rapidly to nitrate by nitrifying bacteria (Gross 1972). Nitrate samples for all stations across all sample periods averaged 0.06 mg/l with a standard deviation of 0.08 mg/l or about 133% of the mean. Of the 71 samples, 45 were below the detection limit of 0.01 mg/l and the maximum value recorded was 0.31 mg/l. Examination of averages by station indicated higher mean values at the shallow water Stations 1 and 2. Stations 3, 5, and 6, associated with the barge channel on the west side of the lagoon, had the lowest average values. Spearman Rank Correlation analysis indicated NO_3 values were weakly positively correlated with TOC ($r = .185$, $p = .008$).

In sediments, NO_2 levels averaged 0.27 mg/kg and ranged between 0.33 and 9.29 mg/kg. Nitrite was significantly correlated with NH_4 ($r = .7143$, $p < .001$), NO_3 ($r = .6760$, $p = .016$), pH ($r = -.3723$, $p = .043$), PHE ($r = .6902$, $p < .001$), and TKN ($r = .3935$, $p = .031$). Sediment NO_3 values ranged between 0.33 mg/kg and 9.29 mg/kg with an average of 3.78 mg/kg. The lowest and highest values were collected from Station 2 during September and November of 1992.

2.3.3.2 Total Kjeldahl Nitrogen (TKN)

Measurement of organic and ammonia nitrogen at the six stations as estimated by the TKN method averaged 0.84 mg/l with a standard deviation of 0.49 mg/l (Tables A-1, A-6, and A-7). The minimum value observed was 0.05 mg/l and the maximum value was 3.04 mg/l. The average from each station across all sample periods suggested no large north to south trend. Stations 4 and 6 had average values of 0.84 mg/l and 0.89 mg/l respectively. The maximum value was recorded at Station 6 on January 19, 1993. The Florida DEP has no specific criteria for TKN in coastal water. Results of the Spearman Rank Correlation analysis indicated some statistically significant but weak correlations between TKN and other parameters. Correlations were observed with Al ($r = .2764$, $p = .037$), BOD ($r = .3747$, $p = .002$), COL ($r = .3297$, $p = .006$), CPA ($r = .5038$, $p < .001$), pH ($r = -.2579$, $p = .032$), Si ($r = .3656$, $p = .007$), and TB ($r = .3391$, $p = .005$)..



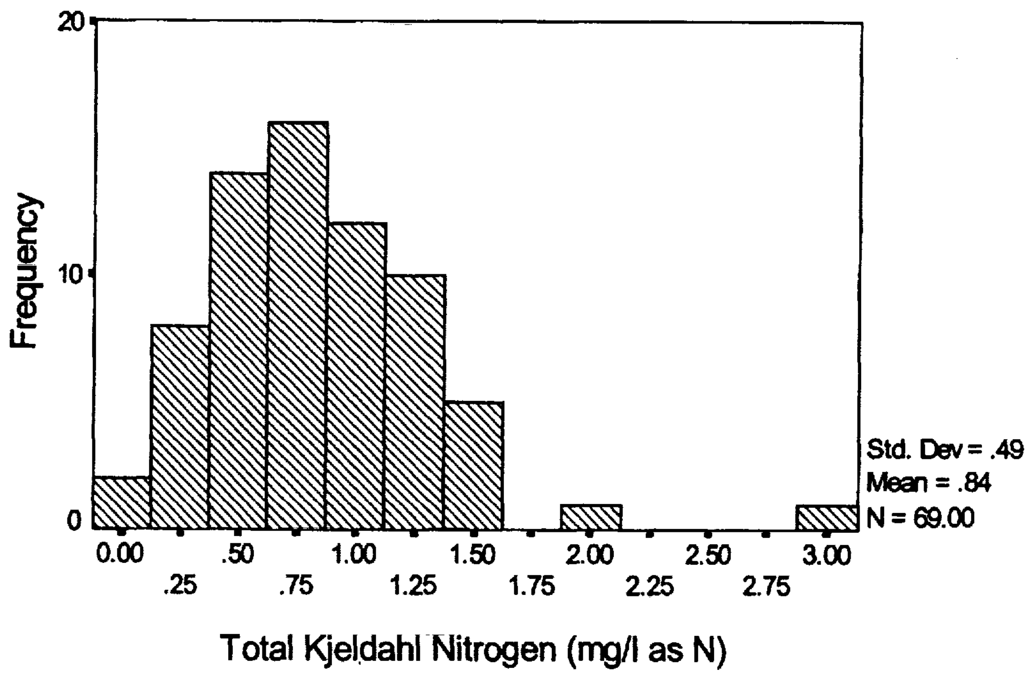


Figure 16. Water quality sample frequency distributions for ammonia and total Kjeldahl nitrogen (TKN). There are no Class II criteria for ammonia and TKN.

Results of sediment analyses for TKN are presented in Tables A-10, A-13, and A-14. The minimum value was 6.46 mg/kg and the maximum value was 1522.14 mg/kg. TKN averaged 506.01 mg/kg across all stations and sampling periods. Results of bivariate correlation analyses for TKN are shown in Table A-15. TKN was weakly but significantly correlated with Al ($r = .3721$, $p = .002$), Be ($r = .4271$, $p < .001$), Cd ($r = .3610$, $p = .009$), Cr ($r = .2705$, $p = .029$), Fe ($r = .4377$, $p < .001$), K ($r = .3458$, $p = .006$), Mg ($r = .4696$, $p < .001$), Mn ($r = .4402$, $p < .001$), NO_3 ($r = .3935$, $p = .031$), TKN ($r = .5515$, $p < .001$), PHE ($r = .4393$, $p = .009$), and SO_4 ($r = .2839$, $p = .053$).

2.3.3.3 Total Phosphorus (TP) and Orthophosphate (PO_4)

From an ecological perspective phosphorus (P) is often considered the most critical single factor in the maintenance of biogeochemical cycles (Reid 1961). Phosphorus is necessary at the cell level for energy transfer systems and in the natural environment it is often found in small quantities where it is a limiting factor in system primary production. The concentration of P in the open ocean is approximately 0.7 mg/l (Gross 1972). In shallow estuarine systems like Mosquito Lagoon the concentration of phosphorus compounds in the water column may be directly related to assimilation by algae and submerged aquatic vegetation, storm-water runoff, tidal mixing, groundwater seepage, and benthic remineralization. In surface waters, the phosphate ion may enter into combination with a number of other ions depending on pH and relative abundance. The two most common phases are calcium phosphate and ferric phosphate. The interaction with Fe is especially significant because under anaerobic conditions, as are often found in the benthic environment in summer months in Mosquito Lagoon, the P ion is released from the ferric-phosphorus complex allowing it to recycle into the overlying water column stimulating primary production if other nutrients are not limiting (Reid 1961).

Results of TP analyses are presented in Tables A-1, A-6, A-7, and Figure 17. Total phosphorous averaged 0.09 mg/l with a standard deviation of 0.05 mg/l. The minimum value reported was at the detection limit of 0.02 mg/l. This was recorded on March 2, 1992 at Station 2. Average values for each station ranged between 0.08 and 0.10 mg/l with no obvious spatial or temporal trends. These data are virtually identical to previous samples collected in Mosquito Lagoon between 1982 and 1991 (Woodward Clyde 1994). The maximum value of 0.25 mg/l was recorded at Station 4 on June 16, 1993. Total phosphorus was correlated with COL ($r = 0.3747$, $p = 0.002$), K ($r = -0.2354$, $p = 0.052$), Ni ($r = -0.5665$, $p = 0.007$), NO_2 ($r = 0.3800$, $p = 0.009$), pH ($r = -0.3749$, $p = 0.002$, SAL ($r = 0.4486$, $p < 0.001$), TB ($r = 0.3368$, $p = .005$), TOC ($r = -0.5470$, $p < 0.001$), and TSS ($r = 0.4701$, $p < 0.001$).

Total Phosphorus in sediments ranged from a minimum of 0.61 mg/kg to a maximum value of 1250.00 mg/kg (Table A-10). The overall mean concentration was 141.04 mg/kg. Total phosphorous was significantly negatively correlated with Al ($r = -.3366$, $p = .021$), Be ($r = -.3830$, $p = .008$), Cr ($r = -.4614$, $p = .001$), Fe ($r = -.3681$, $p = .011$), and Mn ($r = -.2842$, $p = .053$) (Table A-16).

Measurements of dissolved PO_4 at all stations in Mosquito Lagoon consistently fell at or below the detection limit. Data are presented in Figure 17 and Tables A-1, A-4, and A-5). The minimum recorded value was 0.02 mg/l and the maximum value was 0.05 mg/l. The average of reported values was 0.03 mg/l. Orthophosphate was significantly correlated with BOD ($r = -.4924$, $p = .007$), GO ($r = .5045$, $p = .012$), NH_4-N ($r = .4890$, $p = .010$), and NO_2 ($r = -.4601$, $p = .036$).

In sediments, the minimum recorded value was 0.51 mg/kg and the maximum value was 4.57 mg/kg. The average sediment value was 1.99 mg/kg however, only 11 samples had concentrations reported above the detection limit. For these few samples PO_4 was significantly correlated with Al ($r = .6000$, $p = .051$), Be ($r = .6378$, $p = .035$), Cr ($r = .7091$, $p = .015$), Fe ($r = .6545$, $p = .029$), K ($r = .6818$, $p = .021$), and Pb ($r = .6455$, $p = .032$). In general, phosphorous levels in Mosquito Lagoon appear low with potential sources being fertilizer runoff, septic tank seepage, and possible point source discharges.

2.3.3.4 Potassium (K)

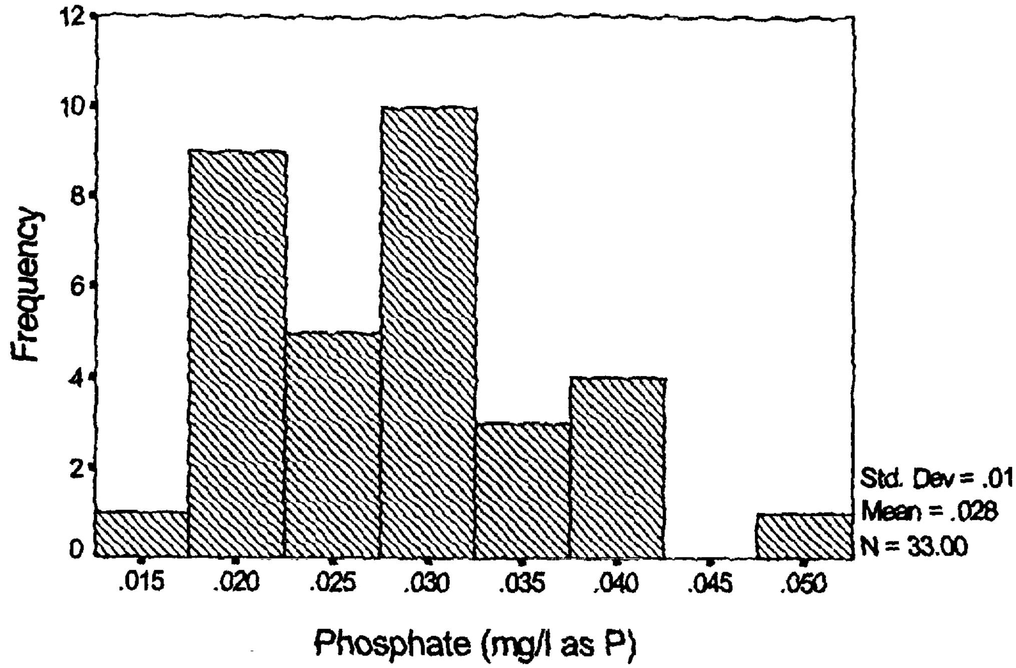
The Florida DEP does not set criteria for K. Potassium is a common element in seawater. Results of chemical analyses for K in Mosquito Lagoon surface waters are summarized in Figure 18 and Table A-1. Spatial and temporal data for K are presented in Tables A-6 and A-7. Potassium was found in all 71 samples, ranging between 225 mg/l and 998 mg/l. The average value was 402 mg/l.

Results of sediment analyses for K are presented in Tables A-10, A-12 and A-13. The minimum value of 0.24 mg/kg was collected on November 16, 1992 from Station 6. The maximum value of 5902 mg/kg was collected in May 1992 at Station 1. The average K value was 991 mg/kg. Potassium in sediments was significantly correlated with Al ($r = .6767$, $p < .001$), B ($r = .6393$, $p = .010$), Be ($r = .4781$, $p < .001$), Cr ($r = .7668$, $p < .001$), Cu ($r = .5407$, $p = .001$), Fe ($r = .5205$, $p < .001$), GO ($r = -.4284$, $p = .003$), Mg ($r = .3900$, $p = .002$), Mn ($r = .6335$, $p < .001$), NO_2 ($r = .4077$, $p = .053$), Pb ($r = .6190$, $p < .001$), PO_4 ($r = .6818$, $p = .021$), and TKN ($r = .3458$, $p = .006$).

2.3.3.5 Sulfate (SO_4)

The Florida DEP does not provide criteria for SO_4. The minimum value of 2000.0 mg/l occurred on January 19, 1993 at Station 1. The maximum value of 7140 mg/l occurred on July 27, 1992 at Station 6. For all stations combined the average value was 2860.18 mg/l (Table A-1, Figure 18). Sulfate concentrations were significantly positively correlated with Be ($r = .3826$, $p = .037$), Cd ($r = .3617$, $p = .016$), CON ($r = .3803$, $p = .001$), Cr ($r = .3992$, $p = .003$), Cu ($r = .5595$, $p = .037$), PHE ($r = .4511$, $p < .001$), TDS ($r = .3604$, $p = .002$), and TSS ($r = .2841$, $p = .016$). Sulfates in surface waters displayed a negative correlation with Al ($r = -.2745$, $p = .035$), CPA ($r = -.2940$, $p = .038$), and Si ($r = -.2913$, $p = .031$).

The minimum sediment value was 96.70 mg/kg that was recorded at Station 5 on September 18, 1991. The maximum value of 3510.49 mg/kg was recorded at Station 3 in July 1992. The average SO_4 value across all sample periods and stations was 1284.55 mg/kg. Sulfate concentrations were significantly correlated with Al ($r = .5459$, $p < .001$), Be ($r = .3808$, $p = .008$), Cd ($r = .3960$, $p = .008$), Cr ($r = .3328$, $p = .022$), Fe ($r = .5324$, $p < .001$), GO ($r = -.2874$, $p = .050$), Mg ($r = .4702$, $p = .001$), Mn ($r = .4431$, $p = .002$), Ni ($r = .4013$, $p = .021$), Pb ($r = .4653$, $p = .001$), TKN ($r = .2839$, $p = .053$), TOC ($r = .5737$, $p < .001$), TSS ($r = -.4792$, $p = .001$), and Zn ($r = .4573$, $p = .002$).



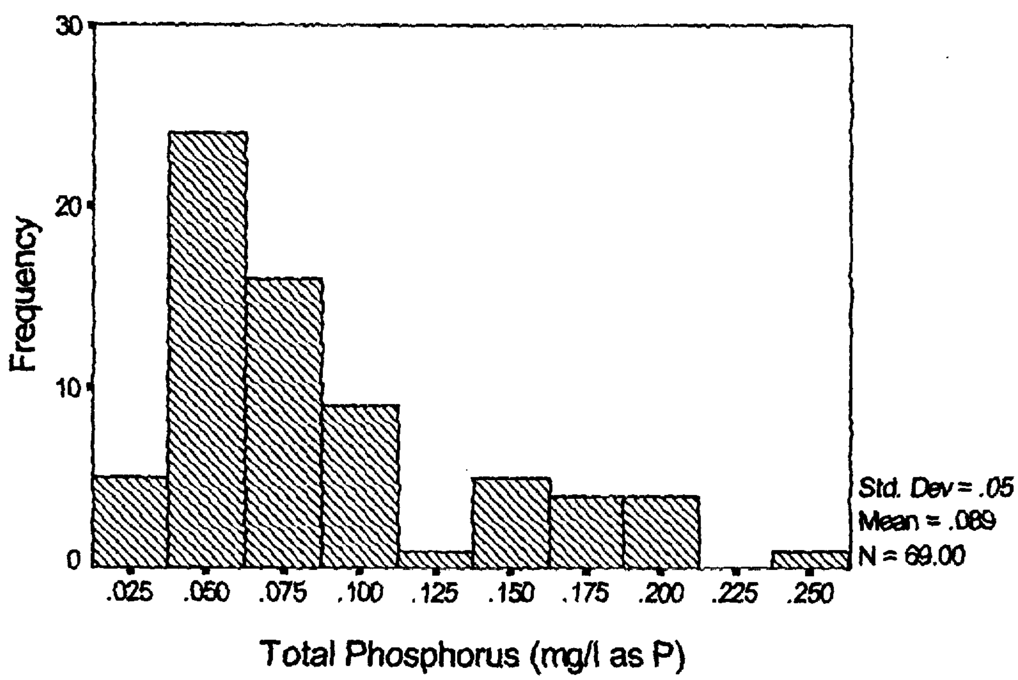
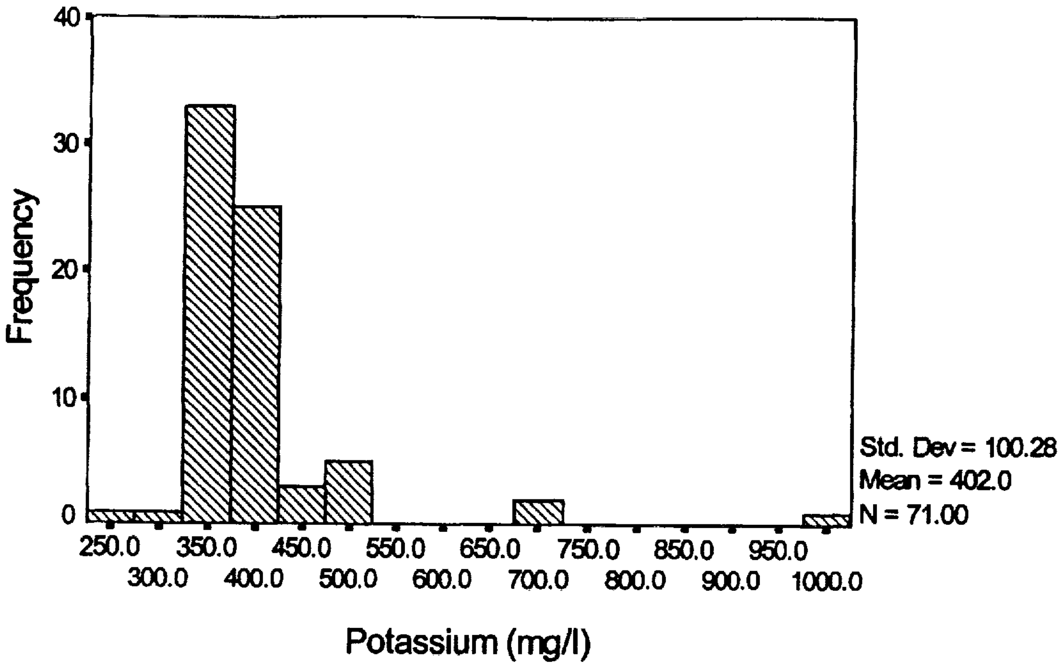


Figure 17. Water quality sample frequency distributions for phosphate and total phosphorus. Florida DEP criteria *state that in no case shall nutrient levels be altered in a way that causes an imbalance in natural populations of flora or fauna.*



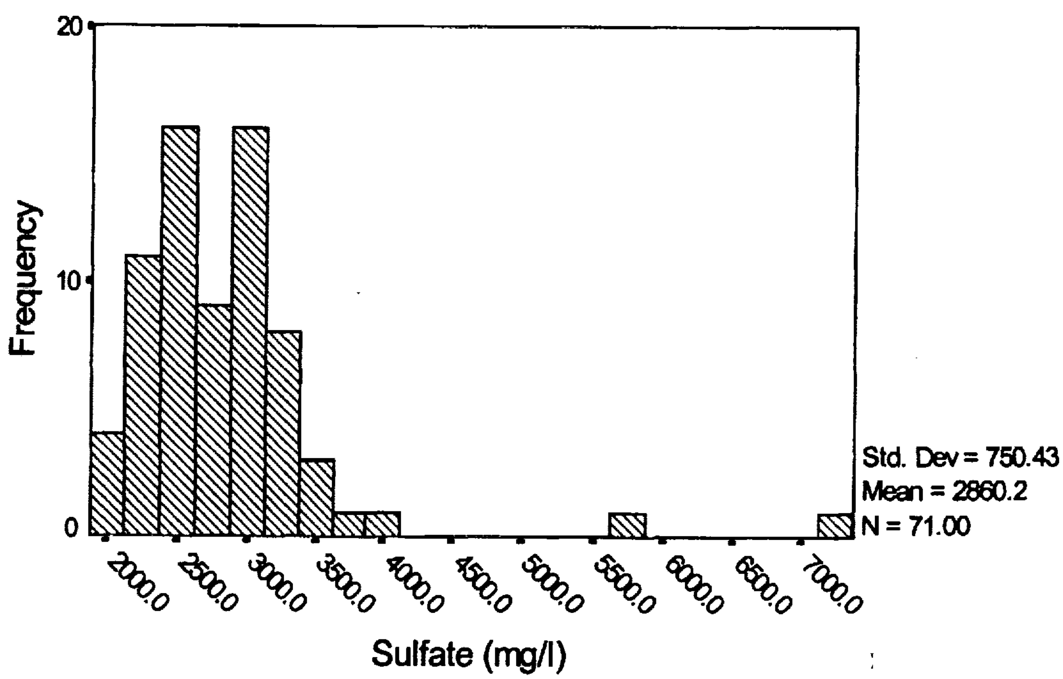


Figure 18. Water quality sample frequency distributions for potassium and sulfate. There are no state criteria for potassium or sulfate.

2.3.4 Organic Chemistry

2.3.4.1 Grease and Oil (GO)

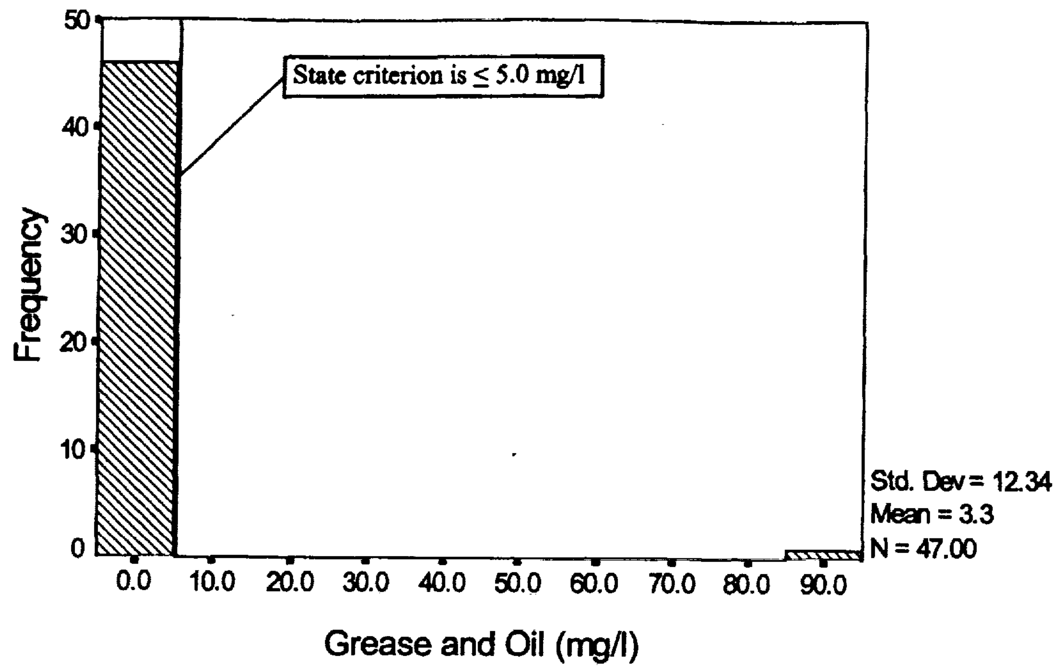
The Florida DEP criteria for GO is stated as " no undissolved oil, or visible oil as defined as iridescence, shall be present so as to cause taste or odor or otherwise interfere with beneficial use of waters". Sources of grease and oil include industrial and municipal discharges, boat operations, and stormwater runoff. The minimum value reported was 0.52 mg/l from Station 6 on July 27, 1992. The maximum value recorded was 86.0 mg/l for Station 2 on September 18, 1991. Results are summarized in Figure 19. The average for all stations was 3.31 mg/l. Grease and oil in the water column displayed significant correlations with Be ($r = -.5121, p = .015$), Cd ($r = -.3525, p = .052$), CPA ($r = -.3446, p = .037$), PO_4 ($r = .5045, p = .012$), and TSS ($r = .3762, p = .009$).

The minimum sediment value of 1.86 mg/kg was observed at Station 2 on November 20, 1991. The maximum value of 1280.00 mg/kg was recorded at Station 4. The average concentration for sediment GO was 243.92 mg/kg. Grease and oil was significantly correlated with Cd ($r = -.3525, p = .019$), Cr ($r = -.4100, p = .004$), K ($r = -.4284, p = .003$), NO_2 ($r = -.5643, p = .005$), PHE ($r = .3549, p = .039$), SO_4 ($r = -.2874, p = .050$), and Zn ($r = -.3362, p = .028$).

2.3.4.2 Phenols (PHE)

The Florida DEP provides a complex set of standards for phenolic compounds with emphasis on man-made derivatives such as chlorophenols and nitrophenols. The Florida DEP recognizes that naturally occurring PHE resulting from the decay of plant materials may be present in relatively high quantities. Phenolic compounds are known to taint the flesh of fish and shellfish and can produce objectionable odor and taste in water. At all stations for all sample periods, measured values of total PHE in Mosquito Lagoon exceeded the Florida DEP criteria of 1.0 ug/l (62-302.530, F.A.C). The overall average was 111.35 ug/l with a standard deviation of 50.05 ug/l. The minimum value was 43.8 ug/l and the maximum was 399.0 ug/l. There was no obvious spatial trend in the data. The highest value of 399.0 ug/l was observed at Station 5 on June 6, 1993. Phenol concentrations were significantly negatively correlated with CPA ($r = -0.3256, p = 0029$), NH_4-N ($r = -0.2643, p = 0.047$), NO_3 ($r = -0.3961, p = 0.050$), Si ($r = -0.281, p = 0.050$),) and Zn ($r = -0.4508, p = 0.021$). Phenols were positively correlated with Cr ($r = 0.2172, p = 0.047$), and SO_4 ($r = 0.4511, p < 0.001$).

The minimum value of PHE in sediments was 0.07 ug/kg. The maximum value of 4766.08 ug/kg was observed at Station 4. Sediment total PHE averaged 271.37 ug/kg. Total phenols were significantly correlated with GO ($r = .3549, p = .039$), NH_4 ($r = .5597, p = .001$), NO_3 ($r = .6902, p < .001$), TKN ($r = .4393, p = .009$), and TSS ($r = -.3540, p = .041$).



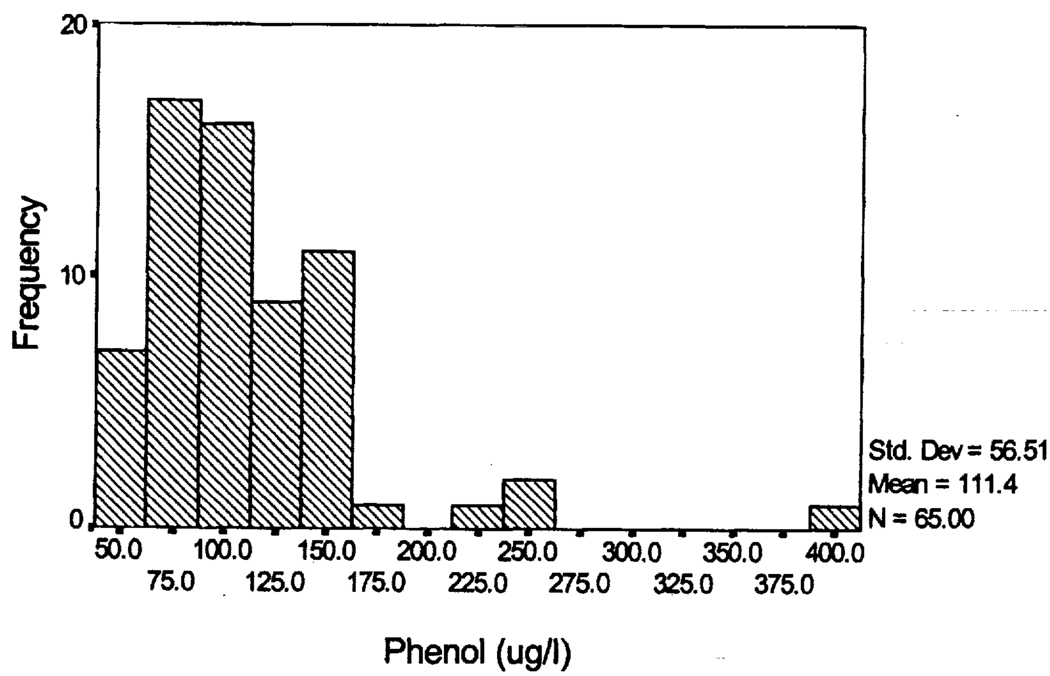


Figure 19. Water quality sample frequency distributions for grease and oil and phenol compared to the Florida Class II: Shellfish Propagation or Harvesting Criteria for Surface Water Quality (62-302.530 F.A.C.). Criteria concentrations are depicted by a vertical line. The state criteria for phenolic compounds is ≤ 1.0 ug/l unless higher values are shown not to be chronically toxic.

2.3.4.3 Total Organic Carbon (TOC)

Total organic carbon in Mosquito Lagoon is composed of a variety compounds in various oxidation states. These organic compounds contribute to BOD and COD and, depending on structure, can serve as electron donors in the complexation process with metals and other cations. The Florida DEP provides no criteria for TOC. Results of analyses are presented in Table A-1 and Figure 20. The maximum value of 20.80 mg/l as C was collected on January 19, 1993 at Station 1. The minimum value of 0.24 mg/l as C occurred at Station 6 on July 16, 1993. The overall average for the study was 2.63 mg/l as C. Total organic carbon was significantly correlated with Ag ($r = 0.3506$, $p = 0.010$), Cd ($r = 0.6473$, $p < 0.001$), COL ($r = -0.4091$, $p < 0.001$), Cr ($r = 0.3158$, $p = 0.020$), Cu ($r = -0.6787$, $p = 0.008$), Ni ($r = 0.4826$, $p = 0.023$), NO_2 ($r = -0.3351$, $p = 0.023$), pH ($r = 0.4836$, $p < 0.001$), SAL ($r = -0.2585$, $p = 0.029$), Si ($r = -0.3042$, $p = 0.024$), TB ($r = -0.4179$, $p < 0.001$), TKN ($r = -0.2433$, $p = 0.044$), TP ($r = -0.5470$, $p < 0.001$), and TSS ($r = -0.2825$, $p = 0.017$).

Results of sediment sampling for TOC are presented in Table A-10. The minimum value was 189.00 mg/kg recorded from Station 4 and the maximum value of 53031 mg/kg was collected from Station 5. The average sediment TOC value was 4354.45 mg/kg. Sediment TOC concentrations were significantly correlated with Al ($r = .4626$, $p < .001$), Cu ($r = .3743$, $p = .027$), Fe ($r = .2648$, $p = .033$), Mg ($r = .5773$, $p < .001$), Mn ($r = .3106$, $p = .012$), Ni ($r = .4421$, $p = .002$), Pb ($r = .4380$, $p < .001$), SO_4 ($r = .5737$, $p < .001$), and Zn ($r = -.464$, $p < .001$).

3.0 Light Attenuation

3.1 Introduction

Water clarity is an important indicator of water quality (Kirk 1983). Suspended sediments and particulates can reduce light penetration through the water column (Duncan 1990). Reduced light availability potentially affects the existence of submerged aquatic vegetation (SAV) that is considered the ecological foundation of the Indian River Lagoon system (Kenworthy and Haunert 1991). The decline of SAV in various estuaries has been attributed to increases in runoff and associated agricultural herbicides, suspended solids, nutrients, and toxic discharges, many of which alter water clarity, color, and light transmission. Short (1991) conducted a mesocosm study with the seagrass, *Zostera marina*, and determined that decreasing light intensity (analogous to decreasing water clarity) caused a major effect on production, biomass, and morphology. Effects included reduced growth rates, increased leaf

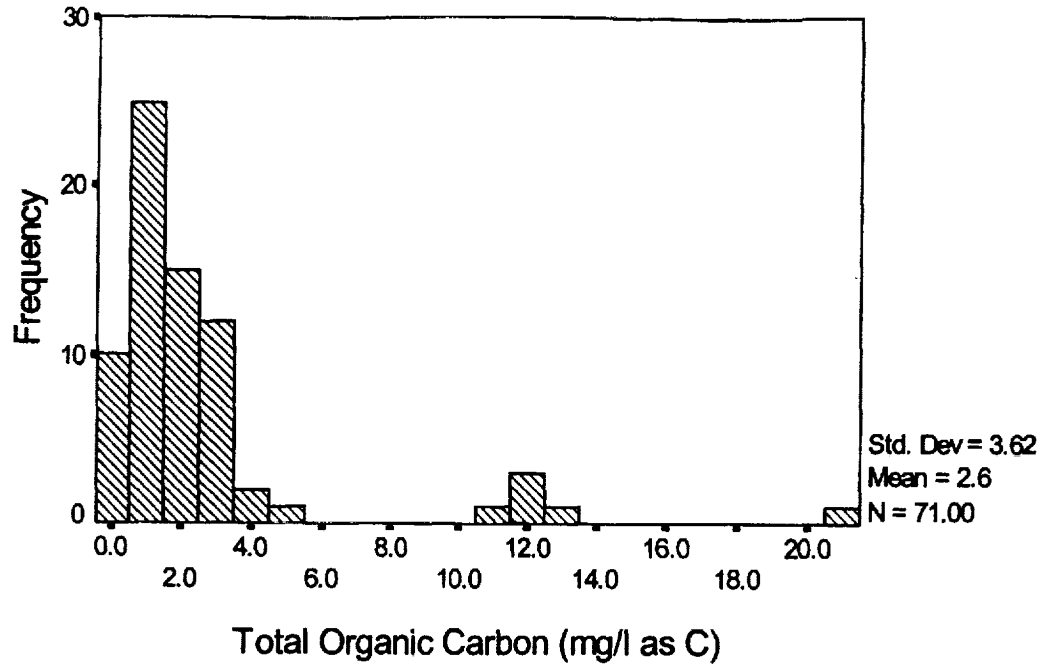


Figure 20. Water quality sample frequency distributions for Total Organic Carbon. There is no Class II criterion for total organic carbon.

size and decreased shoot densities. This project provides data on light attenuation in Mosquito Lagoon using measures of photosynthetically active radiation (PAR). Attenuation is a measure of the rate of loss of light energy along a path in the water column due to absorption and scattering. A review of the measurements and modeling of light energy in the submarine environment can be found in Duncan (1990) and Kirk (1983).

3.2 Methods

Underwater irradiance (light) data were collected from July 1991 through May 1993 at fifteen stations representing five transects (Figure 21). Three transects were oriented in a west to east direction (Transects 1, 2 & 3) and two were oriented south to north (Transects 4 & 5). The positioning of these stations is such that for Transects 1 and 2, the stations labeled A and C are on the west and east edges of the lagoon, respectively, along the outer edge of the SAV in shallow water (Figure 21). Stations labeled B are in the deeper central basin or trough of the lagoon where no seagrasses were observed and the water depth often exceeds 2 meters. For Transect 3, Station 3A is not vegetated with seagrass and is very close to the Intracoastal Waterway, while Station 3B is in the vicinity of a large seagrass meadow. Transects 4 and 5 are shallow (maximum of 1.4 m) with extremely limited vegetative cover. These northern transects are influenced by tidal fluctuations and associated currents.

Data were collected weekly between the hours of 1000 and 1400 during July through September 1992, after which a biweekly schedule was implemented. Data were

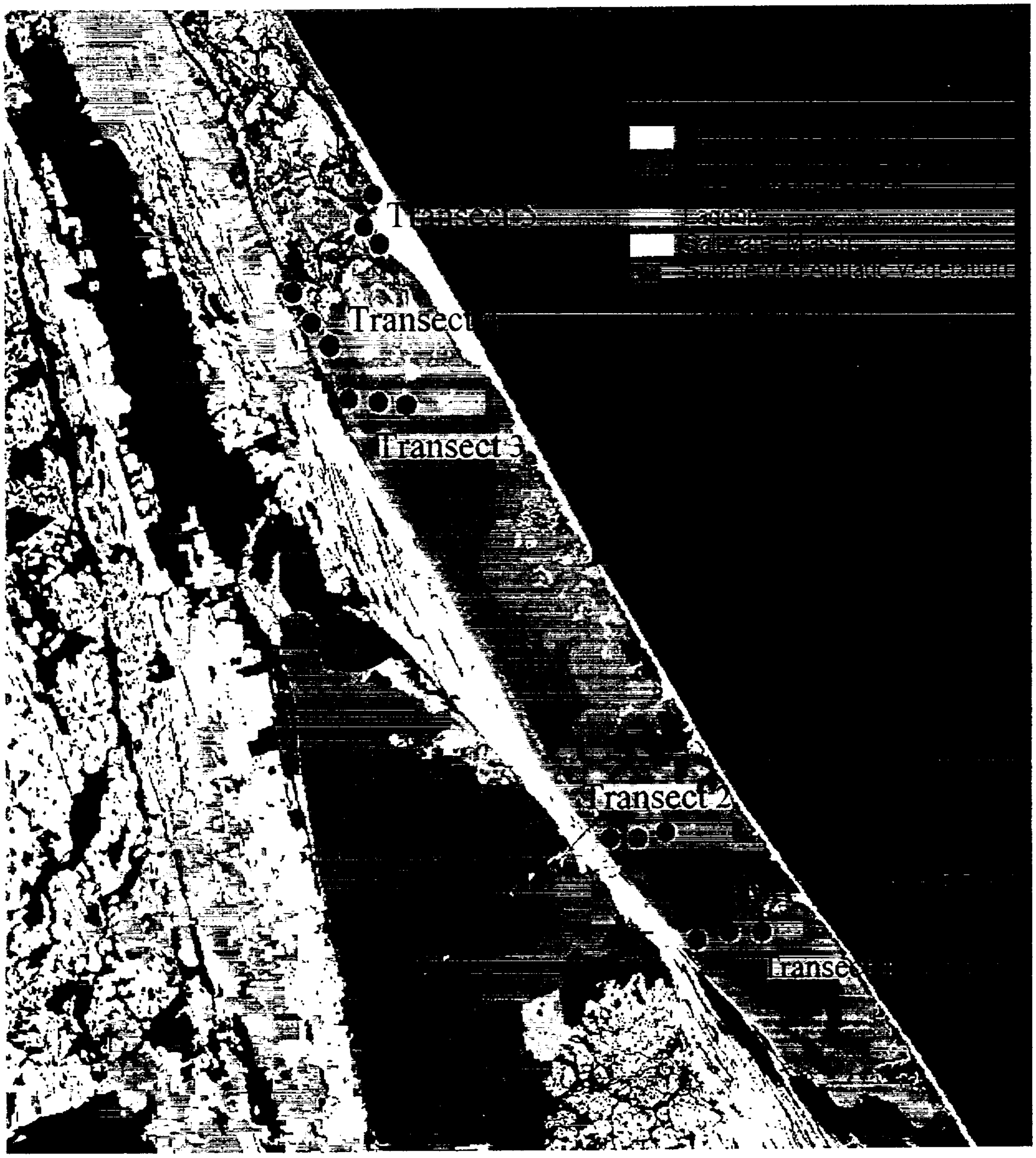


Figure 21. Locations of underwater light attenuation sampling transects in Mosquito Lagoon. Samples were collected on clear days between 10:00 am and 2:00 pm

collected only on days when weather met criteria of calm sea states and no excessive rain or lightning. A Loran-C was used to locate stations. Some of the stations with no obvious landmarks were additionally marked with buoys to alleviate problems associated with Loran-C malfunctions.

Two Licor LI-192SA (4pi) underwater quantum radiation sensors were employed to collect the PAR data. The scalar (spherical) sensors were calibrated on 22 April 1992 and again on 28 October 1992. A Licor LI-1000 data logger recorded each light measurement sensor, simultaneously logging time, date, and energy. The overall sampling protocol was a modification of Kenworthy et al. (1993). The 400-700 nm response sensors were mounted in PVC poles (painted flat black to minimize reflection) that held the sensors approximately 50 cm away from the boat to minimize shadowing effects on the underwater light field. Measurements were made by two methods. Data collected by a fixed depth (15 cm below the surface) sensor was used to account for cloud cover and light reflection caused by waves on the water surface. Some researchers use a fixed sensor mounted above the water on the boat and refer to it as the deck cell. Our modification was assumed to yield a more accurate estimate of the scalar irradiance intensity at the top of the water column. The second sensor measured light energy at different depths with sample depth defined by the maximum depth at the site. Tables 3a and 3b provide details of the depth intervals used. Data were collected at each depth using a three second averaging time.

Table 3a. Depth profile schedule used at each PAR Station in Mosquito Lagoon prior to January 1993.

Station Depth (cm)	*Profile Schedules/Intervals for Variable Depth Cell*				
70	10	20	30	40	N/A
80	10	30	40	50	N/A
90	20	30	45	60	N/A
100	20	40	50	70	N/A
110	20	30	50	60	80
120	20	40	50	70	90
130	20	40	60	80	100
140	20	40	70	90	110
150	20	50	70	100	120
160	30	50	80	100	130
170	30	60	80	110	140
180	30	60	90	120	150
190	31	60	100	130	160
200	30	70	100	130	170
210	40	70	110	140	180
220	40	80	110	150	190
230	40	80	120	160	200
240	40	80	130	170	210
250	40	90	130	180	220
260	50	90	140	180	230
270	50	100	140	190	240
280	50	100	150	200	250

Table 3b. Depth profile schedule used at each PAR Station in Mosquito Lagoon beginning January 1993.

Station Depth (cm)	*Profile Schedules/Intervals for Variable Depth Cell*							
80	15	20	40	60	N/A	N/A	N/A	N/A	N/A
90	15	20	40	60	N/A	N/A	N/A	N/A	N/A
100	20	40	60	80	N/A	N/A	N/A	N/A	N/A
110	20	40	60	80	N/A	N/A	N/A	N/A	N/A
120	20	40	60	80	100	N/A	N/A	N/A	N/A
130	20	40	60	80	100	N/A	N/A	N/A	N/A
140	20	40	60	80	100	120	N/A	N/A	N/A
150	20	40	60	80	100	120	N/A	N/A	N/A
160	20	40	60	80	100	120	140	N/A	N/A
170	20	40	60	80	100	120	140	N/A	N/A
180	20	40	60	80	100	120	140	160	N/A
Any depth >180	20	40	60	80	100	120	140	160	Bottom

On January 13, 1993 the original sampling profile described above was slightly altered based on agreements with the St. Johns River Water Management District PAR network. These changes were to make the data more consistent among all participants of the network sampling throughout the Indian River Lagoon system. Changes included a ten second averaging time, collecting samples in triplicate, and using a slightly altered depth schedule (Table 3b). The schedule changed so that the variable depth PAR sensor was positioned at 20 cm increments up to 160 cm. The constant depth cell remained at 15 cm below the surface.

Other parameters measured during the light attenuation study were TSS, COL, CPA, wind speed, and cloud cover. The first three parameters were collected monthly and analyzed in the laboratory. Cloud cover was determined subjectively by the biologist at each station using relative percent cloud cover in increments of 10. Other physical water parameters collected at each station during each sample period included CON, SAL, DO, pH, temperature, and ORP.

Data were downloaded to a spreadsheet for storage and manipulation that included basic statistics and simple regression analyses. In computing a scalar attenuation coefficient K m^{-1} (K-value), the values collected from the variable depths were divided by values from the constant depth (15 cm) to yield percent light at each depth. The percent light was converted to the natural log and a regression was performed using these values and their corresponding depths to estimate K.

Data were analyzed for seasonal variation in K m^{-1} at each station as well as among stations. For the periods when triplicate samples were collected, the data were averaged. Annual mean K-values were calculated along with the 95% confidence intervals for each station. A graphical comparison was generated for mean K-values and percent scalar irradiance collected at depths ranging from 1.4-1.9 m (the typical edge zone of seagrass growth). To assess relationships between mean K-values and the maximum depth of seagrass growth scalar irradiance was measured for each station located near a seagrass meadow edge using the depths collected at the deep edge of the bed (Kenworthy 1993), The SAV section of this report describes the collection of seagrass positions, density and depth of growth. This calculation of percent scalar irradiance resulted from the equation: depth = lnX/K where depth was the maximum depth of local seagrass growth (based on 1-3 edge measurements); K was the average annual K value for the given PAR station and X was percent light. The Spearman Rank Correlation procedure was used to evaluate relationships between attenuation), TSS, CPA and COL.

3.3 Results and Discussion

Photosynthetically active radiation (PAR) measures were collected on 68 days of the two-year period. The number of sample periods for each season is listed in Table 4. The average attenuation K m^{-1} for all stations combined was 0.92. Figures B-1 through B-5 display average values for each transect by season and year. Transects 3, 4 and 5 displayed a general increase in water clarity in the winter months with means for K m^{-1} ranging from 0.3 to 0.7. The overall range (all seasons) for these station averages was 0.3 (Station 3A) to 1.69 (Station 4A). Transects 1 and 2 tended to have a narrower range of values with reduced water clarity in the fall and spring of each year and the best water clarity in winter and summer. The trend for summer was somewhat surprising based on general observations of reduced water transparency in summer. Seasonal mean K m^{-1} along Transect 2 ranged from 0.59 to 1.23. Station 1A showed the least variation with a range of 0.64 to 0.84. Rainfall data show lowest recorded volumes since 1984 for the October-December 1991 timeframe (Table D-10). Our seasonal K estimates for that period show a corresponding increase in water clarity at the majority of stations. A period of high rain volume occurred in June 1992 but the data for Transects 1 and 2 do not show a relationship with this potential effect. Annual total rainfall volumes for 1991 and 1992 were the highest since 1984, except for 1987 (Table D-10). If a relationship between estuarine water clarity and rainfall inputs exists for Mosquito Lagoon, it is possible that our sample period occurred during a cycle of higher than usual turbidity due to increased rainfall.

In contrast to Mosquito Lagoon, Kenworthy et al. (1991) reported a recurring seasonal cycle at Hobe Sound for the amount of light transmitted to the 2.0 m depth where the minimum values (5-20% transmittance) occurred between September and April and the maximum values (40-50% transmittance) occurred in summer between May and August. Their seasonal trends were attributed primarily to increased boat traffic in the winter months.

Highest wind periods during the Mosquito Lagoon study occurred during October 1991, and January through March 1992. March 13, 1993 was the day the storm of the century passed through east central Florida, with many sites around the state recording winds in excess of 70 mph. PAR data were not collected in association with this storm event. The K values increased (water clarity was reduced) substantially between March 2 and March 29 at all stations on these transects, with the largest change recorded at Station 2A where attenuation increased from 0.6 to 1.5. The relationship between wind mixing, TB and increased light attenuation deserves additional investigation.

Percent PAR data at various depths below the surface for each station are plotted in Figures D-6 to D-10. These data are based on averages calculated for each depth class. Available PAR near the bottom never dropped below 10% (with the exception of Station 1B at 1.5 m) and yet seagrasses did not grow in those 10% zones. Recall that these zones are the deeper trough stations labeled B for transects 1 and 2 and station 3A. The variability at transects 4 and 5 (indicated in Figures B-9 and B-10, respectively) is probably explained by tidal effects. Grizzle (1988) documented a decrease in tidal range from north to south for the northern Mosquito Lagoon portion of CNS. The northern boundary is approximately 15 km south of

Ponce de Leon Inlet with a tidal range of 50 cm and the southern zone, near PAR station 3A, contrasts with a tidal range of 2 cm. Tidal change at PAR Station 4C was estimated to be about 25 cm (Van Cott, personal communication). Grizzle noted that water currents (both wind and tide driven) were strongest along the navigable channels (Transect 4) and along the intracoastal waterway (Transect 5). Currents associated with these sites may reduce the ability of seagrasses to stabilize and survive.

Table 4. Number of collection periods for PAR measurements at each station 1991-1993.

Station Number	*Summer 1991*	*Fall 1991*	*Winter 1992*	*Spring 1992*	*Summer 1992*	*Fall 1992*	*Winter 1993*	*Spring 1993*
1A	6	11	8	11	12	5	3	5
1B	6	11	9	10	11	6	5	6
1C	7	12	10	10	13	5	3	5
2A	6	11	8	10	12	3	2	5
2B	8	11	8	10	12	5	2	5
2C	7	10	9	10	10	5	2	5
3A	7	10	10	12	13	6	3	5
3B	7	11	10	11	13	6	3	5
3C	6	9	10	11	13	6	3	4
4A	7	10	8	12	12	4	4	4
4B	5	10	10	11	13	5	4	4
4C	7	12	9	12	15	4	4	4
5A	7	11	9	10	13	6	4	5
5B	7	10	10	11	13	6	4	5
5C	7	11	10	11	13	5	4	5

Transects 1, 2 and 3 represent the most static environments relative to tidal fluxes and are in a region of the lagoon where seagrass abundance is high. These stations typically had 30% of available light measured near the bottom. The trends in percent available light from the six PAR stations that had seagrass were analyzed in relation to the seagrass ground truth data collected across many areas of the lagoon (N = >160). (See ground truth discussion within the Seagrass Section of this report). Frequency of occurrence dropped markedly for *Halodule wrightii* and *Syringodium filiforme* for depths greater than 1.4 m. In addition, percent cover of these species declined at depths greater than 1.0 m (Figures C-7 and C-8). Figures B-6 to B-10 indicate that at 1.4 m depths, the light availability was reduced to a range of 10-38%. Depth ranges of 2.0 to 3.3 m did not support seagrass beds although occasional shoots were observed. At PAR Station 1B, light availability in the deeper waters ranged between 10-15% of incident light (Figure B-6).

Each station, with its annual mean K value and 95% confidence limit is displayed in Figure B-11. Figure B-12 indicates the average depth measured at each station plotted with the annual mean K. Kenworthy (1993) assessed the relationships between mean K, the maximum depth of seagrass growth, and percent light for Hobe Sound. Similar calculations are reported here for Mosquito Lagoon and as indicated in Figure B-13 no trends are evident. As described in the Methods section, the depths used in the percent light calculations came from locations of deepest seagrass growth relatively near the PAR stations. Figure B-14 is a simple plot of the actual data for K and percent light measured at stations with maximum depths in the 1.4 m to 1.9 m range typical of the seagrass meadow edge. Onuf (1991) studying seagrass meadows in Laguna Madre, Texas, found the outer boundary of the meadows to be in the 5-20% light at the bottom zone. Based on long-term mean values of percent surface PAR reaching the bottom, the level at which light became limiting to meadow development was 12 to 21% with a convergence at 15%. Onuf (1991) concluded that at least a 15% transmission of PAR is required to sustain grass bed development. Kenworthy et al. (1991) also suggested that the ecological light compensation point for *Halodule wrightii* and *Syringodium filiforme* are in excess of 10-15% of incident light and that previously reported values (1-5%) are unsuitable for use as standards by agencies interested in protecting the seagrass resource.

Kenworthy et al. (1991) found *Halodule wrightii* and *Syringodium filiforme* grew to maximum depths of 1.7 to 2.0 m respectively, in Hobe Sound. Onuf (1991) found only minor differences in the depth limits of the three seagrass species in Texas. Mosquito Lagoon shows the same general trend relative to *Syringodium* sp. and *Halodule* sp. Table 5 indicates values for COL, TSS, and CPA from samples taken at the various PAR stations. Color shows a relatively strong relationship with K. Results of Spearman Rank Correlation analyses between K and COL displayed a positive correlation ($r = 0.632$, $p < .001$). TSS and COL also showed a weak significant positive correlation ($r = 0.481$, $p < 0.001$).

4.0 Biota

4.1 Seagrass and Other Submerged Aquatic Vegetation (SAV)

4.1.1 Introduction

Much public and scientific attention has been focused on seagrasses due to the documentation of man's direct and indirect influence on the decline of these habitats worldwide and the increased awareness of the importance of such. The seagrass meadows have been referred to as the ecological foundation of the lagoon system (Kenworthy et al. 1991). Two approaches were taken for the seagrass database in Mosquito Lagoon. One was to map the distribution and relative abundance of the SAV through aerial image interpretation and the other was to establish new fixed and permanent transects that could be sampled each year (minimally). A review of SAV mapping and distribution methods can be found in Kirkman (1990). In addition, a historical perspective could be gained from data collected at existing long-term transects located at the southern end of the lagoon. These sites have been sampled annually since 1983 as part of the KSC Ecological Program.

4.1.2 Methods

A total of thirteen seagrass transects were monitored during the summer of the two year project for species composition, percent cover, water depth and basic water quality parameters. Six transects, all located at the extreme southern end of the lagoon, were sampled on an annual basis since 1983 as part of the KSC Ecological Program. Nine more transects were added for the CNS project but two were lost to vandalism prior to the second year. The seven

Table 5. Total Suspended Solids (TSS), Chlorophyll-A (CPA), and Color (COL) results from samples collected monthly at randomly selected PAR stations.

Date	Station	TSS (mg/l)	COL (pt co unit)	CPA (mg/m³)
07/24/91	1B	24.0	20.0	3.3
08/08/91	1C	49.0	10.0	<4.0
09/05/91	1C	40.0	15.0	5.3
10/03/91	1B	50.0	20.0	11.0
11/08/91	1C	52.0	40.0	4.0
12/06/91	1C	22.0	20.0	3.7
01/08/92	1A	36.0	20.0	<4.0
02/10/92	1A	43.0	20.0	4.0
03/02/92	1C	37.0	10.0	2.7
04/06/92	1C	57.0	20.0	6.7
05/05/92	1C	39.0	5.0	20.0
06/02/92	1C	48.0	40.0	5.3
07/01/92	1B	20.0	5.0	9.3
08/18/92	1B	39.0	20.0	29.4
09/01/92	1B	24.5	10.0	14.7
10/13/92	1C	26.0	5.0	.5
11/23/92	1B	33.0	15.0	33.4
12/17/92	1C	19.0	5.0	6.7
01/06/93	1A	38.0	5.0	<4.0
03/02/93	1A	13.0	<5.0	9.3
04/23/93	1B	58.0	20.0	4.0
05/05/93	1C	28.0	<5.0	10.7
07/24/91	2C	33.0	40.0	10.0
08/08/91	2B	44.0	20.0	6.7
09/05/91	2A	49.0	40.0	5.0
10/03/91	2C	42.0	20.0	4.0
11/07/91	2B	51.0	20.0	10.7
12/06/91	2C	32.0	30.0	2.0
01/08/92	2B	1.0	15.0	<4.0
02/10/92	2C	53.0	15.0	4.0
03/02/92	2C	38.0	5.0	<2.0
04/06/92	2A	129.0	20.0	<1.5
05/05/92	2B	54.0	10.0	<4.0
06/02/92	2C	48.0	20.0	<1.5
07/01/92	2A	28.0	5.0	13.3
08/18/92	2B	21.5	20.0	<4.0
09/01/92	2B	19.0	15.0	5.3
10/13/92	2A	29.0	5.0	8.0
11/23/92	2A	23.0	20.0	14.7
12/17/92	2B	20.0	10.0	4.0
01/06/93	2B	27.0	10.0	<4.0
03/02/93	2B	15.0	<5.0	9.3
04/23/93	2C	33.0	15.0	10.7
05/05/93	2A	24.0	<5.0	9.3
07/24/91	3A	40.0	20.0	2.0
08/08/91	3A	42.0	15.0	8.0
09/05/91	3B	43.0	40.0	18.0
10/03/91	3A	37.0	20.0	2.7
11/07/91	3A	62.0	40.0	6.0
12/06/91	3C	14.0	20.0	<2.0
01/08/92	3C	41.0	10.0	<4.0
02/10/92	3C	42.0	5.0	3.3
03/02/92	3A	32.0	5.0	<2.0
04/06/92	3B	50.0	20.0	<1.5
05/05/92	3C	54.0	10.0	12.0
06/02/92	3A	47.0	10.0	17.4
07/01/92	3B	32.0	5.0	8.0
09/01/92	3A	27.0	15.0	9.3
10/13/92	3B	36.0	15.0	20.0
11/23/92	3B	39.0	15.0	20.0
12/17/92	3A	31.0	5.0	<4.0
01/06/93	3B	24.0	10.0	<4.0
03/02/93	3A	23.0	<5.0	10.7
04/23/93	3A	39.0	10.0	6.7

Table 5 (continued). Total Suspended Solids (TSS), Chlorophyll-A (CPA), and Color (COL) results from samples collected monthly at randomly selected PAR stations.

05/05/93	3C	30.0	<5.0	41.4
07/24/91	4A	92.0	40.0	14.0
08/08/91	4C	92.0	20.0	16.0
09/05/91	4C	56.0	40.0	11.3
10/03/91	4A	40.0	20.0	5.3
11/07/91	4A	55.0	30.0	8.0
12/06/91	4B	42.0	30.0	2.0
01/08/92	4C	47.0	10.0	<4.0
02/10/92	4B	20.0	15.0	<2.0
03/02/92	4A	48.0	5.0	4.7
04/06/92	4C	46.0	10.0	<1.5
05/05/92	4B	53.0	5.0	16.0
06/02/92	4C	34.0	20.0	<4.0
07/01/92	4A	32.0	5.0	18.7
08/18/92	4B	64.0	40.0	22.7
10/13/92	4C	34.0	15.0	17.4
11/23/92	4A	39.0	20.0	16.0
12/17/92	4A	19.0	5.0	<4.0
01/06/93	4C	33.0	20.0	<4.0
03/02/93	4C	21.0	<5.0	16.0
04/23/93	4C	34.0	10.0	<4.0
05/05/93	N/A	N/A	N/A	N/A
07/24/91	5C	110.0	30.0	7.3
08/08/91	5B	65.0	20.0	8.0
09/05/91	5C	49.0	40.0	14.7
10/03/91	5B	32.0	30.0	6.7
11/07/91	5C	68.0	30.0	<2.0
12/06/91	5B	34.0	30.0	<2.0
01/08/92	5B	46.0	10.0	<4.0
02/10/92	5C	30.0	5.0	<0.8
03/02/92	5A	49.0	5.0	4.7
04/06/92	5A	51.0	10.0	<1.5
05/05/92	5C	59.0	15.0	6.7
06/02/92	5C	42.0	10.0	<4.0
07/01/92	5B	27.0	5.0	9.3
08/18/92	5B	37.0	30.0	16.0
09/01/92	5B	29.0	15.0	24.0
10/13/92	5A	30.0	15.0	12.0
11/23/92	5B	28.6	15.0	6.7
12/17/92	5B	25.0	<5.0	<4.0
01/06/93	5C	35.0	10.0	<4.0
03/02/93	5B	23.0	<5.0	8.0
04/23/93	5C	44.0	15.0	<1.5
05/05/93	5B	28.0	<5.0	<4.0

remaining CNS seagrass baseline transects are shown in Figures 22 and 23. The light blue-green regions in the maps are generally SAV and the darker regions are areas with little or no SAV. Three transects are in the south and central regions of the lagoon and four new transects were positioned in the northern reaches of CNS where the lagoon contours become complicated with islands and oyster beds. The seagrass beds are considerably restricted in size at this northern end. Signs were placed at each transect in the northern reaches of the park in late 1992 to aid Park rangers in locating transects and to educate the public. Global Positioning System (GPS) positions for the remaining un-vandalized transects were collected in 1993 (Table 6). The data collection methods for this part of the SAV program were designed, as per request, to allow two rangers or staff members of varying experience to accomplish annual (or seasonal, if desired) sampling with limited assistance.

Table 6. Global Positioning System (GPS) coordinates for submerged aquatic vegetation transects sampled in Mosquito Lagoon. Ends of transects are designated A and B.

Station	*X*	*Y*
SGSCNS1A	1590442.99145	598969.19746
SGSCNS1B	1590513.58688	598822.81000
SGSCNS2A	1605279.91408	583120.36038
SGSCNS2B	1605562.41921	583297.88951
SGSCNS3A	1605695.63014	582749.20235
SGSCNS3B	1605926.18417	582999.49455
SGSCNS6A	1662198.78600	557122.64600
SGSCNS6B	1662054.20300	557170.69200
SGSCNS7A	1662065.03496	557223.89710
SGSCNS8B	1670220.07962	555751.03809
SGSCNS9A	1668782.93256	554830.52108
SGSCNS9B	1668618.42485	554874.59085

Transect (50 m in length) locations were selected and the origin and terminal poles determined. A nylon cord was marked off in 5 m increments and was temporarily connected between the two PVC poles to delineate the line against which all subsequent measures were made. Transects that followed a general north/south orientation were measured on the east side of the line, while those running in a east/west fashion were measured on the north side. Measurements were recorded at each 5 m mark and based on the position from the origin (i.e., meter 0 is the origin, meter 5 is 5 m from the origin, etc.). A meter square plot frame with 16 (25x25 cm) sub-quads was laid along the transect cord with the bottom corner touching the line at each of these loci (i.e., 0, 5, 10). KSC long-term station sampling methods involved collecting percent cover and species composition at 5 m intervals along transects (similar to those described above) but using a canopy coverage technique of vegetation analysis originally developed for terrestrial systems (Daubenmire 1968). This method employs the use of a frame with inside dimensions of 20x50 cm marked off so that coverage estimates can be quickly made using a series of six unequal coverage classes. These classes yield the following density categories 2.5%, 15%, 37.5%, 62.5%, 85% and 97.5%.

Figure 22. Locations of submerged aquatic vegetation sampling transects in southern Mosquito Lagoon.

Figure 23. Locations of submerged aquatic vegetation sampling transects in the Canaveral National Seashore and Mosquito Lagoon.

4.1.3 Results and Discussion

Data collected at the new permanent transects are graphically displayed in Figures C-1 and C-2. The only seagrass species observed were shoal grass (*Halodule wrightii*) and manatee grass (*Syringodium filiforme)*. Seagrass beds are less dense and reduced in distribution at the northern end of the Park where tidal fluctuations and high turbidity are evident.

Temporal trends (1983-1993) in the percent cover of seagrass species on the six long-term KSC transects are displayed in Figures C-3 to C-5. These graphs depict the average percent cover along the entire transect for each species. Figure C-6 employs the same data means from the above figures but indicates the general trends using a linear fit for five of these transects. Transect 12 was not displayed in this manner due to data gaps (Figure C-3). The data displayed in Figure C-6 indicates a slight downward trend in percent cover as shown for Transect 22. Transect 22 is located on the southeast side of Pelican Island, west of Eddy Creek in extreme shallows (0.5 m) and therefore protected from north and easterly winds. Note that the vegetation is still quite lush, but the downward trend will be investigated further.

4.2 Submerged Aquatic Vegetation Mapping

4.2.1 Introduction

Various agencies throughout the State of Florida recently began routine mapping of SAV as part of water quality monitoring protocol. Mapping involves documenting the distribution and to some extent the density of the submerged aquatic vegetation. These maps provide a description of large-scale patterns for a big picture approach to looking at trends within a lagoon system.

4.2.2 Methods

Seagrass beds were mapped using 1:12000 aerial imagery obtained by KSC contract with Aeromap, Inc. The images were collected on 9 April 1992. Base maps, were supplied by SJRWMD and their contractor Natural Systems Analysts, Inc. (NSAI) in mid August 1992. Most of the interpretation was done directly on the base maps that were printed on translucent mylar. Interpretations were shipped to NSAI for computer entry and final map production. Ground truth operations began in late May 1992. The objective was to get a more accurate assessment of the location of the edge of the beds and obtain ground truth sample data from the center of the water body where it is often assumed that seagrasses do not occur. These mid-water regions are often turbid and no data, based on systematic surveys across these zones, are available.

GPS and Loran C receivers were calibrated using known locations at the outset of each trip. Data were collected along eleven east/west transects in Mosquito Lagoon. Each transect generally began in shallow waters where the bottom visibility became reduced enough to question its signature on the aerial imagery. A diver/observer was pulled behind the boat, and instructed to dive to the bottom every 0.1 minutes of longitude to determine SAV composition and coverage. The diver used five coverage categories (0, <10%, 10-40%, 40-70% and 70-100%). Composition categories totaled seven and included the four local seagrasses, drift algae, *Caulerpa prolifera* and *Penicillus capitatus*. The diver then surfaced and relayed (using hand signals) the results, which included the position data (GPS/LORAN), SAV data, and water depth, to a recorder. Depth was collected with a lub line off the bow as soon as the signal was made for the diver to submerge. This allowed the data derived from the diver's scan to be located within a few meters of the determined depth. The overall location data associated with the attribute data are believed to be good within about 10 m (due to boat speed and distance between the diver and the GPS or LORAN). Add to this the accuracy of the GPS/LORAN (up to 30 m). Data were entered in a database spreadsheet for management and analyses. Location coordinates were converted to units used by the Geographical Information System (GIS) for development of an ARC/INFO coverage.

4.2.3 Results and Discussion

One hundred sixty-one positions were sampled in the turbid zones of Mosquito Lagoon along the eleven transects (Figure 24). *Halophila engelmannii* and widgeon grass (*Ruppia maritime)* were not observed during any of the surveys. Widgeon grass is generally considered to be a more fresh water species and so it's absence in this often hypersaline lagoon was not surprising. *Halophila engelmannii*, however, is often found in deeper waters where other seagrasses do not persist. Its absence was a surprise. The marine alga *Caulerpa* sp. and *Penicillus* sp., fairly common in the nearby Banana River and Indian River, were not observed. Manatee grass was observed in 17 of the 161 samples. Shoal grass was seen in 38 samples and drift algae species were observed in 61 samples. Seventy-two percent of the samples provided zero cover or bare bottom.

Data were stratified by depth into four categories to look for patterns in seagrass species and drift algae zonation (Figures C-7 to C-11). As apparent from these figures, manatee grass generally does not occur at depths greater than 1.5 m. While the occurrence of shoal grass was low but more persistent than manatee grass in the 1.5 to 1.9 m range, it was rarely found at greater depths. The average percent cover for both shoal grass and manatee grass was greatest in the depth range of 0.5 to 1.0 m, Figure C-7. Algae tended to be most abundant in two of the four depth zones, the shallowest zone of study (0.5 to 1.0 m) and the deepest (2.0 to 3.3 m).

4.3 Shellfish

4.3.1 Introduction

A screening for metals in clams inhabiting the seashore was conducted to provide baseline data on potential food chain contamination. A lagoon wide project conducted in 1992 (Trocine and Trefry 1993) did not include sampling clams in Mosquito Lagoon. Clams are recognized as good indicator species for potential bioaccumulation of metals in the environment.

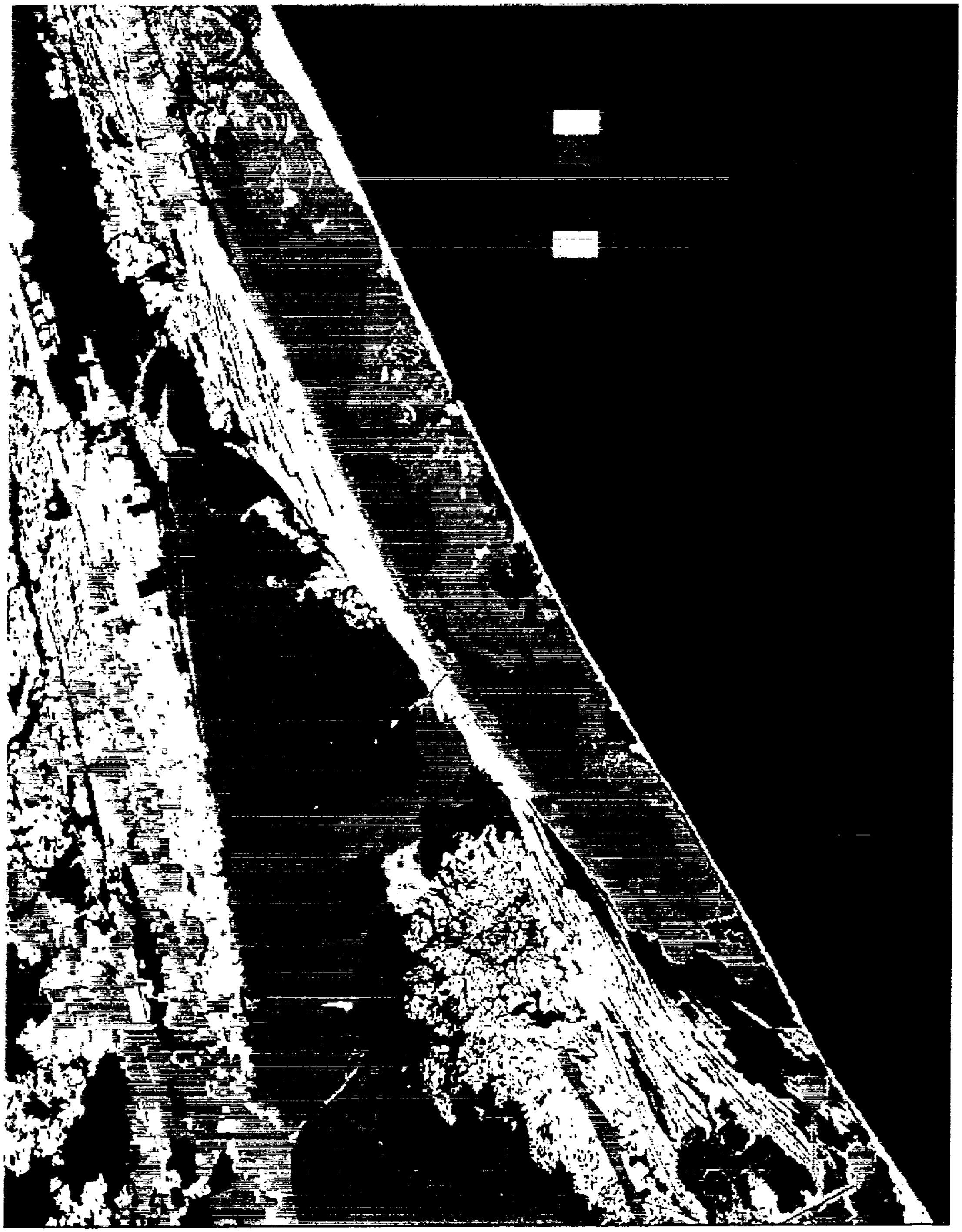


Figure 24. Locations of transects utilized to ground truth maps of the distribution of submerged aquatic vegetation. Transects were located in deeper regions to sample areas not readily observable on aerial photography.

4.3.2 Methods

Clams (*Mercenaria mercenaria*) were collected by hand at five sites in the study area near existing water quality Stations 1, 2, 4, 5 and 6 (see Figure 3). No clams were found at Station 3. Samples were collected at the end of the baseline survey period in July 1993. Clams were gathered randomly at each of the five sites. They were then stored in plastic bags and placed on ice for transport to the laboratory. A wet weight was determined for each clam and the shell width was measured. The clams were then freeze dried using liquid nitrogen, placed in a drying oven for approximately 24 hours, crushed, and microwave digested with nitric acid. They were then analyzed by heated graphite analysis for the following heavy metals: Al, Cd, Cr, Cu, Fe, Pb, Mg, Ni, Ag and Zn. All metals data were recorded in ug/g.

4.3.3 Results and Discussion

The shell widths of the clams yielded a range of 2.5-10.1 cm. The results of chemical analyses are shown in Table 7. Means for the analyses are found in Figures F-1 through F-5. Trocine and Trefry (1993) collected clams from the Indian River Lagoon System, except Mosquito Lagoon, and analyzed them for Cd, Cr, Cu, Fe, Pb, Hg and Zn. Differences in collection and laboratory procedures used by Trocine and Trefry (1993) included: analyses on clams of uniform size, the use of perchloric acid ($HClO_4$) with the graphite furnace analysis, and a depuration of gut contents. Based on these differences our data are not comparable to theirs. The clams examined in this study often showed elevated levels for metals tested but those values may be inflated through the method used. The only other data relative to bioaccumulation of metals in animal tissues were collected by Morrison (unpublished data) for Hg in muscle tissue in seatrout. His values are reported for Banana River and Mosquito Lagoon in Table 8.

An overview of information regarding shellfish in Mosquito Lagoon is found in Provancha et al. 1992. In a 1993 Florida DEP appraisal, 14464 acres of the shellfish area had been changed from approved for harvest to conditionally approved for harvest due to the correlation between fecal coliform levels and three day rainfall volumes. Results of sampling are presented in Table 9. Harvesting was prohibited in the remaining 4910 acres. Between January 1990 and December 1992 the conditionally approved area was closed 33 times for a total of 248 days (Browning and Beadle 1993). The harvesting area has not been closed due to red tide *Gymnodinium breve* (concentrations exceeded 5000 cells per liter) since 1980.

The two municipal domestic wastewater treatment plants in the CNS study area (Edgewater and New Smyrna) have surface water discharge and are predominantly domestic with a small amount of industrial waste. The Edgewater plant pre-treats waste prior to discharge and a recent resolution has been passed to require the same from New Smyrna (Browning and Beadle 1993). The Edgewater plant is undergoing construction to expand the capacity from 1.0 million gallons per day (mgd) to 2.25 mgd. In addition, eleven marinas are located in the area. All of these marinas are located in the zone prohibiting shellfishing.

Three canals in the study area act as the primary source of stormwater drainage and mosquito control. Wildlife is a significant contributor to fecal coliform levels in the area. Twenty-three bacteriological stations are located throughout this portion of the lagoon,

Table 7. Heavy metal concentrations (ug/g dry weight) in clams collected at the six water quality stations in Mosquito Lagoon in 1993.

Station	*Al*	*Cd*	*Cr*	*Cu*	*Fe*	*Pb*	*Mn*	*Ni*	*Ag*	*Zn*
CNS1	236.04	2.28	2.28	18.92	290.19	2.04	8.32	1.60	0.92	19.44
CNS1	323.87	0.72	2.48	12.56	285.29	1.84	18.00	1.44	0.36	22.52
CNS1	157.61	1.04	1.41	12.65	209.09	1.69	9.78	2.69	0.69	18.85
Mean	239.17	1.35	2.06	14.71	261.52	1.86	12.03	1.91	0.66	20.27
Std. Dev.	67.91	0.67	0.46	2.98	37.13	0.14	4.26	0.56	0.23	1.61
CNS2	204.8	0.68	4.08	11.32	623.87	8.16	156.96	5.92	0.72	34.92
CNS2	56.01	1.01	2.32	6.80	245.00	2.24	12.36	3.48	0.56	42.64
CNS2	222.29	0.40	1.84	9.44	264.82	1.72	8.04	1.64	0.92	32.40
CNS2	25.98	0.32	1.36	6.68	156.80	1.52	87.36	1.80	0.12	36.96
CNS2	63.50	0.39	1.83	5.72	142.22	1.18	10.42	1.99	0.70	32.93
CNS2	60.58	0.40	1.80	11.08	121.21	0.84	3.72	1.92	0.72	32.92
Mean	105.53	0.53	2.21	8.51	258.99	2.61	46.48	2.79	0.62	35.46
Std. Dev.	77.52	0.24	0.88	2.21	171.48	2.52	57.22	1.53	0.25	3.57
CNS4	271.64	2.84	7.36	531.24	7.28	35.60	3.48	0.04	54.24	
CNS4	645.85	0.68	2.60	15.16	658.48	3.04	105.88	6.16	0.56	65.04
CNS4	865.08	0.52	2.96	16.96	755.40	1.52	12.52	3.08	0.64	50.00
CNS4	460.48	0.15	2.77	13.17	582.22	4.53	34.76	2.89	1.08	32.37
CNS4	443.20	3.08	16.52	592.13	4.64	38.88	3.36	2.12	43.80	
CNS4	525.70	0.48	2.92	14.72	782.37	11.16	97.64	2.68	1.32	76.88
Mean	530.33	0.46	2.86	13.98	650.31	5.36	54.21	3.61	0.96	53.72
Std. Dev.	187.04	0.19	0.15	3.21	91.97	3.13	34.77	1.17	0.66	14.33
CNS5	152.19	0.72	4.20	9.04	294.80	4.56	99.12	5.96		77.20
CNS5	224.86	0.48	3.28	10.48	321.31	3.00	25.04	2.16	2.32	42.64
CNS5	55.77	0.76	2.64	10.16	395.67	13.88	69.64	1.96	2.92	118.12
CNS5	2398.21	0.92	2.40	9.88	449.02	6.80	54.76	3.32	2.08	44.52
CNS5	260.40	0.19	1.87	10.83	421.19	4.54	4.36	0.31	0.16	36.33
CNS5	40.88	0.96	2.96	7.88	330.62	4.48	12.36	0.52		41.04
Mean	232.05	0.67	2.89	9.71	368.77	6.21	44.21	2.37	1.87	59.98
Std. Dev.	108.93	0.27	0.73	0.99	56.41	3.61	33.52	1.90	1.03	29.25
CNS6	127.91	1.04	1.60	12.60	168.71	5.84	46.12	0.32	3.40	61.80
CNS6	45.60	0.96	1.84	10.12	75.03	3.68	20.32	4.88	0.20	70.20
Mean	86.76	1.00	1.72	11.36	121.87	4.76	33.22	2.60	1.80	66.00
Std. Dev.	41.46	0.04	0.12	1.24	46.84	1.08	12.90	2.28	1.60	4.20

Table 8. Mercury concentrations in seatrout collected in Merritt Island National Wildlife Refuge.

Sample Id	*Date Collected*	*Fish Length (mm)*	*Fish Wt.(g/wet)*	*Sample Wt.(g/wet)*	*Mercury (ppm)*
			South Banana River		
SBR-1	08/10/92	405	511	121.8	0.4
SBR-2	08/10/92	460	795	86.4	0.362
SBR-3	08/10/92	370	341	93.5	0.248
SBR-4	08/10/92	370	426	85.3	0.247
SBR-5	08/10/92	380	426	82.5	0.301
SBR-6	08/10/92	350	369	85.8	0.256
SBR-7	08/10/92	375	454	80.2	0.268
SBR-8	08/10/92	330	284	80.6	0.244
SBR-9	08/10/92	350	341	94.1	0.296
SBR-10	08/10/92	345	284	63.3	0.587
Mean		373.5	423.2		0.321
Std. Dev.		37.05	149.95		0.107
			Mosquito Lagoon		
ML-1	08/12/92	400	483	98.5	0.661
ML-2	08/12/92	375	426	93	0.597
ML-3	08/12/92	320	284	46.8	0.371
ML-4	08/12/92	375	454	82.6	0.429
ML-5	08/12/92	350	369	62.9	0.376
ML-6	08/12/92	356	341	88	0.154
ML-7	08/12/92	305	256	58.6	0.161
ML-8	08/12/92	310	227	60.1	0.223
ML-9	08/12/92	318	227	69.8	0.103
ML-10	08/12/92	310	227	68.7	0.094
Mean		341.9	329.4		0.317
Std. Dev.		33.79	99.51		0.203

eighteen of which are located in the conditionally approved area. Five monitor potential pollution sources from septic systems, nine monitor wildlife waste and nine look at shoreline sources (Browning and Beadle 1993). National Shellfish Sanitation Program (NSSP) standards have been exceeded at two of eighteen stations in the conditionally approved area. Four stations of the eighteen exceeded the NSSP standards when the harvesting area was open. Oyster tissue was collected at one station at the north end of Government Cut. Background levels for fecal coliforms were 75 mpn/100g when the area was open and 78 mpn/100g when it was closed. These numbers were not significantly different, thereby indicating no accumulation of fecal coliforms by the oysters (Browning and Beadle 1993). It was determined that the current designation of conditionally approved is not valid and a comprehensive shellfish harvesting area survey was ordered for April 1993. Since this survey, the new standards have not been

Table 9. Results of total and fecal coliform monitoring in Mosquito Lagoon.

Station	*Date*	*Total coliform (mpn/100ml)*	*Fecal coliform (cfu/100ml)*
CNS1	09/18/91	92	<10
	11/20/91	<11	<100
	02/04/92	<11	<100
	03/03/92	<11	<10
	05/05/92	11	10
	07/27/92	11	10
	09/22/92	11	<10
	11/16/92	N/A	N/A
	01/19/93	<11	<10
	06/16/93	>160	<10
CNS2	09/18/91	5.1	<10
	11/20/91	36	<100
	02/04/92	<11	<100
	03/03/92	<11	<10
	05/05/92	<11	<10
	07/27/92	<11	<10
	09/22/92	51	<10
	11/16/92	11	<10
	01/19/93	11	<10
	06/16/93	>160	<10
CNS3	09/18/91	>16	10
	11/20/91	120	<100
	02/04/92	11	<100
	03/03/92	>230	<10
	05/05/92	22	<10
	07/27/92	<11	<10
	09/22/92	22	<10
	11/16/92	92	10
	01/19/93	11	<10
	06/16/93	160	<10
CNS4	09/18/91	2.2	<10
	11/20/91	>230	<100
	02/04/92	11	<100
	03/03/92	<11	<10
	05/05/92	>230	<10
	07/27/92	51	20
	09/22/92	22	<10
	11/16/92	92	<10
	01/19/93	36	<10
	06/16/93	>160	<10
CNS5	09/18/91	5.1	<10
	11/20/91	22	<100
	02/04/92	<11	<100
	03/03/92	<11	40
	05/05/92	<11	<10
	07/27/92	<11	<10
	09/22/92	<11	<10
	11/16/92	22	10

Table 9 (continued). Results of total and fecal coliform monitoring in Mosquito Lagoon.

	01/19/93	<11	10
	06/16/93	>160	<10
CNS6	09/18/91	16	<10
	11/20/91	<11	<100
	02/04/92	11	<100
	03/03/92	<11	10
	05/05/92	22	<10
	07/27/92	11	<10
	09/22/92	<11	<10
	11/16/92	160	70
	01/19/93	36	<10
	06/16/93	>160	<10

implemented but will be as follows: classification will remain conditionally approved but when rainfall reaches or exceeds 0.3 inches per 24 hour period, area closure will result (The standard was previously 1.5 inches per 72 hour period (H. Beadle, personal communication)).

Body A, the Florida DEP designation for Northern Brevard County including Mosquito Lagoon, has four bacteriological stations in Mosquito Lagoon. The area is classified as approved for harvest with the exception of all man-made canals and marinas, where the classification remains prohibited. The area was reevaluated in 1990 (Royal and Pierce 1991) with all point and non-point pollution sources located and water quality determined. No discharge of industrial waste into the harvesting area was observed. The approved shellfish harvesting area in Mosquito Lagoon is approximately 12 miles long. The soil along the west coast of Mosquito Lagoon was considered to be of the tidal marsh-tidal swamp association and therefore had severe restrictions for housing, septic systems, and roads due to the continual flooding. Fecal coliforms from wildlife do not appear to have significant impacts on the water quality in the area. All bacteriological stations within the lagoon met the Interstate Shellfish Sanitation Program (ISSP) standards and a shellfish tissue station was established at Station 73 (northeast of Haulover Canal). This station was chosen due to its proximity to the conditionally approved area and potential coliform sources and due to the north and south tidal flow transporting pollutants to shellfish in this area (Royal and Pierce 1991). During the period of April 1982 through May 1990 the approved area of Body A was never closed.

4.4 Demersal Fish Community

A monitoring program to evaluate the demersal fish community was conducted by Dr. F.F. Snelson, University of Central Florida, during the summers of 1991 and 1992. Details of the study are reported in Snelson (1993). Five fixed stations were sampled yielding 26,000 fish of 49 species. The fish fauna consisted of few specimens that numerically dominate and a larger number of increasingly rare species. The bay anchovy often composed over 90% of the catch. Although a small species, the bay anchovy often predominates in biomass because of sheer abundance. Other numerically common species are silver perch, pinfish, pigfish, spot, croaker, Gulf pipefish, silver jenny, and code goby.

Some species that reach a large size are relatively rare in trawl collections. When they are caught, however, they may dominate in biomass due to their large size. Typical examples are the butterfly ray, bluntnose stingray, and hardhead catfish. Importance value (IV), an index that incorporates relative abundance, relative biomass, and frequency of capture, is a measure of overall importance of a species. The bay anchovy usually had the highest IV ranking. Other high ranked species were pinfish, spot, silver perch, pigfish, croaker, code goby, silver jenny, and hardhead catfish. Species diversity, evenness, and richness followed patterns predicted largely by the number of species, the size of the sample, and the degree to which the samples were dominated by one species, usually the bay anchovy.

Community composition varied from station to station and between sampling periods. Although this variation was often of large magnitude, most of it proved to be statistically random and insignificant. The patterns of variation that appeared to be consistent and statistically significant over the two year period were: 1) Stations 1 and 2 were highly correlated and were very similar in community composition. (2) Station 4 was consistently uncorrelated with any other station and had a different community composition. (3) The silver jenny was more abundant in 1991 than in 1992. (4) The spot was more abundant in 1992 than 1991. (5) Rare species were encountered more often at the northern stations than at the southern stations. Important environmental considerations that appear to influence community composition are habitat diversity and proximity to ocean access (Stations 1 and 2) and drift algae density (Station 4).

In comparing the historical data from 1979-80 to the recent data from 1991-92, there were few indications of major community change over time at either Station 3 or 5. Although many of the numbers and indices showed differences, most of these were not statistically significant. The differences that proved to be statistically reliable were as follows: (1) There were more silver jenny at both Stations 3 and 5 in 1991-92 than in 1979-80. (2) There were more code goby and Gulf pipefish at Station 3 in 1979-80 than in 1991-1992. There was no clear environmental explanation for the increased abundance of the silver jenny in 1991. The explanation for the increased abundance of the code goby and Gulf pipefish in 1979-80 is that benthic drift algae concentrations were heavier at that time. Both species are known to be positively associated with drift algae cover.

5.0 Meteorology

5.1 Rain Volume and pH

5.1.1 Introduction

Development of a comprehensive understanding of water resources associated with CNS and east central Florida requires quantification of atmospheric inputs to the watersheds and lagoon surfaces of the region. At the southern end of Mosquito Lagoon, in the industrial operations area of KSC, NASA operates a National Atmospheric Deposition Program (NADP) monitoring station. This station was established at KSC in 1982 to expand an acid rain monitoring program being conducted by Dr. Brooks Madsen (1979) of the University of Central Florida in the late 1970s (Dreschel 1984). This station is still in operation.

5.1.2 Methods

Rainfall amounts for the study period (July 1991-March 1993), were recorded at the NADP site (Drese 1991a and b, 1992a, b, c, and d 1993). The rain collecting stations consist of a Belfort Dual Traverse Universal Recording Rain Gage and one or two Aerochem Metrics Automatic Sensing Wet/Dry Precipitation Collectors. The rain gage records rainfall on a weekly basis, in inches, on a chart and the collector collects "wet-only" and "dry-only" samples with a cover which is moved mechanically from the "wet side" collection vessel to the "dry side" collection vessel when water is present on the sensor (Dreschel 1984). During dry periods, the cover remains over the "wet side" collection vessel. These instruments are wired together so that when the collector opens, the event is recorded at the top of the rain gage chart (Dreschel 1984).

The recording charts are changed weekly and the samples are collected in a 13 liter polyethylene bucket. When a sample is collected, the amount of sample is determined (from the rain chart and/or by weight) and a suitable aliquot is removed for analysis of pH and conductivity (Dreschel 1984). The pH and conductivity values are determined from a cumulative weekly sample and not for specific rainfall events. The remaining sample is then sent to the NADP Calibration Laboratory for chemical analysis (Dreschel 1984).

5.1.3 Results and Discussion

Rainfall volumes for the study period July 1991through March 1993 are shown in Figures D-1 to D-7. Tables D-1 to D-7 display conductivity and pH values of rain during the study period. The daily rainfall amounts ranged from 0 to 2.95 in. with recorded precipitation occurring on 207 of the 640 days. The 2.95 inches of rain was recorded on September 29, 1991. The mean volume from the 207 rain days was 0.44 ± 0.55 in. The pH ranged from 3.85 to 7.06 pH units (Figures D-8 to D-14) with a quarterly volume-weighted mean and standard deviation of 4.67 ± 1.09 pH units ($n = 207$). The conductivity values ranged from 0.04 to 72.5 µmho/cm (Figures D-8 to D-14) with a quarterly volume-weighted mean and standard deviation of 9.59 ± 11.43 µmho/cm ($n = 207$).

Rainfall totals for the quarters (October 1983-March 1993) and annual totals from 1984 through 1992 at the NADP rain site, the 86-yr Titusville record, and the 75-yr Merritt Island record are presented in Tables D-8 to D-10. The period July-September of 1991 yielded the highest total rainfall amount of the seven quarters and had the second highest total amount recorded for the period 1984-1992 (Table D-8). In contrast, the fourth quarter (October-December) 1991 had the lowest rainfall during our study and was the second lowest over the period 1984-1992. The 1991 and 1992 total annual rainfall amounts at KSC were higher than all years except 1987 (Table D-10).

The maximum daily rainfall amount for 1992 was 2.29 in and occurred on March 6, 1992. June of 1992 had the highest total rainfall of the seven quarters (21 months) and had the second highest total rainfall for the period 1984-1992. However, there were only 1.83 inches of rain in July that may have contributed to the large number of wildfires that occurred during early July. The water quality data collected for this time period showed no noticeable increase in nitrites, nitrates, phosphorous or other parameters that would be expected to increase after such a heavy rainfall event. The Titusville 86-yr record was exceeded during three out of the seven quarters (Tables D-8 to D-9) and the Merritt Island 75-yr record was exceeded four out of the seven quarters. The 1991 and 1992 annual totals also exceeded the KSC mean and the Merritt Island 75-yr record (Table D-10).

The maximum daily rainfall amount for the period January-March of 1993 was 2.10 in and occurred on March 13, 1993. This rainfall event coincided with a storm front that produced winds ranging from 11-26 miles/hour (mph) and averaged 18 mph over a 24 hour period (Drese 1993). In addition to producing the maximum daily rainfall for this quarter, winds in excess of 67 mph (gusts of 71 mph) were recorded on February 11, 1993 from the wind tower located at the Haulover Canal bridge. That period represented the highest first quarter total amount of rain recorded in the last 10 years. Finally, pH values for the third and fourth quarters of 1991, and the first quarter of 1992 and 1993 were higher than the ten year mean (4.58 pH units). The second, third and fourth quarters of 1992 were lower for the period of October 1977 through December 1987 (Tables D-1 to D-7).

5.2 Wind

5.2.1 Introduction

The northern Indian River Lagoon complex, of which Mosquito Lagoon is a part, is predominantly a wind driven (aeolian) system with regard to circulation processes. Tidal influences in northern Mosquito Lagoon are evident in response to Ponce de Leon Inlet, but wind is the primary force in water movement for the remainder of this lagoon.

5.2.2 Methods

Wind rose plots were developed for each month from May 1991 through May 1993 from data collected at the U.S. Air Force Tower 419 located at the top of the Haulover Canal bridge. Hourly averages were used to generate monthly wind roses. Wind roses provide information on the direction and intensity of local low altitude wind fields.

5.2.3 Results and Discussion

Results are summarized in Appendix E, Figures E-1 to E-25. Winds in spring (March-May) had an eastern and western component to their direction and were predominantly in the 6-15 mph range. In fact, all the seasons yielded wind speeds that were predominantly in this range except summer (June-August) that showed some variability with light winds (mainly westerly) of 2-5 mph in July and August. The fall (September-November) winds were predominantly from the east. As expected, winter (December-February) winds were from the north. Most winds for this period were between 0-30 mph, although four strong wind events (31-70 mph) did occur in the months of October 1992, and January through March of 1993 (Figures E-18 and E-21 to E-23). The maximum winds in October were out of the SSW at 60 mph. January and February produced 43 mph winds out of the SSW and 67 mph (gusts to 71 mph) out of the NNE, respectively. The storm of the century took place in March of 1993 but the data from the Haulover Site indicated WSW winds at only 35 mph, several other stations on KSC recorded winds in excess of 70 mph.

5.3 Solar Insolation

5.3.1 Introduction

Solar radiation is one of the single most important parameters influencing the estuarine ecosystems associated with Mosquito Lagoon. Sunlight, in combination with chemical nutrients, in the presence of plants creates the basis of the food chain through primary production. Daily cycles in light and heat drive both photosynthesis and respiration rates. In addition, solar radiation directly influences all photochemical processes and micro-scale mixing rates in the water column. Heating of the surface layer may induce density stratifications that in turn can lead to the development of anoxic conditions in bottom waters and sediments. This may alter oxidation-reduction potentials at the sediment water interface leading to dramatic changes in chemical partitioning coefficients and concentrations. In extreme cases these anoxic conditions may prove lethal to benthic organisms and fishes resulting in fish kills.

5.3.2 Methods

Solar radiation data were collected by the Florida Solar Energy Center at Port Canaveral, Florida. The collection station is one of twenty located on the Florida Solar Energy Center property, approximately 29 km south of Mosquito Lagoon. A Licor pyranometer (model #PY18239) was used to record the radiation in watts m^{-2}. The data were stored on a Campbell Scientific digital data logger, which takes an integrated average at 15 minute intervals to produce mean hourly averages. The solar radiation data were then reduced into monthly averages for the period January 1990-June 1993.

5.3.3 Results and Discussion

Monthly mean solar insolation data are presented in Figure 25. In general, solar radiation levels follow the annual seasonal pattern with maximum values during May, June, and July and minimum values during November, December, and January. Levels increase between the months of January through May, peaked in late June around the summer solstice and decreased from July through December and the time of the winter solstice. The year 1990 had highest average solar radiation levels during the months of January through June, and October through December suggesting somewhat lower cloud cover. September yielded the highest levels in 1991, while the highest levels in 1992 were in May and July. June 1992 displayed low insolation for a summer time period, most probably as a result of cloud cover.

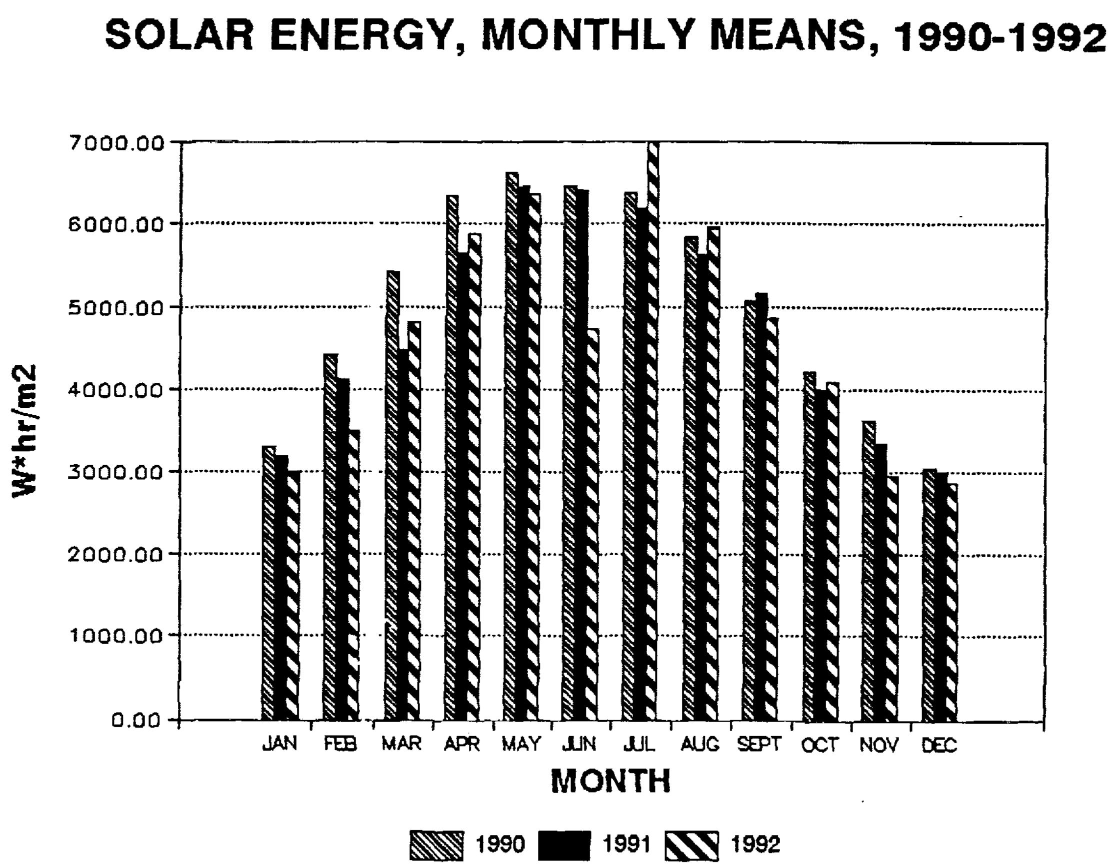


Figure 25. Monthly mean solar insolation values for the east central Florida coastal region. Data were collected by the Florida Solar Energy Center at Port Canaveral Florida.

6.0 Impoundments and Culverts

6.1 Introduction

Mosquito control impoundments were constructed in the late 1950s in Brevard County and the 1960s in Volusia County (Provancha et al. 1992). Other methods of source reduction such as hand ditching (1930's) and grid ditching with draglines (1950s and 1960s) were used in Mosquito Lagoon. These early methods brought environmental changes to the region. Drastic shifts in plant and animal communities, the changing of the food web dynamics, and the loss of biological diversity by preventing exchange between the estuary and the impoundment were only a few of those effects. Impoundment techniques have improved over the years and the negative impacts have been lessened but management remains cumbersome and costly. Brevard County Mosquito Control is not actively managing any impoundment in Mosquito Lagoon at this time. Volusia County and the U.S. Fish and Wildlife Service are actively managing mosquito control impoundments with renewed emphasis on multi-objective management strategies that include mosquito reduction, enhancement of waterfowl and wading bird habitats, and enhanced fisheries productivity.

6.2 Methods

Water quality data were collected monthly by Merritt Island National Wildlife Refuge staff at each impoundment. Collections were made in close proximity to the water level gauge at each site. The parameters included SAL, DO, temperature and water level. Data for 18 impoundments were reviewed, three of which were selected for analyses based on their relative locations within the lagoon. One was located at the northern end of the impoundment system (V-1), one near the central region of the lagoon (T-44) and one at the southern end of the lagoon (T-38) (Figure 26). In the vicinity of the T-44 gauge is another station located just outside of the impoundment referred to as County Line. Data for this site were also plotted.

6.3 Results and Discussion

Figures G-1 through G-8 display the data collected at the impoundment sites. Salinity fluxes showed the greatest variability at the northern impoundment (V-1) and the lowest variability at the southern impoundment (T-38). As expected, SAL was generally inversely related to water level. Data for V-1 and T-38 show large increases in water levels relative to two previous years. Open Marsh Water Management (OMWM) is a progressive mosquito source reduction technique that is currently being used by Volusia County. The main objectives of OMWM are to control saltmarsh mosquitoes, reduce pesticide use, and enhance the tidal food chain (Duhring 1989). OMWM is actually thought to stimulate saltmarsh plant productivity and increase biotic diversity (Duhring 1989). Twelve previously hand-ditched marsh island

Figure 26. Locations of Mosquito Control Impoundment sampling areas along the eastern shoreline of Mosquito Lagoon.

sites and one impoundment C-8 are slated for OMWM. The impoundment dikes on C-8 and D-12 south, both of which had been impounded prior to 1972, were breached in 1986 as part of the OMWM program (East Volusia Mosquito Control District 1993). Impoundment C-8 (90 acres) had 22 primary areas of mosquito habitat made up of potholes and low vegetated areas dominated by *Salicornia virginica* and *Distichlis spicata*. These potholes and low areas were interconnected by a ditching network which was then connected to the perimeter ditch which surrounds the impoundment and finally to the lagoon itself.

Prior to OMWM, mosquito production occurred in 5 acres of potholes and 85 acres of vegetated land and the area had to be larvicided 8 times a year over a total of 720 acres. Since OMWM, mosquito production has occurred in 0.2 acres of potholes and 6 acres of vegetated land and the area has been larvicided 1.5 times a year over a total of 9.3 acres. This represents a 95% reduction in mosquito production and a 99% decrease in larvicid application (Duhring 1989). Salinities and DO fluctuations decreased after OMWM. Prior to OMWM SAL ranged from 3-55 ppt, after OMWM the range was 27-41 ppt Before OMWM DO ranged from 0.2-12 mg/l and after OMWM it was between 3-10 mg/l. Overall fish diversity increased but the three larvivorous species remained dominant Species of shrimp and crab increased. Numerous wading bird species were observed feeding and *Salicornia virginica* and *Distichlis spicata* still dominated with *Borrichia frutescens* and *Iva frutescens* expanding their ranges after OMWM. Two control stations in the marsh, two in the estuary and three stations in impoundment D-12 south (248 acres) were established to collect water depth, surface water chemistry, field SAL and DO. No significant difference between impoundment sites and controls were found (Gamble et al. 1990).

7.0 Summary and Recommendations

7.1 Water and Sediment Quality

Water and sediment quality in Mosquito Lagoon is generally good, meeting the Florida DEP criteria for Class II and Class III waters in most cases. Exceptions include 1) the frequent occurrence of low DO conditions in early morning hours during warm summer months resulting from high system respiration and BOD and 2) the frequent and unexplained elevated levels of metals and GO in surface waters. Pesticide and herbicide sampling consistently produced results that were below detection limits indicating no concern exists for these parameters. The following recommendations are provided for consideration:

1. Continue to develop information necessary to quantify the water budget for Mosquito Lagoon. This should be accomplished at a level of detail that will allow for creation of a simple mass balance model that can be used to support management decisions. One area needing immediate attention is the rate and quality of groundwater leakage into and/or out of Mosquito lagoon.

2. Develop information on the relationship between sediment chemistry and the chemistry of the overlying water column with emphasis on the possible exchange rates for metals and other ions. Define sources of metals in the environment.

3. Work closely with the St. Johns River Water Management District and Volusia County staff to develop and participate in a joint interagency monitoring program that includes Canaveral National Seashore. Participate in the St. Johns River Water Management District Pollution Load Reduction Program.

4. Develop a working adaptive water resources management strategy that defines the goals of the CNS with regard to water quality issues. Set specific objectives and priorities.

By addressing the above concerns, efforts can be directed more efficiently and effectively by eliminating duplicate efforts and standardizing data collection and format. This will also enable the Park Service to integrate data collected from other areas of the Indian River Lagoon complex with CNS data to provide an overview of water quality in this Estuary of National Significance.

7.2 Seagrass Transects

Seagrass transects located at the southern end of Mosquito Lagoon that are part of the KSC long-term system will continue to be monitored annually through the KSC Ecological Program. There are six stations and these data will be made available upon request to NASA. The new CNS sites however, should continue to be monitored by park rangers following the methods described in the seagrass section above. The stations should be sampled annually at a minimum but could be sampled as often as quarterly. In addition to the basic composition and cover data it would be recommended that shoot counting be added at specific locations along the transects for a measure of productivity (density) that can be repeated over time at the same location. The aerial view of the CNS seagrass resources is also an important one. Therefore, mapping of SAV on a regular basis (at least every 3 years) is recommended.

7.3 Fisheries

Several important issues were brought forward as recommendations for future monitoring of the fish community inhabiting Mosquito Lagoon. The key, as with all monitoring programs, is being realistic about the long-term commitment required to evaluate any ecological system. The fish data (comparing 1979-80 to 1991-1992) indicate that there has not been any significant deterioration in this community over the decade. Continuation of periodic fish sampling with a commitment to the long-term (i.e., 20yrs +) is appropriate. We are unsure at this time if fish data currently collected by the state (R. Pepemo, FMRI, pers comm.) is sufficient for CNS to look to as a no-cost source of continuation of the fish community monitoring. It is currently unclear as to the future commitment of the state to Mosquito Lagoon fish community monitoring. There is a need to better understand their long-term goals of comparability and statistical reliability. The current recommendation is to consult with the state, MINWR, and UCF to determine future direction.

A relatively expensive but probably more sensitive approach would be to look at the larval fish population dynamics. This would afford an understanding of recruitment and spawning and how environmental factors influence relative abundance of the larval fish in the lagoon. Adult populations are often months or years removed from the recruitment event. Environmental factors have a larger influence on the larval life history stages than the adult stage. Again, this method of monitoring requires more extensive sampling periods and longer identification time and is therefore, considerably more expensive.

Redfish are abundant in Mosquito Lagoon and have become a large draw for recreational fishermen. Appropriate questions to be answered are:

1. What are fishing pressure effects?
2. What effect does an increase in predators have on various prey species?

7.4 Sea Turtles

A cooperative study of the juvenile population of sea turtles that reside in Mosquito Lagoon is recommended. Both species, *Caretta caretta* and *Chelonia mydas*, are federally listed by the USFWS. These animals have obvious importance to the faunal and floral structure of Mosquito Lagoon, consuming seagrasses, algae, invertebrates, and fish. A netting and tagging survey conducted in cooperation with NASA, FMRI, NPS, and MINWR would enable the following objectives to be met: 1) compare current population structure and distribution to the baseline data collected between 1976 and 1979. 2) evaluate current seasonal distribution and occurrence of sea turtles through analysis of catch per unit effort (CPUE). 3) provide updated statistical summaries of CPUE to determine the regional importance of this lagoon relative to other studied juvenile habitats on the Florida east coast.

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Appendix A: Water and Sediment Chemistry

Table A-1. Summary statistics for water quality samples collected for Mosquito Lagoon. All samples and stations combined. Samples are included only if values are above the method detection limits.

	Statistics for Water				
Parameter	N of cases	Minimum	Maximum	Mean	Standard Dev
AG ug/l	53	.15	2.20	1.07	.57
AL mg/l	59	.11	2.64	.54	.51
B mg/l	71	.24	5.98	2.96	.99
BE ug/l	30	.20	2.20	.54	.52
BOD mg/l	64	1.00	7.00	2.48	1.48
CA mg/l	71	80.00	453.00	297.69	77.29
CD ug/l	44	.10	7.10	1.28	1.85
COD mg/l	71	355	9300	1142	1404
COL pt co units	69	5.00	50.00	21.59	11.26
CON umhos/cm	71	39900	59900	47077	4484
CPA mg/m_3	50	2.7	53.4	10.3	7.8
CR mg/l	54	.002	.258	.03	.06
CU mg/l	14	.02	.15	.05	.04
FE mg/l	44	.05	10.40	.53	1.54
GO mg/l	47	.52	86.00	3.31	12.34
K mg/l	71	225	998	402	100
MG mg/l	71	41.60	1370.00	972.94	214.46
NH4N mg/l as N	61	.02	.46	.12	.09
NI mg/l	22	.004	.580	.10	.15
NO2 mg/l as N	46	.01	.02	.01	.00
NO3 mg/l as N	26	.01	.31	.06	.08
PB mg/l	19	.003	.044	.01	.01
PH pH units	71	7.98	9.04	8.41	.28
PHE ug/l	65	43.80	399.00	111.35	56.51
PO4 mg/l as P	33	.02	.05	.03	.01
SAL ppt	71	4.5	37.2	26.7	6.8
SI mg/l	55	.80	26.60	2.57	3.48
SO4 mg/l	71	2000.00	7140.00	2860.18	750.43
TAK mg/l as $CaCo_3$	71	111.00	622.00	139.38	60.30
TB mg/l	71	.93	22.60	6.15	4.34
TDS mg/l	71	25960	40500	32612	2966
TKN mg/l as N	69	.05	3.04	.84	.49
TOC mg/l as C	71	.24	20.80	2.63	3.62
TP mg/l as P	69	.02	.25	.09	.05
TSS mg/l	71	16.00	350.00	61.49	67.02
ZN mg/l	28	.01	.12	.02	.02

Table A-2. Descriptive statistics for physical/chemical parameters measured at all Mosquito Lagoon water quality stations sorted by sample collection date.

Statistic	*Date*	*COL*	*CON*	*pH*	*SAL*	*TAK*	*TB*	*TDS*	*TSS*
N of cases	910723	6	6	6	6	6	6	6	6
Minimum		20	41400	8.59	16.00	111.00	2.03	30100	33.00
Maximum		40	46400	8.82	33.50	131.80	12.22	35100	47.00
Mean		30	43350	8.72	28.00	123.47	8.99	31800	38.83
Standard Dev		6	1921	0.08	7.25	8.70	3.72	1809	5.08
N of cases	910918	6	6	6	6	6	6	6	6
Minimum		20	45800	8.02	28.00	139.00	4.90	30700	40.00
Maximum		50	49000	8.31	32.00	146.00	17.80	34300	58.00
Mean		35	47967	8.19	30.00	142.57	11.03	33067	51.50
Standard Dev		11	1211	0.12	1.67	2.67	4.47	1422	7.15
N of cases	911120	6	6	6	6	6	6	6	6
Minimum		15	40230	8.14	16.00	126.70	3.11	25960	22.00
Maximum		40	57770	8.31	19.00	174.20	8.08	32240	58.00
Mean		29	47143	8.23	18.33	145.40	5.47	29730	36.33
Standard Dev		12	5772	0.07	1.17	18.63	1.69	2307	12.21
N of cases	920203	6	6	6	6	6	6	6	6
Minimum		5	45000	8.32	20.00	124.00	1.87	29700	28.00
Maximum		20	47800	8.42	29.00	158.00	6.54	34700	53.00
Mean		12	46567	8.39	26.42	134.67	3.26	32950	42.33
Standard Dev		5	948	0.04	3.23	13.38	1.78	1776	8.91
N of cases	920302	6	6	6	6	6	6	6	6
Minimum		5	42300	8.78	16.00	141.40	1.33	31900	30.00
Maximum		15	45600	9.00	18.00	165.20	8.28	33300	51.00
Mean		10	43717	8.86	16.83	147.23	3.70	32783	39.83
Standard Dev		3	1094	0.08	0.75	9.05	2.56	500	7.78
N of cases	920505	6	6	6	6	6	6	6	6
Minimum		10	47800	8.78	31.00	120.00	1.79	33700	35.00
Maximum		30	52900	9.04	33.00	166.00	3.18	37100	114.00
Mean		15	51483	8.87	32.50	132.83	2.35	35733	68.67
Standard Dev		8	1871	0.11	0.84	17.57	0.51	1232	26.91

Table A-2 (continued). Descriptive statistics for physical/chemical parameters measured at all Mosquito Lagoon water quality stations sorted by sample collection date.

Statistic	*Date*	*COL*	*CON*	*pH*	*SAL*	*TAK*	*TB*	*TDS*	*TSS*
N of cases	920727	6	6	6	6	6	6	6	6
Minimum		20	41000	8.34	4.5	120.00	4.59	31400	34.00
Maximum		40	49600	8.83	25.0	622.00	14.20	34500	52.00
Mean		27	46917	8.51	15.7	222.67	8.86	33000	43.75
Standard Dev		8	3131	0.18	6.6	198.28	3.34	986	7.37
N of cases	920922	5	5	6	6	6	6	6	6
Minimum		20	45300	8.04	29.0	119.00	2.89	27000	24.00
Maximum		40	47800	8.34	31.0	129.00	22.60	36400	98.00
Mean		28	46640	8.20	30.0	123.50	11.28	31067	58.17
Standard Dev		8	913	0.11	0.6	3.83	7.01	3227	26.28
N of cases	921116	5	5	5	5	5	5	5	5
Minimum		20	45300	8.03	30.5	121.00	4.72	30600	210.00
Maximum		30	47800	8.16	32.2	124.00	10.90	32000	350.00
Mean		26	46640	8.08	31.6	121.80	7.88	31140	290.00
Standard Dev		6	913	0.05	0.7	1.30	2.70	573	62.05
N of cases	930119	6	6	6	6	6	6	6	6
Minimum		5	43700	7.98	27.5	111.00	0.93	30700	22.00
Maximum		20	46700	8.32	29.4	143.00	5.69	32400	42.00
Mean		9	45733	8.13	28.7	117.33	2.31	31417	30.00
Standard Dev		6	1093	0.12	0.6	12.60	1.90	682	7.12
N of cases	930331	5	6	6	6	6	6	6	6
Minimum		5	42100	8.27	26.1	116.00	1.64	27700	16.00
Maximum		20	46000	8.49	29.4	143.00	5.68	31200	42.00
Mean		12	44350	8.35	28.1	127.17	4.31	29483	31.67
Standard Dev		6	1401	0.08	1.1	9.50	1.51	1251	9.14
N of cases	930616	6	6	6	6	6	6	6	6
Minimum		20	52400	8.18	31.6	127.00	2.07	34800	33.00
Maximum		30	59900	8.55	37.2	142.00	8.14	40500	53.00
Mean		27	57483	8.29	35.4	131.00	4.71	38933	44.83
Standard Dev		5	2822	0.13	2.1	5.51	2.20	2108	8.59

Table A-3. Descriptive statistics for physical/chemical parameters measured at each Mosquito Lagoon water quality station for all sample collection dates.

Statistic	*Station*	*COL*	*CON*	*pH*	*SAL*	*TAK*	*TB*	*TDS*	*TSS*
N of cases	CNS1	9	11	11	11	11	11	11	11
Minimum		5	40230	8.22	16.0	111	1.14	25960	16.00
Maximum		20	52400	9.04	31.6	165	6.54	35100	53.00
Mean		16	45439	8.55	25.1	141	3.15	31087	32.86
Standard Dev.		5	3497	0.27	5.9	16	1.84	3250	9.17
N of cases	CNS2	12	12	12	12	12	12	12	12
Minimum		5	44400	8.03	4.5	111	1.87	29500	22.00
Maximum		40	59900	9.00	37.2	207	14.20	39300	310.00
Mean		22	48137	8.40	25.3	138	6.72	33115	63.50
Standard Dev.		12	4341	0.31	9.2	25	3.80	2665	78.32
N of cases	CNS3	12	12	12	12	12	12	12	12
Minimum		5	41400	8.10	16.0	113	1.32	29300	28.00
Maximum		30	57100	8.88	34.9	166	12.10	39900	350.00
Mean		20	46788	8.41	26.9	131	6.91	32398	70.42
Standard Dev.		11	4178	0.27	6.3	15	3.94	2956	89.13
N of cases	CNS4	12	12	12	12	12	12	12	12
Minimum		10	42300	7.98	17.0	113	3.02	31200	22.00
Maximum		50	59300	8.78	37.2	174	22.60	40500	240.00
Mean		29	47688	8.29	27.7	132	8.79	33660	71.58
Standard Dev.		13	4364	0.29	6.6	17	5.63	2920	58.81
N of cases	CNS5	12	12	12	12	12	12	12	12
Minimum		5	39900	8.16	14.5	112	0.93	28100	31.00
Maximum		40	56700	8.97	35.6	622	8.65	40200	210.00
Mean		19	45993	8.46	27.4	168	4.30	32417	53.83
Standard Dev.		10	4661	0.28	7.0	143	2.72	3223	49.962
N of cases	CNS6	12	12	12	12	12	12	12	12
Minimum		5	41800	8.06	17.0	112	1.29	28900	28.00
Maximum		40	59500	8.81	35.9	147	17.80	38900	340.00
Mean		22	48280	8.35	27.8	128	6.81	32870	74.33
Standard Dev.		12	5702	0.28	6.6	11	5.11	2768	84.89

Table A-4. Descriptive statistics for metals measured at all Mosquito Lagoon water quality stations sorted by sample collection date.

Statistic	*Date*	*AG*	*AL*	*BE*	*B*	*CA*	*CD*	*CR*	*CU*	*FE*	*MG*	*NI*	*PB*	*SI*	*ZN*
N of cases	910723	6	0	2	6	6	6	6	0	1	6	1	2	6	6
Minimum		0.53	.	0.20	3.65	346.00	0.11	0.002	.	0.41	831.00	0.095	0.004	1.01	0.020
Maximum		2.20	.	0.25	4.04	408.00	0.23	0.012	.	0.41	991.00	0.095	0.005	2.86	0.049
Mean		1.69	.	0.23	3.84	369.17	0.16	0.005	.	0.41	889.83	0.095	0.005	2.04	0.039
Standard Dev		0.62	.	0.04	0.18	22.57	0.05	0.004	.	.	59.11	.	0.001	0.61	0.011
N of cases	910918	6	5	6	6	6	6	6	0	6	6	1	2	6	2
Minimum		0.46	0.46	0.31	3.06	336.00	0.15	0.005	.	0.09	1000.00	0.004	0.003	1.31	0.016
Maximum		1.30	0.93	0.43	3.37	425.00	0.44	0.008	.	0.74	1150.00	0.004	0.004	3.35	0.018
Mean		0.82	0.75	0.38	3.23	376.67	0.30	0.007	.	0.52	1080.00	0.004	0.004	2.46	0.017
Standard Dev		0.31	0.19	0.06	0.10	29.53	0.09	0.001	.	0.24	49.40	.	0.001	0.74	0.001
N of cases	911120	6	6	2	6	6	2	6	0	6	6	0	5	0	3
Minimum		0.30	0.15	0.21	0.24	210.00	0.10	0.004	.	0.09	817.00	.	0.004	.	0.014
Maximum		1.10	0.40	0.32	0.30	239.00	0.14	0.012	.	0.22	1016.00	.	0.005	.	0.039
Mean		0.76	0.23	0.27	0.26	226.50	0.12	0.006	.	0.13	941.33	.	0.004	.	0.027
Standard Dev		0.34	0.10	0.08	0.02	10.45	0.03	0.003	.	0.05	69.82	.	0.000	.	0.013
N of cases	920203	6	6	6	6	6	0	6	0	6	6	0	0	3	2
Minimum		1.40	0.13	0.80	2.52	233.00	.	0.005	.	0.08	910.00	.	.	0.80	0.012
Maximum		2.15	0.45	2.20	2.99	319.00	.	0.024	.	0.25	983.00	.	.	1.10	0.017
Mean		1.68	0.24	1.47	2.84	277.50	.	0.012	.	0.13	957.83	.	.	0.98	0.015
Standard Dev		0.33	0.12	0.50	0.17	39.02	.	0.007	.	0.06	26.95	.	.	0.16	0.004
N of cases	920302	6	5	6	6	6	6	6	6	6	6	5	1	3	0
Minimum		0.55	0.11	0.25	2.61	212.00	0.65	0.036	0.060	0.18	872.00	0.005	0.019	0.92	.
Maximum		1.50	0.34	0.35	3.06	232.00	2.35	0.250	0.150	0.80	1006.00	0.057	0.019	1.41	.
Mean		1.00	0.25	0.32	2.89	224.83	1.19	0.137	0.090	0.40	940.50	0.029	0.019	1.14	.
Standard Dev		0.39	0.11	0.05	0.17	7.39	0.63	0.092	0.030	0.22	53.37	0.020	.	0.25	
N of cases	920505	6	5	4	6	6	6	6	0	6	6	6	2	4	3
Minimum		0.60	0.40	0.25	3.10	421.00	2.60	0.006	.	0.05	1180.00	0.075	0.004	0.98	0.010
Maximum		1.40	2.60	0.55	3.85	453.00	7.10	0.020	.	0.53	1370.00	0.580	0.018	1.73	0.010
Mean		0.93	1.08	0.34	3.52	435.83	5.13	0.013	.	0.26	1303.33	0.271	0.011	1.47	0.010
Standard Dev		0.31	0.90	0.14	0.29	12.89	1.86	0.005	.	0.17	69.76	0.194	0.010	0.35	0.0

Table A-4 (continued). Descriptive statistics for metals measured at all Mosquito Lagoon water quality stations sorted by sample collection date.

Statistic	*Date*	*AG*	*AL*	*BE*	*B*	*CA*	*CD*	*CR*	*CU*	*FE*	*MG*	*NI*	*PB*	*SI*	*ZN*
N of cases	920727	6	6	0	6	6	6	6	0	3	6	1	5	6	3
Minimum		1.15	0.18	.	2.47	113.00	0.65	0.008	.	0.12	231.00	0.011	0.003	2.010	0.010
Maximum		2.15	0.79	.	3.35	393.00	4.70	0.013	.	0.18	1210.00	0.011	0.044	4.480	0.040
Mean		1.64	0.47	.	2.85	339.83	1.83	0.010	.	0.15	1021.83	0.011	0.012	3.375	0.023
Standard Dev		0.35	0.28	.	0.35	111.20	1.45	0.002	.	0.03	387.84	.	0.018	0.936	0.015
N of cases	920922	6	5	4	6	6	6	6	0	4	6	2	1	5	1
Minimum		0.15	0.33	0.20	2.49	235.00	0.14	0.002	.	0.26	753.00	0.005	0.005	1.950	0.020
Maximum		0.95	2.64	0.27	2.96	243.00	0.55	0.009	.	1.12	834.00	0.009	0.005	6.780	0.020
Mean		0.42	1.23	0.23	2.70	237.67	0.33	0.006	.	0.56	788.00	0.007	0.005	3.680	0.020
Standard Dev		0.28	0.86	0.03	0.20	3.78	0.17	0.003	.	0.38	31.58	0.003	.	1.846	.
N of cases	921116	5	5	0	5	5	1	5	0	4	5	5	0	5	1
Minimum		0.47	0.24	.	3.08	271.00	0.58	0.006	.	0.06	869.00	0.004	.	1.120	0.010
Maximum		0.68	1.48	.	3.14	273.00	0.58	0.034	.	0.57	878.00	0.026	.	3.650	0.010
Mean		0.57	0.76	.	3.10	271.60	0.58	0.015	.	0.27	874.00	0.016	.	2.186	0.010
Standard Dev		0.09	0.47	.	0.02	0.89	.	0.012	.	0.22	3.54	0.008	.	0.995	.
N of cases	930119	0	5	0	6	6	1	0	6	1	6	0	0	6	2
Minimum		.	0.24	.	2.84	246.00	0.90	.	0.02	0.20	824.00	.	.	0.860	0.012
Maximum		.	0.98	.	3.12	270.00	0.90	.	0.02	0.20	910.00	.	.	2.830	0.012
Mean		.	0.49	.	2.98	261.83	0.90	.	0.02	0.20	876.17	.	.	1.370	0.012
Standard Dev		.	0.30	.	0.09	8.64	.	.	0.0	.	30.39	.	.	0.741	0.0
N of cases	930331	0	5	0	6	6	1	1	2	1	6	1	1	5	3
Minimum		.	0.15	.	2.89	80.00	0.28	0.258	0.04	10.40	41.60	0.140	0.004	1.430	0.010
Maximum		.	0.71	.	4.75	291.00	0.28	0.258	0.06	10.40	1020.00	0.140	0.004	26.600	0.118
Mean		.	0.33	.	3.30	248.17	0.28	0.258	0.05	10.40	817.43	0.140	0.004	6.754	0.047
Standard Dev		.	0.23	.	0.72	82.74	.	.	0.01	.	381.57	.	.	11.098	0.062
N of cases	930616	0	6	0	6	6	3	0	0	0	6	0	0	6	2
Minimum		.	0.14	.	3.55	289.00	0.10	.	.	.	811.00	.	.	1.320	0.010
Maximum		.	0.39	.	5.98	302.00	0.21	.	.	.	1270.00	.	.	2.490	0.010
Mean		.	0.29	.	4.08	298.33	0.17	.	.	.	1168.50	.	.	1.720	0.010
Standard Dev		.	0.09	.	0.94	5.09	0.06	.	.	.	176.39	.	.	0.538	0.0

Table A-5. Descriptive statistics for metals measured at each Mosquito Lagoon water quality station for all sample collection dates.

Statistic	*Station*	*AG*	*AL*	*BE*	*B*	*CA*	*CD*	*CR*	*CU*	*FE*	*MG*	*NI*	*PB*	*SI*	*ZN*
N of cases	CNS1	8	6	6	11	11	8	8	2	6	11	4	3	6	4
Minimum		0.15	0.15	0.23	0.25	210.00	0.12	0.005	0.02	0.05	810.00	0.005	0.004	1.01	0.01
Maximum		1.90	2.60	2.20	5.98	421.00	5.90	0.227	0.07	0.41	1190.00	0.174	0.044	2.01	0.05
Mean		1.04	0.62	0.62	3.14	294.91	1.11	0.037	0.05	0.20	944.82	0.077	0.022	1.35	0.02
Standard Dev		0.64	0.98	0.78	1.36	79.15	1.99	0.077	0.04	0.17	137.74	0.075	0.020	0.35	0.02
N of cases	CNS2	9	11	3	12	12	6	9	2	9	12	5	3	10	7
Minimum		0.29	0.23	0.31	0.24	226.00	0.23	0.005	0.02	0.11	834.00	0.009	0.003	0.80	0.01
Maximum		2.15	1.20	1.70	3.90	440.00	7.10	0.173	0.15	0.64	1310.00	0.145	0.005	4.03	0.05
Mean		1.02	0.64	0.79	3.02	315.08	2.29	0.027	0.09	0.28	1036.58	0.043	0.004	2.49	0.02
Standard Dev		0.74	0.36	0.79	0.95	74.36	2.91	0.055	0.09	0.17	155.51	0.058	0.001	0.89	0.02
N of cases	CNS3	9	10	4	12	12	6	9	2	7	12	2	4	10	5
Minimum		0.45	0.13	0.21	0.25	228.00	0.20	0.003	0.02	0.10	782.00	0.026	0.004	0.86	0.01
Maximum		1.65	1.28	1.70	3.79	430.00	6.45	0.046	0.06	0.56	1290.00	0.220	0.005	3.84	0.04
Mean		0.96	0.45	0.65	2.90	307.92	1.61	0.014	0.04	0.26	1006.83	0.123	0.004	1.89	0.02
Standard Dev		0.40	0.36	0.71	0.90	69.41	2.42	0.014	0.03	0.18	161.83	0.137	0.001	1.11	0.01
N of cases	CNS4	9	11	6	12	12	9	10	3	9	12	4	3	11	3
Minimum		0.55	0.14	0.25	0.26	80.00	0.11	0.007	0.02	0.06	41.60	0.013	0.004	1.04	0.04
Maximum		2.20	2.64	1.20	4.75	447.00	3.05	0.258	0.07	10.40	1370.00	0.140	0.004	26.60	0.12
Mean		1.02	0.74	0.51	3.07	290.42	0.99	0.060	0.04	1.58	933.05	0.071	0.004	4.88	0.07
Standard Dev		0.52	0.67	0.36	1.05	95.84	1.07	0.103	0.03	3.33	331.50	0.053	0.0	7.40	0.05
N of cases	CNS5	9	11	6	12	12	7	9	3	6	12	3	4	9	4
Minimum		0.25	0.11	0.20	0.27	220.00	0.10	0.002	0.02	0.08	753.00	0.004	0.003	1.06	0.01
Maximum		1.90	1.48	1.20	4.04	453.00	2.60	0.091	0.10	0.57	1370.00	0.434	0.019	3.65	0.04
Mean		1.11	0.38	0.43	2.87	301.17	0.75	0.017	0.06	0.29	994.92	0.148	0.008	2.09	0.02
Standard Dev		0.57	0.38	0.39	0.92	74.38	0.90	0.028	0.04	0.19	178.27	0.248	0.008	0.85	0.01
N of cases	CNS6	9	10	5	12	12	8	9	2	7	12	4	2	9	5
Minimum		0.40	0.15	0.22	0.30	113.00	0.10	0.002	0.02	0.09	231.00	0.004	0.005	0.87	0.01
Maximum		2.15	1.00	0.80	3.65	424.00	5.70	0.036	0.09	0.74	1300.00	0.580	0.005	2.96	0.03
Mean		1.24	0.42	0.39	2.80	276.42	1.21	0.012	0.06	0.27	919.08	0.156	0.005	1.86	0.02
Standard Dev		0.66	0.27	0.24	0.86	79.01	1.88	0.013	0.05	0.23	267.42	0.283	0.0	0.75	0.01

Table A-6. Descriptive statistics for inorganics measured at all water quality stations sorted by sample collection date.

Statistic	*Date*	*NH4-N*	*NO2*	*NO3*	*PO4*	*K*	*SO4*	*TKN*	*TP*
N of cases	910723	6	6	3	2	6	6	6	6
Minimum		0.06	0.010	0.01	0.026	370	2110.00	0.54	0.05
Maximum		0.27	0.020	0.05	0.038	416	2620.00	0.97	0.08
Mean		0.12	0.012	0.03	0.032	386	2418.33	0.70	0.06
Standard Dev.		0.08	0.004	0.02	0.008	16.6	189.89	0.15	0.01
N of cases	910918	6	6	1	3	6	6	6	6
Minimum		0.12	0.010	0.03	0.026	462	2093.00	0.85	0.04
Maximum		0.20	0.010	0.03	0.034	515	2780.00	1.29	0.09
Mean		0.16	0.010	0.03	0.031	497	2532.17	0.94	0.07
Standard Dev.		0.03	0.0	.	0.004	18.8	252.44	0.17	0.02
N of cases	911120	6	6	6	3	6	6	6	6
Minimum		0.13	0.010	0.03	0.026	346	2595.00	0.57	0.04
Maximum		0.23	0.010	0.20	0.036	429	3415.00	1.27	0.08
Mean		0.17	0.010	0.07	0.031	398	3030.00	0.75	0.06
Standard Dev.		0.03	0.0	0.07	0.005	32.6	322.08	0.27	0.02
N of cases	920203	6	1	0	2	6	6	6	6
Minimum		0.06	0.020	.	0.027	357	2640.00	0.55	0.03
Maximum		0.26	0.020	.	0.040	413	3160.00	1.03	0.21
Mean		0.11	0.020	.	0.034	393	2920.00	0.74	0.10
Standard Dev.		0.07	.	.	0.009	21.4	187.51	0.18	0.06
N of cases	920302	6	0	2	6	6	6	6	4
Minimum		0.05	.	0.02	0.016	371	2430.00	0.31	0.02
Maximum		0.45	.	0.03	0.041	400	5640.00	0.72	0.07
Mean		0.19	.	0.03	0.027	389	3703.33	0.47	0.04
Standard Dev.		0.15	.	0.01	0.009	12.8	1058.52	0.17	0.02
N of cases	920505	6	4	1	0	6	6	6	6
Minimum		0.04	0.010	0.02	.	394	2690.00	0.37	0.04
Maximum		0.09	0.010	0.02	.	700	3100.00	1.20	0.08
Mean		0.08	0.010	0.02	.	461	2911.67	0.65	0.06
Standard Dev.		0.02	0.0	.	.	118	132.88	0.32	0.02

Table A-6 (continued). Descriptive statistics for inorganics measured at all water quality stations sorted by sample collection date.

Statistic	*Date*	*NH4-N*	*NO2*	*NO3*	*PO4*	*K*	*SO4*	*TKN*	*TP*
N of cases	920727	6	0	6	2	6	6	6	6
Minimum		0.03	.	0.02	0.020	225	2120.00	0.87	0.03
Maximum		0.13	.	0.31	0.020	998	7140.00	1.93	0.07
Mean		0.08	.	0.12	0.020	426	3233.33	1.33	0.06
Standard Dev.		0.04	.	0.15	0.0	285	1934.79	0.37	0.02
N of cases	920922	2	6	1	6	6	6	6	6
Minimum		0.26	0.010	0.17	0.030	330	2230.00	1.12	0.08
Maximum		0.46	0.020	0.17	0.040	442	2490.00	1.61	0.21
Mean		0.36	0.012	0.17	0.032	367	2355.00	1.36	0.16
Standard Dev.		0.14	0.004	.	0.004	42.5	103.68	0.21	0.05
N of cases	921116	2	5	5	4	5	5	5	5
Minimum		0.03	0.010	0.03	0.020	361	3060.00	0.88	0.11
Maximum		0.06	0.020	0.05	0.020	369	3282.00	1.60	0.18
Mean		0.05	0.018	0.04	0.020	365	3193.40	1.22	0.14
Standard Dev.		0.02	0.004	0.01	0.0	3.21	82.50	0.26	0.03
N of cases	930119	4	6	1	0	6	6	6	6
Minimum		0.02	0.010	0.02	.	348	2000.00	0.18	0.03
Maximum		0.07	0.010	0.02	.	414	2970.00	3.04	0.10
Mean		0.05	0.010	0.02	.	369	2651.67	0.73	0.05
Standard Dev.		0.02	0.0	.	.	22.91	360.97	1.14	0.03
N of cases	930331	6	0	0	3	6	6	4	6
Minimum		0.03	.	.	0.020	354	2222.00	0.05	0.06
Maximum		0.14	.	.	0.030	680	2426.00	0.64	0.10
Mean		0.06	.	.	0.023	422	2298.83	0.24	0.08
Standard Dev.		0.04	.	.	0.006	128	75.90	0.27	0.02
N of cases	930616	5	6	0	2	6	6	6	6
Minimum		0.06	0.010	.	0.030	334	2570.00	0.60	0.11
Maximum		0.15	0.010	.	0.050	358	4070.00	1.12	0.25
Mean		0.11	0.010	.	0.040	346	3130.00	0.86	0.18
Standard Dev.		0.04	0.0	.	0.014	10.9	501.00	0.18	0.05

Table A-7. Descriptive statistics for inorganics measured at each Mosquito Lagoon water quality station for all sample collection dates.

Statistic	*Station*	*NH4-N*	*NO2*	*NO3*	*PO4*	*K*	*SO4*	*TKN*	*TP*
N of cases	CNS1	10	8	4	4	11	11	11	11
Minimum		0.05	0.010	0.03	0.030	225	2000.00	0.05	0.03
Maximum		0.27	0.020	0.31	0.041	462	2940.00	1.40	0.21
Mean		0.16	0.011	0.14	0.037	361	2443.27	0.89	0.08
Standard Dev		0.09	0.004	0.14	0.005	58.5	277.24	0.44	0.06
N of cases	CNS2	11	8	4	8	12	12	12	12
Minimum		0.04	0.010	0.03	0.020	355	2420.00	0.20	0.02
Maximum		0.45	0.020	0.31	0.040	700	4070.00	1.19	0.20
Mean		0.13	0.011	0.11	0.028	418	2892.25	0.77	0.09
Standard Dev		0.12	0.004	0.13	0.006	97.0	507.65	0.29	0.05
N of cases	CNS3	9	7	3	5	12	12	12	11
Minimum		0.03	0.010	0.03	0.019	287	2210.00	0.13	0.03
Maximum		0.15	0.020	0.04	0.030	505	3300.00	1.28	0.20
Mean		0.09	0.011	0.03	0.023	395	2741.75	0.67	0.09
Standard Dev		0.05	0.004	0.01	0.005	54.3	379.04	0.37	0.06
N of cases	CNS4	12	8	7	8	12	12	11	12
Minimum		0.03	0.010	0.01	0.020	326	2120.00	0.19	0.04
Maximum		0.46	0.020	0.17	0.050	680	3610.00	1.60	0.25
Mean		0.14	0.014	0.05	0.030	412	2776.58	0.84	0.10
Standard Dev		0.11	0.005	0.06	0.010	98.3	441.12	0.45	0.06
N of cases	CNS5	9	8	3	2	12	12	12	11
Minimum		0.04	0.010	0.02	0.016	336	2260.00	0.12	0.04
Maximum		0.16	0.010	0.04	0.030	998	3770.00	1.93	0.18
Mean		0.08	0.010	0.03	0.023	435	2872.67	0.89	0.09
Standard Dev		0.04	0.0	0.01	0.010	182	450.63	0.57	0.05
N of cases	CNS6	10	7	5	6	12	12	11	12
Minimum		0.02	0.010	0.02	0.020	334	2110.00	0.48	0.03
Maximum		0.26	0.020	0.04	0.033	507	7140.00	3.04	0.17
Mean		0.11	0.011	0.03	0.027	388	3399.83	1.04	0.08
Standard Dev		0.08	0.004	0.01	0.006	46.0	1482.92	0.72	0.04

Table A-8. Descriptive statistics for organics measured at all Mosquito Lagoon water quality stations sorted by sample collection date.

Statistic	*Date*	*BOD*	*COD*	*CPA*	*G&O*	*PHE*	*TOC*
N of cases	910723	6	6	6	4	6	6
Minimum		1	493	4.7	0.86	59.80	1.87
Maximum		2	1330	16.0	2.71	114.00	2.54
Mean		1.8	671	10.5	2.07	87.95	2.09
Standard Dev		0.4	326	4.0	0.87	20.03	0.24
N of cases	910918	6	6	4	6	6	6
Minimum		2	355	10.7	0.71	66.00	0.93
Maximum		3	740	13.4	86.00	92.50	2.47
Mean		2.5	617	12.4	15.22	75.75	1.28
Standard Dev		0.6	137	1.3	34.68	9.23	0.60
N of cases	911120	6	6	4	5	6	6
Minimum		1	441	4.0	0.71	62.00	0.71
Maximum		2	834	8.0	1.71	104.00	2.22
Mean		1.5	620	6.4	1.43	89.98	0.98
Standard Dev		0.6	142	1.7	0.44	14.67	0.61
N of cases	920203	6	6	3	3	6	6
Minimum		1	510	3.3	0.71	98.70	1.24
Maximum		3	870	6.7	1.86	138.00	2.16
Mean		2	690	4.4	1.19	117.95	1.45
Standard Dev		0.6	127	2.0	0.60	13.17	0.36
N of cases	920302	6	6	5	5	6	6
Minimum		1	541	2.7	1.14	91.40	2.57
Maximum		2	823	4.7	1.57	166.00	3.26
Mean		1.5	639	3.7	1.34	125.90	2.82
Standard Dev		0.6	109	0.8	0.19	25.44	0.29
N of cases	920505	6	6	1	0	6	6
Minimum		1	1350	12.0	.	46.70	2.40
Maximum		2	3510	12.0	.	158.00	4.98
Mean		1.3	2340	12.0	.	102.23	3.66
Standard Dev		0.5	795	.	.	45.39	1.03
N of cases	920727	6	6	6	2	6	6
Minimum		4	860	9.3	0.52	74.30	2.29
Maximum		5	9300	53.4	0.71	399.00	2.95
Mean		4.8	2647	21.1	0.62	137.37	2.58
Standard Dev		0.4	3273	16.3	0.13	128.37	0.29
N of cases	920922	5	6	4	6	6	6
Minimum		2	400	10.7	0.83	58.90	0.63
Maximum		2	1540	22.7	2.93	113.00	1.53
Mean		2.0	837	14.7	1.92	76.82	0.90
Standard Dev		0.0	478	5.7	0.92	19.36	0.33

Table A-8 (continued.). Descriptive statistics for organics measured at all Mosquito Lagoon water quality stations sorted by sample collection date.

Statistic	*Date*	*BOD*	*COD*	*CPA*	*G&O*	*PHE*	*TOC*
N of cases	921116	5	5	5	2	5	5
Minimum		5	690	8.0	0.74	143.00	0.40
Maximum		7	830	18.7	1.03	160.00	0.58
Mean		5.8	764	11.7	0.89	156.60	0.47
Standard Dev		1.1	56	4.4	0.21	7.60	0.07
N of cases	930119	6	6	5	6	0	6
Minimum		1	660	5.3	0.81	.	11.10
Maximum		4	830	10.7	3.00	.	20.80
Mean		2.3	747	7.5	1.97	.	13.48
Standard Dev		1.0	58	2.4	0.77	.	3.63
N of cases	930331	0	6	4	3	6	6
Minimum		.	550	6.7	0.75	43.80	0.33
Maximum		.	7700	10.7	1.21	160.00	1.50
Mean		.	2253	9.0	0.96	89.90	0.62
Standard Dev		.	2803	2.0	0.23	42.36	0.44
N of cases	930616	6	6	3	5	6	6
Minimum		1	540	5.3	1.26	65.80	0.24
Maximum		4	950	6.7	2.30	250.00	1.70
Mean		2.2	817	5.8	1.89	171.98	0.83
Standard Dev		1.0	145	0.8	0.38	78.82	0.54

Table A-9. Descriptive statistics for organics measured at each Mosquito Lagoon water quality station for all sample collection dates.

Statistic	*Station*	*BOD*	*COD*	*CPA*	*G&O*	*PHE*	*TOC*
N of cases	CNS1	10	11	7	6	10	11
Minimum		1	355	3.3	1.29	46.70	1.50
Maximum		5	9300	9.3	2.73	127.00	20.80
Mean		2.2	1697	6.1	1.97	79.61	4.19
Standard Dev		1.5	2620	2.2	0.56	21.99	5.60
N of cases	CNS2	10	12	7	7	11	12
Minimum		1	493	4.7	0.75	54.10	0.58
Maximum		5	7700	22.7	86.00	224.00	12.80
Mean		2.6	1483	12.8	13.62	110.76	2.62
Standard Dev		1.4	2000	6.1	31.93	51.51	3.40
N of cases	CNS3	11	12	11	10	11	12
Minimum		1	493	3.3	0.71	72.00	0.41
Maximum		5	1560	18.7	2.20	161.00	11.90
Mean		2.6	829	10.0	1.21	114.22	2.40
Standard Dev		1.4	338	6.1	0.49	31.65	3.22
N of cases	CNS4	11	12	7	8	11	12
Minimum		1	400	2.7	0.93	58.80	0.33
Maximum		7	3510	12.4	3.00	160.00	12.30
Mean		2.6	1054	10.2	1.78	98.28	2.32
Standard Dev		1.6	840	3.4	0.78	30.82	3.28
N of cases	CNS5	11	12	8	8	11	12
Minimum		1	480	5.3	0.71	58.90	0.41
Maximum		7	2850	53.4	2.71	399.00	12.00
Mean		2.5	1038	13.2	1.72	152.72	2.23
Standard Dev		1.9	770	16.4	0.69	98.25	3.19
N of cases	CNS6	11	12	10	8	11	12
Minimum		1	400	4.0	0.52	43.80	0.24
Maximum		5	1890	16.0	2.00	239.00	11.10
Mean		2.5	796	9.9	1.05	109.65	2.15
Standard Dev		1.3	444	3.9	0.49	51.53	2.97

Table A-10. Summary statistics for sediment quality samples collected for Mosquito Lagoon. All samples and stations combined. Samples are included only if values are above the method detection limits.

Parameter	*N of cases*	*Minimum*	*Maximum*	*Mean*	*Standard Dev*
AG mg/kg	10	.05	10.13	1.78	2.99
AL mg/kg	65	325	21166	4258	4267
B mg/kg	16	6.15	66.18	27.04	15.52
BE mg/kg	64	.03	2.04	.32	.36
CA mg/kg	65	1460	134000	24732	27619
CD mg/kg	51	.01	.80	.10	.12
CR mg/kg	65	.17	251.00	18.53	39.59
CU mg/kg	35	.26	59.00	5.95	10.98
FE mg/kg	65	349	253401	9039	31919
GO mg/kg	47	1.86	1280	243.9	312.1
K mg/kg	63	.24	5901.84	857.13	990.70
MG mg/kg	65	245	5828	1976	1240
MN mg/kg	65	4.17	97.90	21.78	15.31
NH4N mg/kg N	65	.73	47.79	11.03	11.92
NI mg/kg	46	.16	12.26	3.02	2.84
NO2 mg/kg	23	.01	1.76	.27	.38
NO3 mg/kg	30	.33	9.29	3.78	2.71
PB mg/kg	61	.11	11.24	3.58	2.66
PH pH units	65	6.82	8.58	7.75	.38
PHE ug/kg	34	.07	4766	271.4	819.7
PO4 mg/kg	11	.51	4.57	1.99	1.25
SO4 mg/kg	47	97	3511	1285	711
TKN mg/kg	65	6.46	1522.14	506.01	369.36
TOC mg/kg	65	189	53031	4355	8324
TP mg/kg	47	.61	1250	141	204
ZN mg/kg	61	2.15	74.20	14.07	12.66

Table A-11. Descriptive statistics for metals measured in sediment at all sampling stations sorted by sample collection date.

Statistic	*Date*	*AG*	*AL*	*B*	*BE*	*CA*	*CD*	*CR*	*CU*	*FE*	*K*	*MG*	*MN*	*NI*	*PB*	*ZN*
N of cases	910918	0	6	4	6	6	6	6	0	6	6	6	6	4	6	5
Minimum		.	325	23.80	0.033	1460	0.012	0.17	.	349	232	722	4.17	0.67	0.96	2.15
Maximum		.	4890	38.10	0.220	89300	0.110	13.00	.	5860	1760	4410	32.20	2.16	7.84	16.70
Mean		.	2562	33.05	0.119	28988	0.052	6.47	.	2826	917	2693	18.26	1.39	3.66	9.66
Standard Dev		.	1957	6.54	0.086	32140	0.034	5.51	.	2433	604	1639	12.30	0.65	3.04	6.03
N of cases	911120	0	6	0	6	6	4	6	0	6	6	6	6	6	6	5
Minimum		.	1660	.	0.130	1680	0.070	8.65	.	2120	622	337	15.40	0.97	2.62	5.15
Maximum		.	16900	.	1.130	134000	0.160	251.00	.	10200	3050	1560	54.30	5.50	10.40	27.50
Mean		.	6328	.	0.413	49830	0.103	56.49	.	4337	1404	805	35.03	2.46	5.60	16.61
Standard Dev		.	5478	.	0.359	58034	0.040	95.52	.	2987	879	538	14.82	1.61	3.67	10.51
N of cases	920203	1	6	1	6	6	6	6	0	6	6	6	6	5	6	5
Minimum		10.13	1083	34.32	0.112	2643	0.032	6.66	.	873	421	922	12.59	0.66	1.65	3.78
Maximum		10.13	10297	34.32	0.397	48204	0.166	182.24	.	7188	1847	3063	33.25	8.62	2.92	15.70
Mean		10.13	4078	34.32	0.210	14574	0.067	57.87	.	3185	832	1840	22.04	4.56	2.38	7.13
Standard Dev		.	3332	.	0.104	17791	0.049	71.10	.	2194	531	793	7.32	3.70	0.52	5.14
N of cases	920302	0	6	1	6	6	6	6	6	6	6	6	6	1	6	6
Minimum		.	577	24.06	0.079	2678	0.028	4.19	0.62	742	291	843	6.13	1.23	1.14	2.30
Maximum		.	5362	24.06	0.322	75302	0.085	15.90	14.00	5984.	1448	2789	25.47	1.23	5.35	14.83
Mean		.	1835	24.06	0.142	18813	0.047	6.84	3.69	2208	585	1329	11.65	1.23	2.00	5.08
Standard Dev		.	1770	.	0.092	28362	0.020	4.56	5.08	1937	434	758	7.10	.	1.65	4.81
N of cases	920505	0	6	1	6	6	6	6	0	6	6	6	6	3	6	5
Minimum		.	611	7.31	0.046	3235	0.041	4.81	.	1927	362	881	6.16	0.62	1.05	5.21
Maximum		.	18197	7.31	0.329	33123	0.255	65.82	.	253401	5902	4082	49.66	5.44	8.95	26.36
Mean		.	7183	7.31	0.170	14040	0.105	19.79	.	54497	1667	2330	23.53	2.24	4.45	13.54
Standard Dev		.	5948	.	0.108	13371	0.079	23.11	.	99953	2115	1113	14.27	2.77	2.98	8.40
N of cases	920727	0	6	0	6	6	6	6	0	6	6	6	6	3	6	6
Minimum		.	923	.	0.050	1636	0.050	3.14	.	823	247	833	6.27	2.50	1.35	6.17
Maximum		.	21166	.	1.632	64358	0.280	62.01	.	32914	4289	5828	97.90	12.26	11.24	24.24
Mean		.	5913	.	0.402	19212	0.101	16.18	.	7503	1291	2850	28.09	6.08	4.39	13.40
Standard Dev		.	7658	.	0.608	23304	0.090	22.70	.	12528	1522	2019	35.08	5.37	3.64	6.73

Table A-11 (continued). Descriptive statistics for metals measured in sediment at all sampling stations sorted by sample collection date.

Statistic	*Date*	*AG*	*AL*	*B*	*BE*	*CA*	*CD*	*CR*	*CU*	*FE*	*K*	*MG*	*MN*	*NI*	*PB*	*ZN*
N of cases	920922	0	6	3	6	6	5	6	6	6	6	6	6	6	6	6
Minimum		.	795	26.46	0.053	7354	0.028	2.42	4.76	712	195	676	9.26	1.52	1.09	4.77
Maximum		.	14625	66.18	0.622	87682	0.117	28.70	59.00	18318	2450	3876	48.63	10.82	6.18	26.02
Mean		.	5281	40.81	0.239	33900	0.058	10.49	20.64	5292	841	2001	21.96	5.27	3.01	12.97
Standard Dev		.	5138	22.03	0.206	28447	0.035	9.70	21.44	6585	835	1181	14.42	3.68	2.02	9.61
N of cases	921116	0	5	1	5	5	5	5	5	5	5	5	5	5	5	5
Minimum		.	637	28.30	0.110	3690	0.030	1.19	0.39	767	0.240	603	5.59	1.61	1.26	2.51
Maximum		.	7790	28.30	0.810	43800	0.100	7.09	2.72	13000	1.520	4140	34.80	6.47	7.06	17.10
Mean		.	4545	28.30	0.472	23784	0.068	4.46	1.69	5997	0.924	2337	19.32	4.02	4.19	10.05
Standard Dev		.	3593	.	0.342	18414	0.026	2.96	1.11	5207	0.614	1505	12.93	2.25	2.75	6.54
N of cases	930119	2	6	3	6	6	4	6	6	6	6	6	6	6	6	6
Minimum		0.05	570	6.15	0.160	4756	0.050	2.96	2.16	985	97.14	245	5.48	1.16	1.52	4.40
Maximum		0.08	7272	41.24	0.710	77934	0.280	13.79	8.52	16219	1446	3263	47.75	1.84	9.28	17.72
Mean		0.07	3750	21.77	0.392	21307	0.182	8.01	4.16	5508	708	1916	20.26	1.38	4.15	10.49
Standard Dev		0.02	2525	17.86	0.205	28002	0.101	4.45	2.66	5703	552	1203	14.50	0.28	2.74	5.08
N of cases	930331	1	6	2	5	6	2	6	6	6	4	6	6	2	5	6
Minimum		0.12	535	8.24	0.240	4496	0.150	1.72	1.53	1173	81.54	518	9.68	0.88	0.84	5.88
Maximum		0.12	7829	10.52	2.040	39081	0.320	14.40	6.20	8474	1085	3292	29.85	1.11	6.36	21.56
Mean		0.12	3722	9.38	0.818	23589	0.235	7.18	3.49	4525	642	1903	19.35	1.00	2.94	11.72
Standard Dev		.	2819	1.61	0.744	13519	0.120	5.06	1.92	2920	416	1148	7.34	0.16	2.08	6.14
N of cases	930616	6	6	0	6	6	1	6	6	6	6	6	6	5	3	6
Minimum		1.00	860	.	0.090	3720	0.800	5.88	0.26	1260	40.10	1491	11.64	0.16	0.11	25.04
Maximum		1.36	3314	.	0.520	49660	0.800	10.76	3.80	5084	672	2554	31.12	2.24	3.40	74.20
Mean		1.24	1690	.	0.268	23856	0.800	7.73	1.35	3046	327	1797	19.65	1.48	1.64	41.95
Standard Dev		0.13	894	.	0.140	15405	.	1.97	1.53	1718	262	423	8.10	0.89	1.66	18.03

Table A-12. Descriptive statistics for metals measured in sediment at each sampling station for all sample collection dates.

Statistic	*Station*	*AG*	*AL*	*BE*	*B*	*CA*	*CD*	*CR*	*CU*	*FE*	*K*	*MG*	*MN*	*NI*	*PB*	*ZN*
N of cases	CNS1	1	10	10	4	10	8	10	5	10	9	10	10	7	8	10
Minimum		1.24	860	0.08	6.15	19481	0.028	3.41	0.62	1105	287	1515	10.48	0.67	1.14	2.99
Maximum		1.24	5932	0.40	33.10	134000	0.280	28.78	12.11	4030	5902	4358	44.60	4.95	10.20	50.28
Mean		1.24	2950	0.20	19.32	53313	0.093	9.89	3.83	2149	1258	2555	20.14	2.79	3.28	11.68
Standard Dev		.	1903	0.10	14.09	37427	0.080	8.94	4.69	964	1786	886	9.93	1.38	2.98	13.93
N of cases	CNS2	1	11	11	3	11	6	11	6	11	11	11	11	8	10	11
Minimum		1.24	1137	0.09	10.52	2643	0.035	4.48	0.28	1203	1.52	337	6.13	0.92	1.23	2.97
Maximum		1.24	7790	0.81	26.46	34719	0.100	12.89	6.38	7940	1126	4140	34.80	6.47	6.25	28.92
Mean		1.24	3668	0.28	20.26	17697	0.059	7.94	2.87	3323	568.47	1974	17.71	2.22	3.14	11.08
Standard Dev		.	2087	0.20	8.54	13197	0.023	2.85	1.99	1922	352.25	1102	8.33	1.89	1.47	7.33
N of cases	CNS3	3	11	10	4	11	8	11	6	11	11	11	11	9	11	11
Minimum		0.05	1152	0.07	7.31	1636	0.028	4.48	0.76	2230	1.31	845	8.11	0.16	1.40	3.72
Maximum		1.36	21166	1.63	66.18	43800	0.280	104.78	59	25340 1	4289	5828	97.90	12.26	11.24	38.04
Mean		0.51	7337	0.47	38.21	15010	0.109	29.02	11.47	32256	1085	2576	35.59	5.20	4.91	17.82
Standard Dev		0.74	7291	0.49	24.13	12826	0.101	33.58	23.30	73961	1294	1709	25.12	4.43	3.16	11.05
N of cases	CNS4	3	11	11	5	11	8	11	6	11	11	11	11	9	11	11
Minimum		0.08	3314	0.22	17.93	2863	0.012	6.88	2.72	4366	1.27	566	15.41	0.67	2.80	10.27
Maximum		10.13	16900	2.04	37.20	17592	0.166	251.00	33	10200	3050	4380	54.30	8.86	10.40	74.20
Mean		3.82	7426	0.61	28.36	9445	0.102	50.08	11.01	6633	1362	2843	27.76	3.64	6.23	23.44
Standard Dev		5.50	3720	0.54	7.76	5367	0.052	83.82	11.47	1712	761	953	10.02	3.28	2.37	17.55
N of cases	CNS5	1	11	11	0	11	11	11	6	11	10	11	11	5	11	8
Minimum		1.36	325	0.03	.	16484	0.030	0.17	0.26	349	0.28	245	4.17	1.24	0.11	2.30
Maximum		1.36	5790	0.33	.	113000	0.800	22.70	8.58	59181	1290	1531	40.20	3.76	3.46	25.04
Mean		1.36	1178	0.12	.	49009	0.152	5.08	4.10	6441	318	847	11.10	2.08	1.33	9.15
Standard Dev		.	1547	0.09	.	30672	0.231	6.17	3.920	17513	367	399	10.09	0.98	0.82	8.12

Table A-12 (continued). Descriptive statistics for metals measured in sediment at each sampling station for all sample collection dates.

N of cases	CNS6	1	11	11	0	11	10	11	6	11	11	11	11	8	10	10
Minimum		1.00	559	0.03	.	1460	0.030	1.33	0.28	709	0.24	510	4.27	0.62	1.16	2.15
Maximum		1.00	5797	1.01	.	30077	0.240	22.50	4.76	7138	1140	1706	35.60	2.20	4.20	35.20
Mean		1.00	2871	0.26	.	6517	0.081	8.40	2.08	2807	576	1115	18.23	1.44	2.35	9.28
Standard Dev		.	1850	0.26	.	8209	0.065	5.95	1.62	1829	287	393	10.03	0.64	1.12	9.81

Table A-13. Descriptive statistics for inorganic and organic parameters measured in sediment at all sampling stations sorted by sample collection date.

Statistic	*Date*	*G&O*	*NH4-N*	*NO2*	*NO3*	*pH*	*PHE*	*PO4*	*SO4*	*TKN*	*TOC*	*TP*
N of cases	910918	6	6	30	6	6	6	5	6	6	6	6
Minimum		121.000	4.810	.	4.890	7.490	61.300	0.510	96.700	246.000	328.000	237.000
Maximum		582.000	25.700	.	7.170	8.300	334.000	4.570	1950.000	1360.000	2270.000	655.000
Mean		325.000	16.485	.	5.800	7.948	161.050	1.484	848.117	731.500	1210.000	352.167
Standard Dev		193.018	7.724	.	0.842	0.347	110.223	1.734	897.253	444.546	776.922	153.030
N of cases	911120	6	6	0	6	6	6	6	6	6	6	6
Minimum		1.860	5.700	.	4.730	7.680	23.900	1.980	782.000	211.000	189.000	7.600
Maximum		47.500	39.600	.	9.290	8.290	180.000	3.080	1870.000	1140.000	5700.000	93.700
Mean		20.610	21.015	.	6.195	7.898	76.333	2.413	1141.333	565.667	1337.833	30.533
Standard Dev		15.175	13.721	.	1.875	0.251	59.584	0.494	412.771	413.256	2153.750	32.583
N of cases	920203	6	6	3	5	6	6	0	6	6	6	6
Minimum		28.145	2.962	0.170	0.515	7.540	0.066	.	533.608	6.461	518.800	5.777
Maximum		84.034	6.164	1.760	1.354	8.130	0.169	.	1847.006	160.428	1913.900	264.919
Mean		63.377	4.768	0.753	0.968	7.840	0.106	.	1170.765	81.732	1137.983	115.918
Standard Dev		26.662	1.128	0.875	0.299	0.207	0.038	.	464.250	60.080	574.292	99.469
N of cases	920302	6	6	0	2	6	0	0	6	6	6	6
Minimum		590.015	4.188	.	0.756	6.820	.	.	374.480	19.970	293.500	0.605
Maximum		801.034	19.261	.	0.881	8.090	.	.	1190.252	883.721	731.300	195.973
Mean		723.239	11.049	.	0.818	7.775	.	.	787.795	353.508	487.333	45.263
Standard Dev		84.275	6.126	.	0.088	0.482	.	.	299.337	333.361	192.096	75.112
N of cases	920505	6	6	5	5	6	6	0	6	6	6	6
Minimum		5.405	1.189	0.160	0.333	7.800	0.081	.	1648.426	119.984	540.500	25.510
Maximum		26.954	8.184	0.200	1.013	8.580	0.152	.	2295.918	1267.007	53031.000	106.143
Mean		13.848	3.663	0.176	0.630	8.188	0.121	.	1894.443	522.867	18244.283	84.673
Standard Dev		7.221	2.400	0.017	0.296	0.265	0.029	.	224.459	404.348	18195.377	30.851
N of cases	920727	6	6	6	6	6	6	0	6	6	6	6
Minimum		7.937	8.469	0.210	3.764	7.220	84.442	.	798.036	181.703	1683.000	56.410
Maximum		48.527	47.786	0.770	7.496	7.930	909.091	.	3510.490	1522.145	29603.700	151.207
Mean		31.352	21.792	0.472	5.287	7.633	289.675	.	1523.375	534.498	10506.883	96.215
Standard Dev		16.971	16.310	0.213	1.531	0.255	315.371	.	1007.323	505.587	10141.132	34.562

Table A-13 (continued). Descriptive statistics for inorganic and organic parameters measured in sediment at all sampling stations sorted by sample collection date.

Statistic	*Date*	*G&O*	*NH4-N*	*NO2*	*NO3*	*pH*	*PHE*	*PO4*	*SO4*	*TKN*	*TOC*	*TP*
N of cases	920922	6	6	4	0	6	3	0	6	6	6	6
Minimum		73.126	0.731	0.010	.	7.480	144.180	.	676.093	91.005	1455.000	43.693
Maximum		231.788	21.770	0.050	.	7.760	4766.082	.	2138.940	685.393	18464.300	1250.000
Mean		154.106	4.852	0.030	.	7.580	1849.301	.	1173.156	353.708	7131.033	289.519
Standard Dev		67.443	8.317	0.016	.	0.097	2538.028	.	532.272	243.507	6533.043	475.272
N of cases	921116	5	5	5	0	5	1	0	5	5	5	5
Minimum		200.000	15.800	0.010	.	7.970	515.000	.	1220.000	9.780	900.000	47.200
Maximum		1280.000	47.100	0.080	.	8.440	515.000	.	3280.000	590.000	11200.000	155.000
Mean		695.000	30.860	0.036	.	8.234	515.000	.	1828.000	264.136	5700.000	108.620
Standard Dev		406.540	11.886	0.030	.	0.206	.	.	888.634	279.659	4666.369	46.371
N of cases	930119	0	6	0.	0	6	0	0	0	6	6	0
Minimum		.	1.560	.	.	6.920	.	.	.	368.000	471.600	.
Maximum		.	10.600	.	.	7.490	.	.	.	1117.000	1516.000	.
Mean		.	4.647	.	.	7.192	.	.	.	721.667	965.900	.
Standard Dev		.	4.257	.	.	0.194	.	.	.	250.755	368.266	.
N of cases	930331	0	6	0	0	6	0	0	0	6	6	0
Minimum		.	2.080	.	.	7.250	.	.	.	422.000	270.300	.
Maximum		.	4.520	.	.	7.680	.	.	.	1107.000	970.400	.
Mean		.	2.953	.	.	7.378	.	.	.	659.000	629.033	.
Standard Dev		.	1.062	.	.	0.160	.	.	.	240.569	252.150	.
N of cases	930616	0	6	0	0	6	0	0	0	6	6	0
Minimum		.	1.560	.	.	7.500	.	.	.	463.000	449.500	.
Maximum		.	4.440	.	.	7.740	.	.	.	1134.000	1263.000	.
Mean		.	2.560	.	.	7.620	.	.	.	737.500	772.967	.
Standard Dev		.	1.042	.	.	0.097	.	.	.	237.435	301.604	.

Table A-14. Descriptive statistics for inorganic and organic parameters measured in sediment at each sampling station for all sample collection dates.

Statistic	*Station*	*G&O*	*NH4-N*	*NO2*	*NO3*	*pH*	*PHE*	*PO4*	*SO4*	*TKN*	*TOC*	*TP*
N of cases	CNS1	7	10	3	5	10	6	2	7	10	10	7
Minimum		7.94	2.24	0.17	0.57	6.82	0.08	0.99	762	150	721	16.4
Maximum		779.2	39.60	0.48	7.69	8.16	909.1	3.00	1950	1040	11544	1250
Mean		223.6	14.78	0.28	3.88	7.56	284.2	2.00	1447	631	4339	281
Standard Dev		319.0	14.32	0.18	3.13	0.34	390.5	1.42	412.	286	4134	437
N of cases	CNS2	8	11	3	5	11	7	2	8	11	11	8
Minimum		1.86	1.06	0.01	0.33	7.28	0.13	0.72	116	41.9	343	33.8
Maximum		875.0	35.50	0.46	9.29	8.44	515.0	2.26	3280	666	53031	328
Mean		289.4	8.94	0.17	3.93	7.91	171.7	1.49	1133	349	6354	109
Standard Dev		347.1	10.25	0.25	3.70	0.35	183.6	1.09	989	247	15704	95.8
N of cases	CNS3	8	11	5	5	11	5	1	8	11	11	8
Minimum		13.61	0.73	0.05	0.85	6.92	0.07	2.09	114	71.2	230	5.78
Maximum		801.0	47.79	0.77	6.62	8.35	334.0	2.09	3510	1522	29604	264
Mean		253.4	12.28	0.29	3.83	7.78	118.6	2.09	1625	781	7226	57.6
Standard Dev		306.6	13.41	0.29	2.74	0.44	149.7	.	1081	462	10351	85.6
N of cases	CNS4	8	11	4	6	11	6	2	8	11	11	8
Minimum		11.41	1.17	0.03	0.38	7.08	0.15	2.07	1006	20.5	189	1.57
Maximum		1280	47.10	0.27	7.50	8.58	4766	4.57	1930	1140	15059	237
Mean		308.6	16.03	0.13	3.71	7.84	890.5	3.32	1469	728	4800	78.0
Standard Dev		451.8	14.47	0.11	3.24	0.52	1901	1.77	368	398	5475	78.3
N of cases	CNS5	8	11	4	4	11	5	2	8	11	11	8
Minimum		5.41	1.19	0.01	1.01	7.14	0.08	0.63	96.7	116	448	76.9
Maximum		798.7	32.20	1.76	4.89	8.10	85.00	3.08	1648	463	2635	655
Mean		225.9	6.90	0.54	3.63	7.67	42.51	1.86	906	284	965	217
Standard Dev		286.1	9.01	0.82	1.82	0.30	42.31	1.73	472	143	669	190
N of cases	CNS6	8	11	4	5	11	5	2	8	11	11	8
Minimum		21.60	1.67	0.01	0.76	7.24	0.08	0.51	534	6.46	270	0.605
Maximum		590.0	23.90	0.64	5.64	8.06	85.52	1.98	1870	635	11321	336
Mean		160.1	7.60	0.21	3.68	7.71	34.18	1.25	1147	275	2441	121
Standard Dev		190.3	8.38	0.29	2.57	0.26	38.08	1.04	513	231	3680	105

Table A-15. Results of bivariate Spearman Rank Correlation analyses between water quality sample variables for all stations and sample periods combined.

Parameter	*AG*	*AL*	*BE*	*B*	*BOD*	*CA*	*CD*	*COD*	*COL*	*CON*	*CPA*	*CR*	*CU*	*FE*	*GO*	*K*	*MG*	*NH4-N*
AG coeff																		
AG sig																		
AL coeff	-.4028																	
AL sig	.007																	
BE coeff	.3012	-.2527																
BE sig	.106	.233																
B coeff	.1976	.2976	-.0640															
B sig	.156	.022	.737															
BOD coeff	.0058	.1779	.2081	-.0543														
BOD sig	.967	.203	.270	.670														
CA coeff	.2052	.2826	.0726	.6302	.1322													
CA sig	.141	.030	.703	.000	.298													
CD coeff	.0810	.1712	.2807	-.1405	.0118	.2977												
CD sig	.624	.333	.194	.363	.941	.050												
COD coeff	.0730	.0999	.0930	.1770	.0446	.3370	.572											
COD sig	.604	.452	.625	.140	.726	.004	0											
COL coeff	-.1452	.3531	-.2001	.1569	.3033	.2060	-.3996	.1929										
COL sig	.304	.007	.298	.198	.016	.090	.008	.112										
CON coeff	.1128	.1307	.4150	.3751	.0483	.4399	.2728	.2887	.2445									
CON sig	.421	.324	.023	.001	.704	.000	.073	.015	.043									
CPA coeff	-.0501	.5178	-.1344	.1358	.4577	.4165	.125	.2327	.5384	.0568								
CPA sig	.765	.001	.583	.347	.002	.003	.488	.104	.000	.695								
CR coeff	.0854	.0260	.3567	.1331	-.0636	-.0724	.6208	.3719	-.4411	.1930	-.2551							
CR sig	.543	.867	.053	.337	.654	.603	0	.006	.001	.162	.117							
CU coeff	.1449	-.4250	.4201	-.2889	.4807	-.6124	.3735	-.4068	.1440	-.6232	-.6524	-.4144						
CU sig	.784	.168	.407	.316	.114	.020	.362	.149	.623	.017	.021	.355						

Table A-15 (continued). Results of bivariate Spearman Rank Correlation analyses between water quality sample variables for all stations and sample periods combined.

Parameter	*AG*	*AL*	*BE*	*B*	*BOD*	*CA*	*CD*	*COD*	*COL*	*CON*	*CPA*	*CR*	*CU*	*FE*	*GO*	*K*	*MG*	*NH4-N*
FE coeff	-.4090	.5249	-.0930	.3054	.0414	.0007	-.1471	.1148	.2342	-.0662	.1047	.1798	.1437					
FE sig	.007	.001	.651	.044	.794	.996	.438	.458	.126	.669	.575	.249	.734					
GO coeff	-.2678	-.1419	-.5121	.1847	-.2340	.0793	-.3525	.0417	-.0620	-.1720	-.3446	-.2855	-.4447	.0936				
GO sig	.132	.395	.015	.214	.131	.596	.052	.781	.683	.248	.037	.102	.147	.636				
K coeff	.0119	.1297	.2730	.0995	-.2588	.1988	.1481	.0789	-.0266	.0553	-.0043	.0895	.4632	.3106	-.2312			
K sig	.933	.328	.144	.409	.039	.097	.337	.513	.828	.647	.976	.520	.095	.040	.118			
MG coeff	.2198	-.0532	.3366	.3071	-.0536	.6394	.4888	.2982	.0387	.6209	-.0646	.1934	.4724	-.0938	.1140	.2698		
MG sig	.114	.689	.069	.009	.674	.000	.001	.012	.752	.000	.656	.161	.088	.545	.445	.023		
NH4-N coeff	-.3148	.0293	.0489	-.1965	-.1356	-.2743	-.2657	.4948	.3184	.0094	-.2004	-.1059	.5774	.3500	-.0458	.2561	-.0962	
NH4-N sig	.033	.840	.805	.129	.323	.032	.098	.000	.013	.943	.198	.479	.049	.027	.779	.046	.461	
NI coeff	.3542	-.0801	-.2048	.4367	-.5095	.4458	.571	.3275	-.4436	.5379	-.4378	.1729	-.6088	-.1053	-.1372	.6167	.5867	.0037
NI sig	.115	.752	.546	.030	.022	.038	.013	.137	.044	.010	.103	.442	.200	.658	.705	.002	.004	.989
NO2 coeff	.0779	.0859	.1152	-.1049	.4562	-.1163	.0542	.0046	.1981	-.0661	.1683	.2191	.	-.0857	-.1211	-.2531	-.2827	-.0194
NO2 sig	.662	.613	.649	.488	.002	.441	.78	.976	.192	.662	.357	.213	.	.671	.495	.090	.057	.911
NO3 coeff	-.3062	-.0748	.3087	-.1364	.0690	-.1268	-.1486	.2715	.2375	.0480	-.1227	-.0475	.0000	-.2145	.0427	-.2205	-.0063	.2935
NO3 sig	.137	.747	.457	.507	.738	.537	.569	.180	.243	.816	.577	.822	1.000	.378	.885	.272	.976	.174
PB coeff	.3933	-.1691	.1773	.1387	-.0912	-.1256	.1194	.3484	-.2765	.	-.0868	.2980	1.000	-.4185	.2267	-.6490	-.0290	-.3371
PB sig	.106	.516	.704	.571	.728	.609	.672	.144	.252	.	.778	.215	1.000	.136	.456	.003	.906	.171
PH coeff	.4277	-.3016	-.0707	.1665	-.3170	.2409	.4352	.1533	-.3406	.1605	-.2737	.2905	.8815	-.1092	-.0202	.1431	.2805	-.0758
PH sig	.001	.020	.710	.165	.011	.043	.003	.202	.004	.181	.054	.033	.000	.481	.893	.234	.018	.561
PHE coeff	.0148	-.2066	.3288	-.0496	.1895	-.0730	.2104	.1442	-.1842	.1357	-.3256	.2172	.2169	-.0812	.1395	.0287	.1625	-.2643
PHE sig	.916	.134	.076	.695	.154	.564	.176	.252	.148	.281	.029	.047	.606	.605	.384	.821	.196	.047
PO4 coeff	-.2018	.1593	.1020	-.0911	-.4924	.1077	-.3744	-.1286	.1925	-.0404	-.1374	-.2302	.0360	.1771	.5045	.1287	.2045	.4890
PO4 sig	.303	.418	.718	.614	.007	.551	.078	.476	.291	.823	.512	.230	.939	.408	.012	.475	.254	.010
SAL coeff	-.2387	.3549	-.2290	.6149	-.0045	.3908	-.1712	.1616	.2053	.3808	.1512	-.2215	-.8261	.1791	.2205	-.0317	.1283	-.2143
SAL sig	.085	.006	.224	.000	.972	.001	.266	.178	.091	.001	.295	.107	.000	.245	.136	.793	.286	.097

Table A-15 (continued). Results of bivariate Spearman Rank Correlation analyses between water quality sample variables for all stations and sample periods combined.

Parameter	*AG*	*AL*	*BE*	*B*	*BOD*	*CA*	*CD*	*COD*	*COL*	*CON*	*CPA*	*CR*	*CU*	*FE*	*GO*	*K*	*MG*	*NH4-N*
SI coeff	-.1493	.5906	-.2400	-.0349	.3384	.1045	.0187	.1890	.6314	-.0304	.6703	-.1269	.2286	.3544	.2417	-.0198	-.0973	.1887
SI sig	.371	.000	.322	.800	.017	.448	.914	.167	.000	.826	.000	.441	.499	.055	.162	.886	.480	.209
SO4 coeff	.0831	-.2745	.3826	-.0606	-.0615	-.2122	.3617	.0033	-.0806	.3803	-.2940	.3992	.5595	-.1562	-.2380	.1107	.1938	.1285
SO4 sig	.554	.035	.037	.616	.629	.076	.016	.978	.510	.001	.038	.003	.037	.311	.107	.358	.105	.324
TAK coeff	.0525	-.1315	.2664	-.1347	-.0568	-.0678	.1802	.1428	.0888	-.0569	-.0912	.1193	.6956	.0088	-.0446	.2220	.2195	.3689
TAK sig	.709	.321	.155	.263	.656	.574	.242	.235	.468	.637	.529	.390	.006	.955	.766	.063	.066	.003
TB coeff	-.1841	.4469	-.1750	.0265	.4605	.1028	-.2497	.2324	.7757	-.0322	.6598	-.3373	.3646	.3414	-.2496	.0056	-.1099	.2336
TB sig	.187	.000	.355	.827	.000	.393	.102	.051	.000	.790	.000	.013	.200	.023	.091	.963	.362	.070
TDS coeff	.3315	.1091	.2568	.4264	-.1601	.4575	.3592	.2019	.0988	.7228	-.0343	.3705	.6014	.1736	-.0917	.0810	.6011	.0818
TDS sig	.015	.411	.171	.000	.206	.000	.017	.091	.419	.000	.813	.006	.023	.260	.540	.502	.000	.531
TKN coeff	-.2590	.2764	-.1287	-.0555	.3747	.1088	-.1791	.0286	.3297	.0653	.5038	-.2561	.2783	.0606	-.0172	-.2243	-.1403	.1797
TKN sig	.061	.037	.498	.651	.002	.373	.251	.816	.006	.594	.000	.064	.357	.700	.910	.064	.250	.173
TOC coeff	.3506	-.0012	-.0200	.0223	-.2263	.1447	.6473	.1689	-.4091	-.0794	-.1708	.3158	-.6787	-.0588	.2291	.0557	1.000	-.0764
TOC sig	.010	.993	.916	.853	.072	.228	0	.159	.000	.510	.236	.020	.008	.705	.121	.644	.407	.558
TP coeff	-.2679	.2031	.1642	.1377	.2322	-.0671	.2723	.0723	.3747	.2052	.2446	-.0791	-.2307	.2218	-.0942	-.2354	-.1077	.0145
TP sig	.057	.130	.404	.259	.069	.584	.081	.555	.002	.091	.090	.577	.471	.158	.538	.052	.379	.913
TSS coeff	-.2085	.4882	.1375	.1872	.3361	.2413	.2628	.0064	.4626	.3990	.4391	.0350	.4860	.3119	.3762	.1550	.1510	.1235
TSS sig	.134	.000	.469	.118	.007	.043	.085	.958	.000	.001	.001	.802	.078	.039	.009	.197	.209	.343
ZN coeff	.3306	.0027	-.3964	.0788	.1053	-.1285	-.3883	.4361	.5397	-.4855	.3795	-.2341	1.0000	.1408	.0465	.2879	-.3904	.4653
ZN sig	.143	.991	.379	.690	.616	.515	.091	.020	.003	.009	.082	.294	.000	.603	.850	.137	.040	.017

Table A-15 (continued). Results of bivariate Spearman Rank Correlation analyses between water quality sample variables for all stations and sample periods combined.

Parameter	*NI*	*NO2*	*NO3*	*PB*	*PH*	*PHE*	*PO4*	*SAL*	*SI*	*SO4*	*TAK*	*TB*	*TDS*	*TKN*	*TOC*	*TP*	*TSS*
NO2 coeff	-.0892																
NO2 sig	.772																
NO3 coeff	-.4978	-.0648															
NO3 sig	.143	.805															
PB coeff	-.6156	.	.2338														
PB sig	.269	.	.516														
PH coeff	.5330	-.2783	-.1477	.4706													
PH sig	.011	.061	.471	.042													
PHE coeff	-.0816	.2937	-.3961	.1566	.0422												
PHE sig	.718	.066	.050	.522	.739												
PO4 coeff	.0451	-.4601	.1227	.2958	-.0887	-.3115											
PO4 sig	.878	.036	.663	.477	.623	.078											
SAL coeff	.3584	.1119	-.1378	.0645	-.2266	.1281	.1459										
SAL sig	.101	.459	.502	.793	.057	.309	.418										
SI coeff	-.5449	.0340	.1128	.2430	-.2139	-.2817	.0691	-.0069									
SI sig	.029	.839	.656	.447	.117	.050	.737	.960									
SO4 coeff	-.1207	.1687	-.1230	.1909	-.0178	.4511	-.1864	.0021	-.2913								
SO4 sig	.593	.262	.549	.434	.883	.000	.299	.986	.031								
TAK coeff	-.0982	-.2190	.1463	.4646	.2952	-.0260	.2658	-.3754	.0337	.0694							
TAK sig	.664	.144	.476	.045	.012	.837	.135	.001	.807	.565							
TB coeff	-.4662	.3351	.1830	.4367	-.3256	-.1351	-.0215	.0646	.7080	-.1908	.0766						
TB sig	.029	.023	.371	.062	.006	.283	.906	.593	.000	.111	.525						
TDS coeff	.6665	-.1026	-.1664	.1143	.2072	.1767	.0478	.2935	-.0165	.3604	.0447	-.0586					
TDS sig	.001	.497	.417	.641	.083	.159	.792	.013	.905	.002	.711	.627					
TKN coeff	-.4088	.1391	.2542	.1301	-.2579	-.1650	-.0164	.0574	.3656	-.1307	-.0280	.3351	.0096				

Table A-15 (continued). Results of bivariate Spearman Rank Correlation analyses between water quality sample variables for all stations and sample periods combined.

Parameter	*NI*	*NO2*	*NO3*	*PB*	*PH*	*PHE*	*PO4*	*SAL*	*SI*	*SO4*	*TAK*	*TB*	*TDS*	*TKN*	*TOC*	*TP*	*TSS*
TKN sig	.066	.357	.210	.607	.032	.196	.929	.640	.007	.284	.819	.005	.938				
TOC coeff	.4826	-.3351	-.2683	.3862	.4836	-.1412	.1445	-.2585	-.3042	-.0028	.1017	-.4179	.1795	-.2433			
TOC sig	.023	.023	.185	.102	.000	.262	.422	.029	.024	.982	.399	.000	.134	.044			
TP coeff	-.5665	.3800	.0086	.2716	-.3749	.1976	.0221	.4486	.2463	.1179	-.0629	.3368	.1300	.2326	.5470		
TP sig	.007	.009	.967	.276	.002	.121	.906	.000	.073	.335	.608	.005	.287	.058	.000		
TSS coeff	-.0034	.4952	-.1160	.0963	-.1977	.1785	.1638	.3843	.2813	.2841	-.0434	.4536	.3260	.3290	.2825	.4701	
TSS sig	.988	.000	.573	.695	.098	.155	.362	.001	.037	.016	.720	.000	.006	.006	.017	.000	
ZN coeff	-.3719	-.1227	-.2539	.3146	-.0328	-.4508	.0159	-.3865	.5122	-.3670	-.0175	.4940	-.2433	.0436	.0899	-.2187	.1192
ZN sig	.468	.606	.479	.346	.868	.021	.957	.042	.009	.055	.930	.008	.212	.829	.649	.264	.546

Table A-16. Results of bivariate Spearman Rank Correlation analyses between sediment sample variables for all stations and sample periods combined.

Parameter	*AG*	*AL*	*B*	*BE*	*CA*	*CD*	*CR*	*CU*	*FE*	*GO*	*K*	*MG*	*MN*
AG coeff													
AG sig													
AL coeff	-.2523												
AL sig	.482												
B coeff	-.5000	.2353											
B sig	.667	.380											
BE coeff	-.6234	.7218	.2474										
BE sig	.073	.000	.356										
CA coeff	.2462	-.1645	-.2029	-.0757									
CA sig	.493	.190	.451	.552									
CD coeff	.5000	.4318	-.5385	.4984	.0693								
CD sig	.667	.002	.071	.000	.629								
CR coeff	-.0862	.8093	.3088	.5787	-.2516	.3044							
CR sig	.813	.000	.244	.000	.043	.030							
CU coeff	-.5727	.4570	.6606	.3166	-.0228	.1176	.3709						
CU sig	.107	.006	.038	.068	.896	.593	.028						
FE coeff	-.3631	.8440	.2471	.7050	-.1877	.3447	.7418	.3621					
FE sig	.302	.000	.356	.000	.134	.013	.000	.033					
GO coeff	.	-.2454	-.1273	-.1106	.0489	-.3525	-.4100	-.4657	-.1968				
GO sig	.	.096	.709	.459	.744	.019	.004	.060	.185				
K coeff	-.1846	.6767	.6393	.4781	-.1806	.2372	.7668	.5407	.5205	-.4284			
K sig	.610	.000	.010	.000	.157	.097	.000	.001	.000	.003			
MG coeff	-.0677	.6227	.1735	.4058	.0296	.2229	.4284	.3004	.5682	.1038	.3900		
MG sig	.853	.000	.520	.001	.815	.116	.000	.079	.000	.487	.002		
MN coeff	-.0369	.8656	.4176	.6948	-.0796	.4293	.8344	.3142	.8184	-.2195	.6335	.5553	
MN sig	.919	.000	.107	.000	.528	.002	.000	.066	.000	.138	.000	.000	
NH4 coeff	-.3385	.2030	.3194	.0663	-.0634	-.1075	.1354	-.1395	.1014	.2177	.1848	.1855	.2064
NH4 sig	.339	.105	.228	.603	.616	.453	.282	.424	.421	.141	.147	.139	.099
NI coeff	.2530	.3221	.1473	.1350	.1629	.1405	.2466	.2636	.2307	.0428	.0128	.2316	.2276
NI sig	.545	.029	.615	.371	.279	.414	.098	.203	.123	.813	.933	.121	.128
NO3 coeff	.	-.1546	.6786	.0863	.2392	.0285	-.0839	1.0000	-.0483	.1671	.1497	-.0176	.0590
NO3 sig	.	.415	.094	.650	.203	.886	.659	1.000	.800	.378	.430	.927	.757
PB coeff	-.8108	.8812	.0607	.7228	-.1773	.3827	.7495	.4383	.7837	-.1967	.6190	.5799	.7806
PB sig	.027	.000	.830	.000	.172	.006	.000	.014	.000	.185	.000	.000	.000
PH coeff	.9355	.2525	.0927	-.0902	-.1158	-.0220	.1939	-.2409	.1809	.0231	.0400	.0672	.2023
PH sig	.000	.042	.733	.479	.359	.878	.122	.163	.0149	.878	.756	.595	.106
PHE coeff	.	.1413	.4524	.2297	.1939	.1534	-.1740	.8000	.1126	.3549	.1257	.3262	.0863
PHE sig	.	.425	.260	.191	.272	.410	.325	.200	.526	.039	.479	.060	.627
PO4 coeff	.	.6000	1.000	.6378	.2091	.3333	.7091	.	.6545	-.4273	.6818	-.0364	.5818
PO4 sig	.	.051	.000	.035	.537	.381	.015	.	.029	.190	.021	.915	.060
SO4 coeff	.	.5459	.1364	.3808	-.0194	.3960	.3328	.2206	.5324	-.2874	.2473	.4702	.4431
SO4 sig	.	.000	.689	.008	.897	.008	.022	.395	.000	.050	.094	.001	.002
TKN coeff	-.3877	.3721	-.0382	.4271	.1606	.3610	.2705	.1226	.4377	.-.0791	.3458	.4696	.4402
TKN sig	.268	.002	.888	.000	.201	.009	.029	.483	.000	.597	.006	.000	.000

Table A-16 (continued). Results of bivariate Spearman Rank Correlation analyses between sediment sample variables for all stations and sample periods combined.

Parameter	*AG*	*AL*	*B*	*BE*	*CA*	*CD*	*CR*	*CU*	*FE*	*GO*	*K*	*MG*	*MN*
TOC coeff	.2462	.4626	.3355	.1223	.1428	.2042	.2128	.3743	.2648	-.2334	.1957	.5773	.3106
TOC sig	.493	.000	.204	.336	.256	.151	.089	.027	.033	.114	.124	.000	.012
TP coeff	.	-.3366	.1091	-.3830	.2815	-.1983	-.4614	.1005	-.3681	.1131	-.2596	.1076	-.2842
TP sig	.	.021	.750	.008	.055	.197	.001	.701	.011	.449	.078	.472	.053
TSS coeff	-.1600	-.2242	.1853	-.5507	-.0513	-.6374	-.1450	.1465	-.3600	-.1277	-.0910	-.3908	-.3105
TSS sig	.659	.073	.492	.000	.685	.000	.249	.401	.003	.392	.478	.001	.012
ZN coeff	.3570	.4729	.2000	.4898	-.0547	.4830	.4629	.1637	.6023	-.3362	.2414	.4796	.5831
ZN sig	.311	.000	.458	.000	.676	.001	.000	.347	.000	.028	.065	.000	.000

Table A-16 (continued). Results of bivariate Spearman Rank Correlation analyses between sediment sample variables for all stations and sample periods combined.

Parameter	*NH4*	*NI*	*NO2*	*NO3*	*PB*	*PH*	*PHE*	*PO4*	*SO4*	*TKN*	*TOC*	*TP*	*TSS*
NI coeff	.1677												
NI sig	.265												
NO3 coeff	.7143	.1325	.6760										
NO3 sig	.000	.567	.016										
PB coeff	.3335	.2794	.1471	.1760									
PB sig	.009	.070	.503	.352									
PH coeff	.3846	.1510	-.2685	-.3723	.2002								
PH sig	.002	.317	.215	.043	.122								
PHE coeff	.5597	.3277	-.0724	.6902	.3070	-0.1096							
PHE sig	.001	.110	.782	.000	.077	0.537							
PO4 coeff	.3273	.3333	.	.2364	.6455	0.3273	.0273						
PO4 sig	.326	.381	.	.484	.032	0.326	.937						
SO4 coeff	.1643	.4013	.0986	-.0514	.4653	0.1596	-.0915	.2818					
SO4 sig	.270	.021	.654	.787	.001	0.284	.607	.401					
TKN coeff	.0917	-.0426	.2794	.3935	.5515	-0.1653	.4393	.4455	.2839				
TKN sig	.468	.779	.197	.031	.000	0.188	.009	.170	.053				
TOC coeff	.1678	.4421	.2170	-.0171	.4380	0.1638	.1488	.4328	.5737	.1696			
TOC sig	.182	.002	.320	.928	.000	0.192	.401	.184	.000	.177			
TP coeff	.0210	-.2473	.0699	.1776	-.2650	-0.0497	.1653	-.5604	-.0725	.0518	.1779		
TP sig	.888	.165	.751	.348	.072	0.74	.350	.073	.628	.729	.232		
TSS coeff	.2472	.1198	-.0391	-.2067	-.3474	0.4065	-.3530	.2636	-.4792	-.5855	.0935	.0956	
TSS sig	.047	.428	.859	.273	.006	0.001	.041	.433	.001	.000	.459	.523	
ZN coeff	-.0598	.0973	.1713	.1172	.5956	-0.0021	.3113	.4603	.4573	.5341	-.4645	-.1599	-.4645
ZN sig	.647	.525	.458	.560	.000	0.987	.094	.213	.002	.000	.000	.306	.000

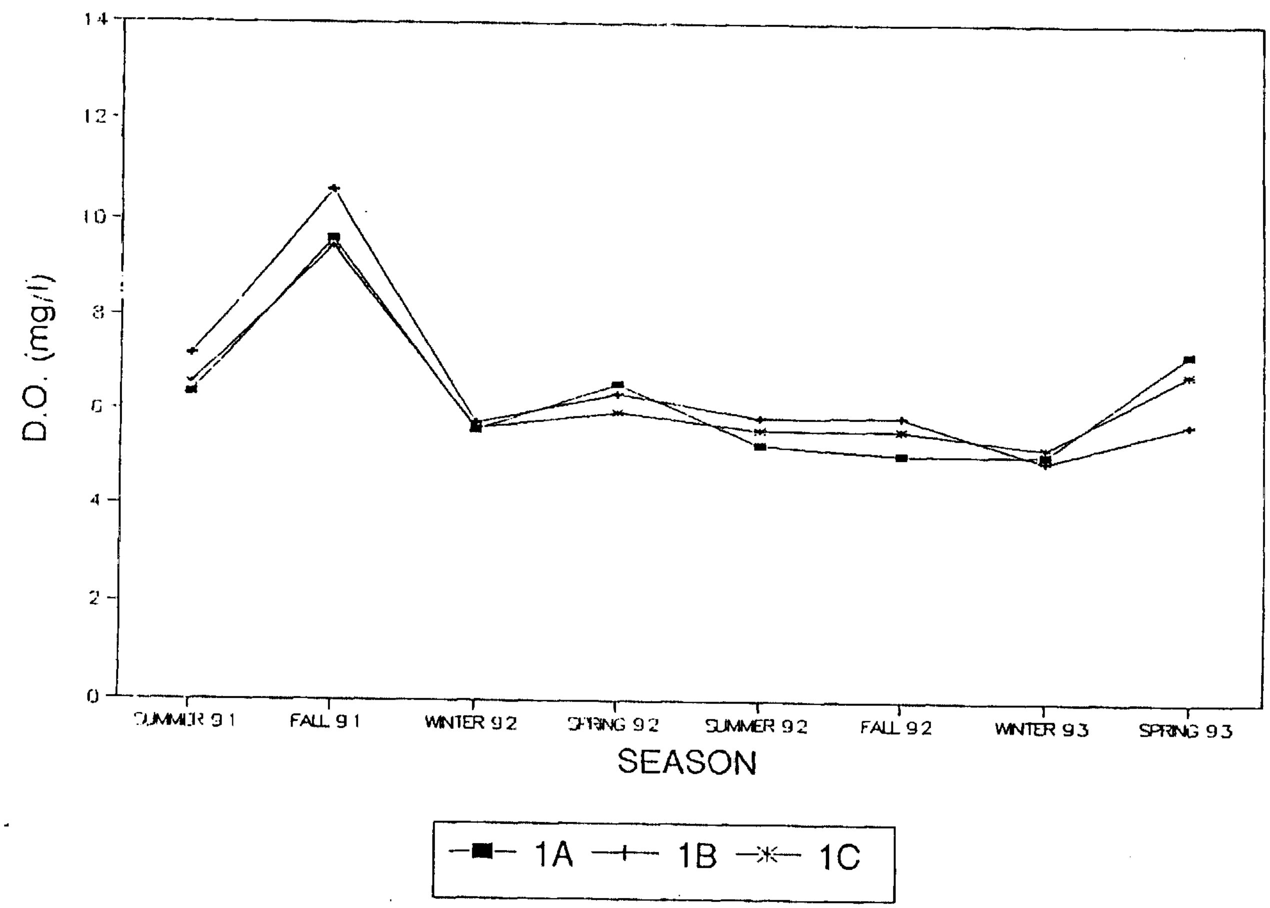


Figure A-1. Seasonal dissolved oxygen (mg/l) concentrations collected on Transect 1. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

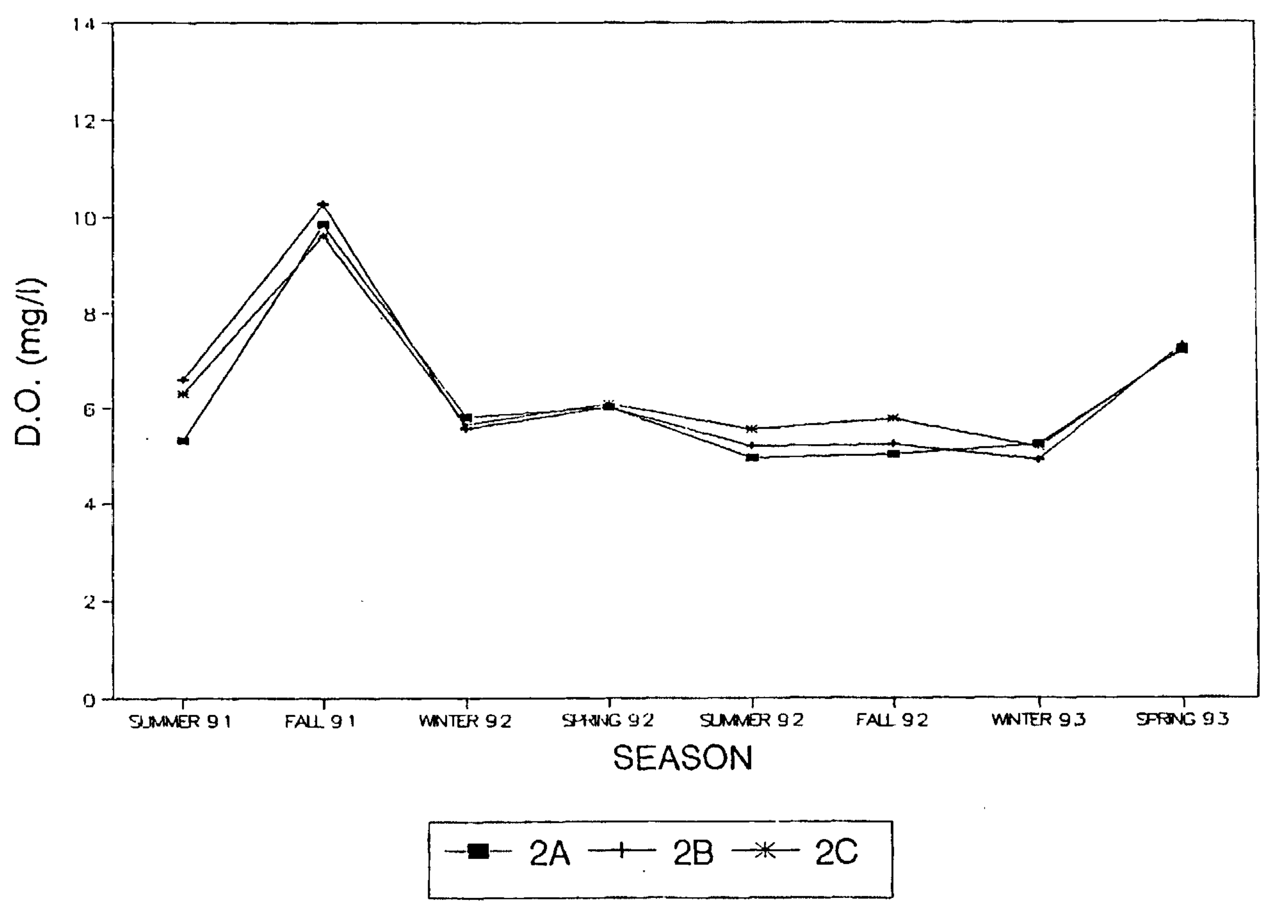


Figure A-2. Seasonal dissolved oxygen (mg/l) concentrations collected on Transect 2. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

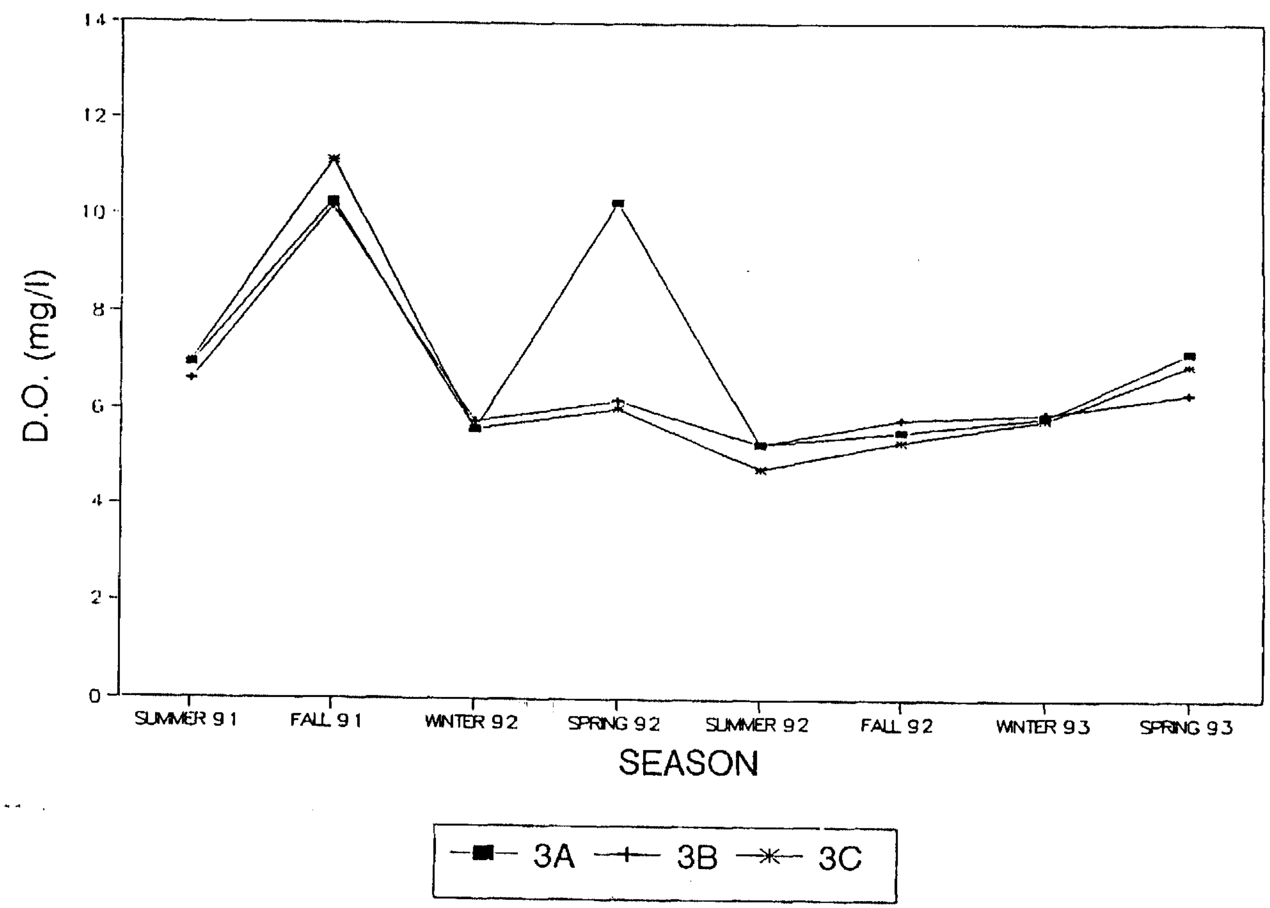


Figure A-3. Seasonal dissolved oxygen (mg/l) concentrations collected on Transect 3. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

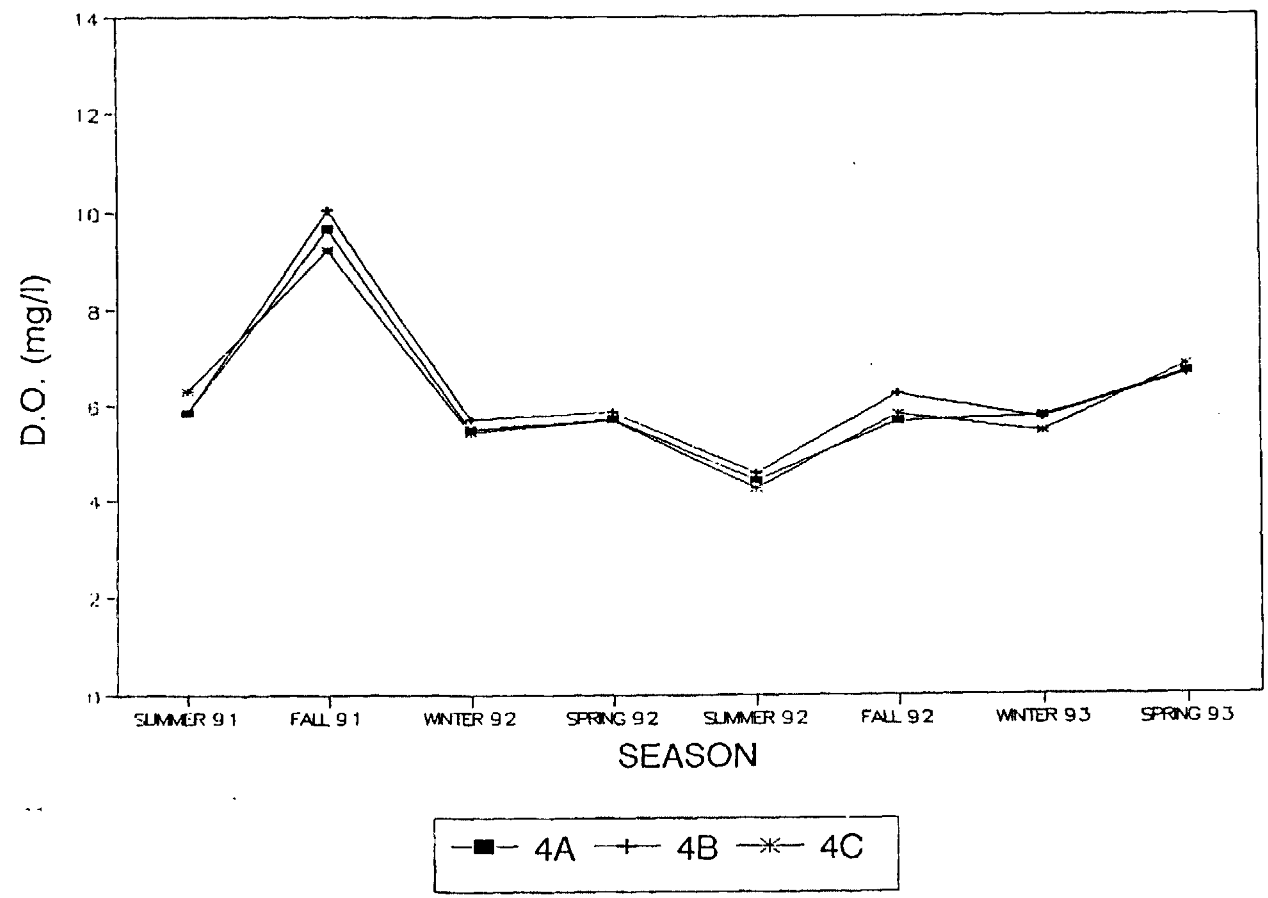


Figure A-4. Seasonal dissolved oxygen (mg/l) concentrations collected on Transect 4. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

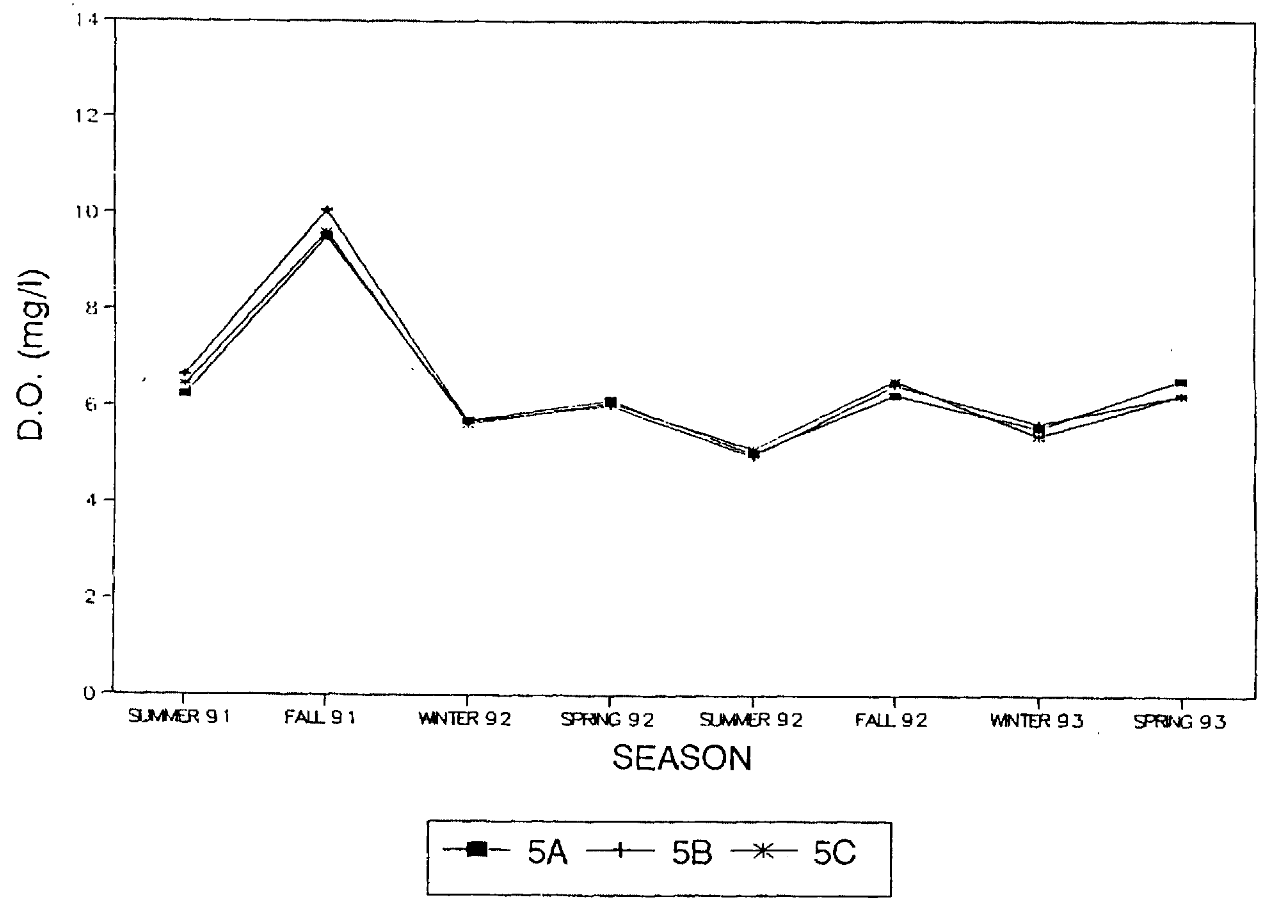


Figure A-5. Seasonal dissolved oxygen (mg/l) concentrations collected on Transect 5. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

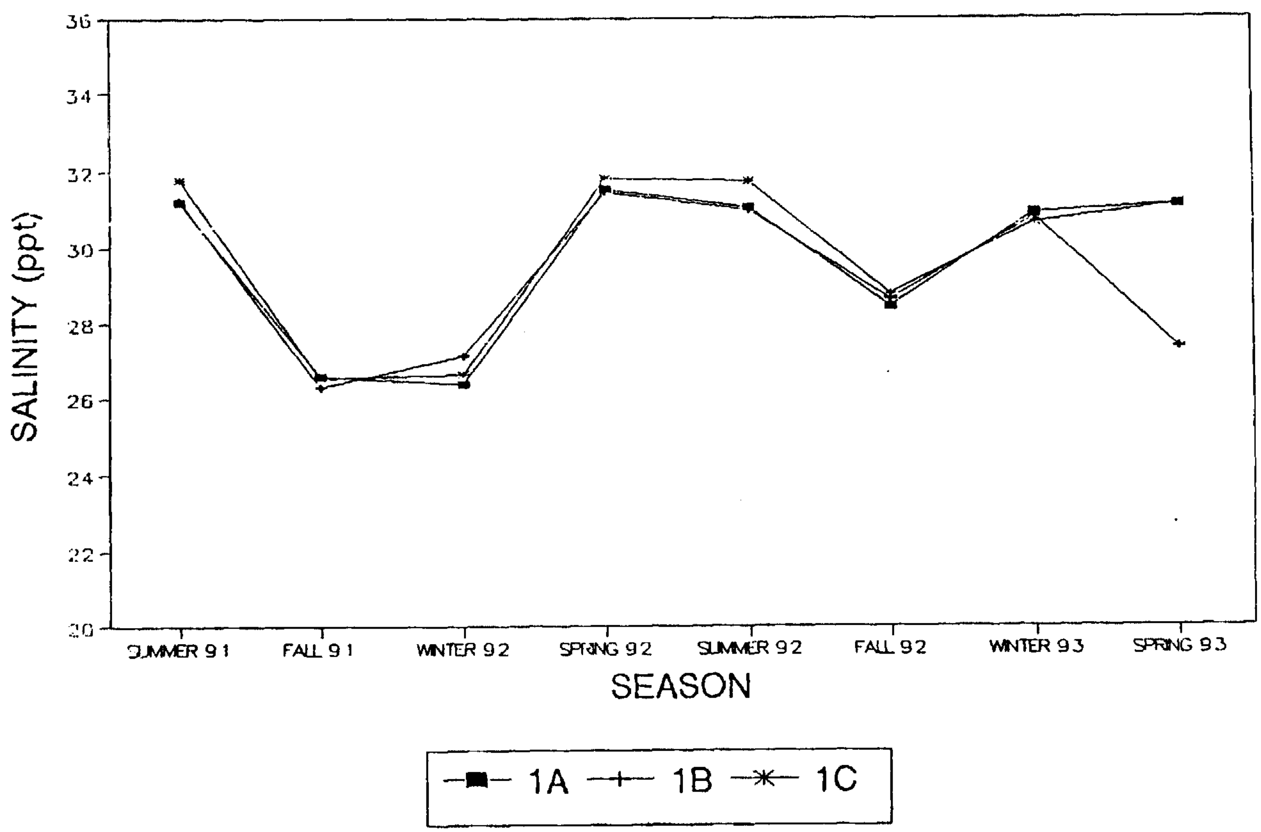


Figure A-6. Seasonal salinity (ppt) concentrations collected on Transect 1. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

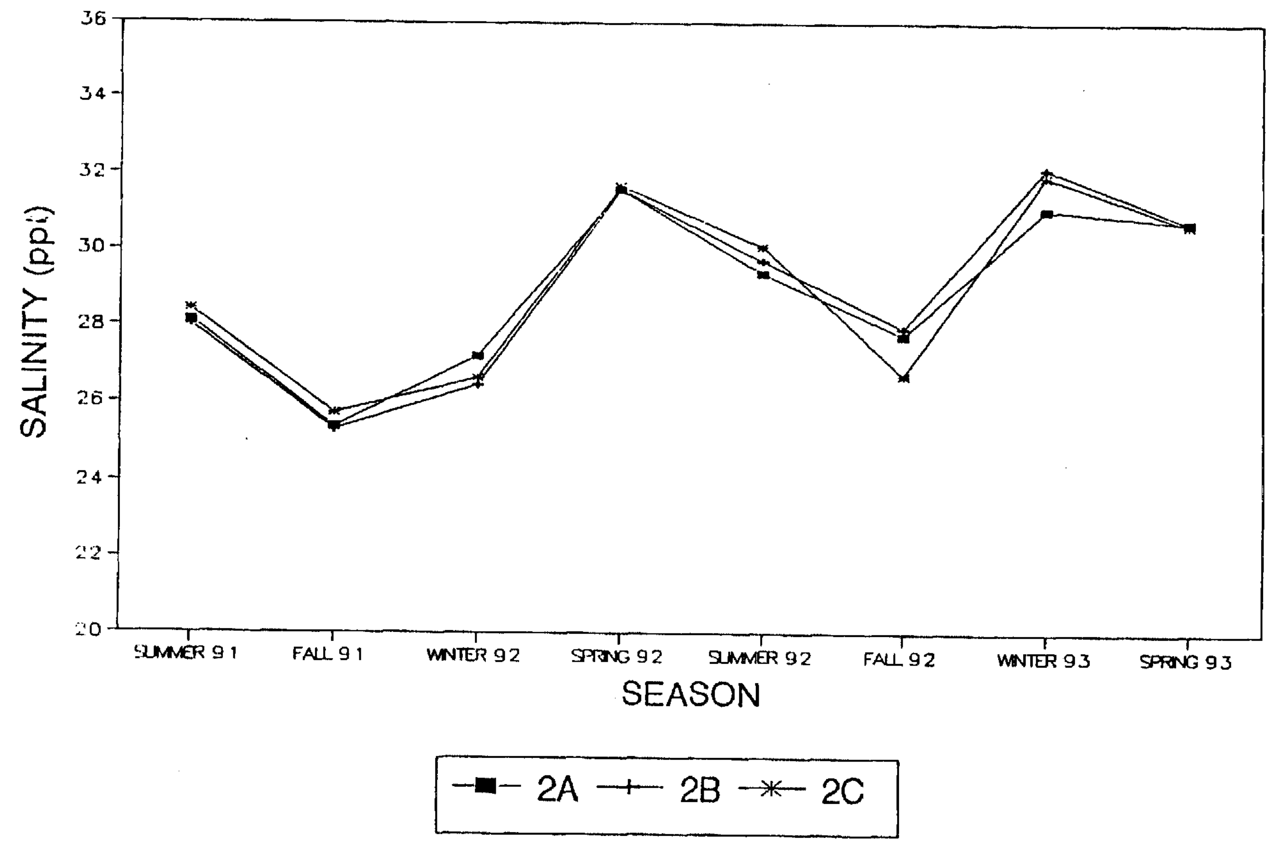


Figure A-7. Seasonal salinity (ppt) concentrations collected on Transect 2. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

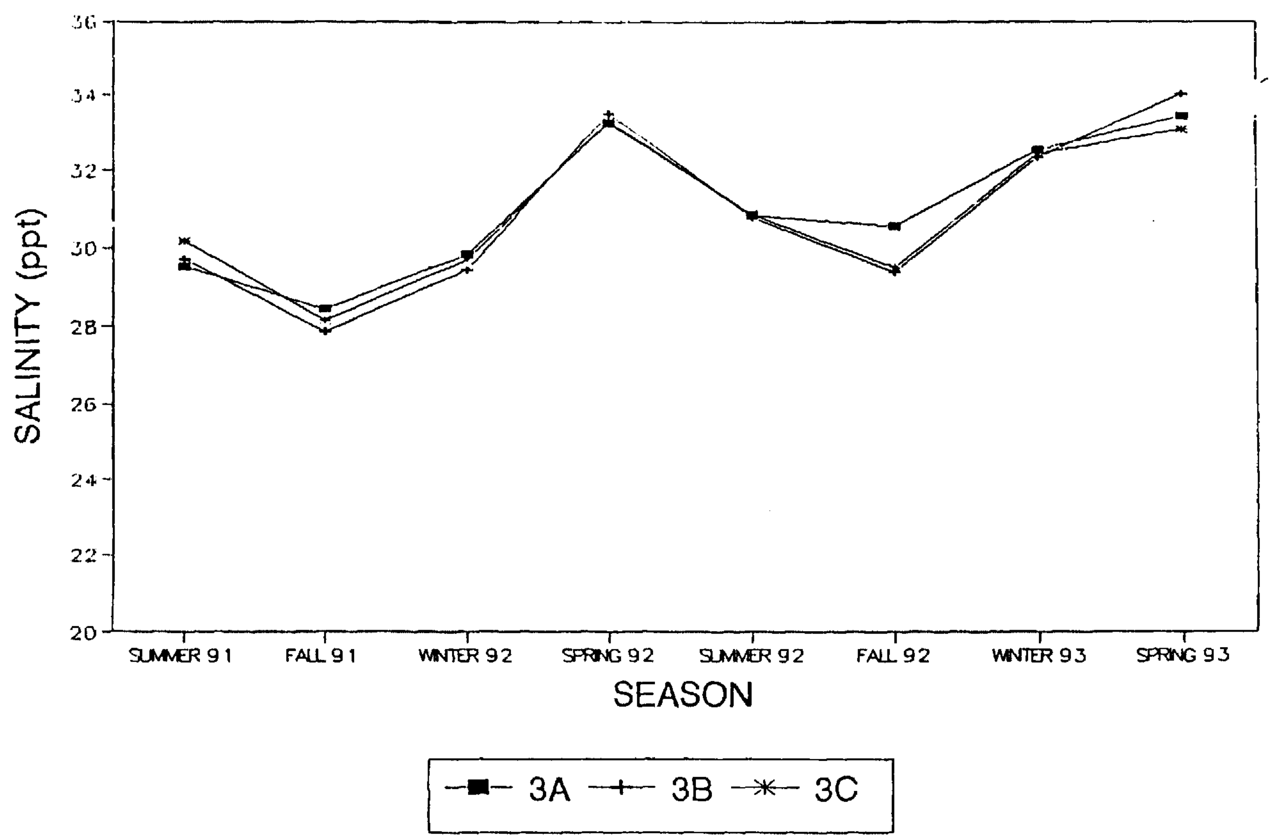


Figure A-8. Seasonal salinity (ppt) concentrations collected on Transect 3. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

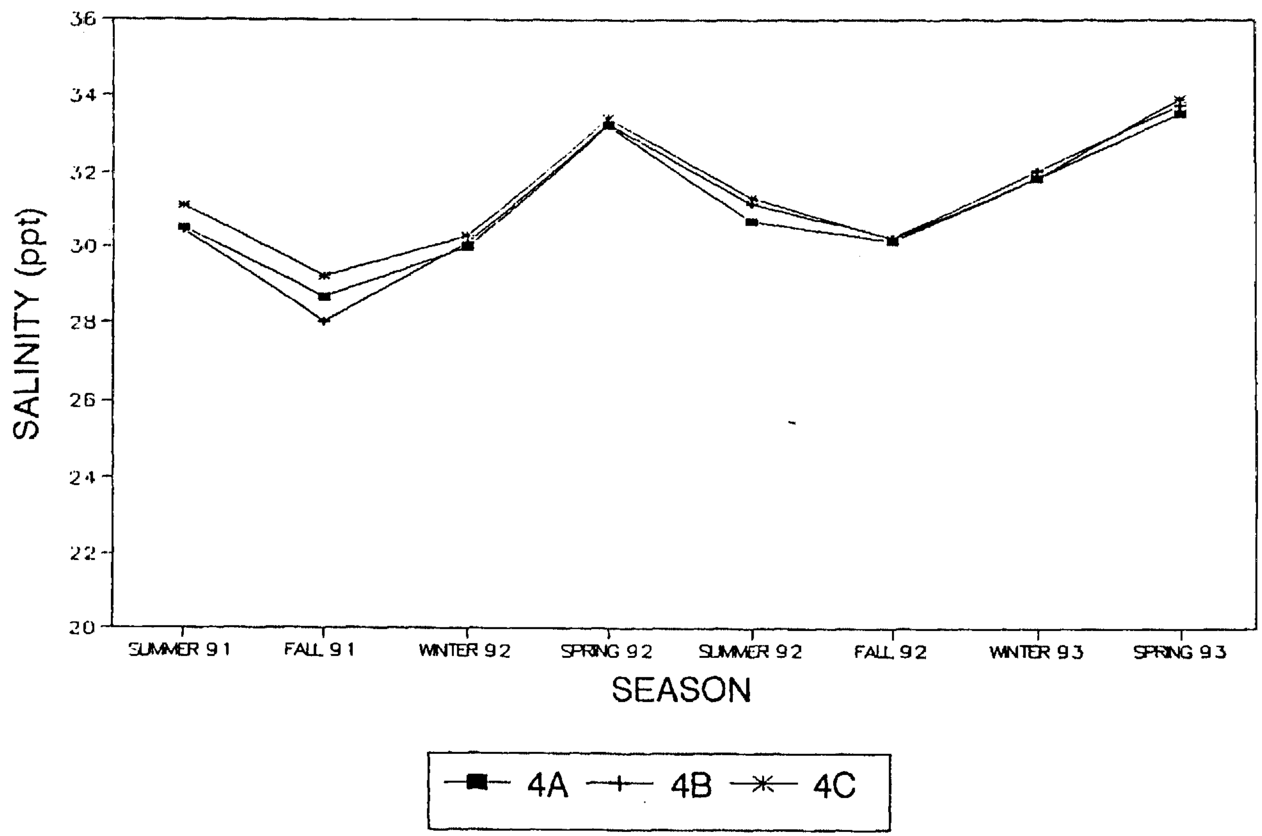


Figure A-9. Seasonal salinity (ppt) concentrations collected on Transect 4. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

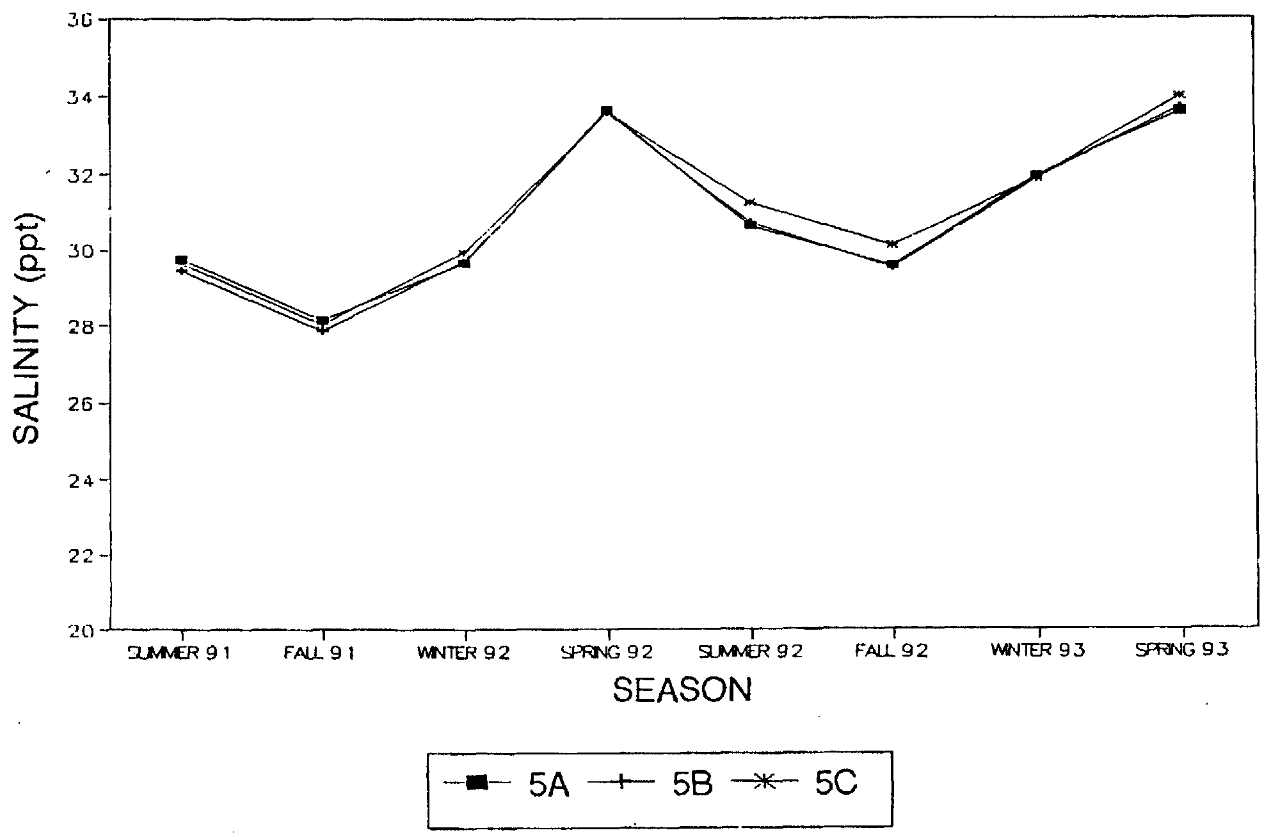


Figure A-10. Seasonal salinity (ppt) collected on Transect 5. Samples were collected between 10:00 and 14:00 h on clear days with relatively calm waters as part of an investigation into underwater light attenuation and seagrass bed distributions.

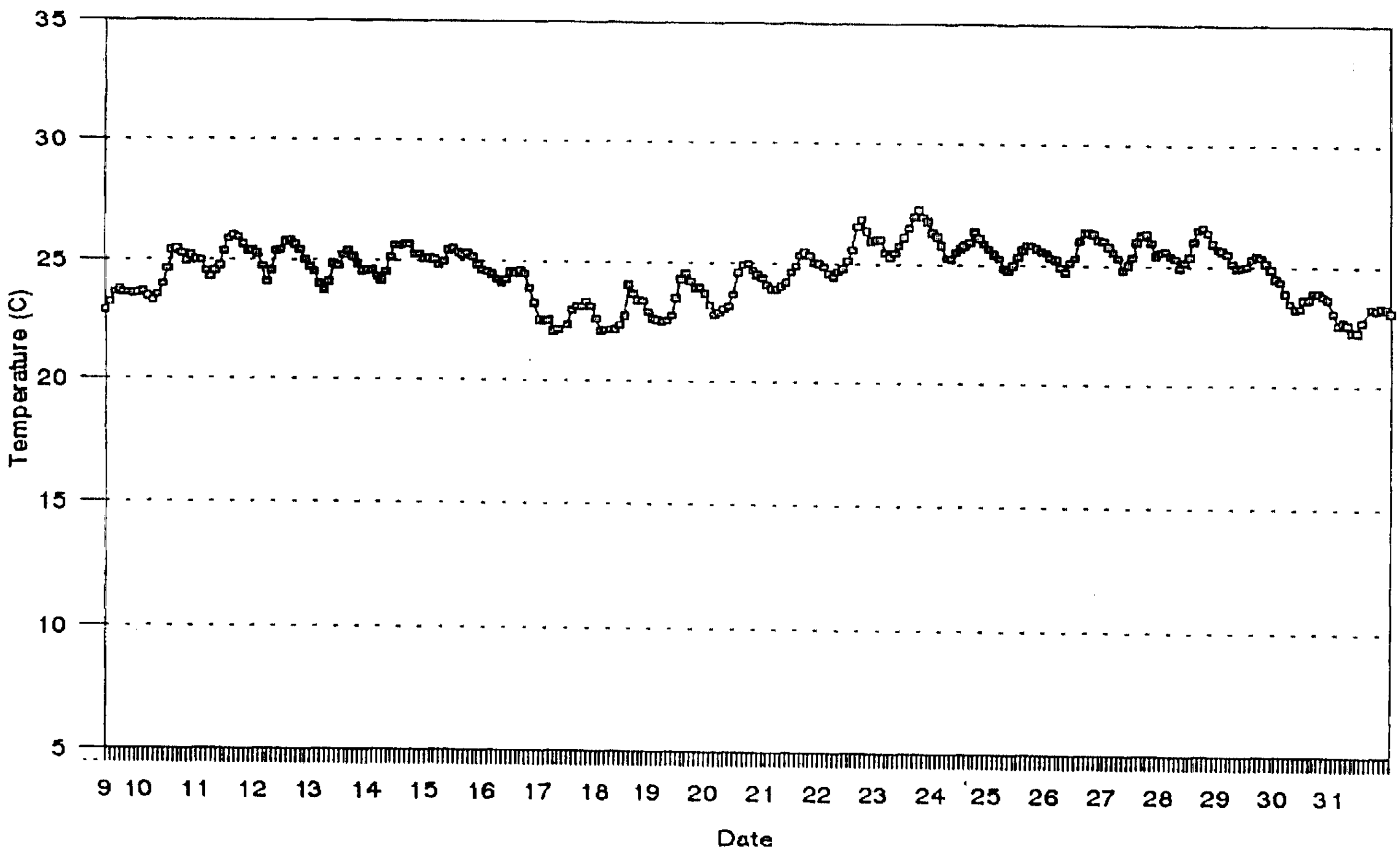


Figure A-11. October, 1991 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

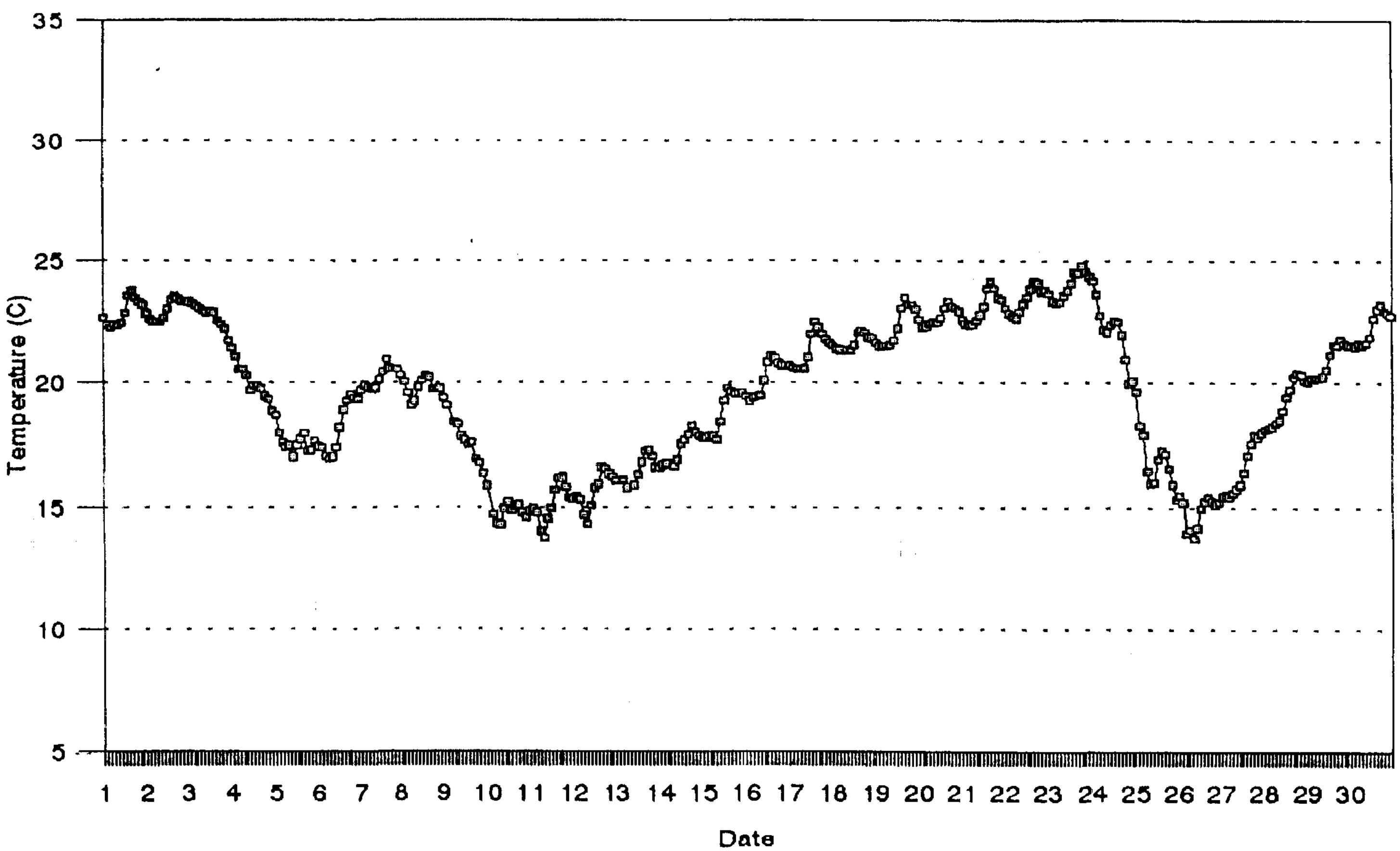


Figure A-12. November, 1991 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

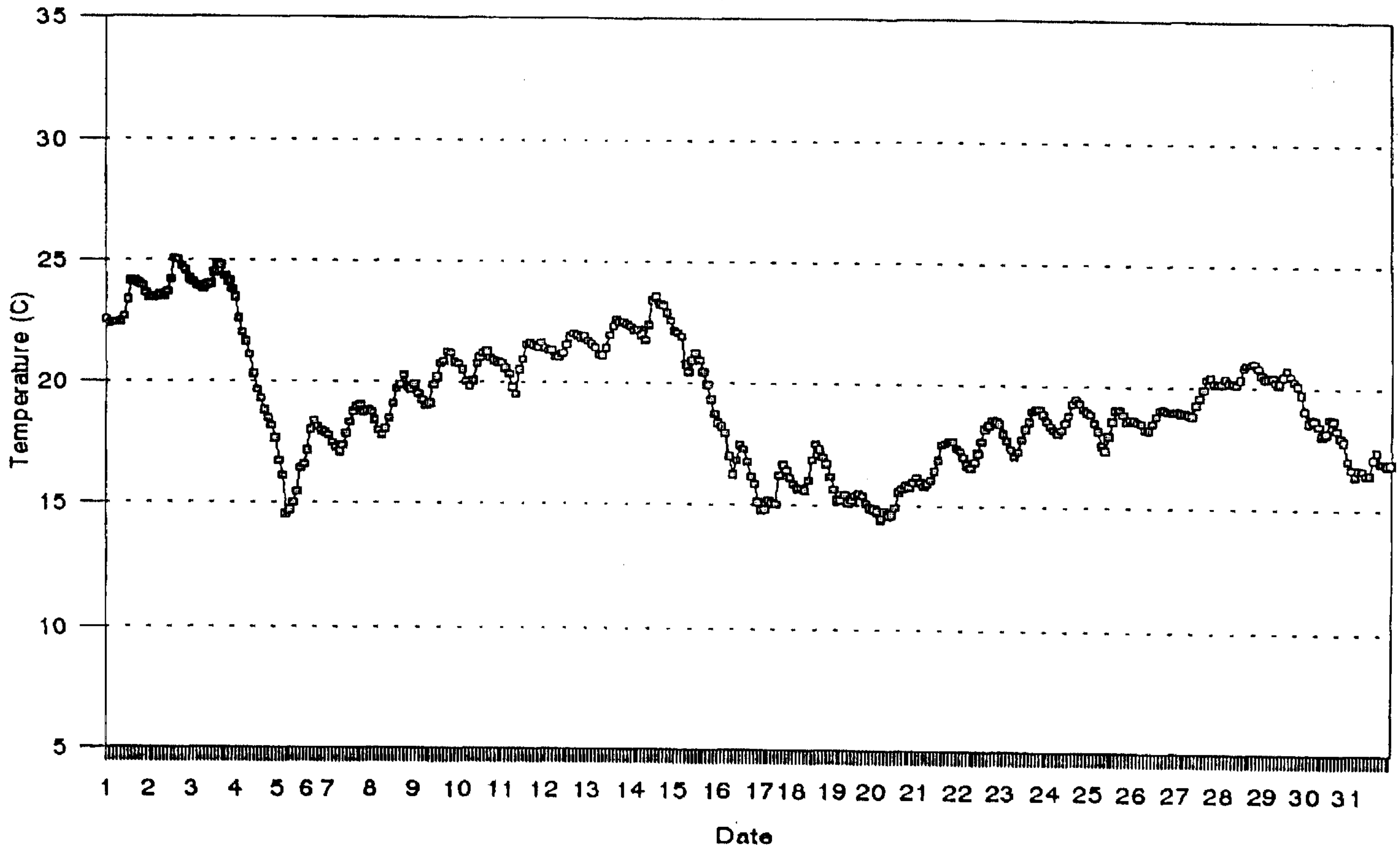


Figure A-13. December, 1991 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

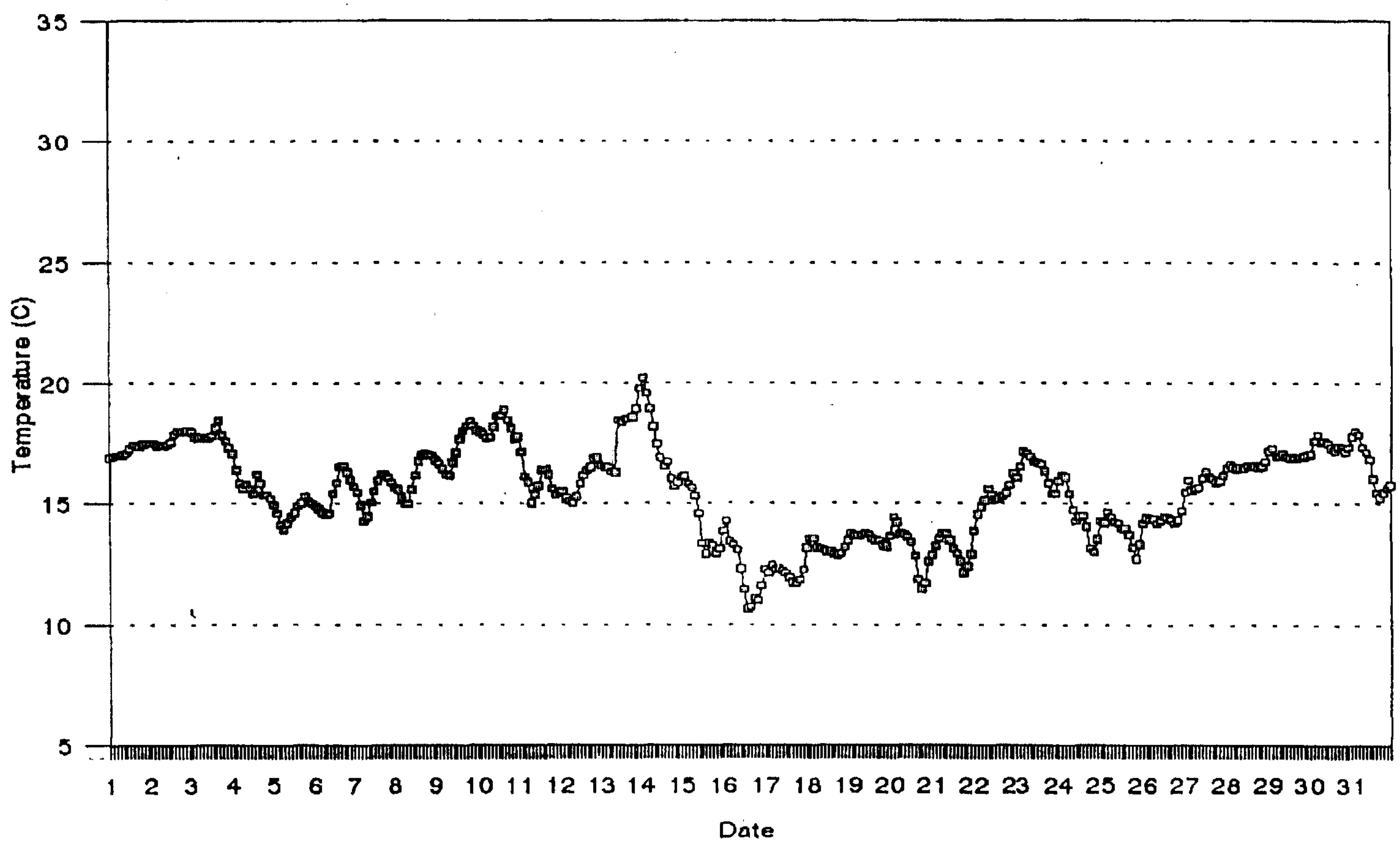


Figure A-14. January, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

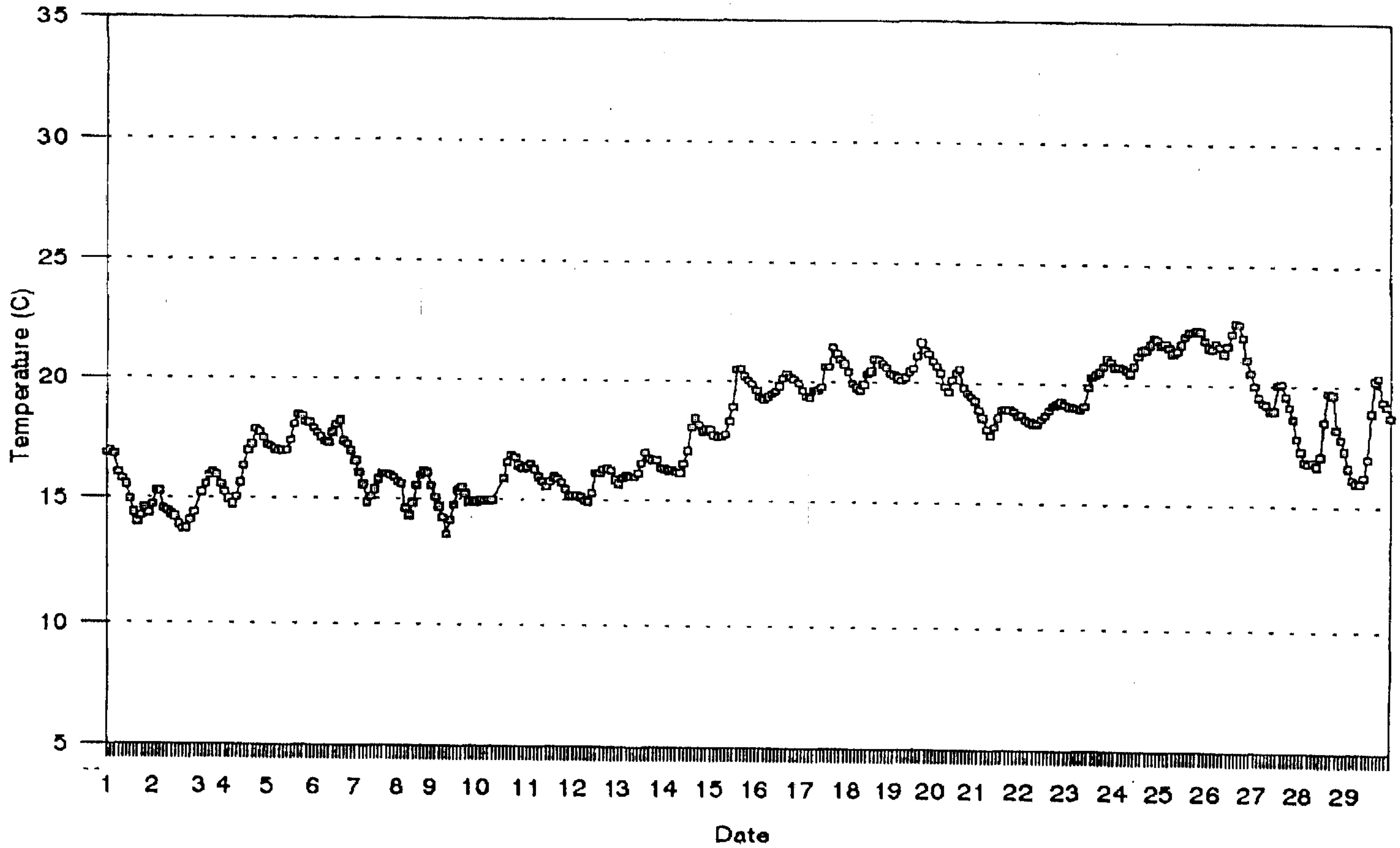


Figure A-15. Feburary, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

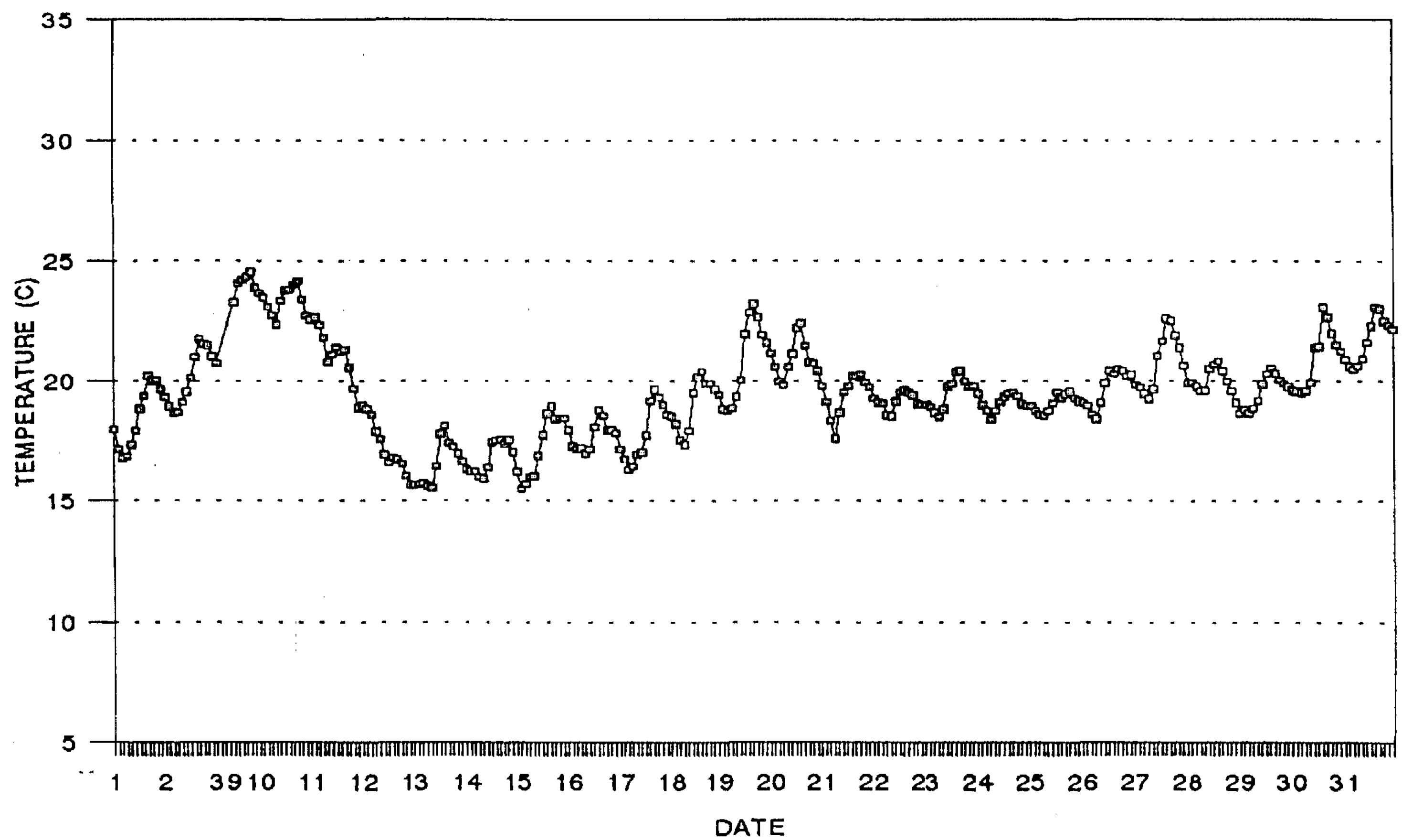


Figure A-16. March, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

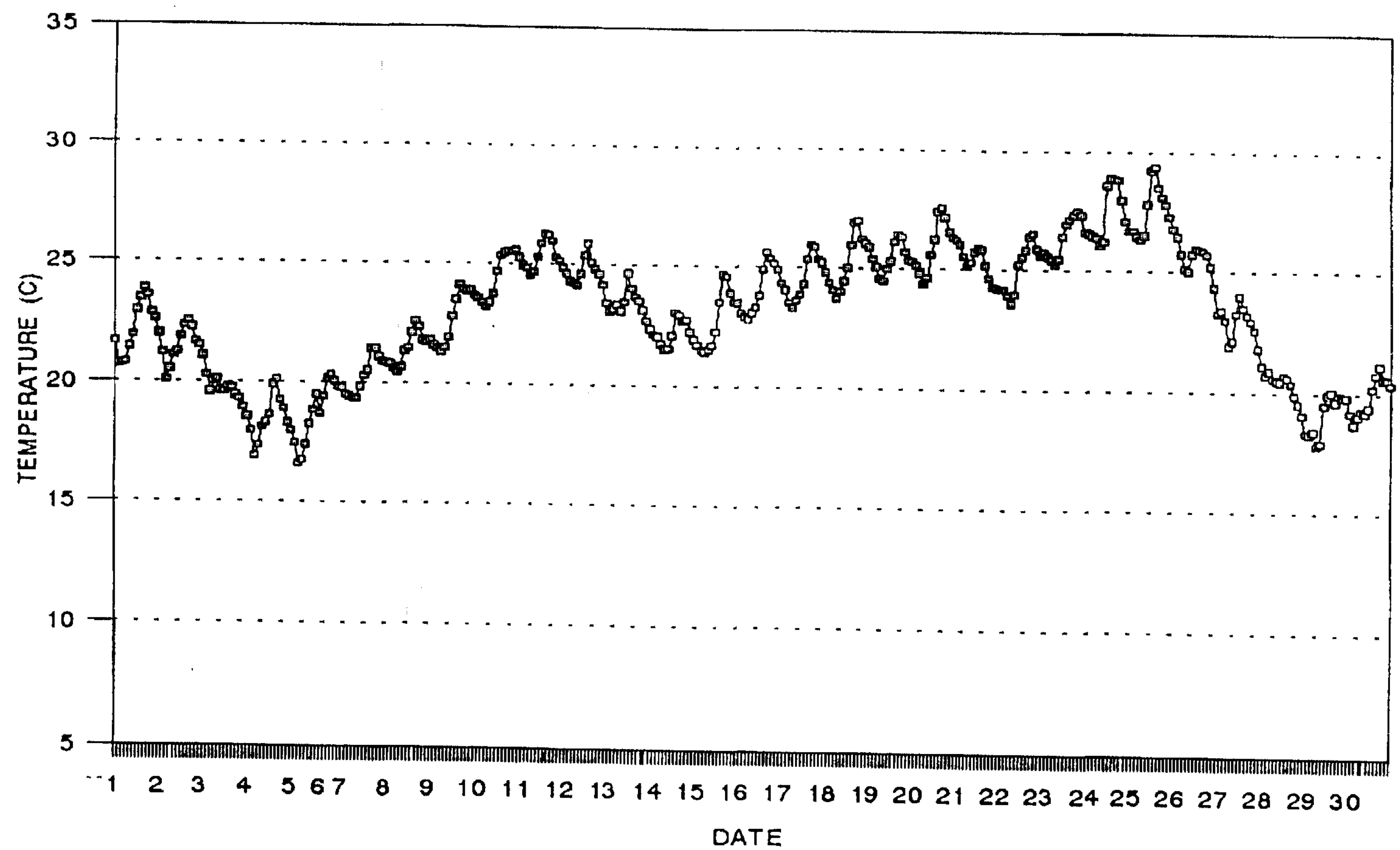


Figure A-17. April, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

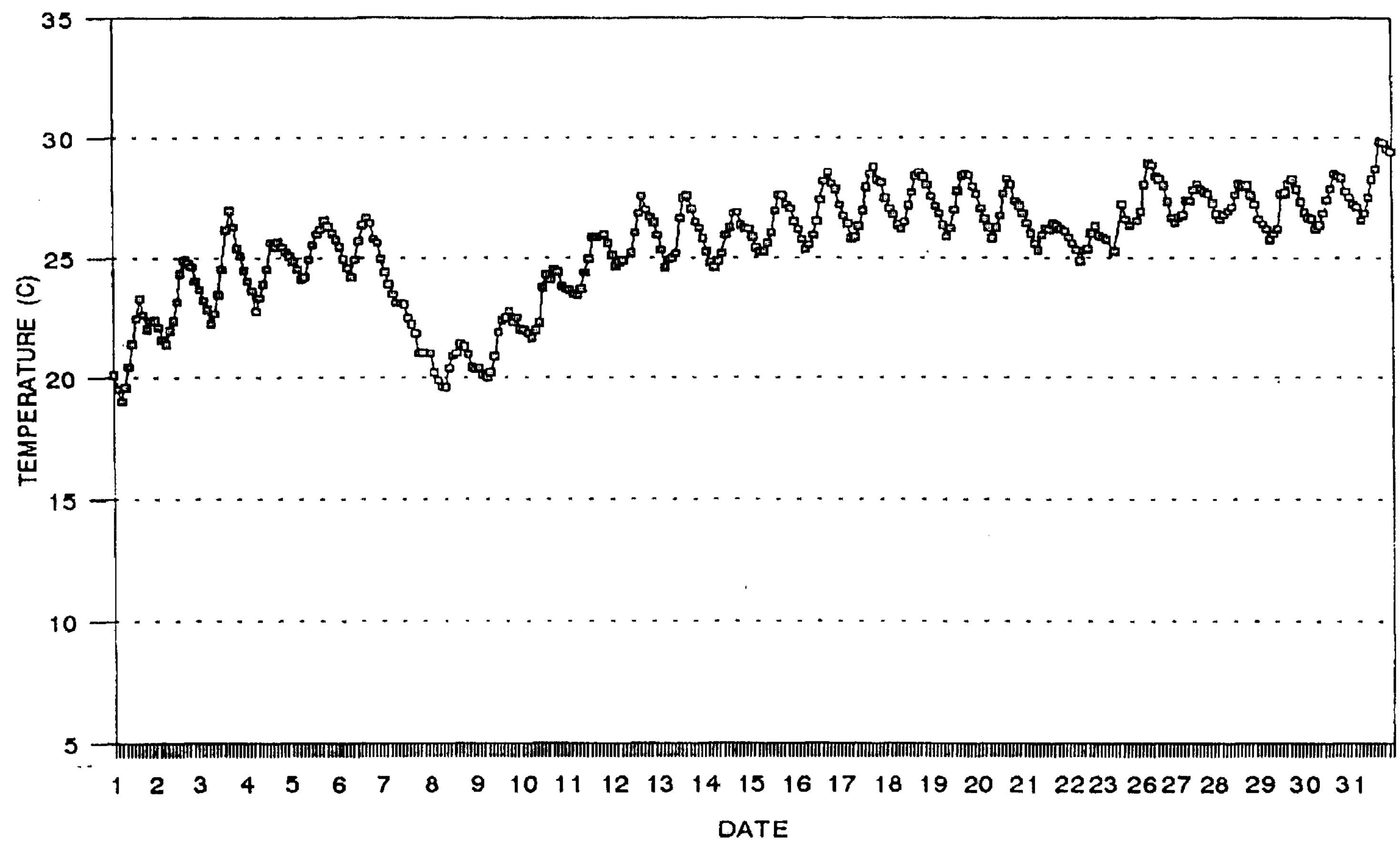


Figure A-18. May, 1992 bi-hourly water temperature (^{o}C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

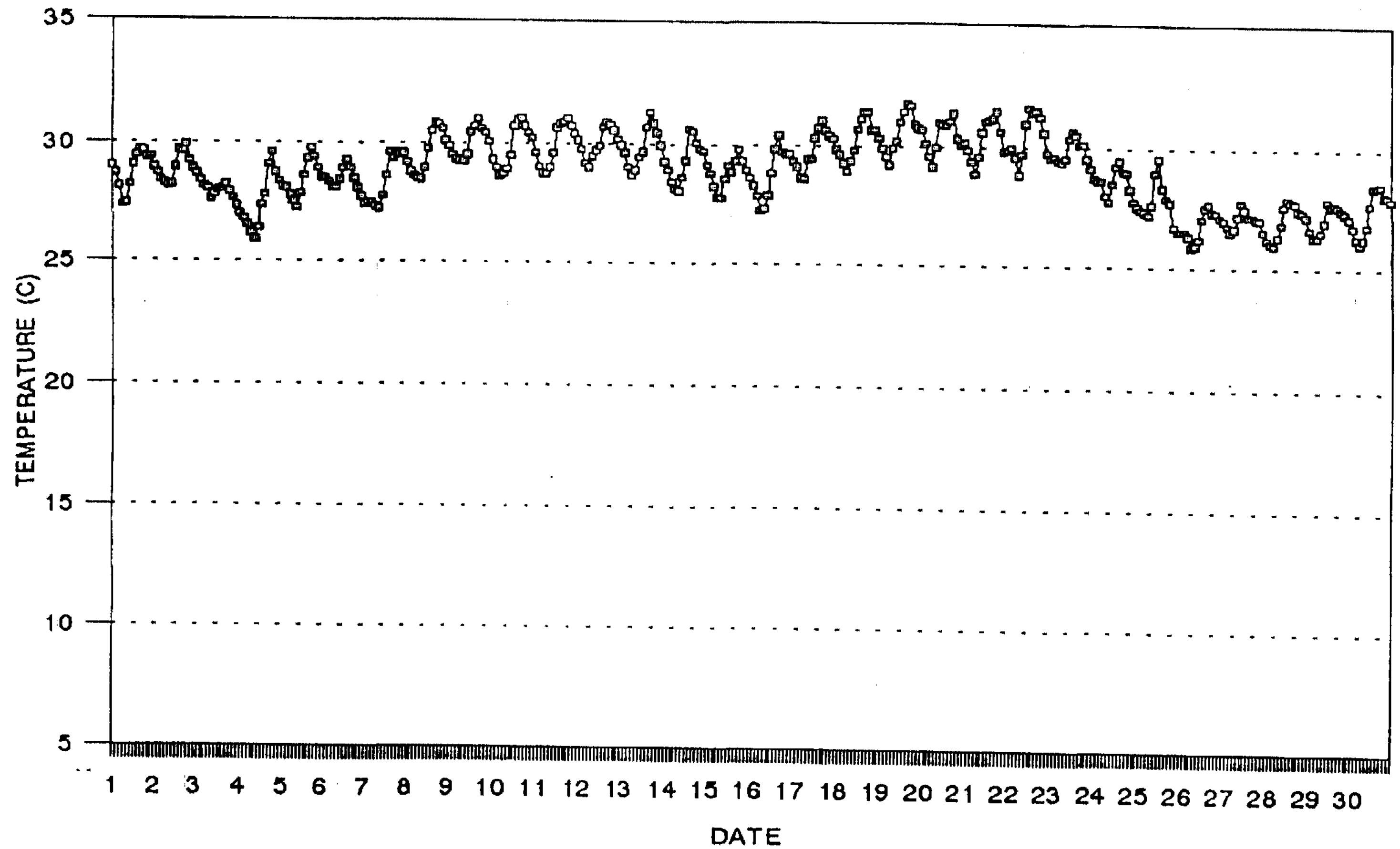


Figure A-19. June, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

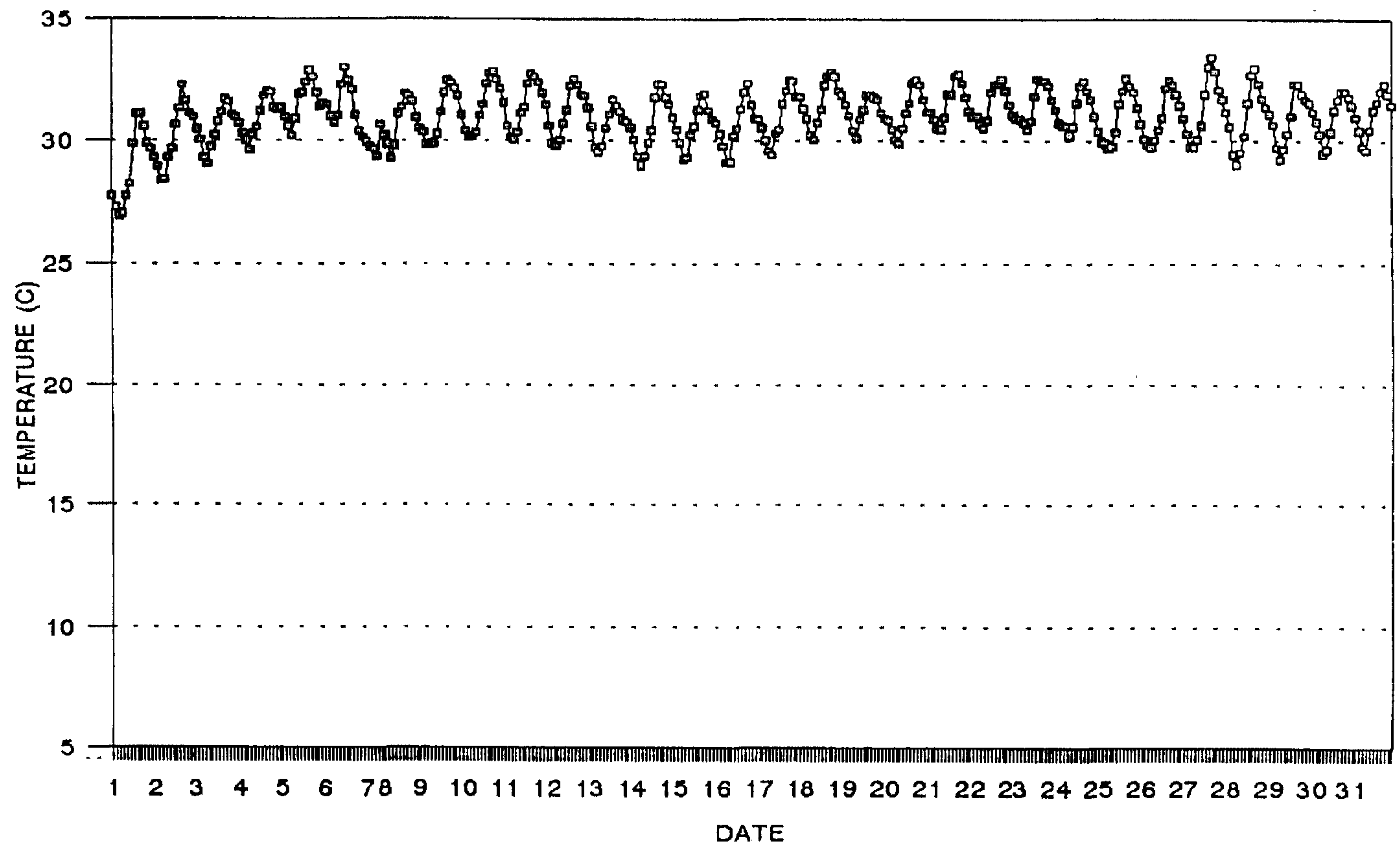


Figure A-20. July, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

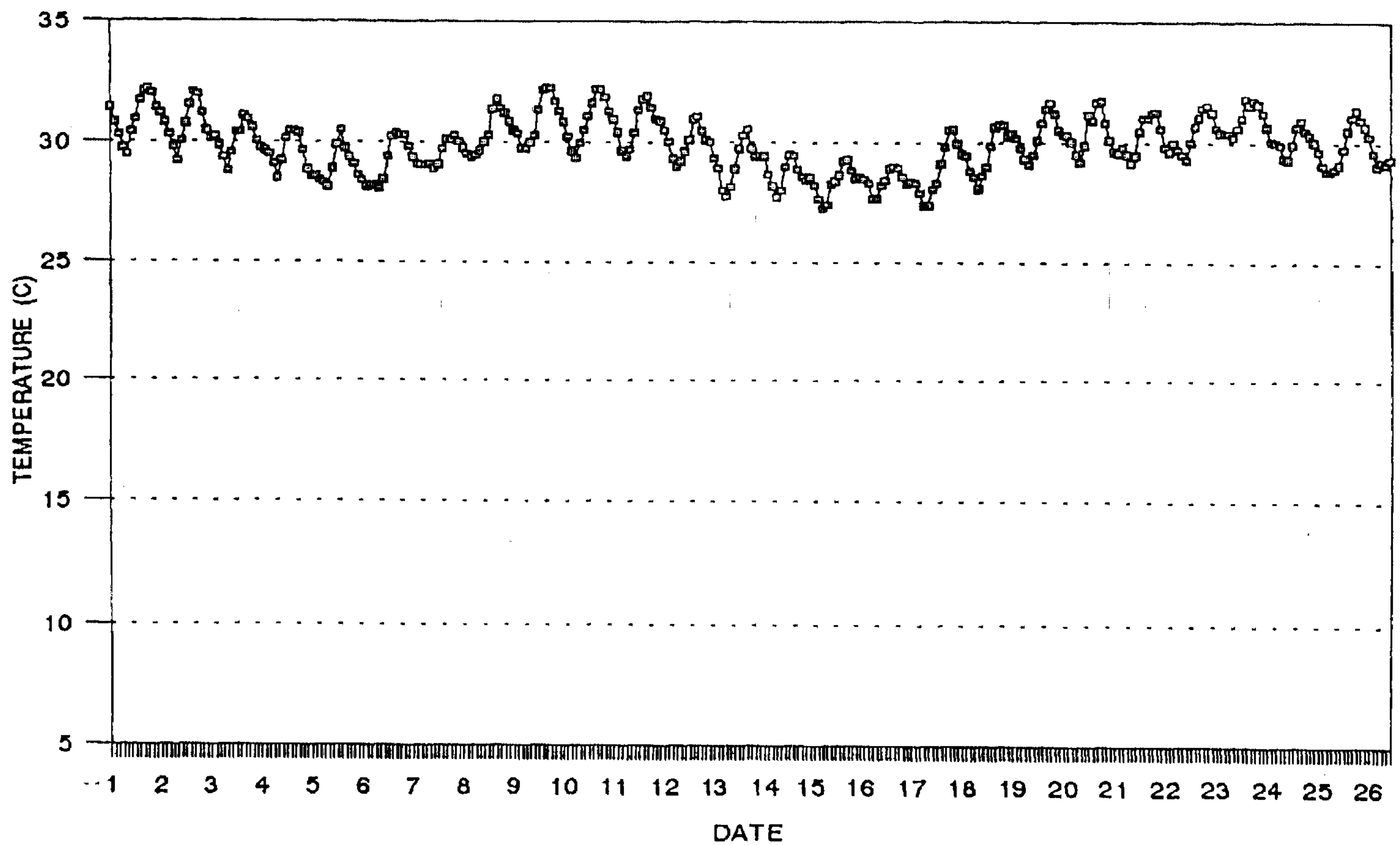


Figure A-21. August, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

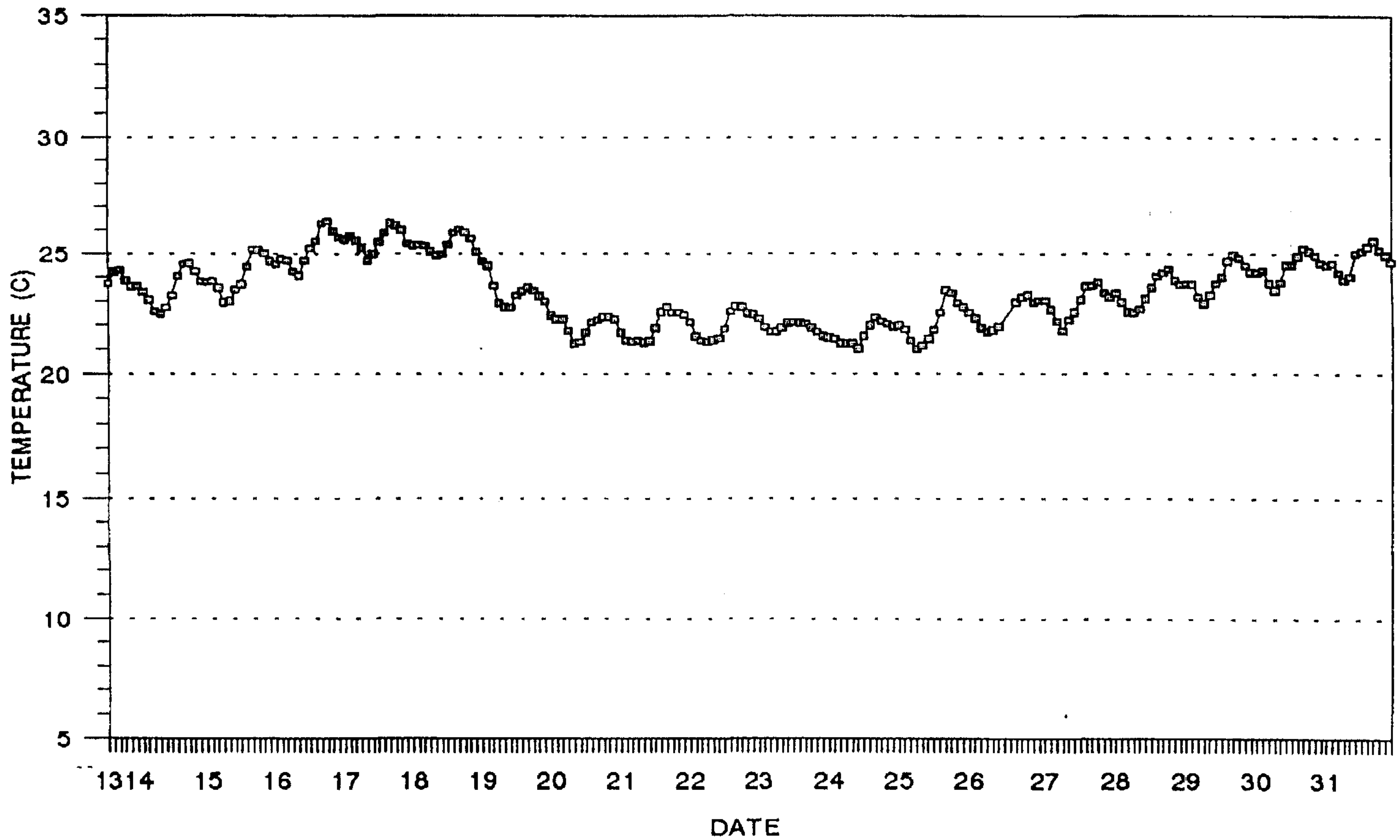


Figure A-23. October, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

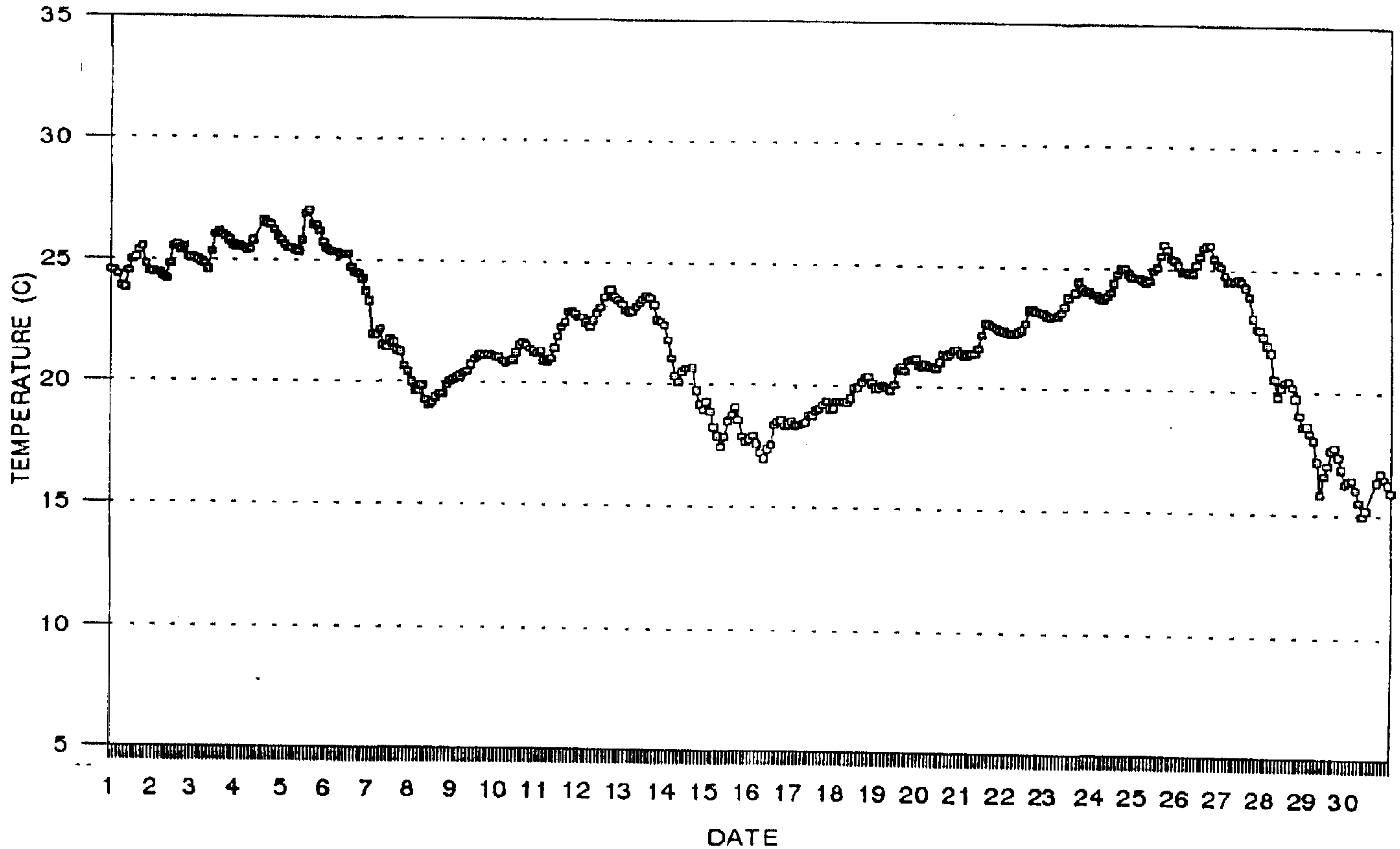


Figure A-24. November, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

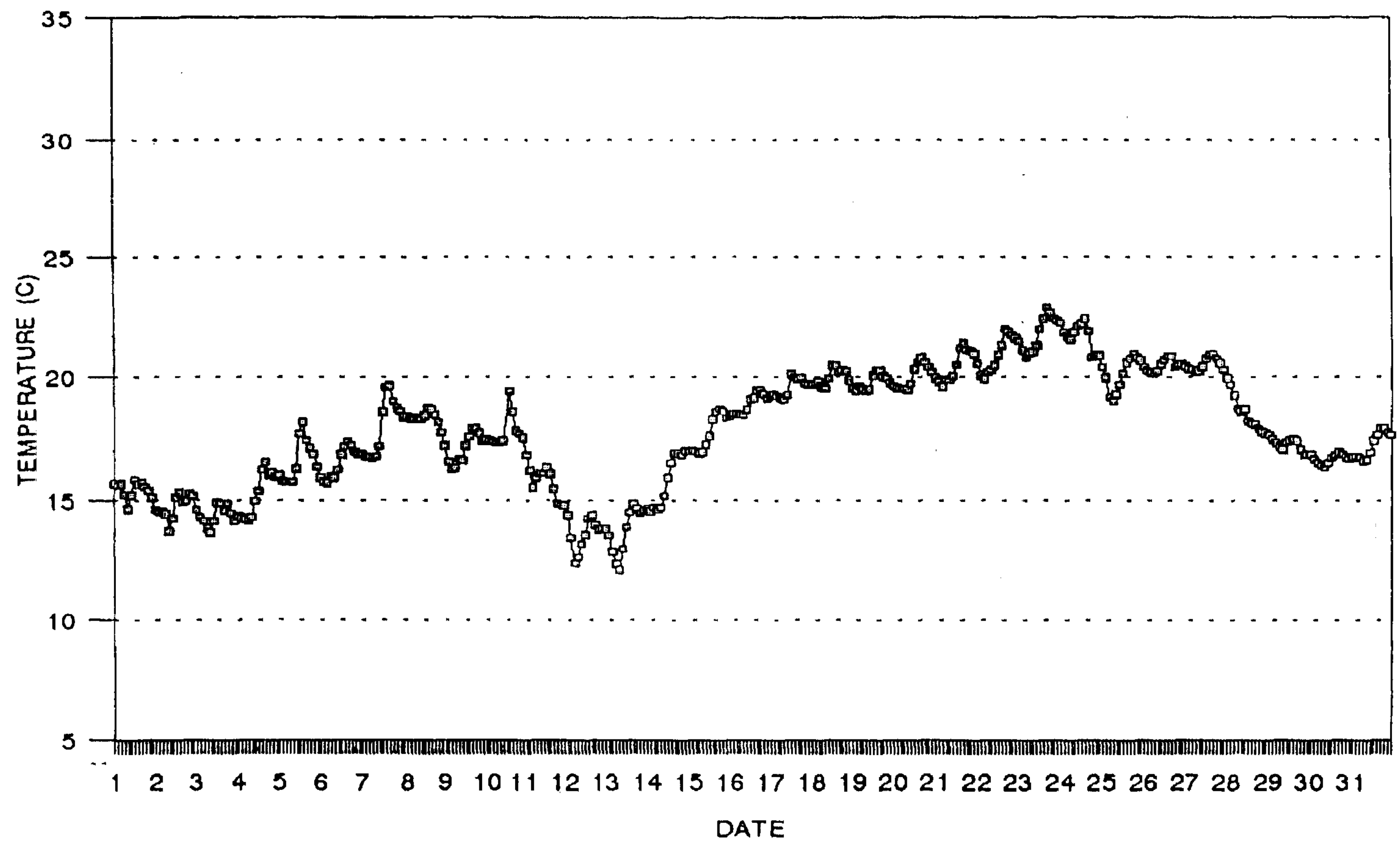


Figure A-25. December, 1992 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

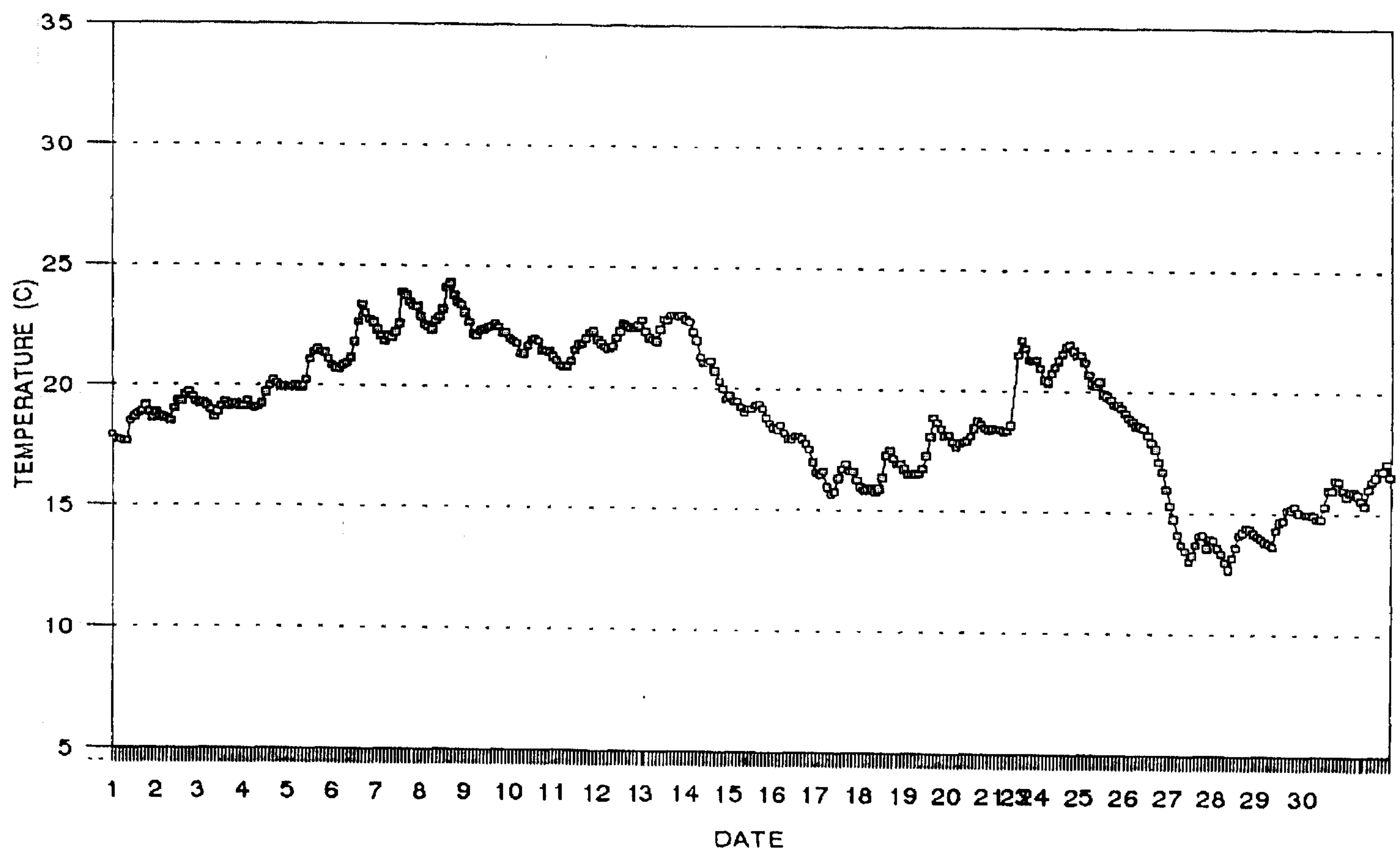


Figure A-26. January, 1993 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

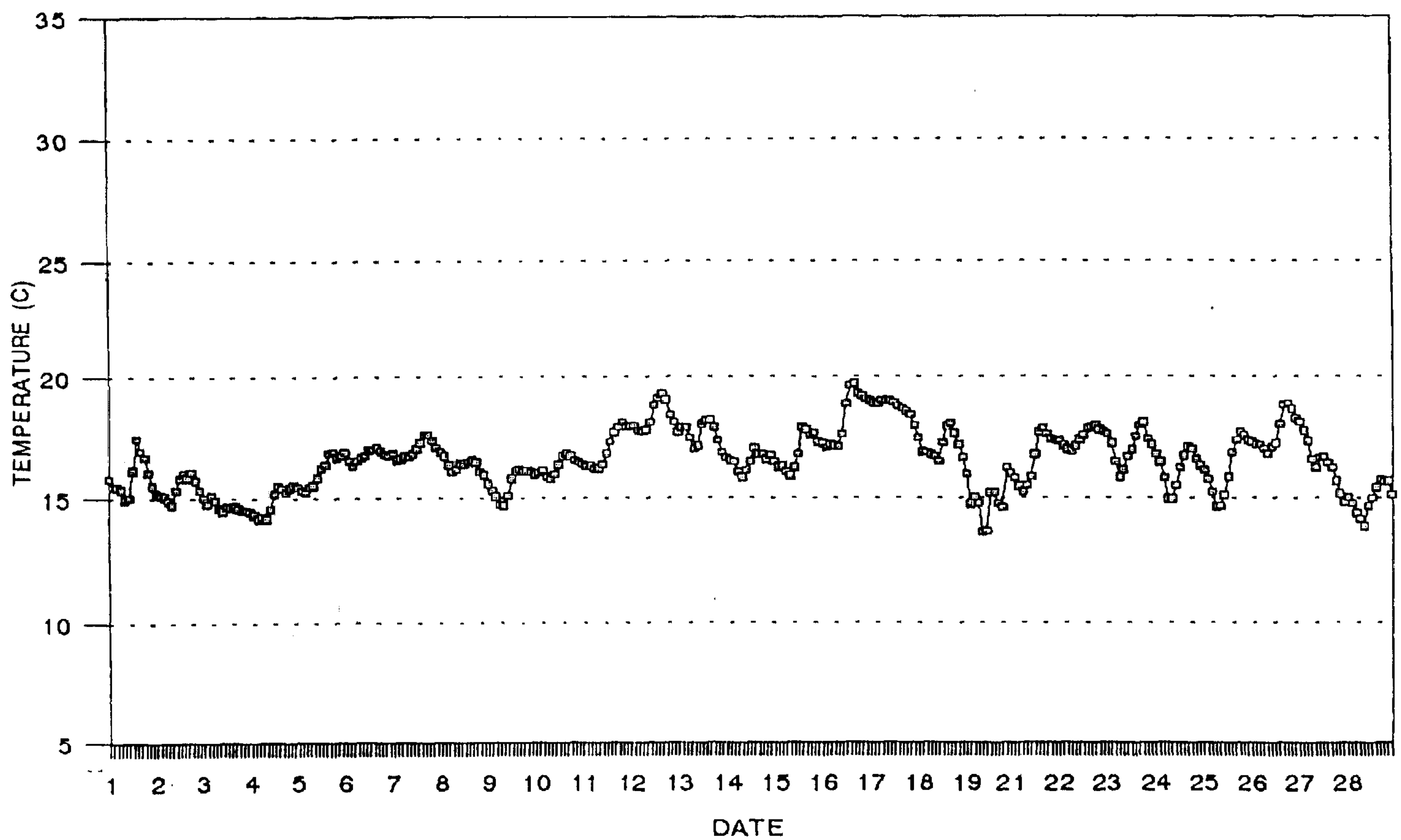


Figure A-27. Febuary, 1993 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

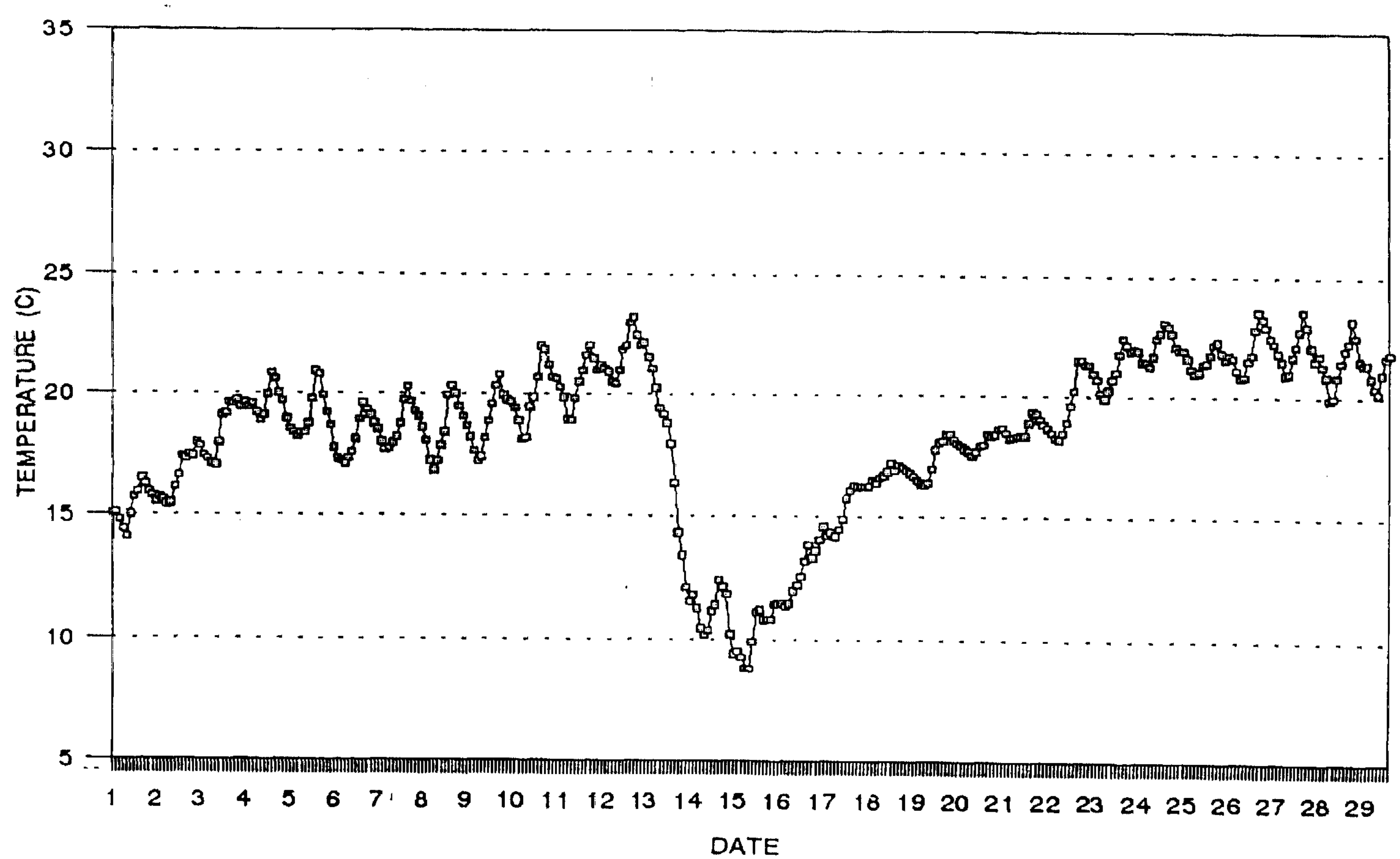


Figure A-28. March, 1993 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

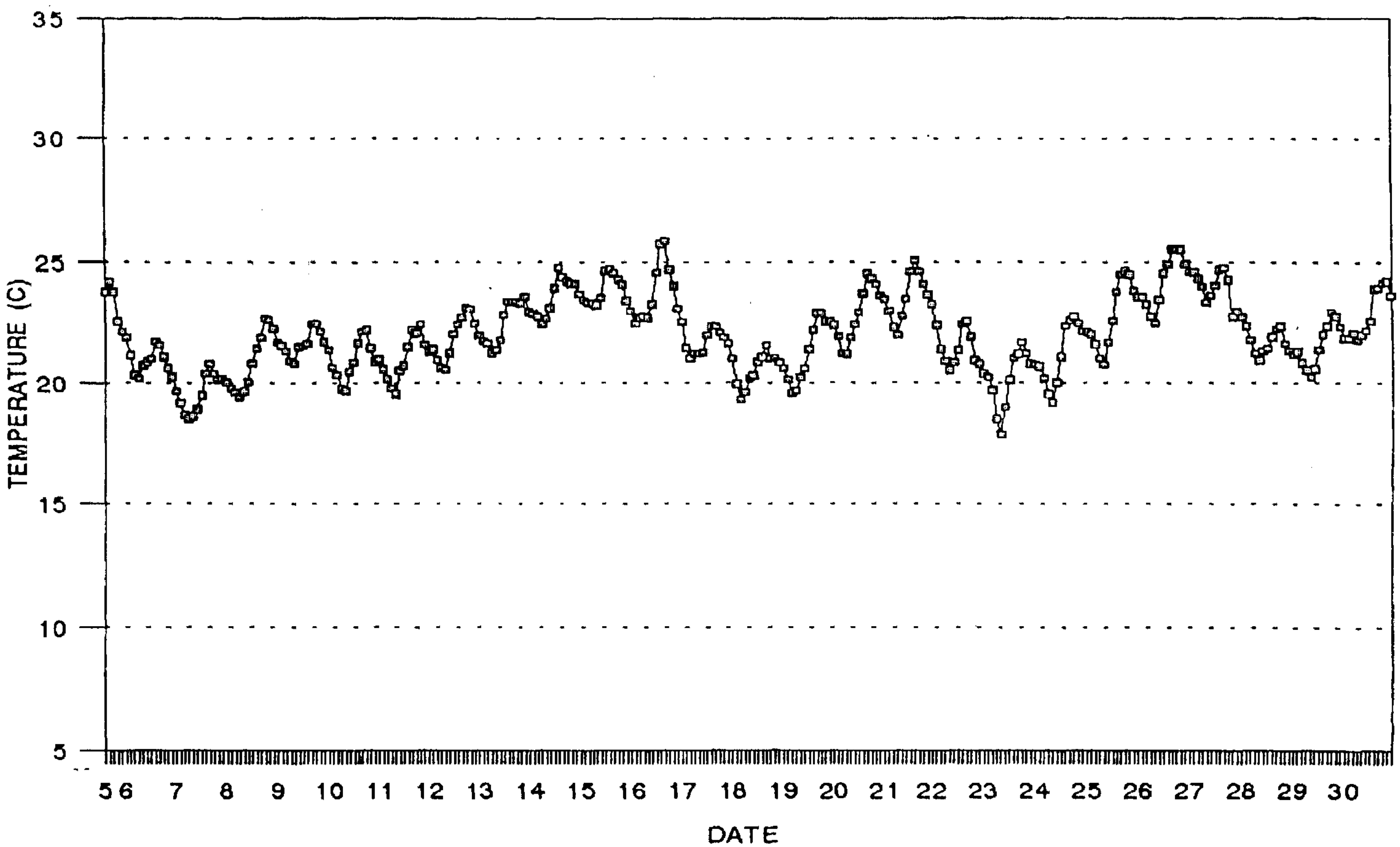


Figure A-29. April, 1993 bi-hourly water temperature (°C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

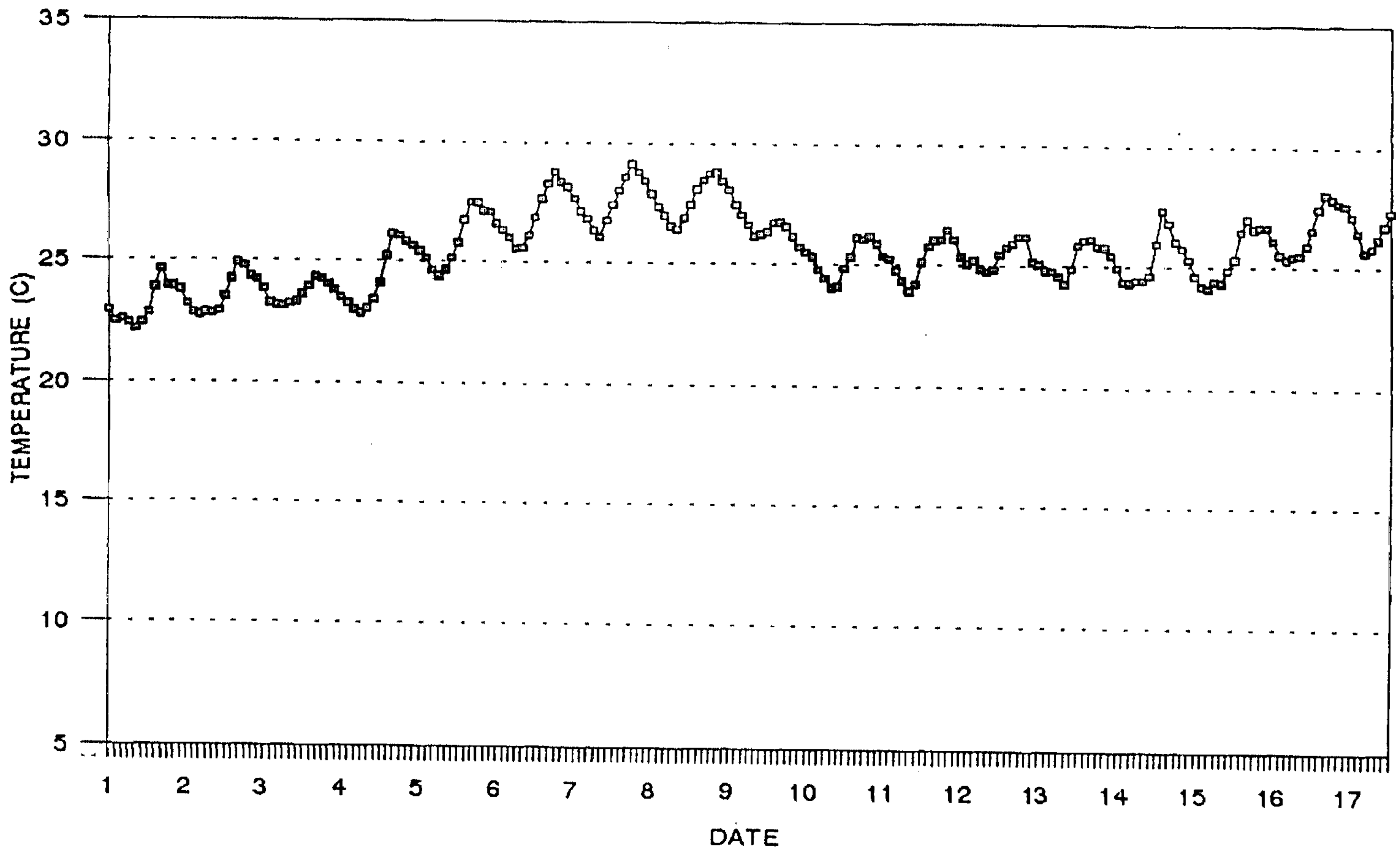


Figure A-30. May, 1993 bi-hourly water temperature (^{o}C) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

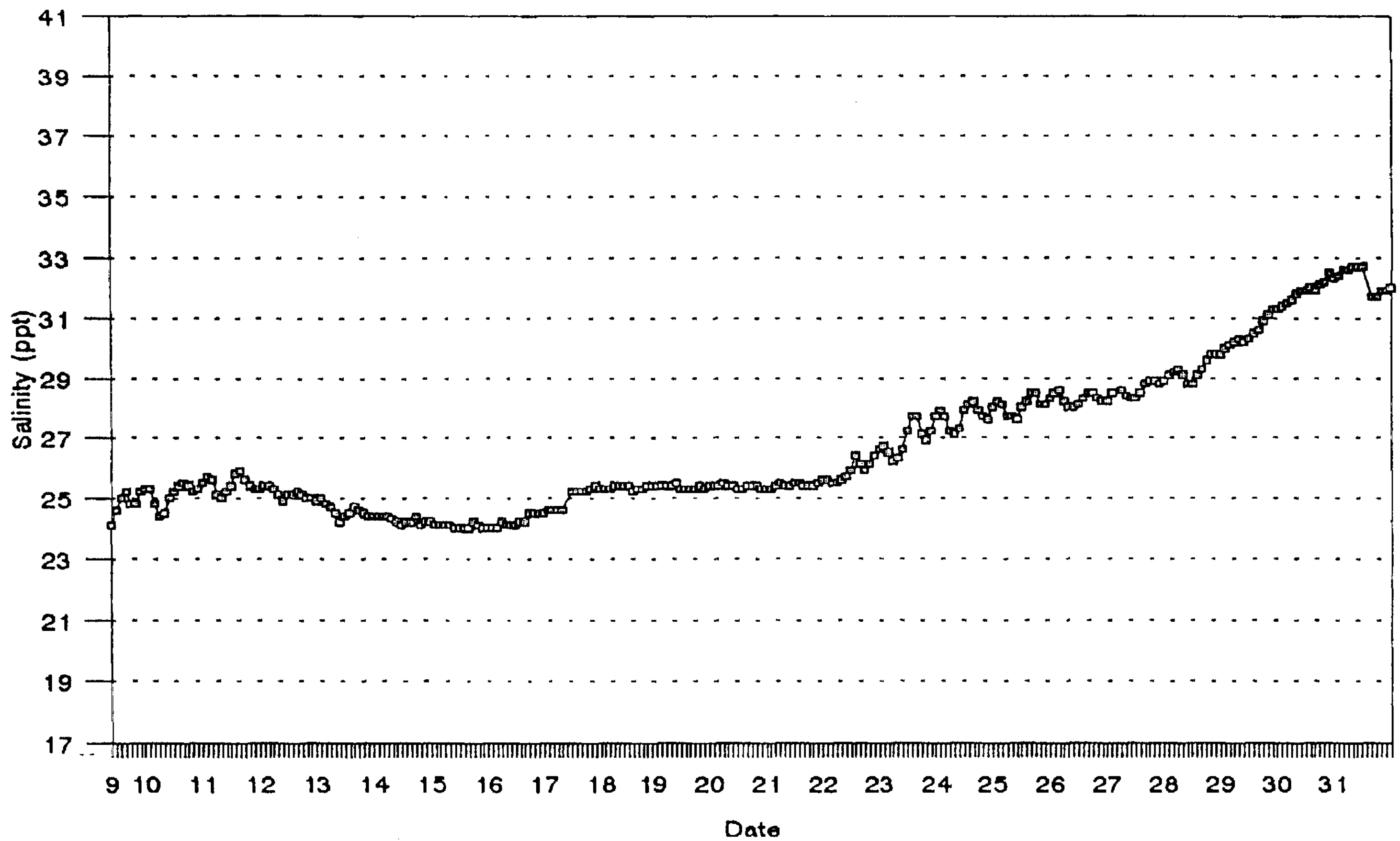


Figure A-31. October, 1991 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

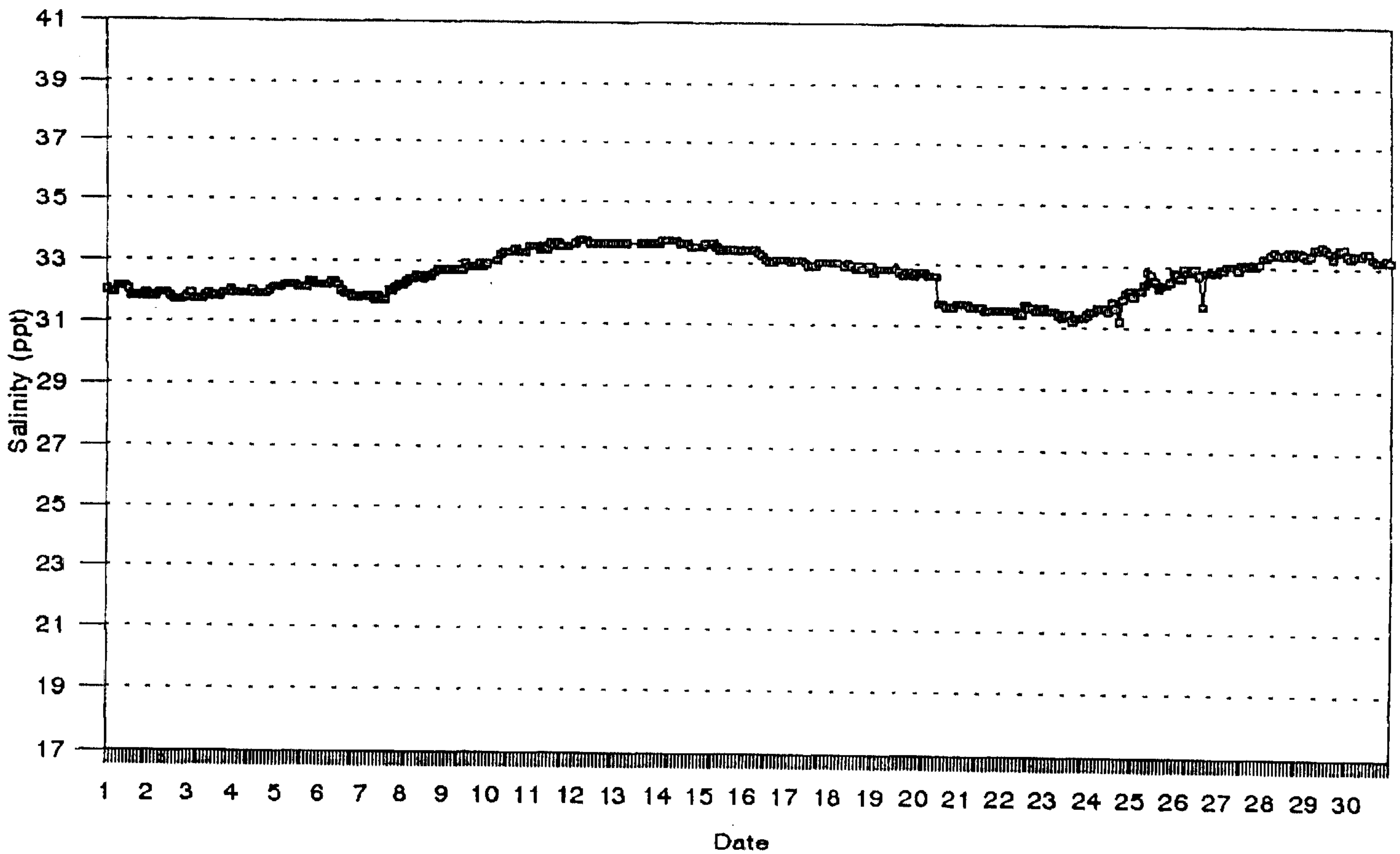


Figure A-32. November, 1991 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

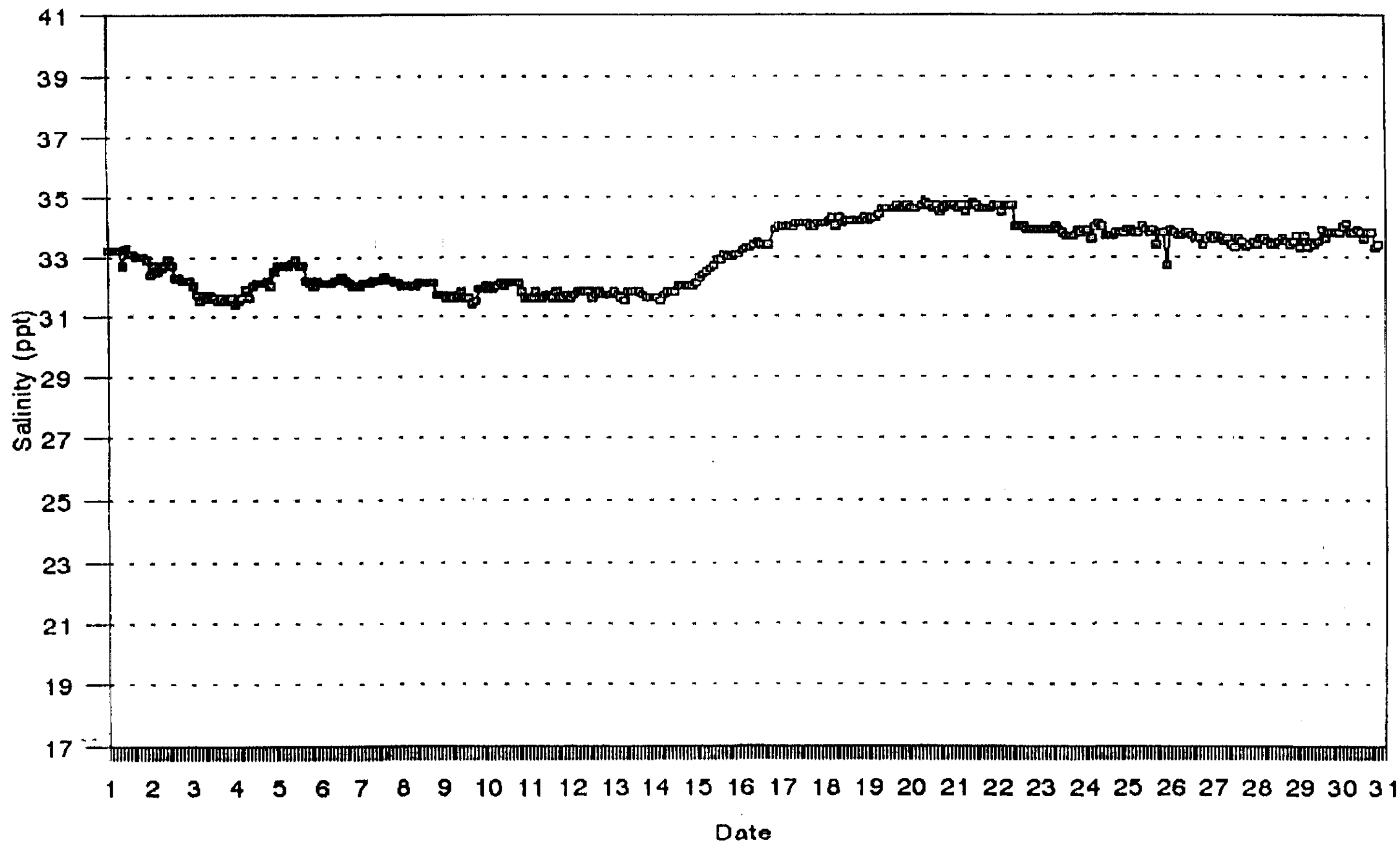


Figure A-33. December, 1991 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

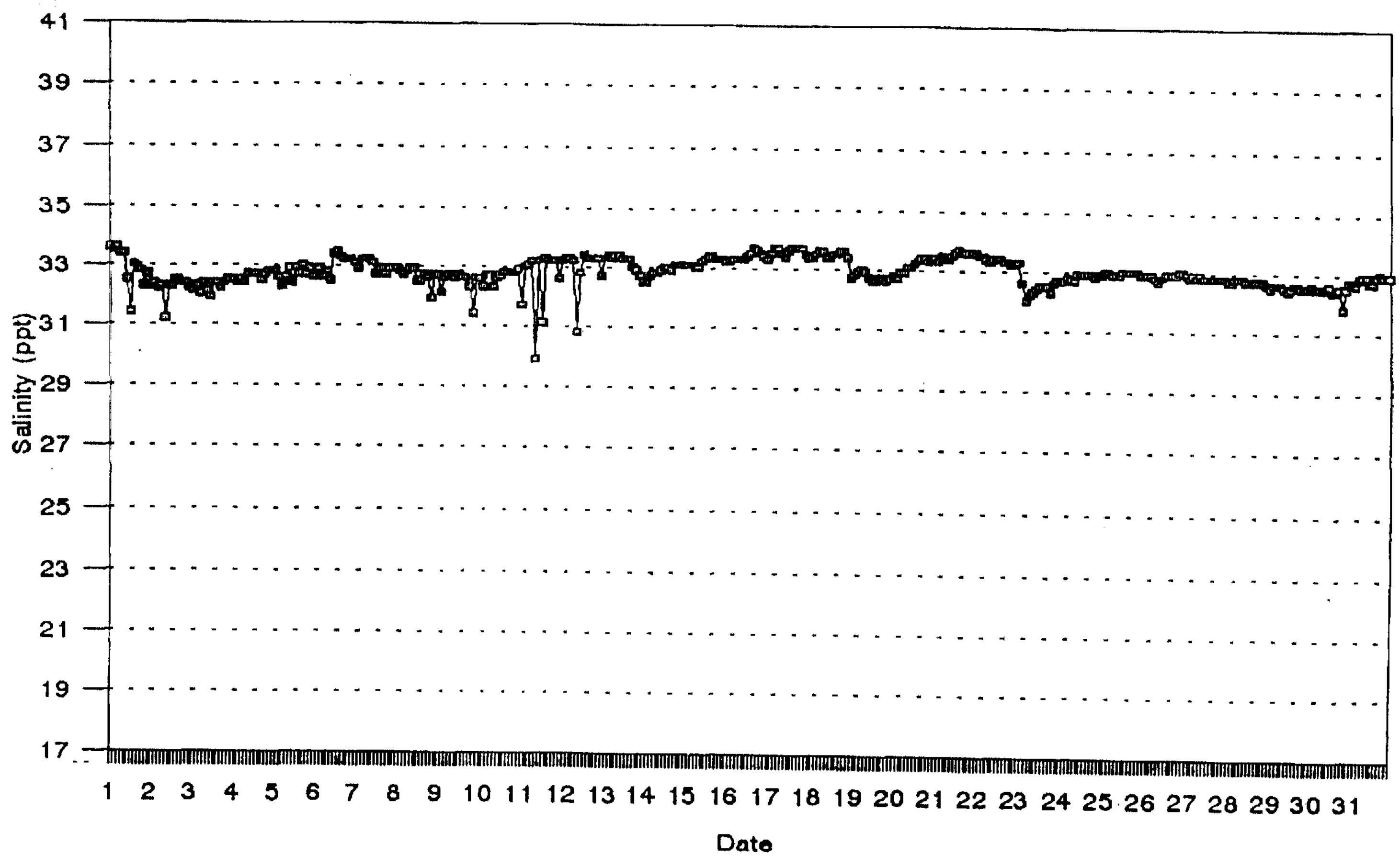


Figure A-34. January, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

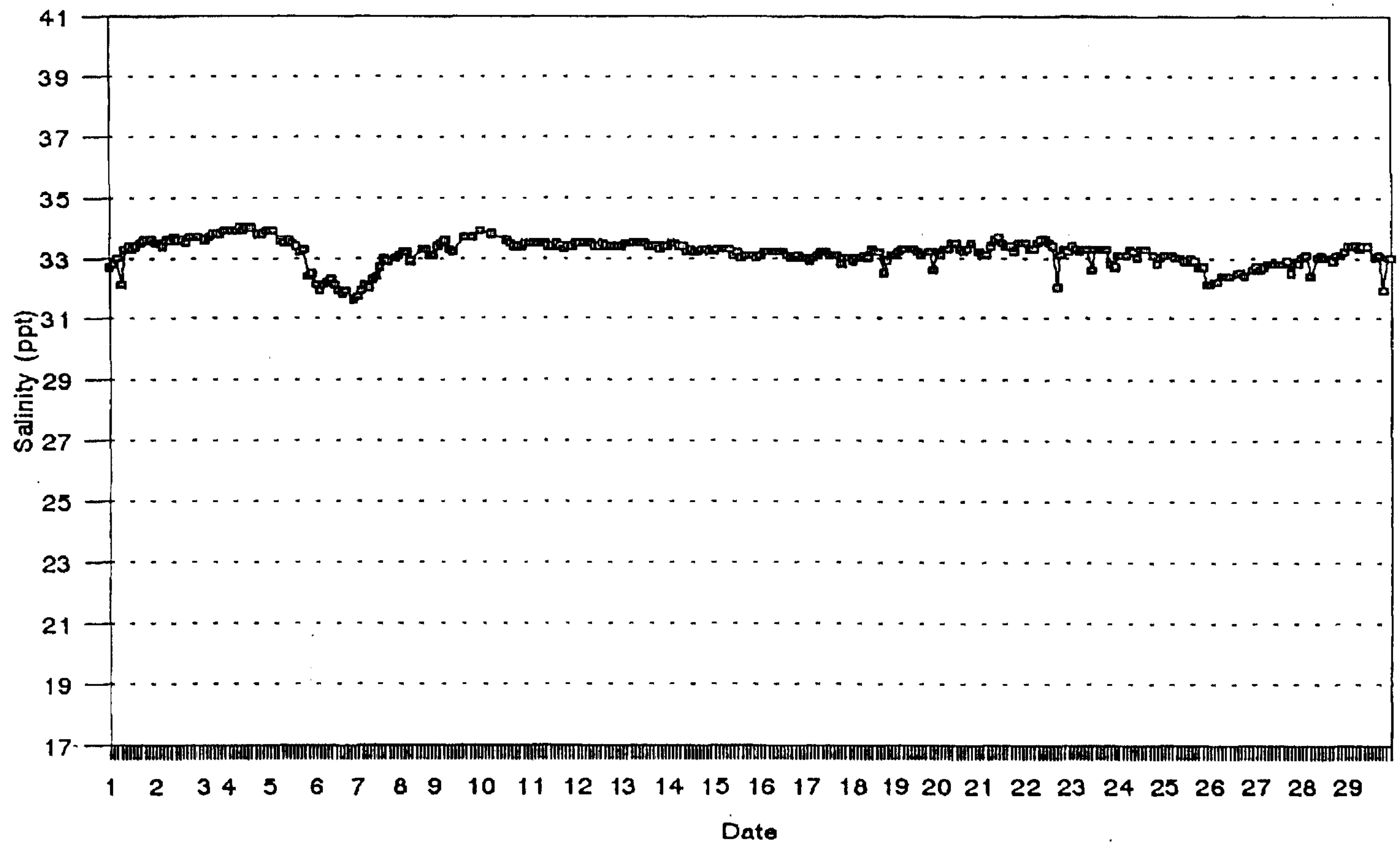


Figure A-35. Febuary, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

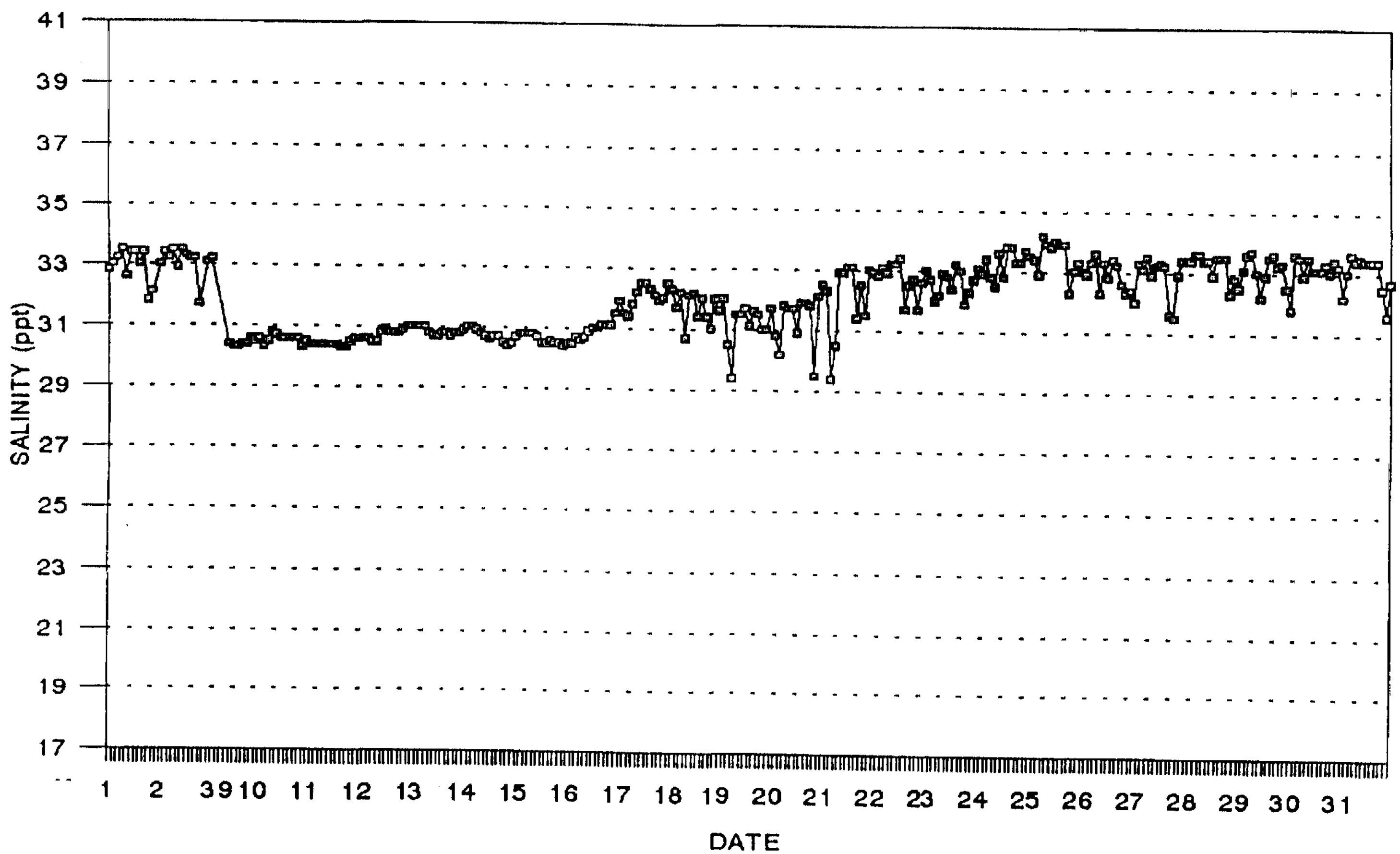


Figure A-36. March, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

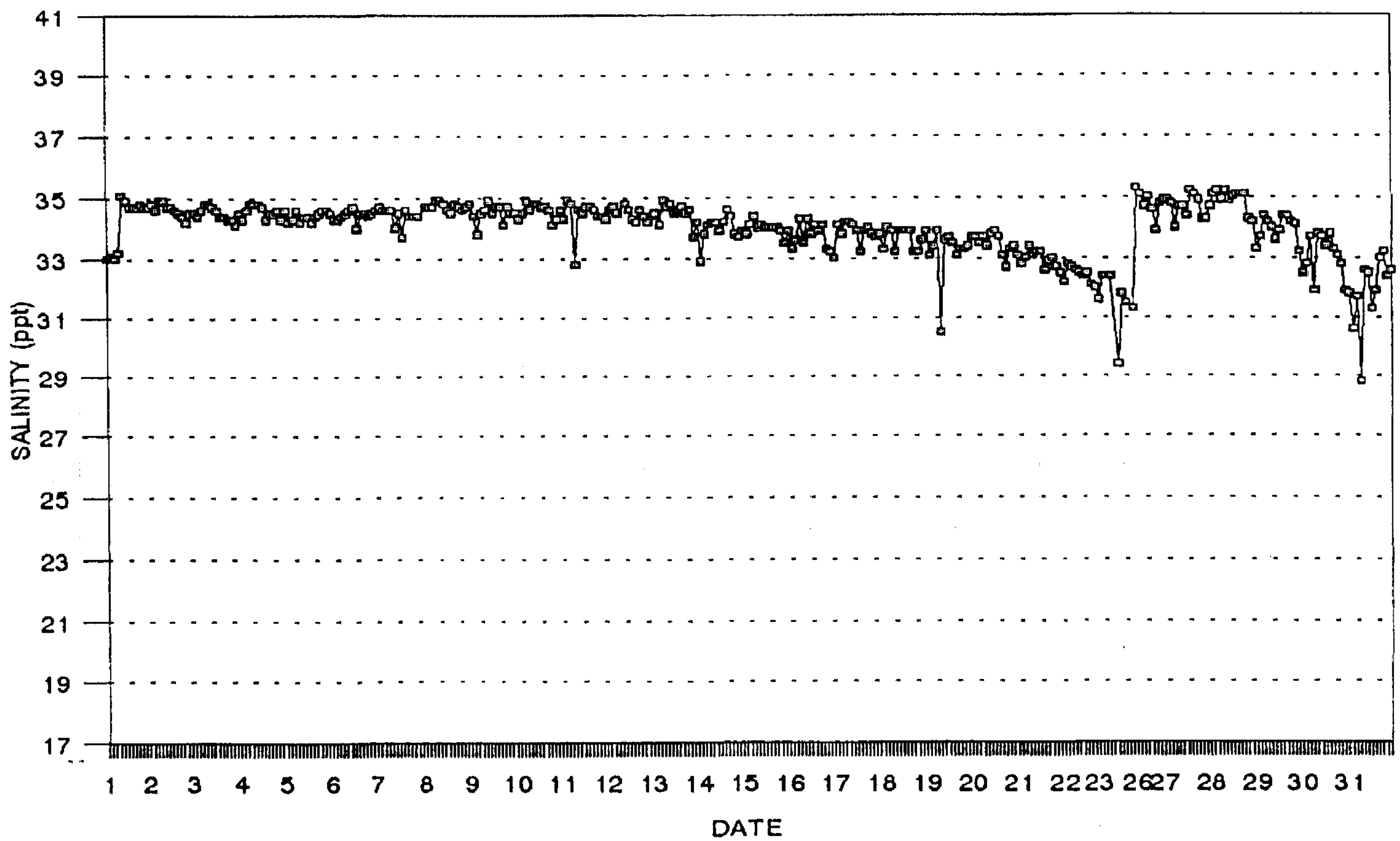


Figure A-38. May, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

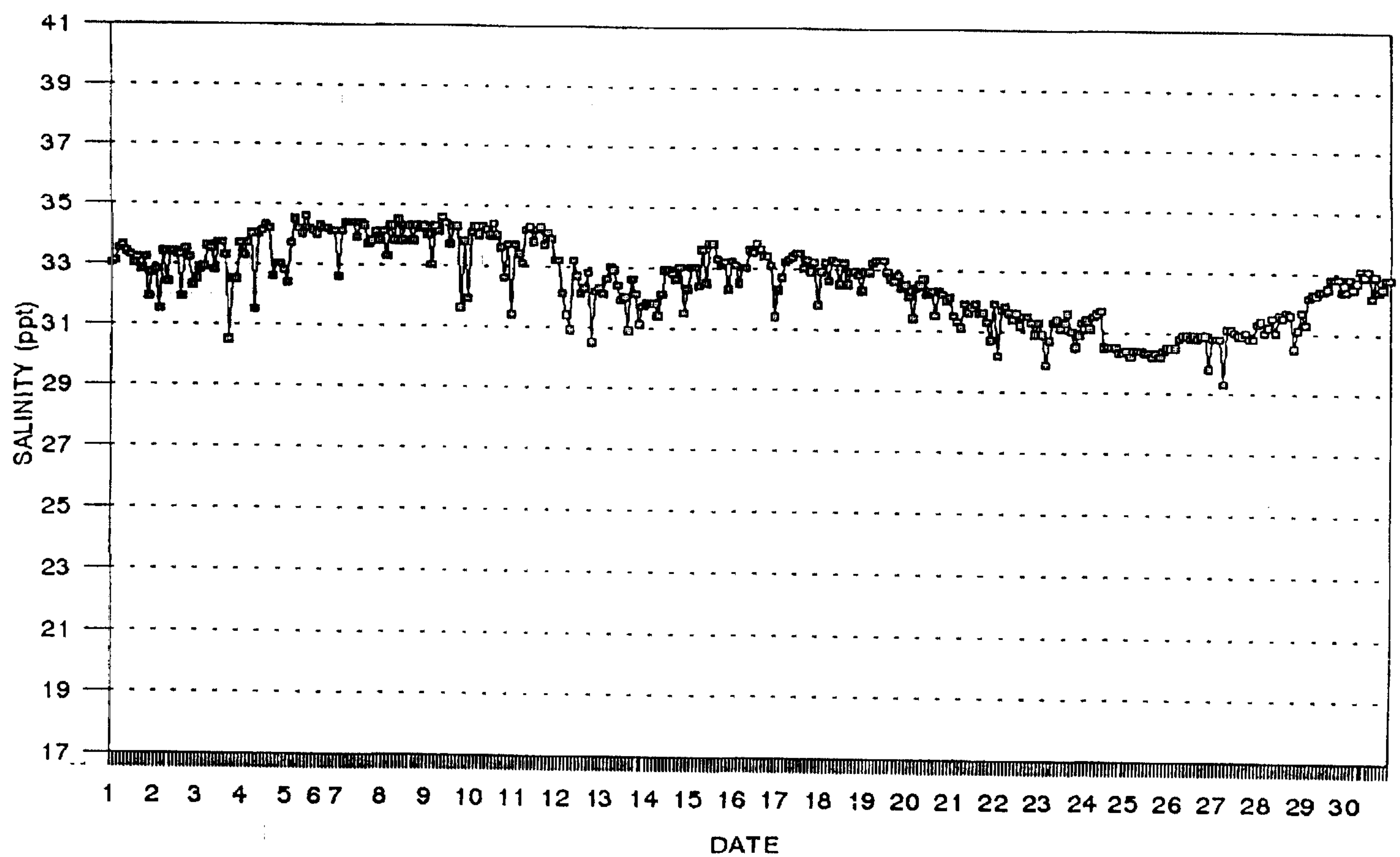


Figure A-37. April, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

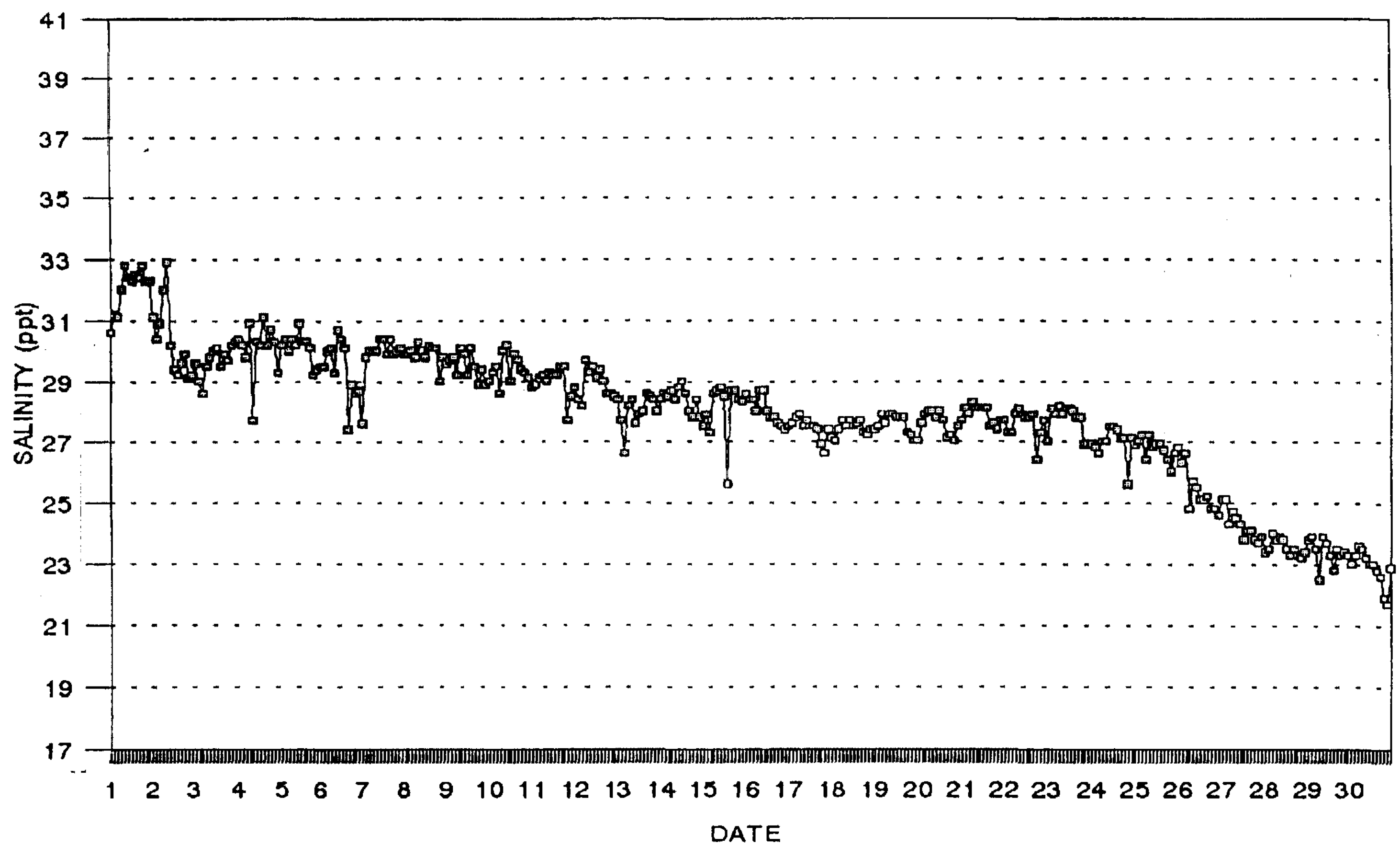


Figure A-39. June, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

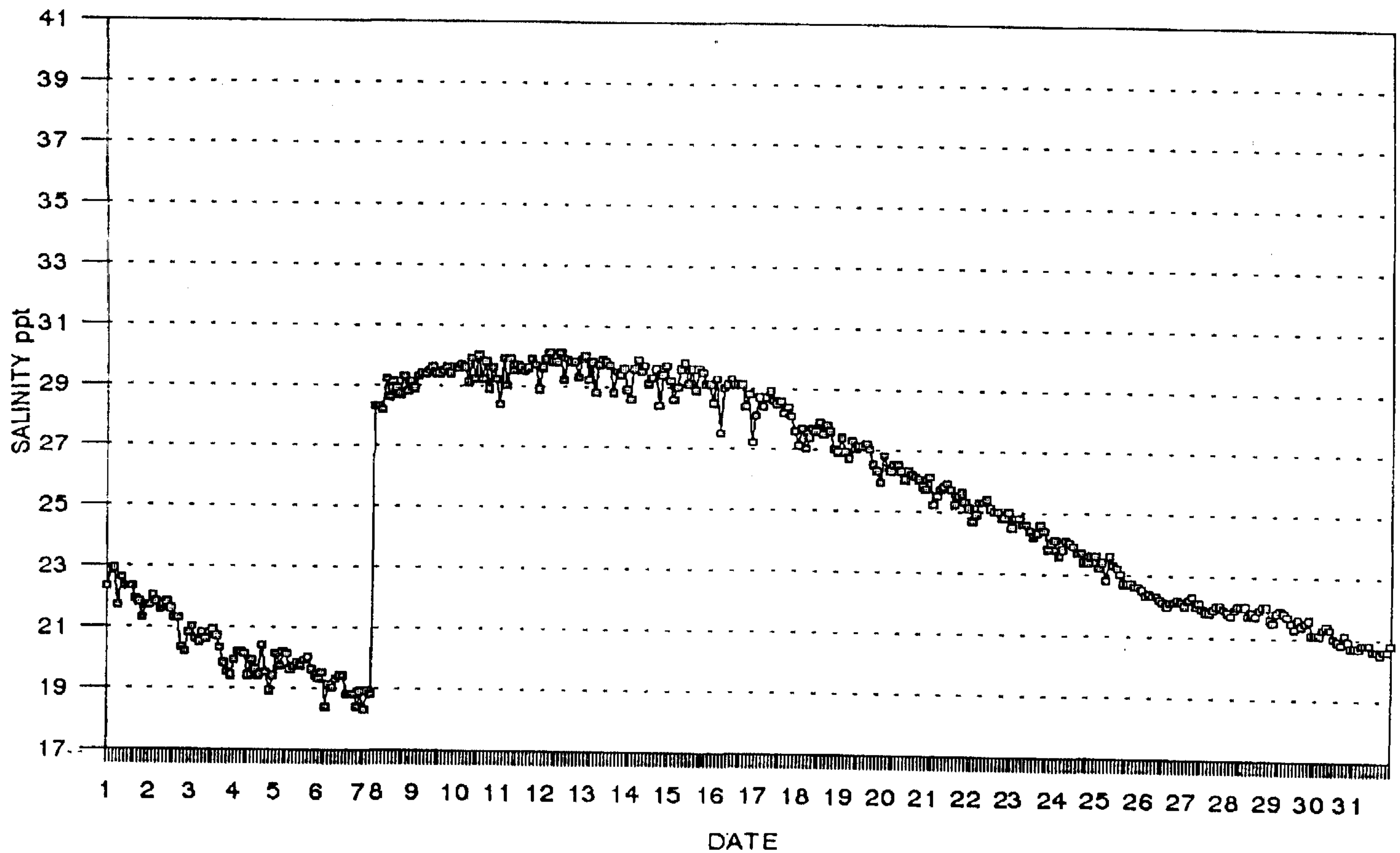


Figure A-40. July, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

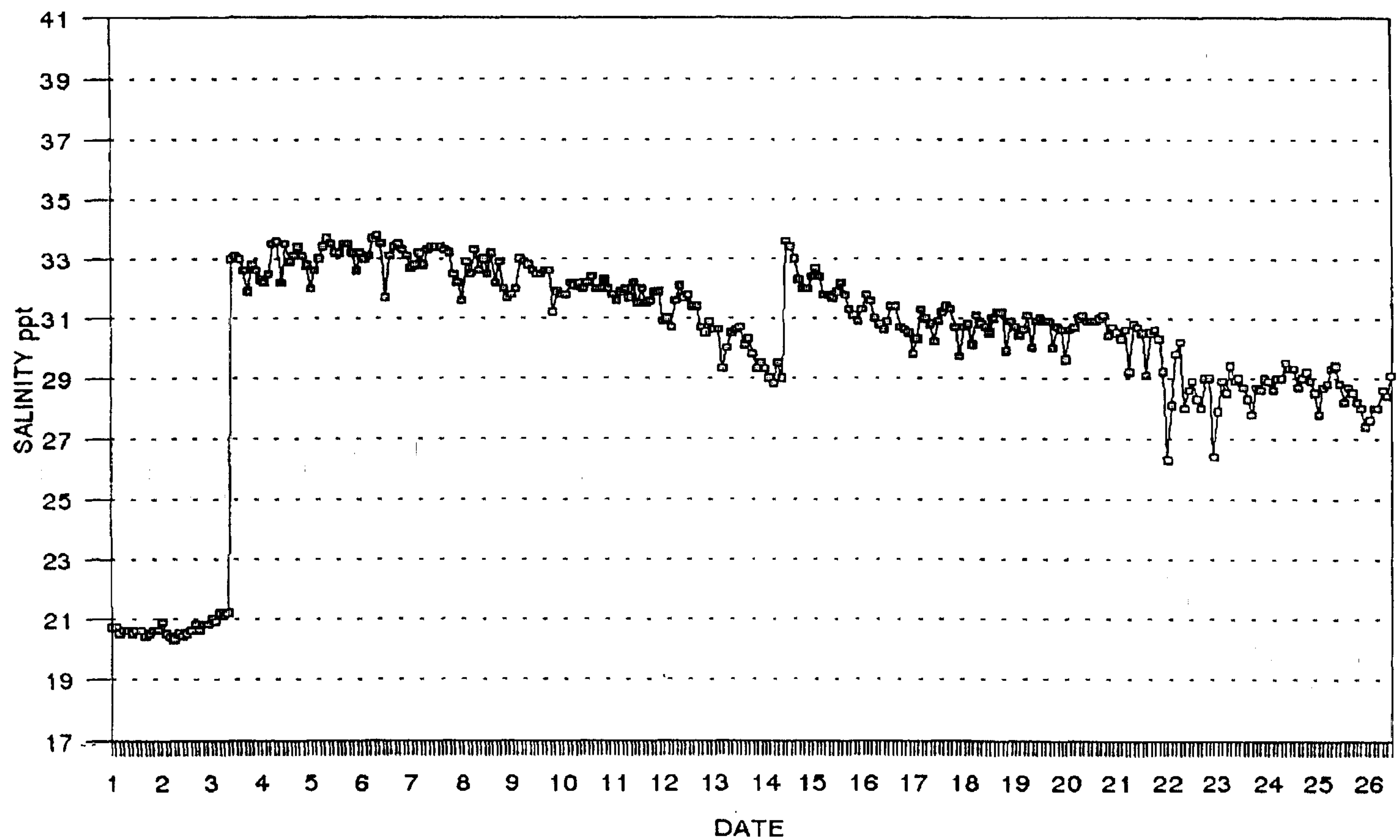


Figure A-41. August, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

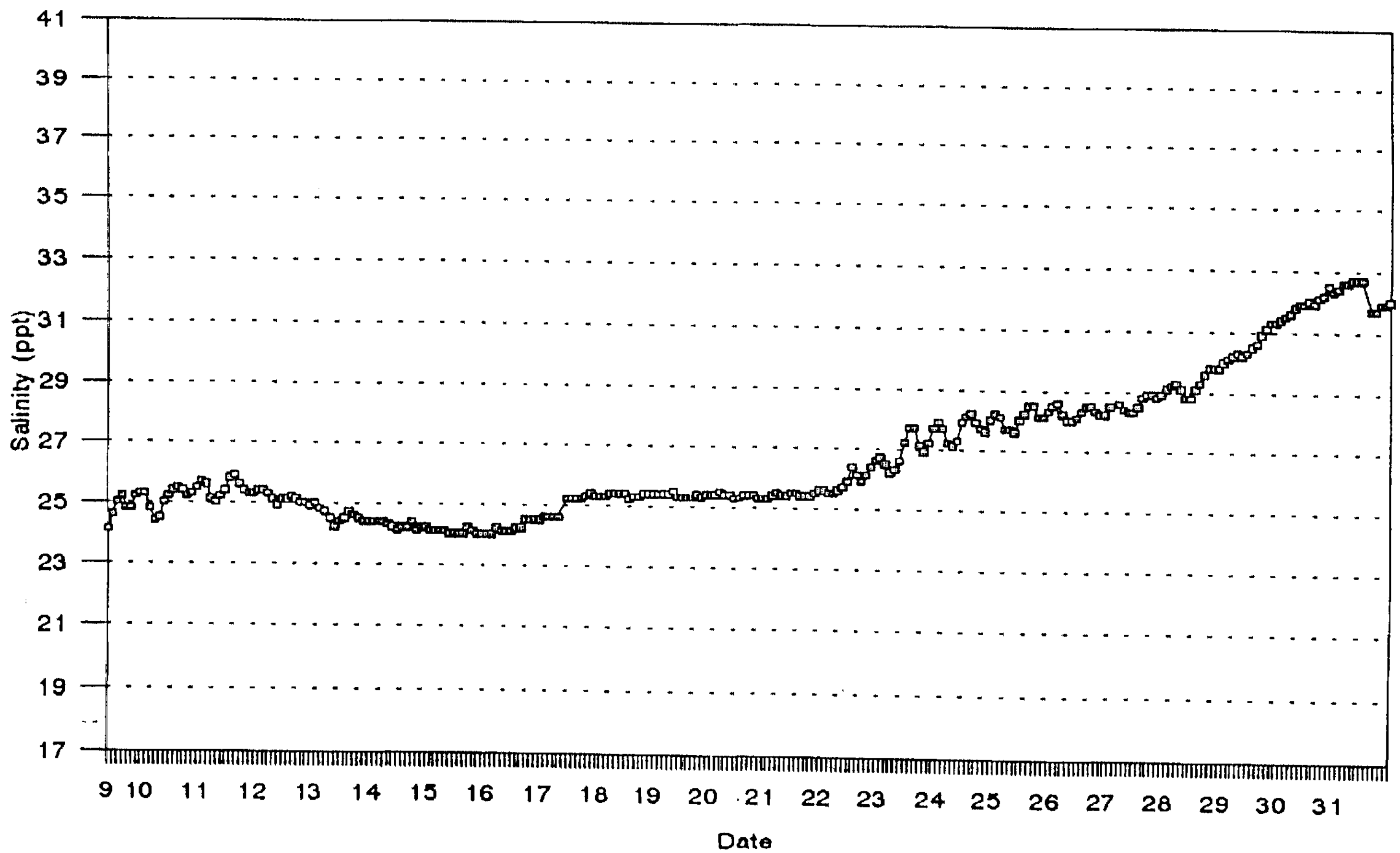


Figure A-43. October, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

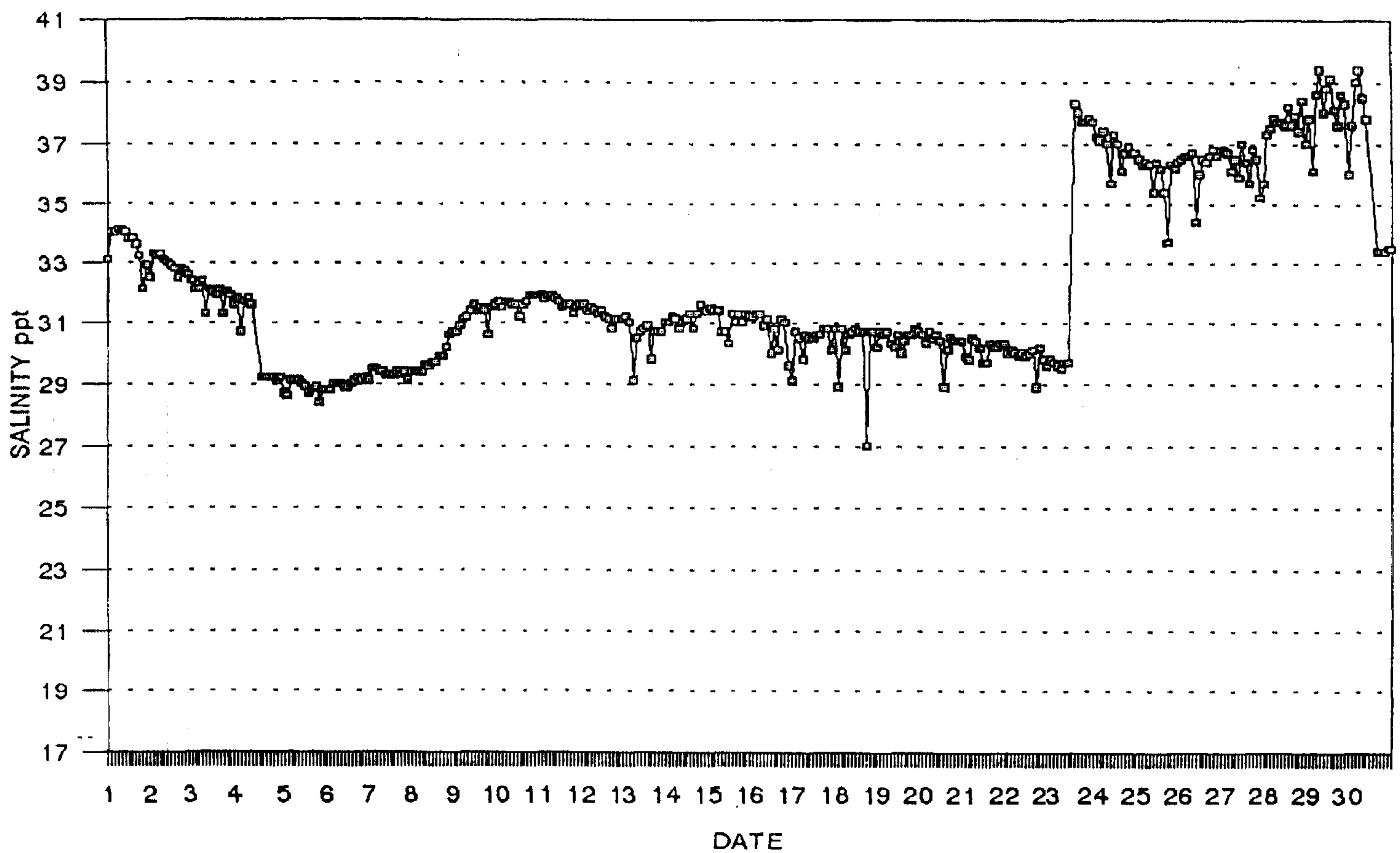


Figure A-44. November, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

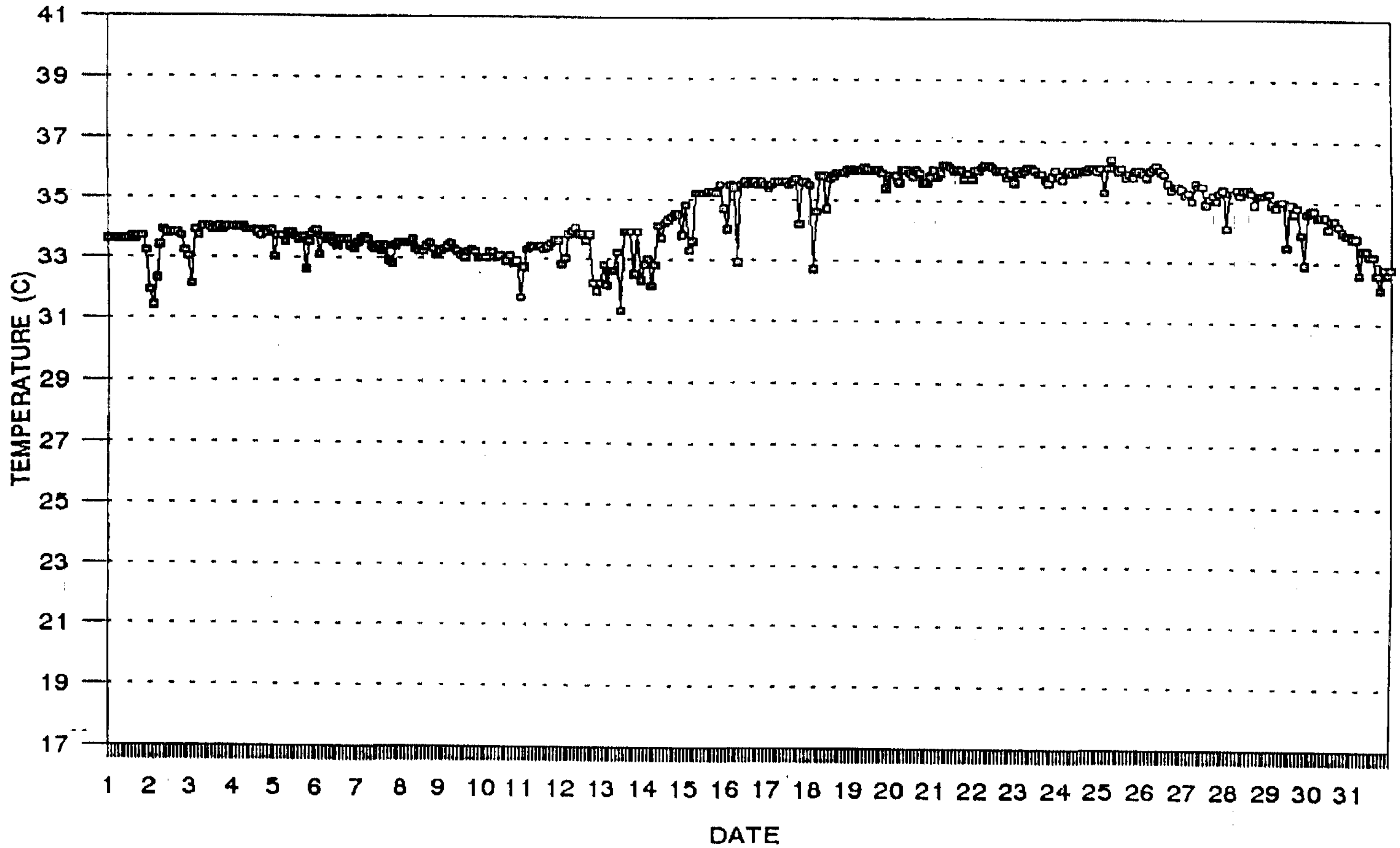


Figure A-45. December, 1992 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

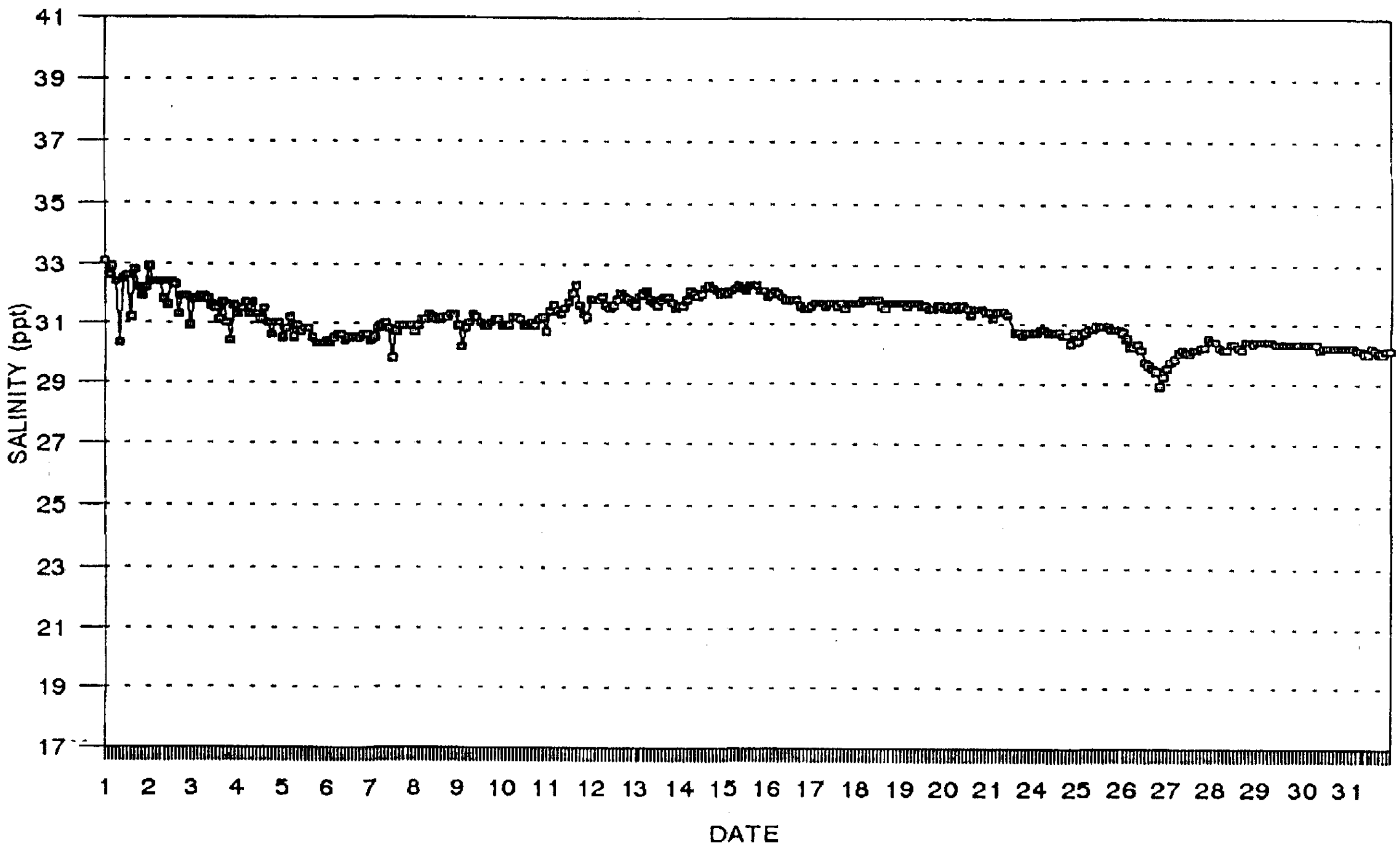


Figure A-46. January, 1993 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

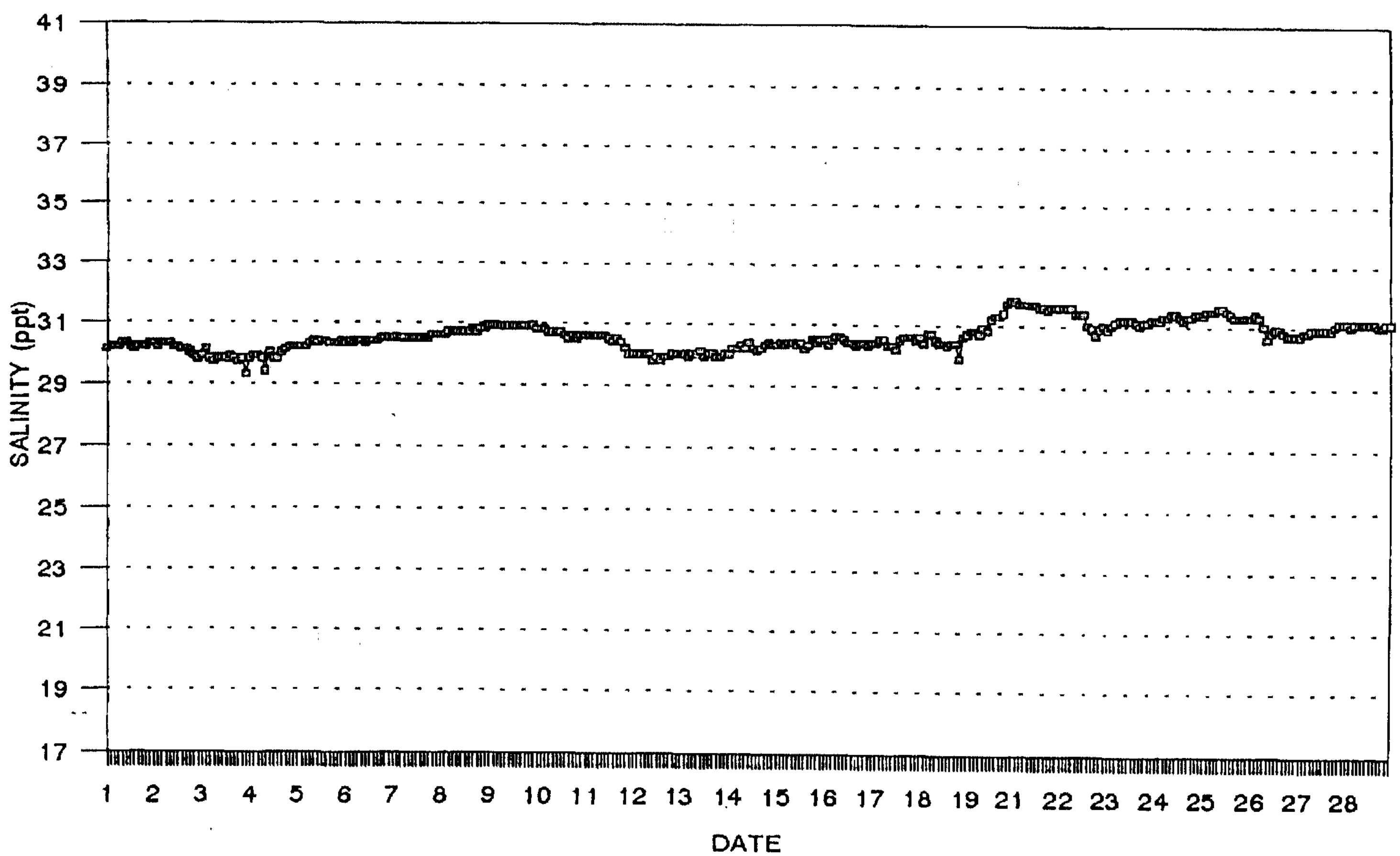


Figure A-47. Feburary, 1993 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

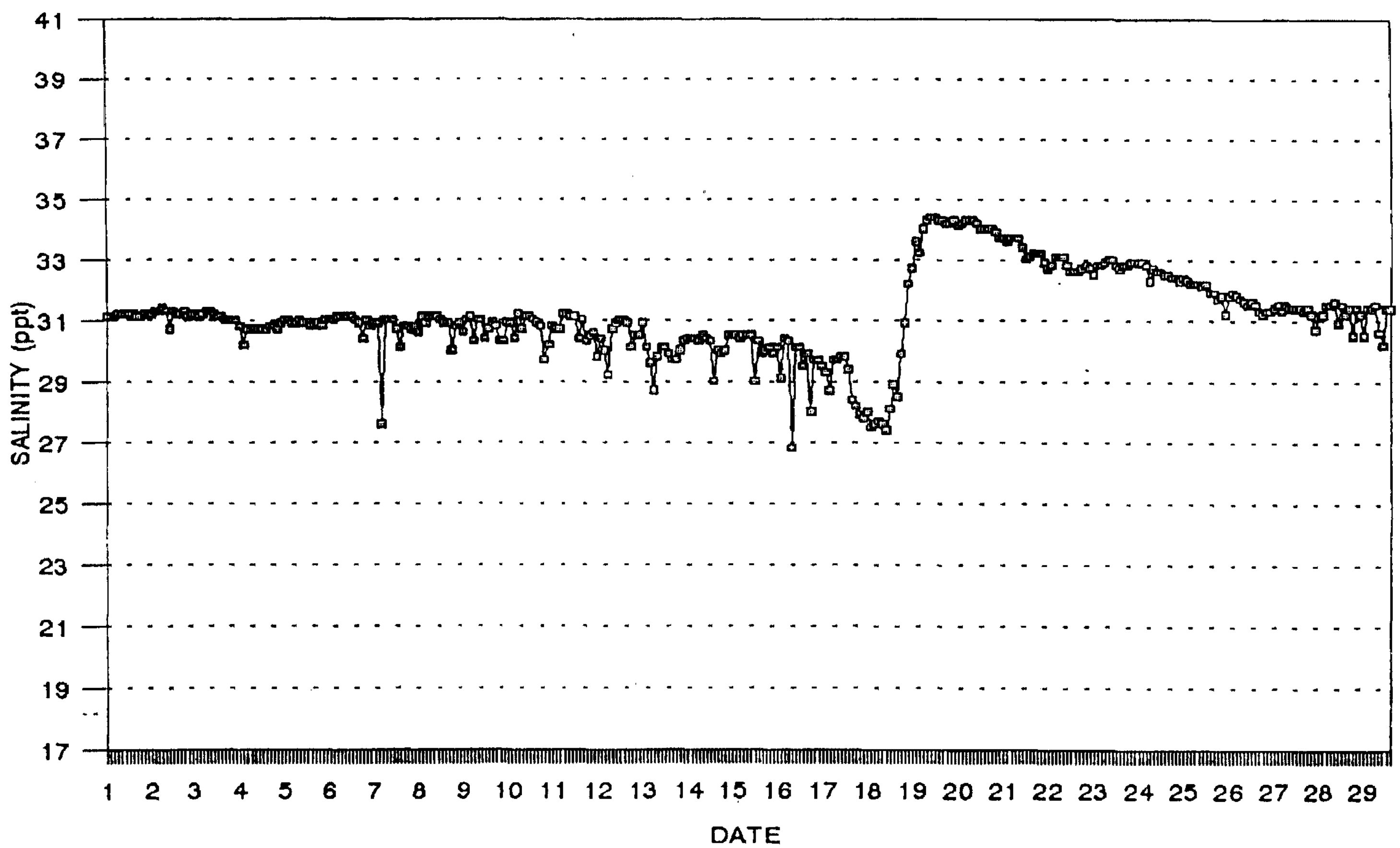


Figure A-48. March, 1993 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

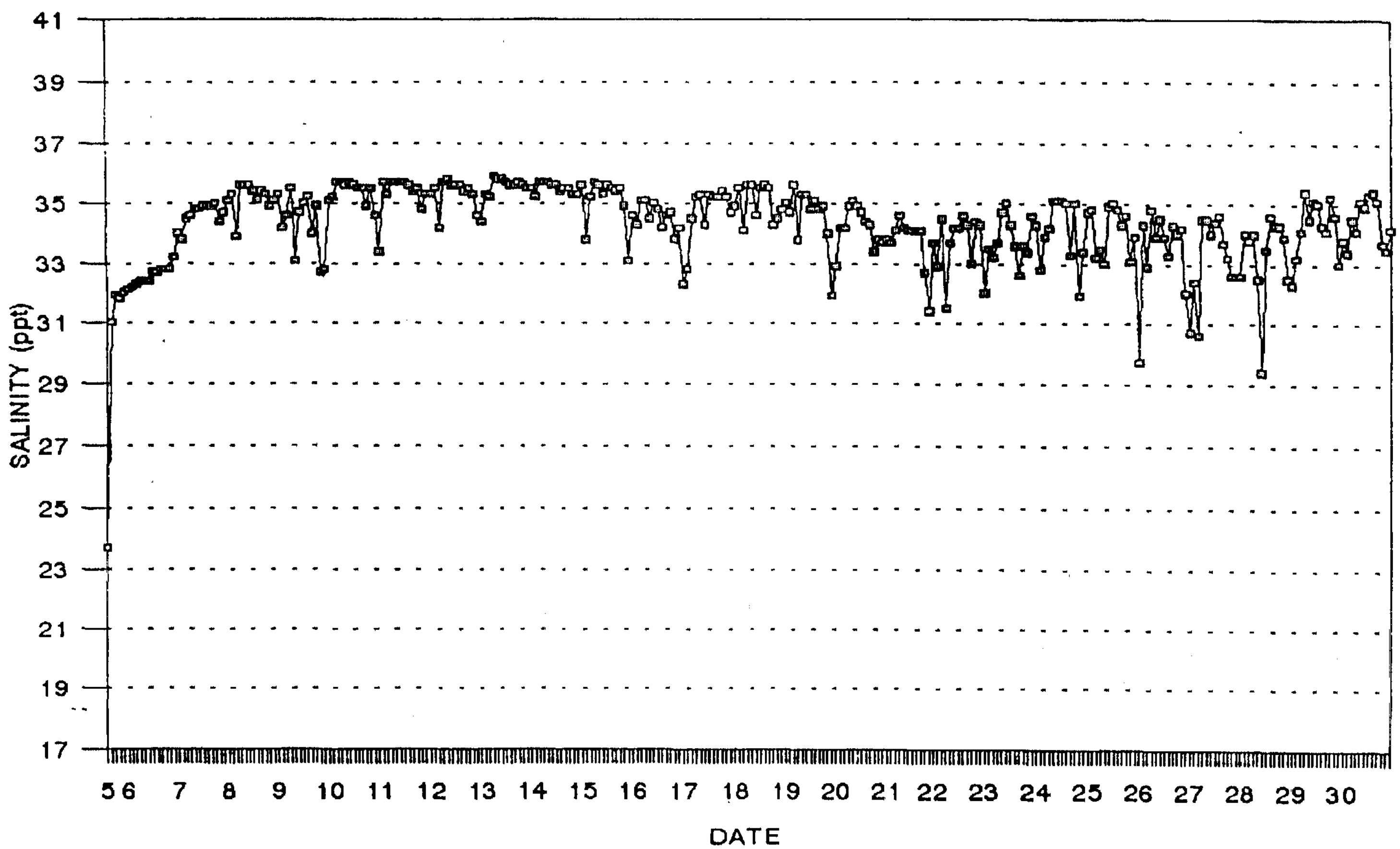


Figure A-49. April, 1993 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

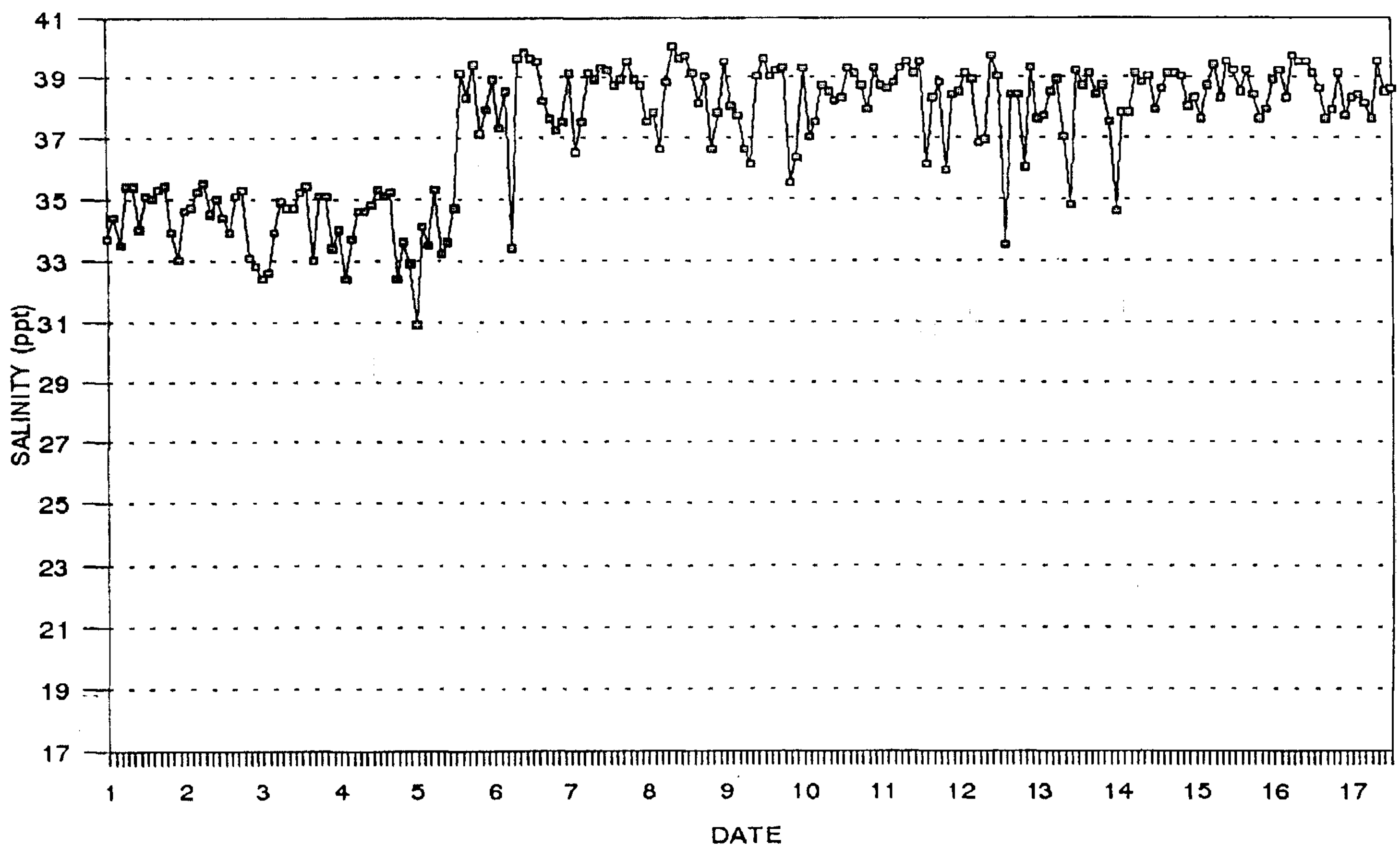


Figure A-50. May, 1993 bi-hourly salinity (ppt) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

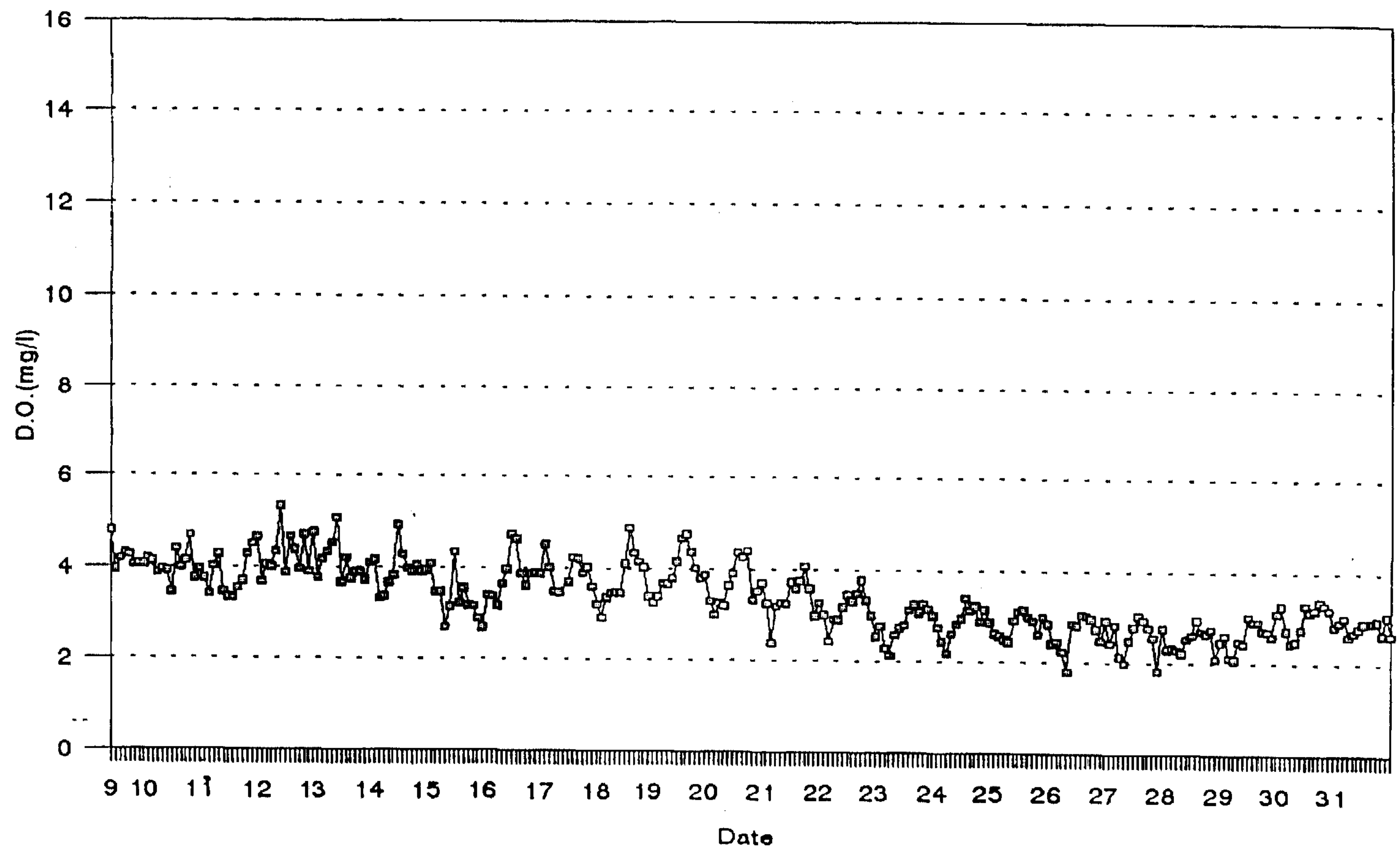


Figure A-51. October, 1991 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

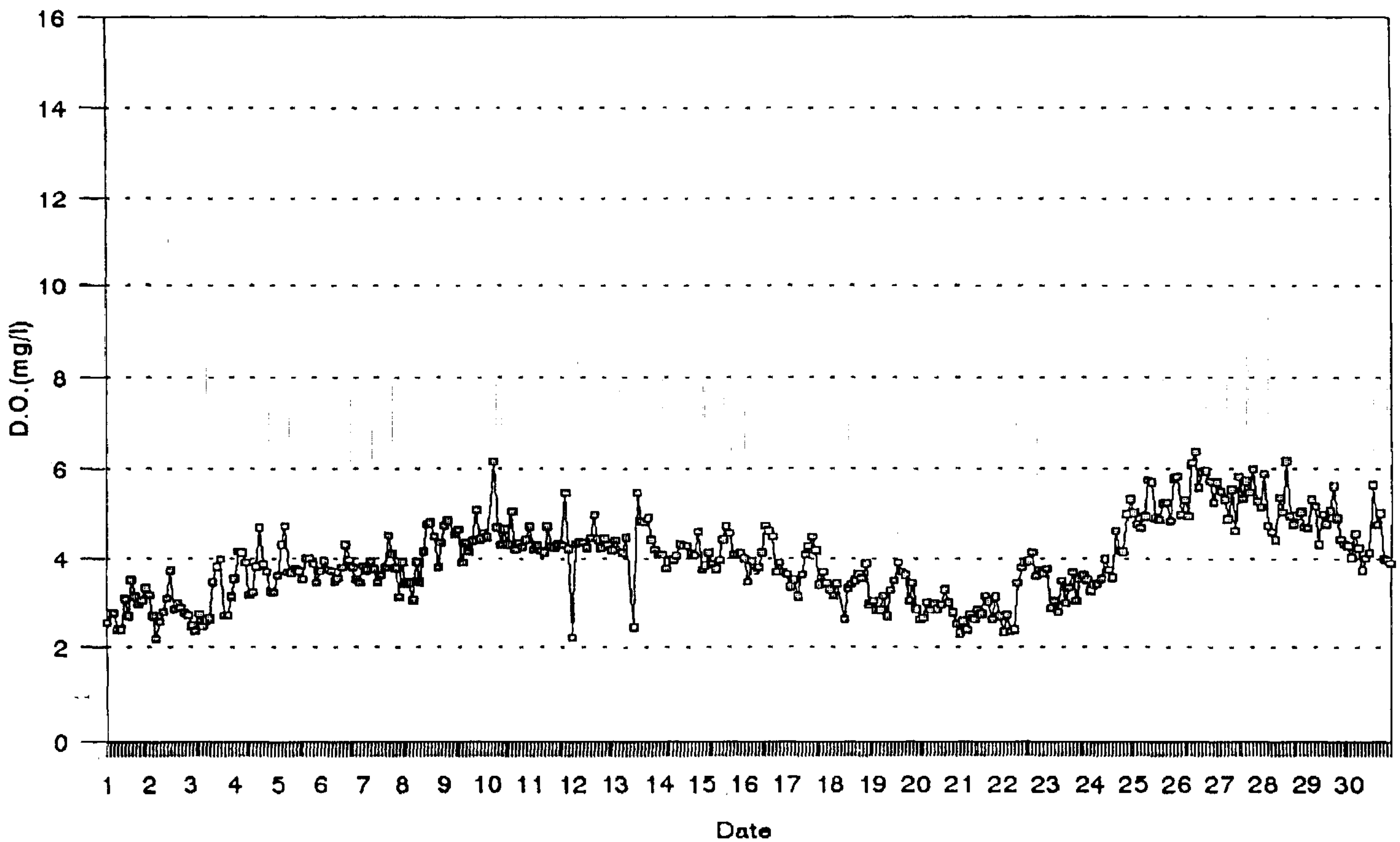


Figure A-52. November, 1991 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

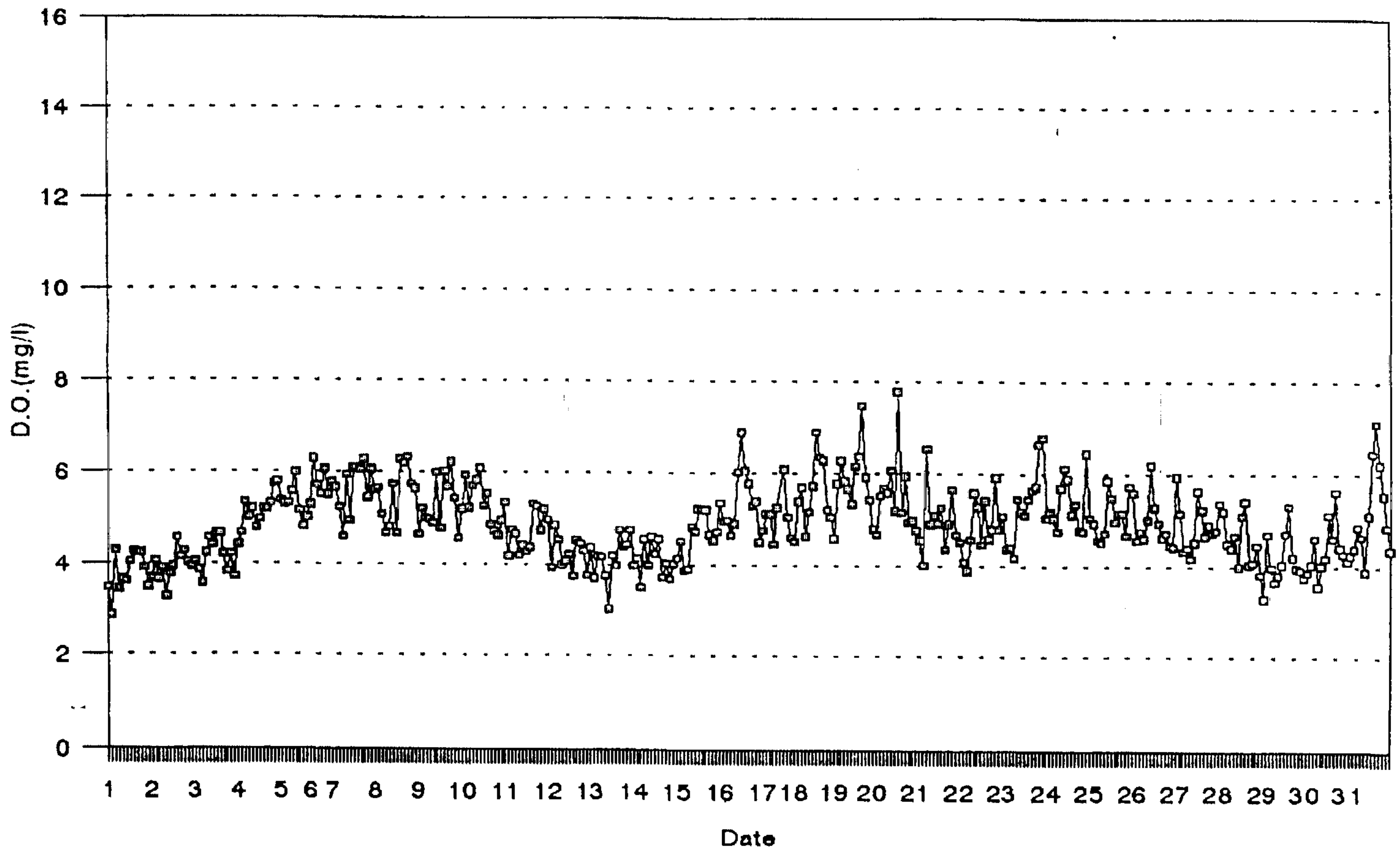


Figure A-53. December, 1991 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

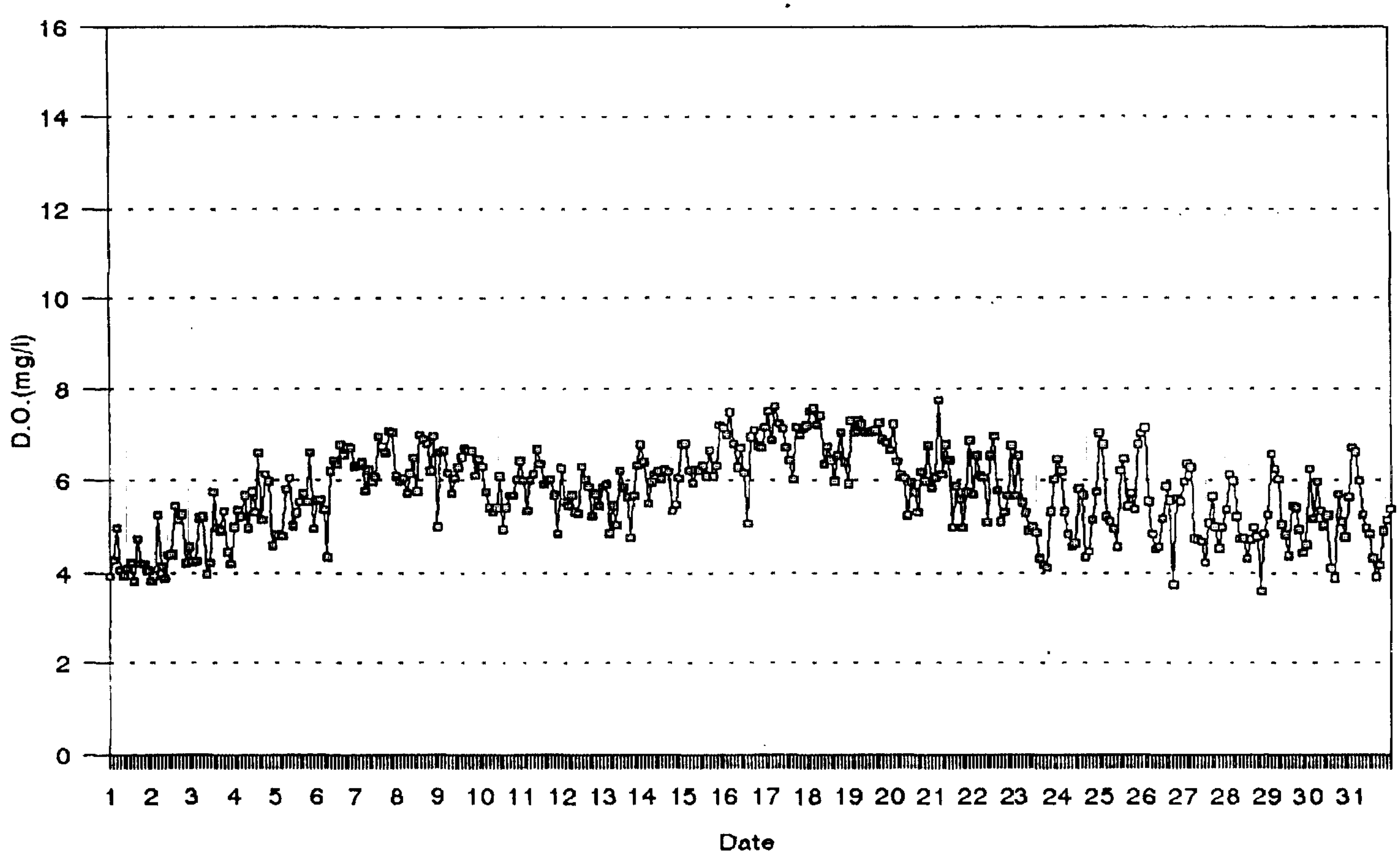


Figure A-54. January, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

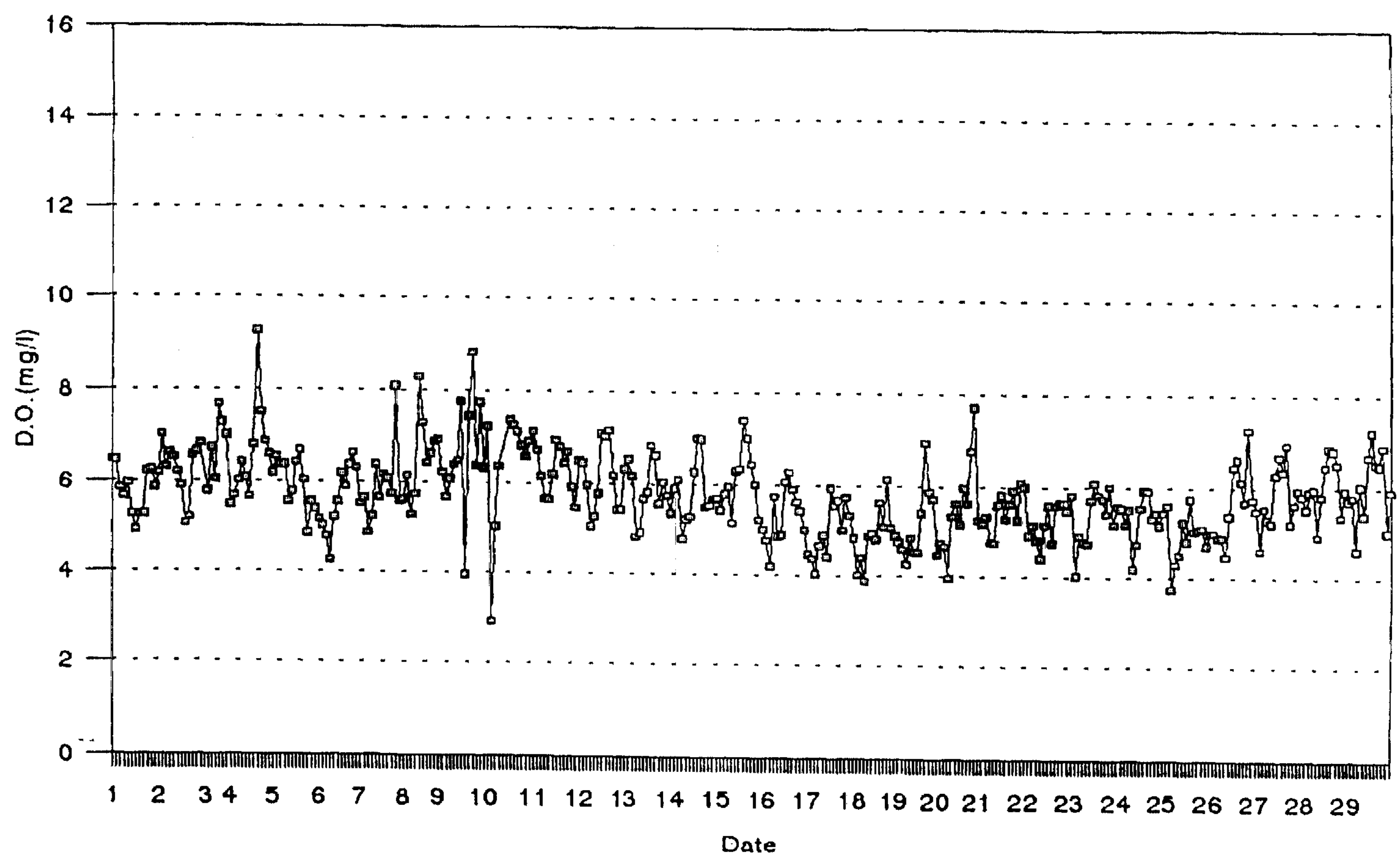


Figure A-55. Febuary, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

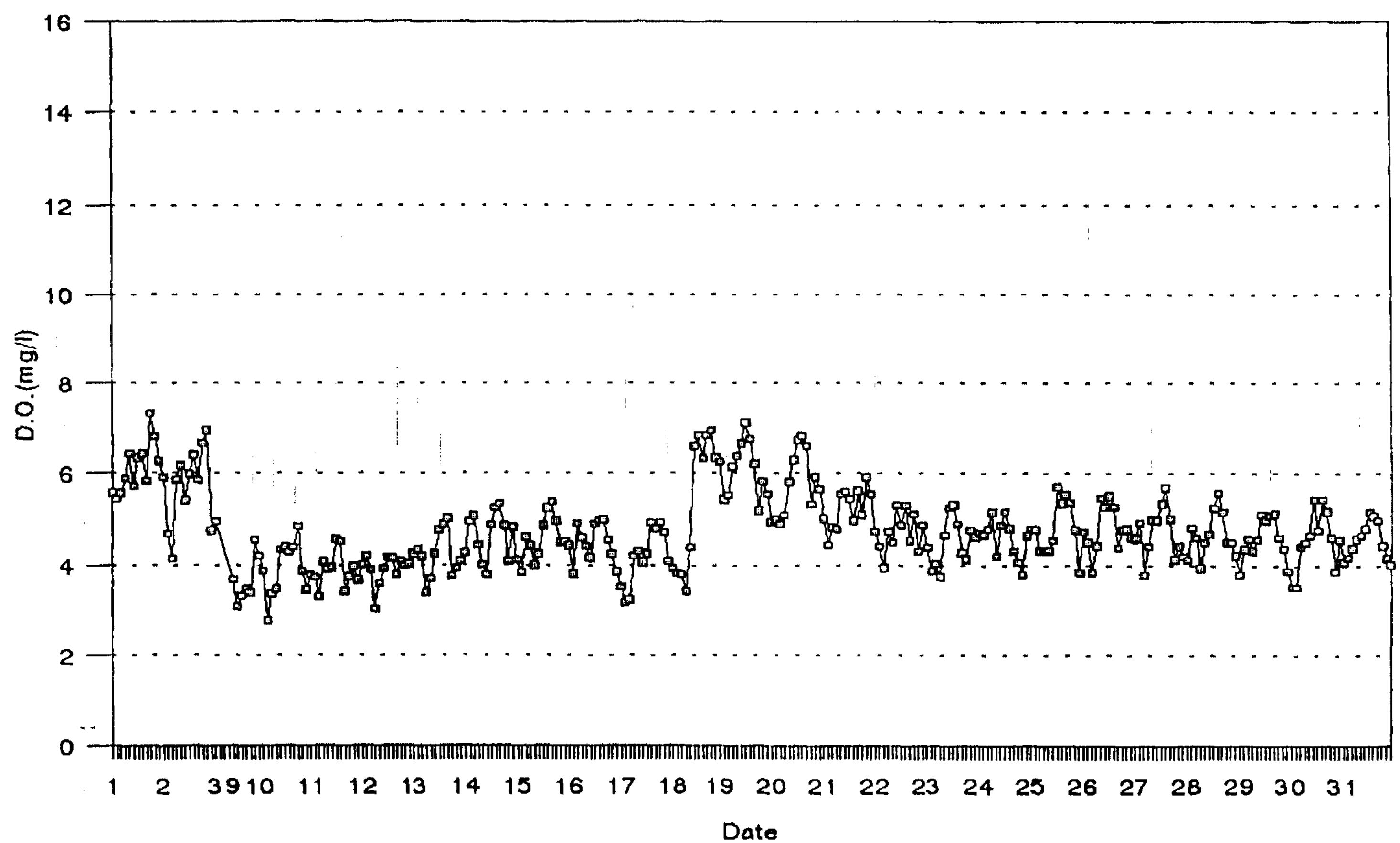


Figure A-56. March, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

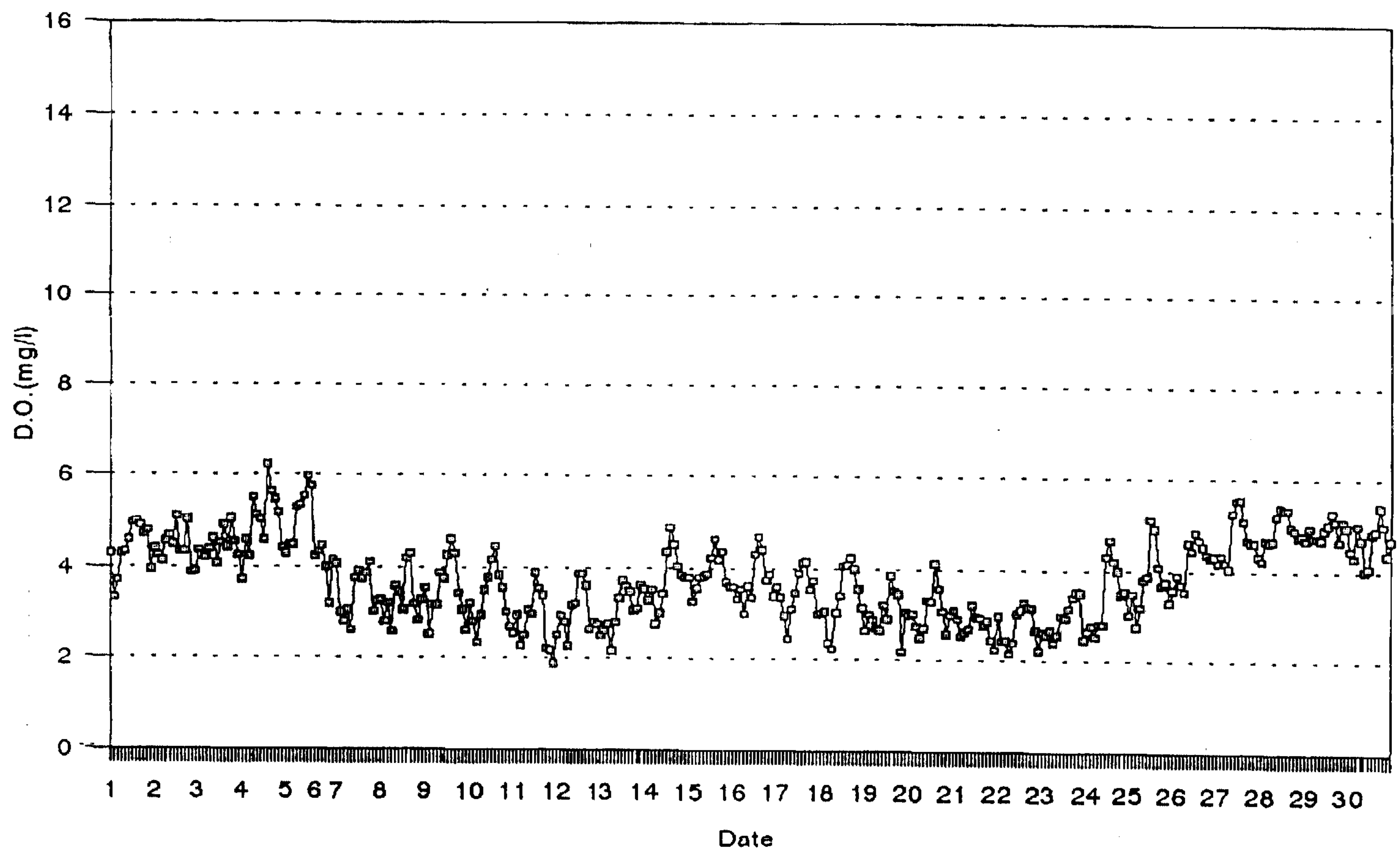


Figure A-57. April, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

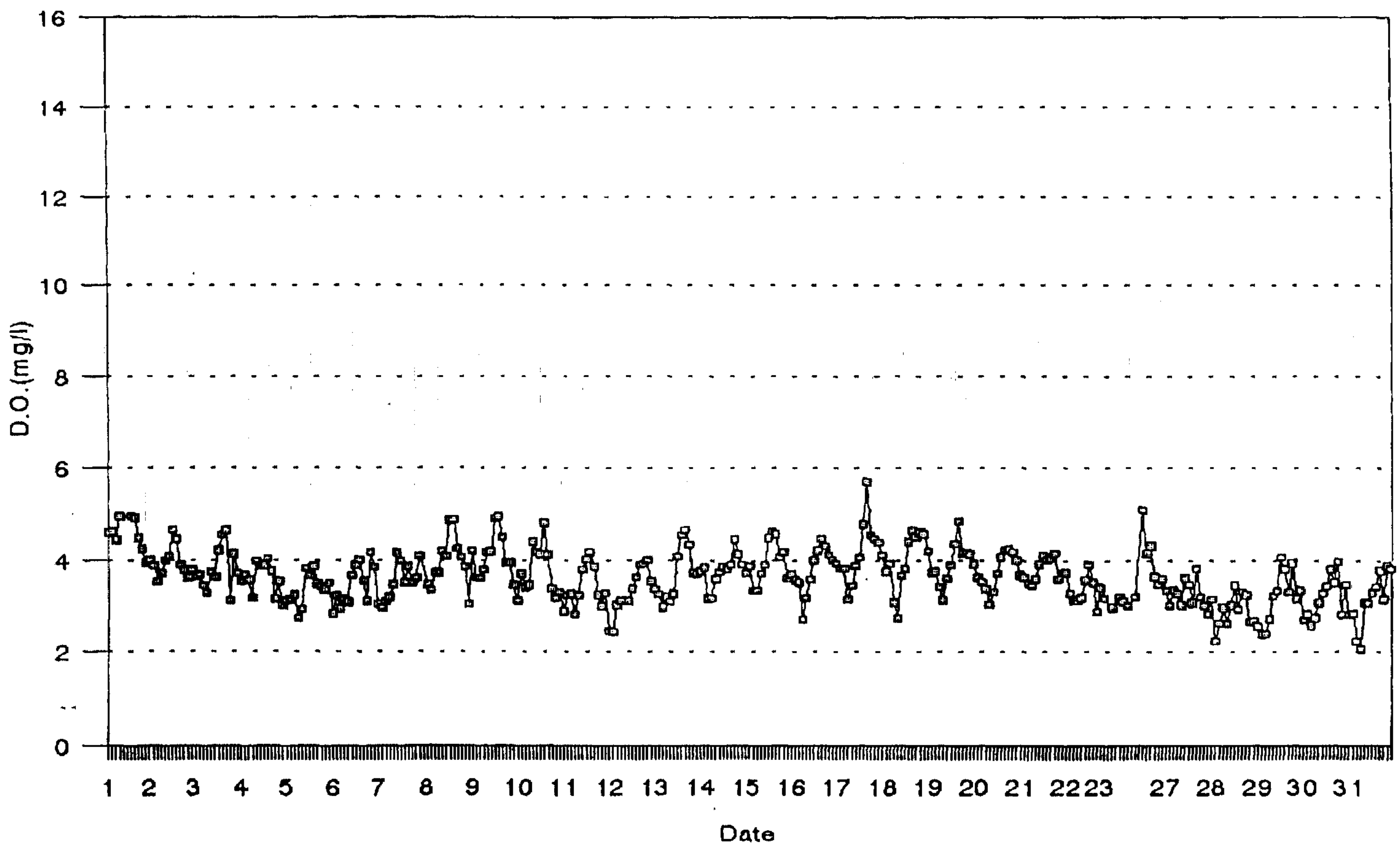


Figure A-58. May, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

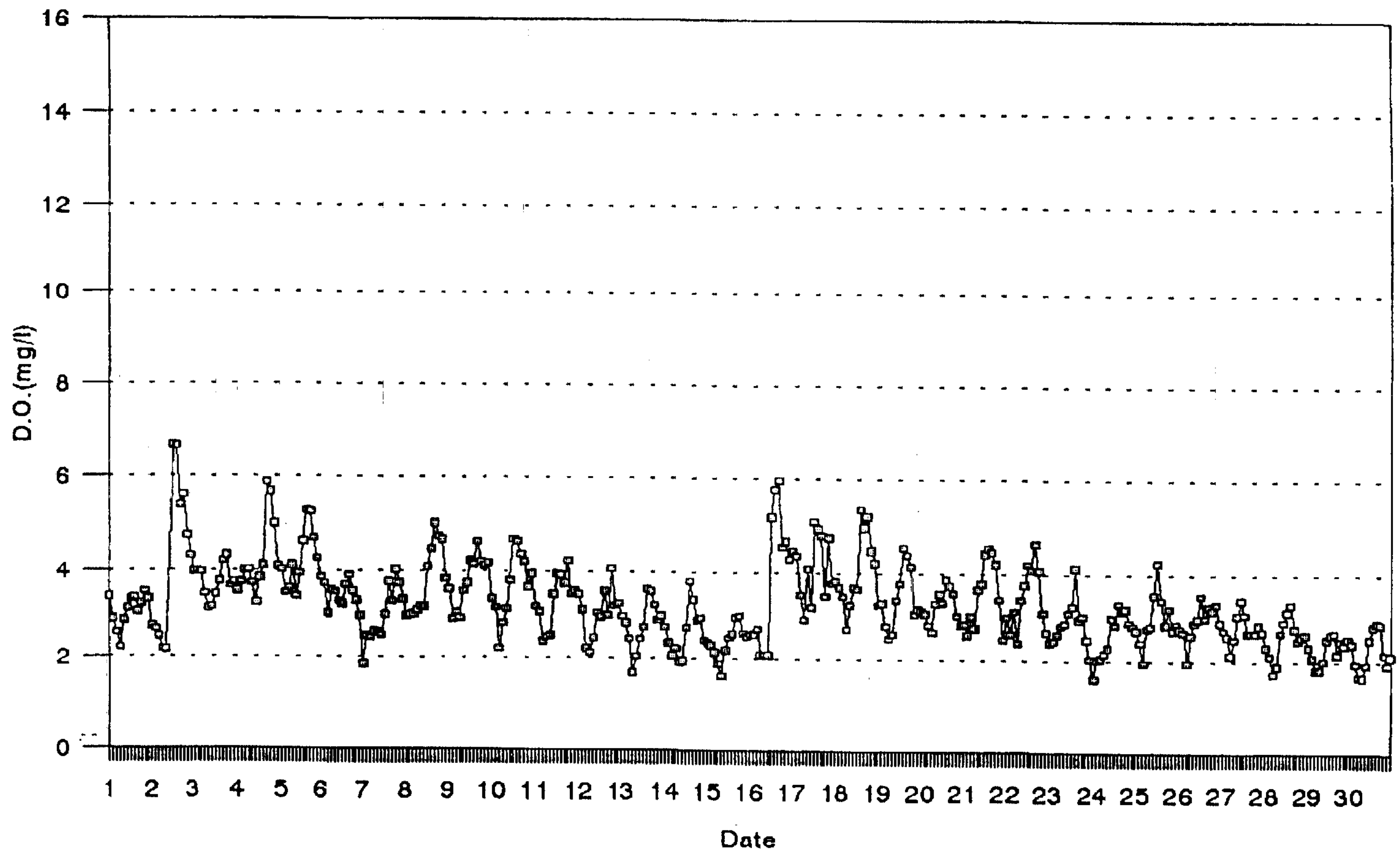


Figure A-59. June, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

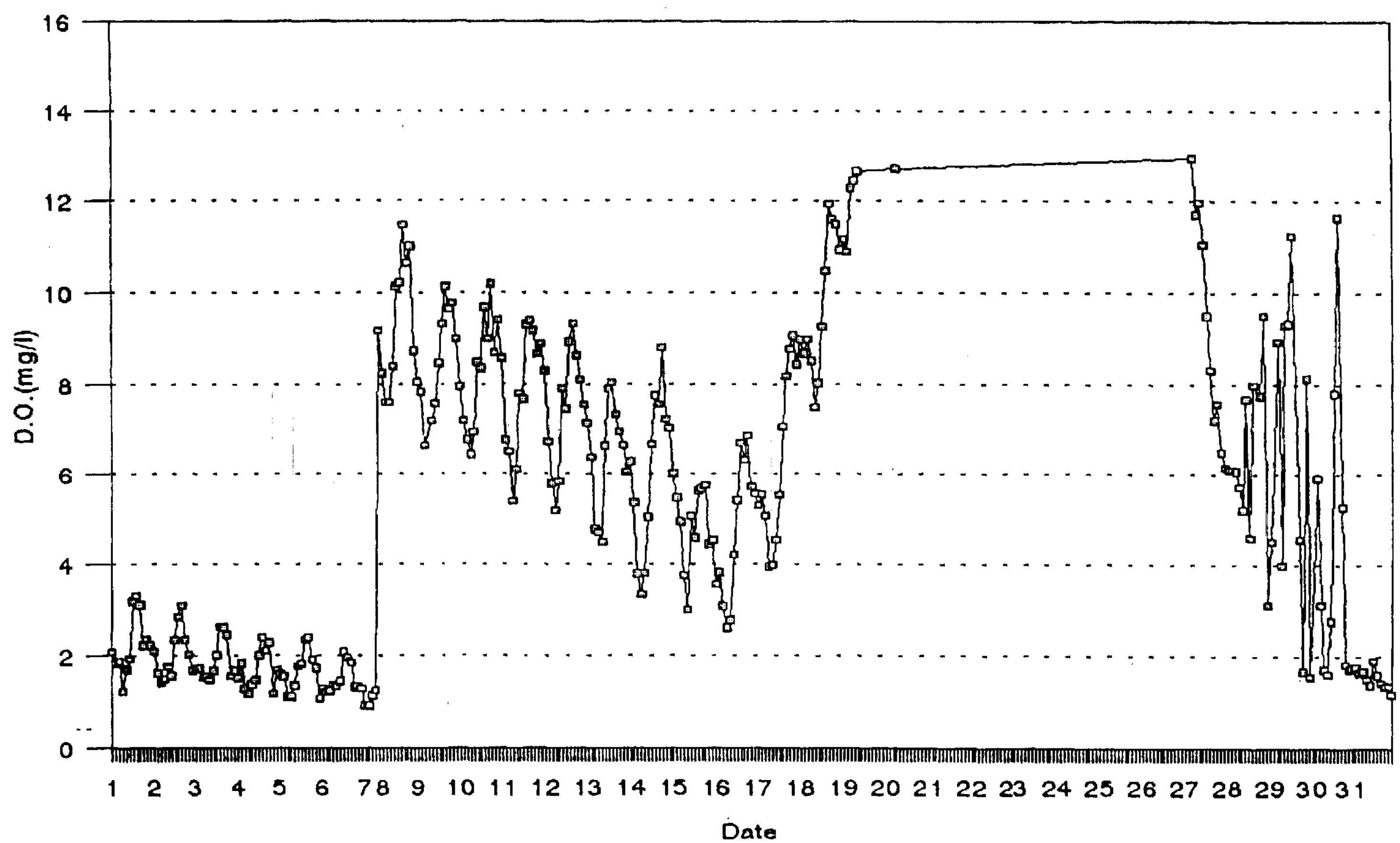


Figure A-60. July, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

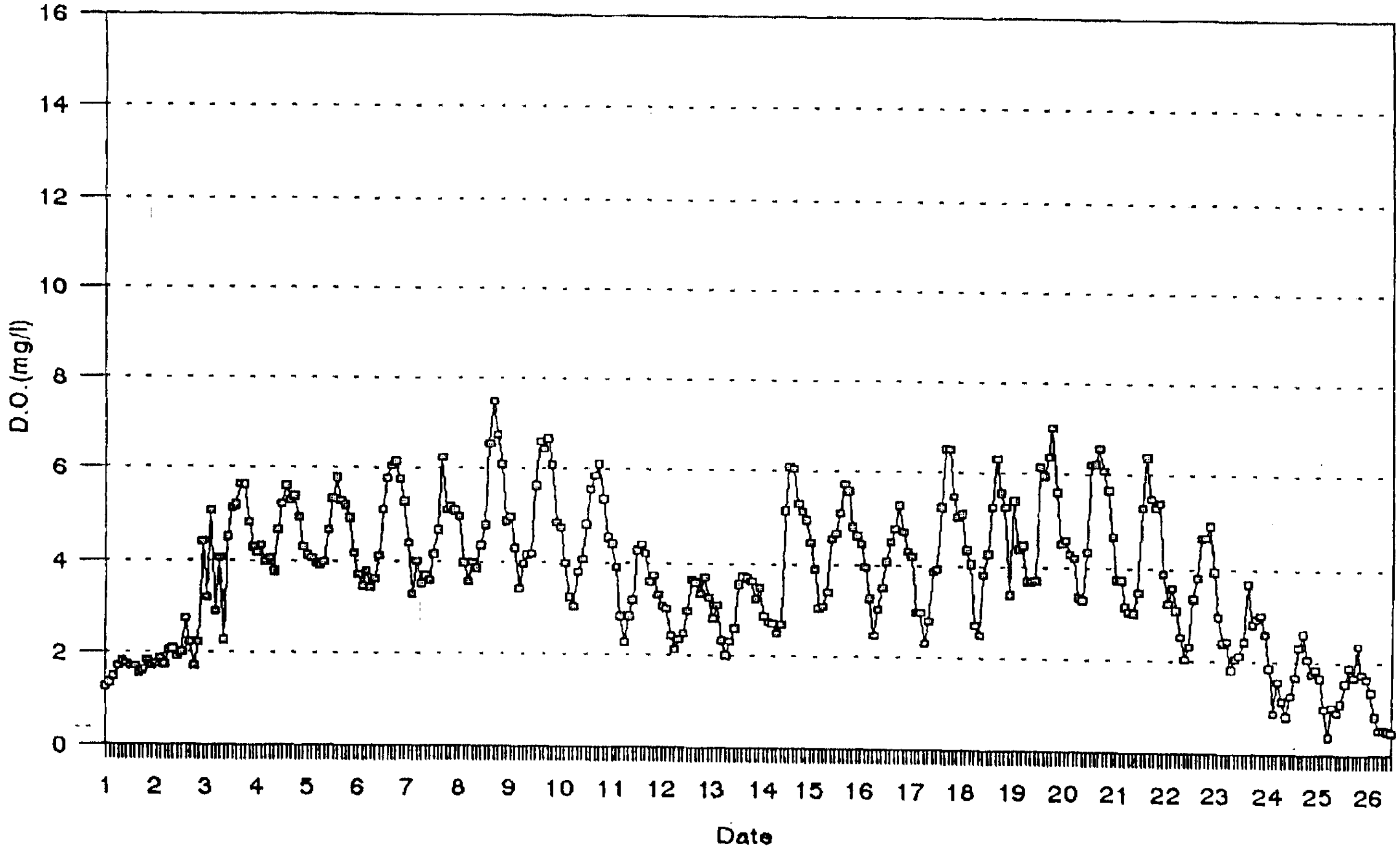


Figure A-61. August, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

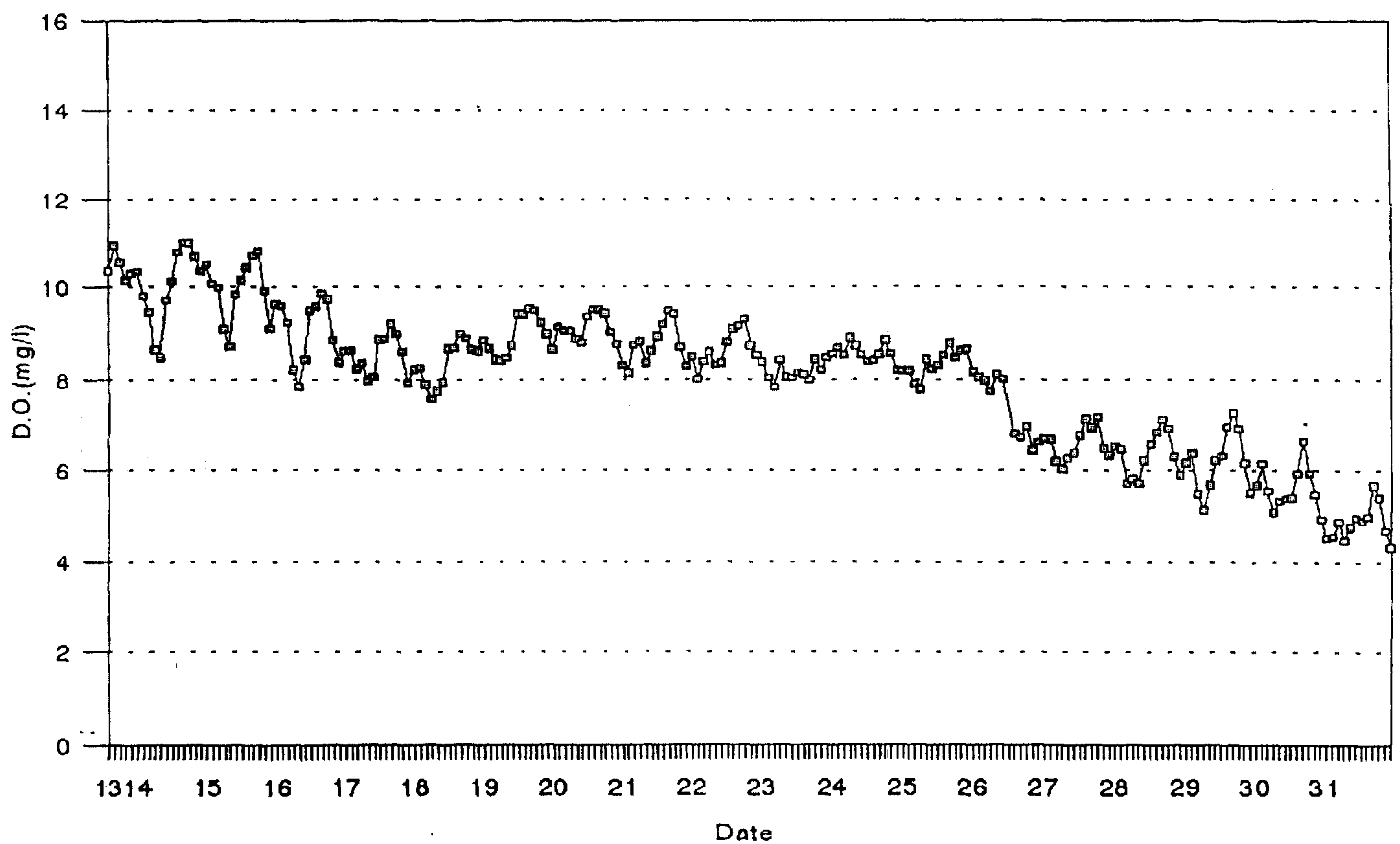


Figure A-63. October, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

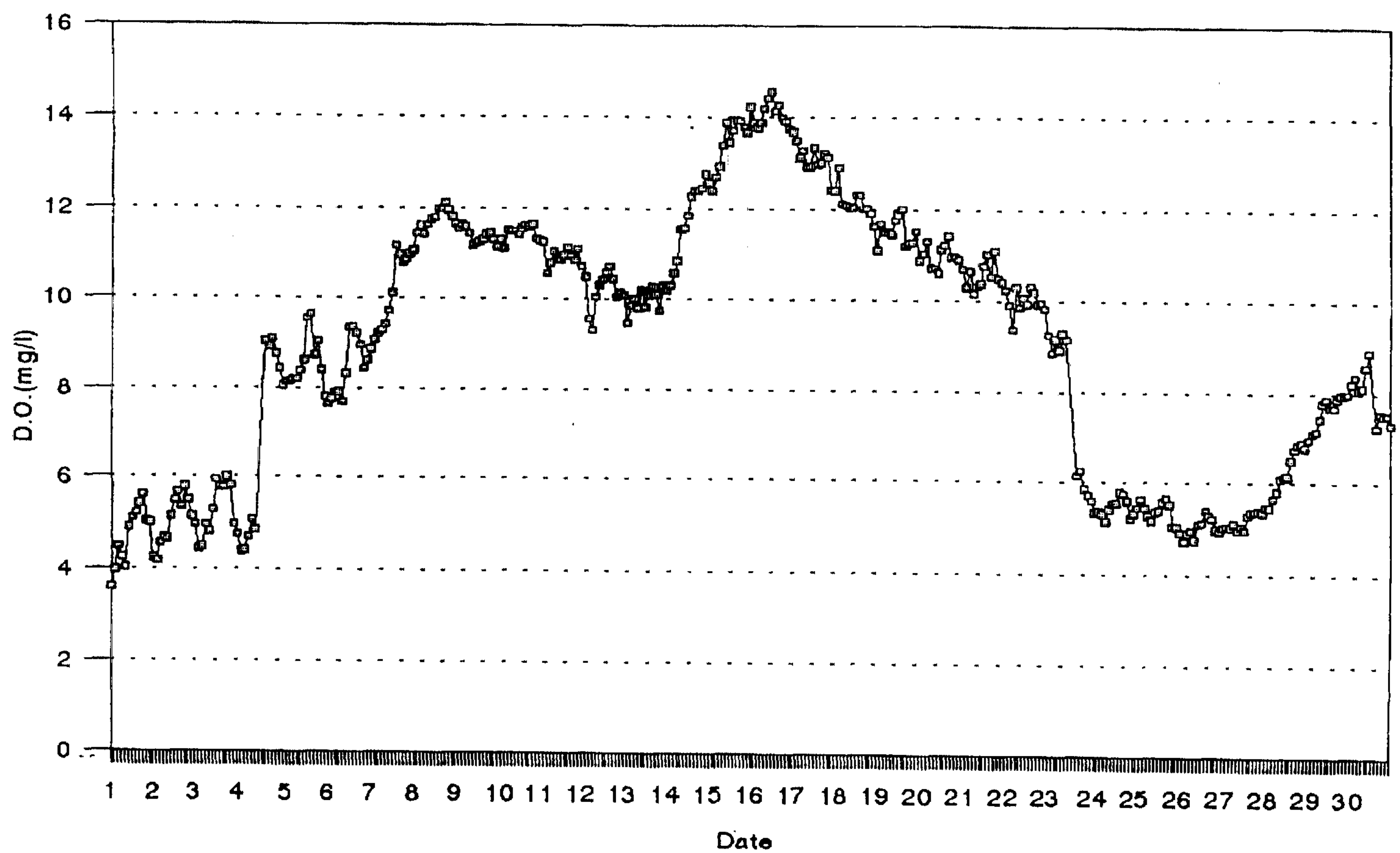


Figure A-64. November, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

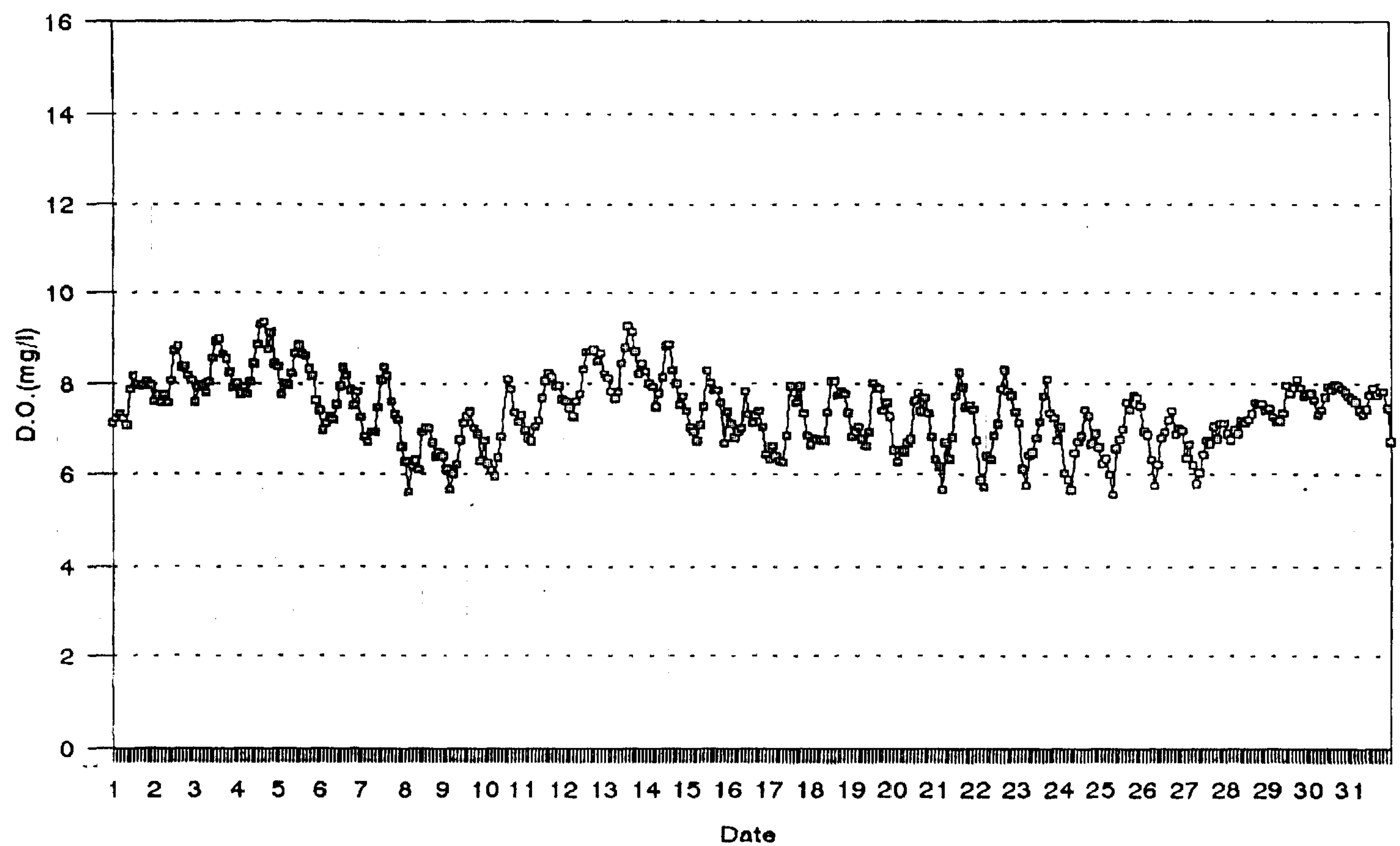


Figure A-65. December, 1992 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

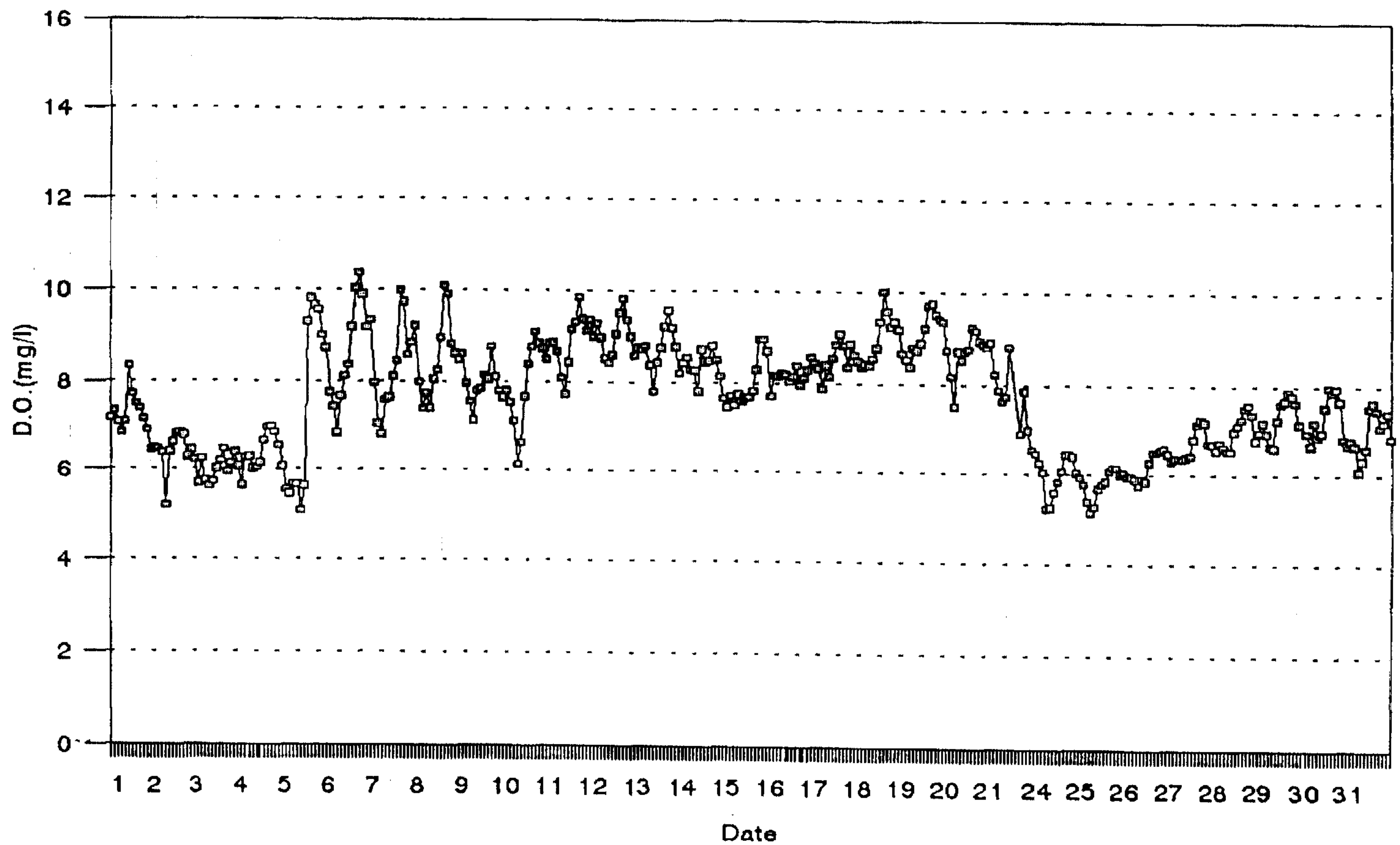


Figure A-66. January, 1993 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

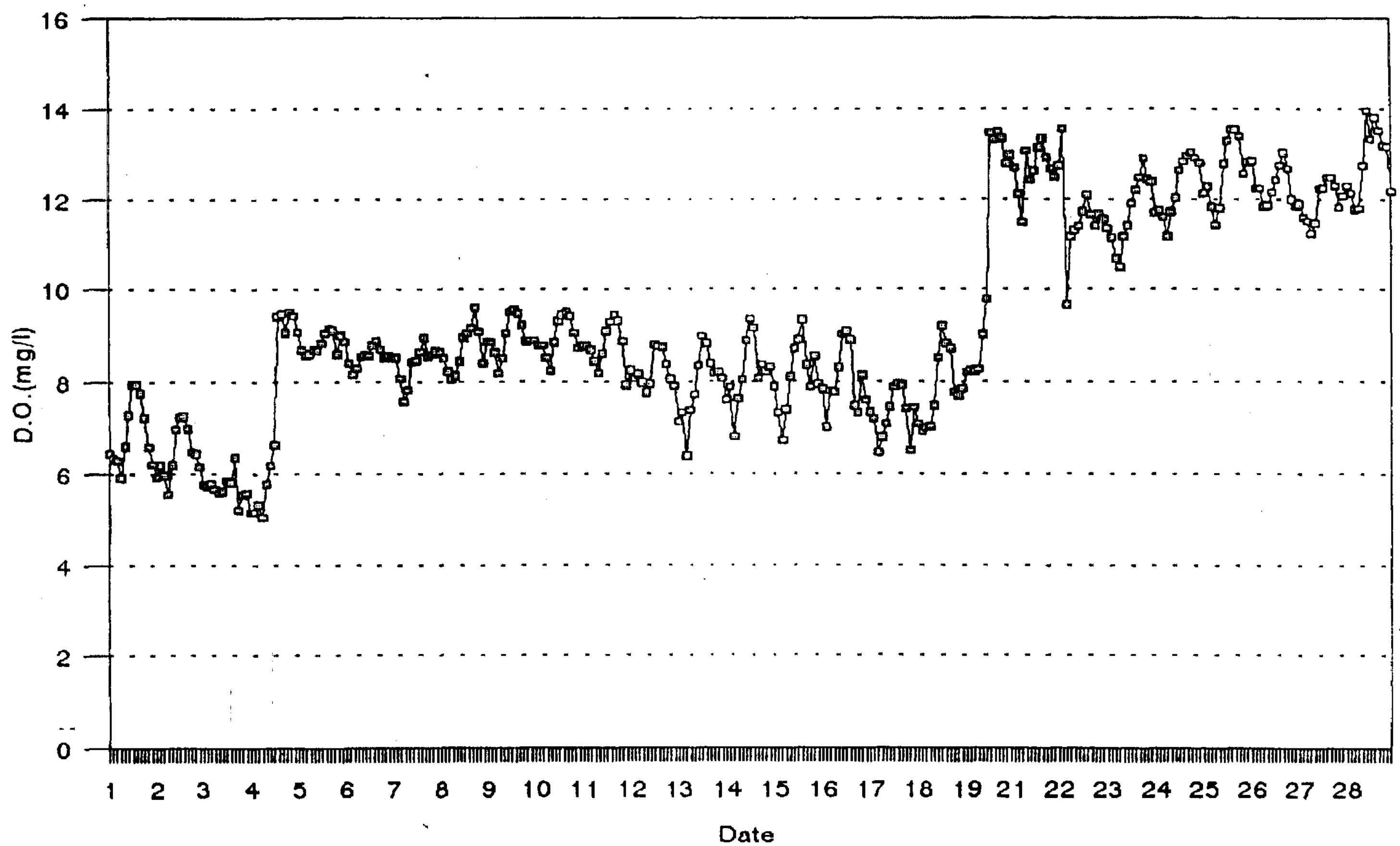


Figure A-67. Febuary, 1993 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

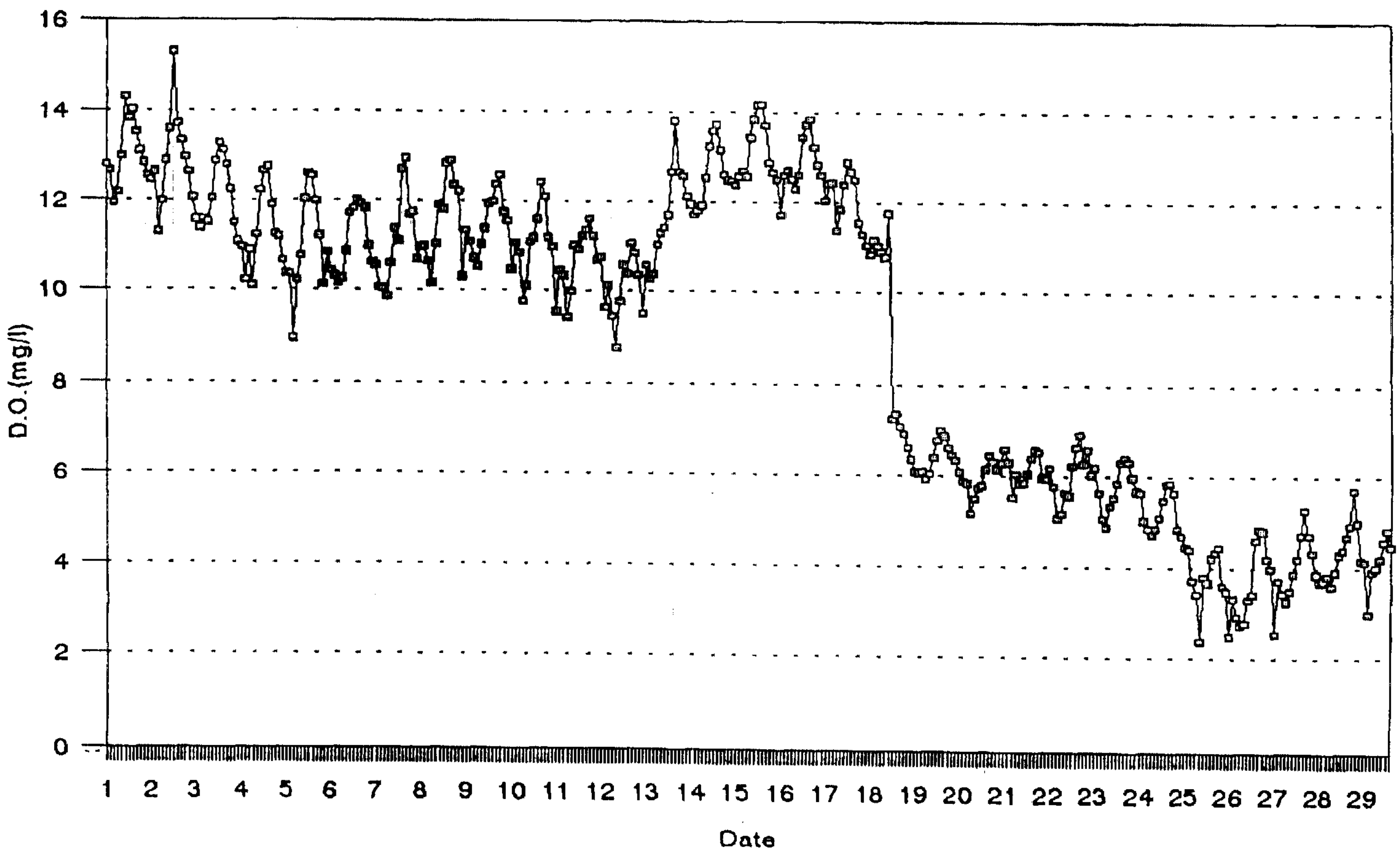


Figure A-68. March, 1993 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

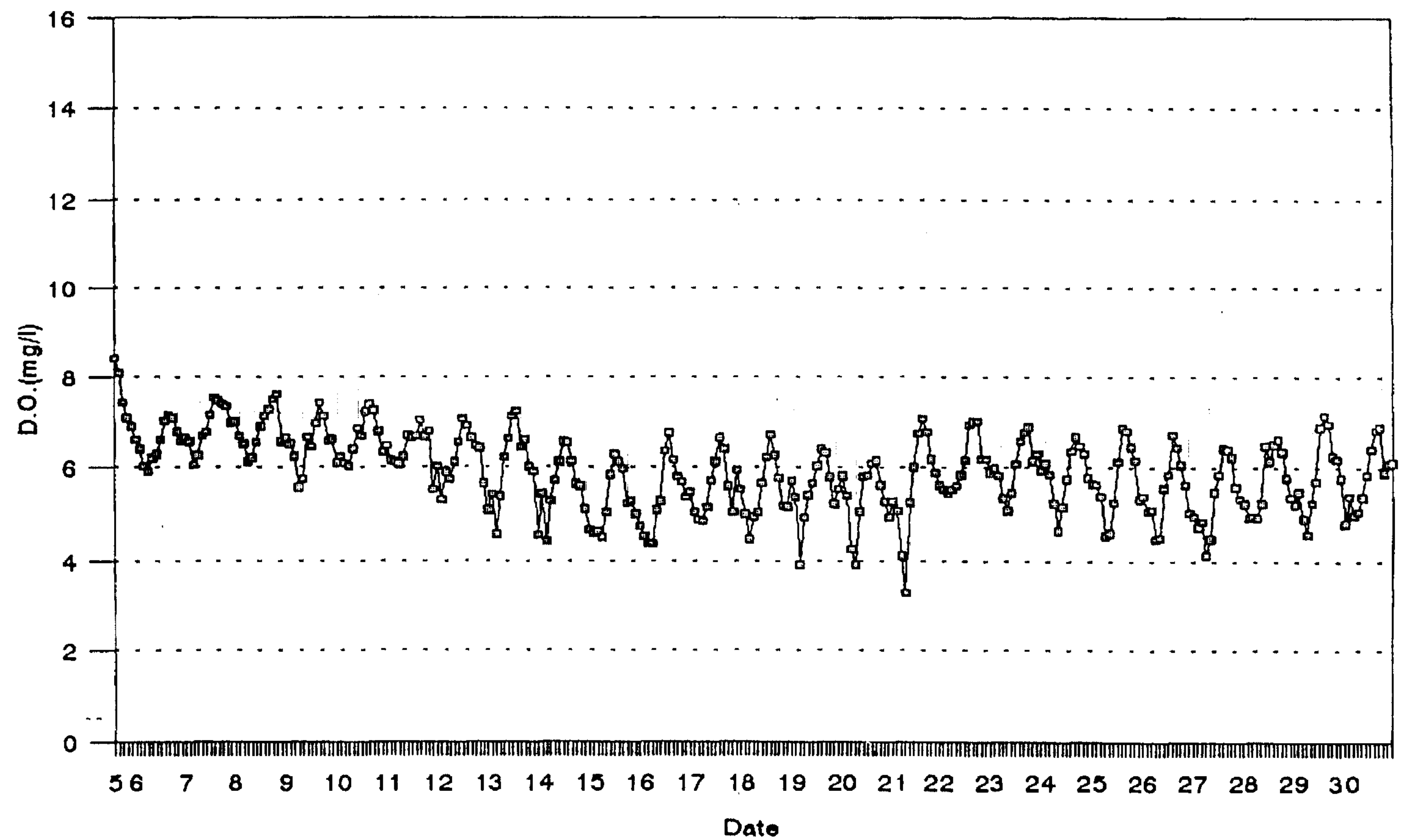


Figure A-69. April, 1993 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

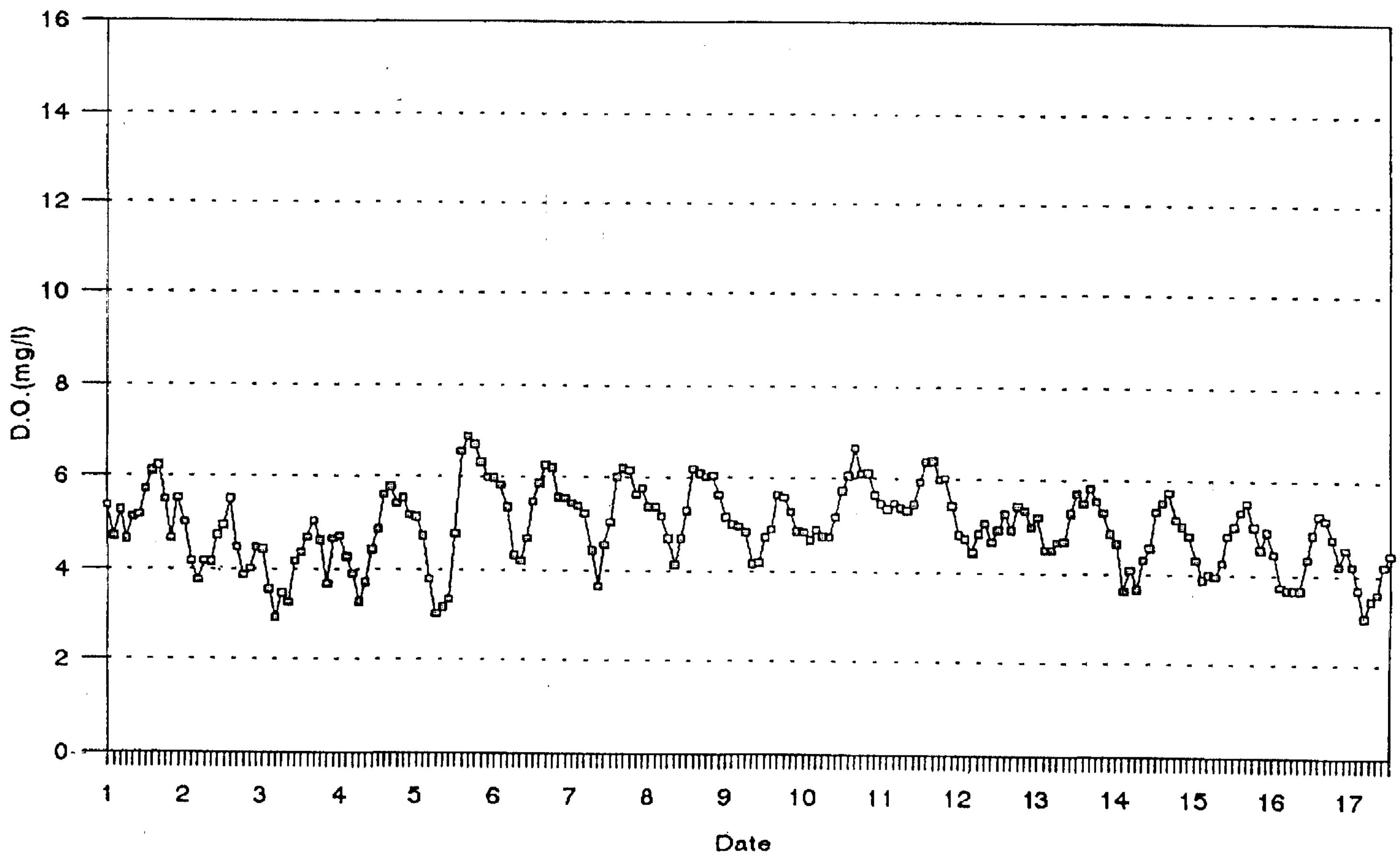


Figure A-70. May, 1993 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.

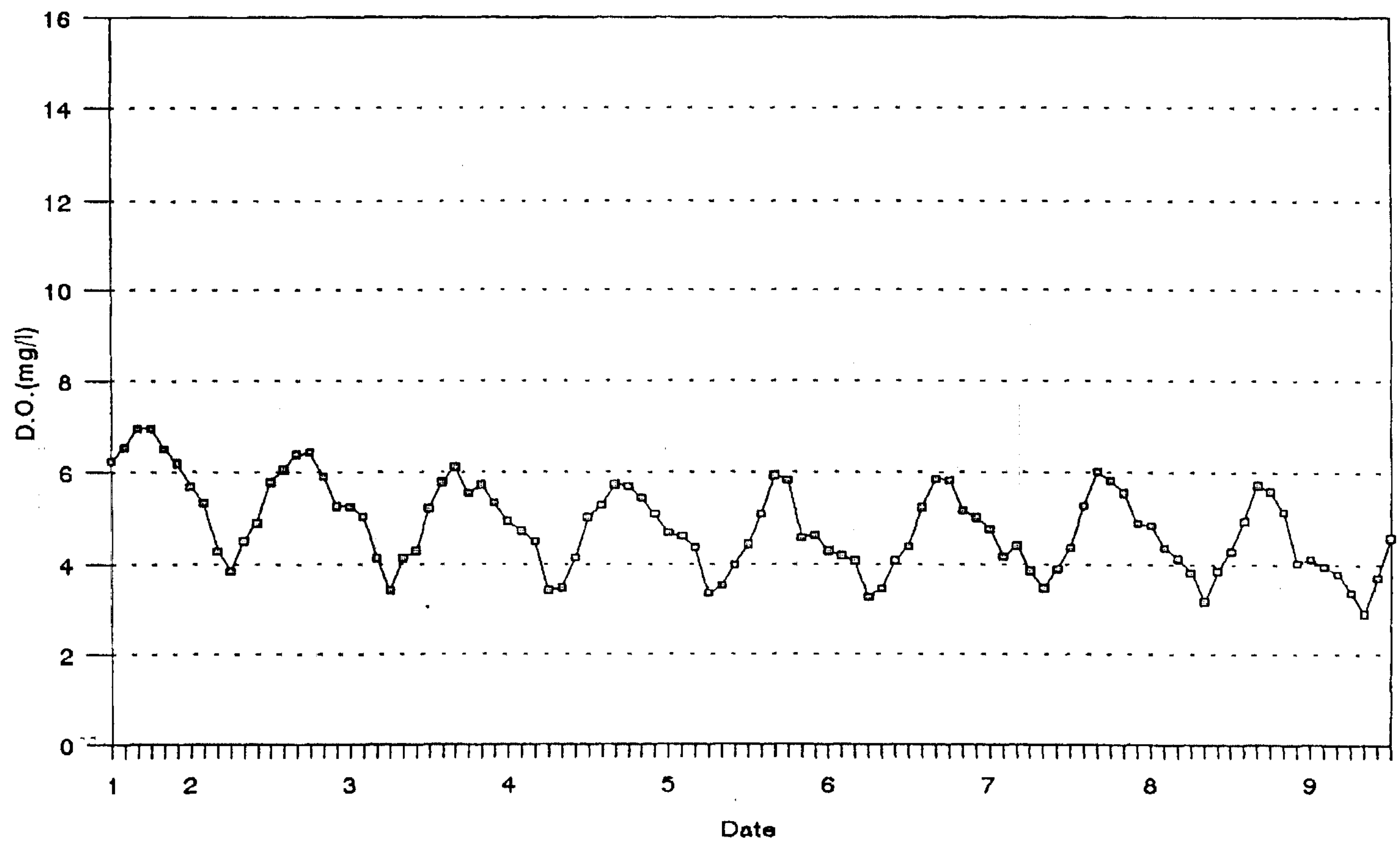
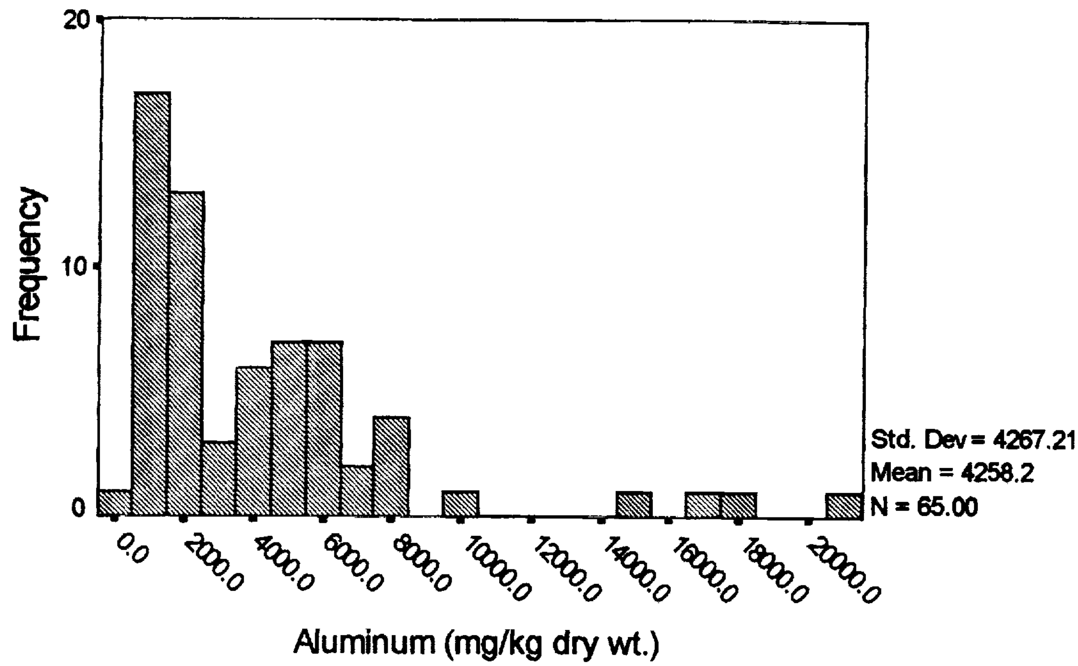


Figure A-71. June, 1993 bi-hourly dissolved oxygen (mg/l) data collected at the Canaveral National Seashore boat dock. Data were collected utilizing a programmable Hydrolab data logger with a two hour sampling interval. Probes were located 30 - 40 cm above the bottom in approximately 1.2 m of water.



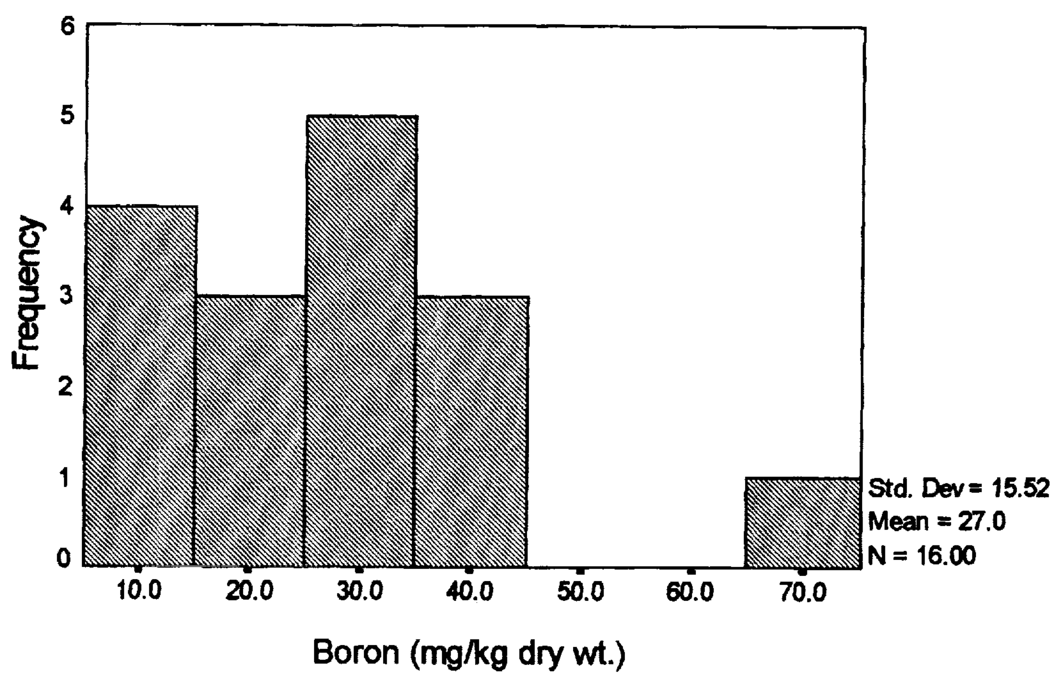
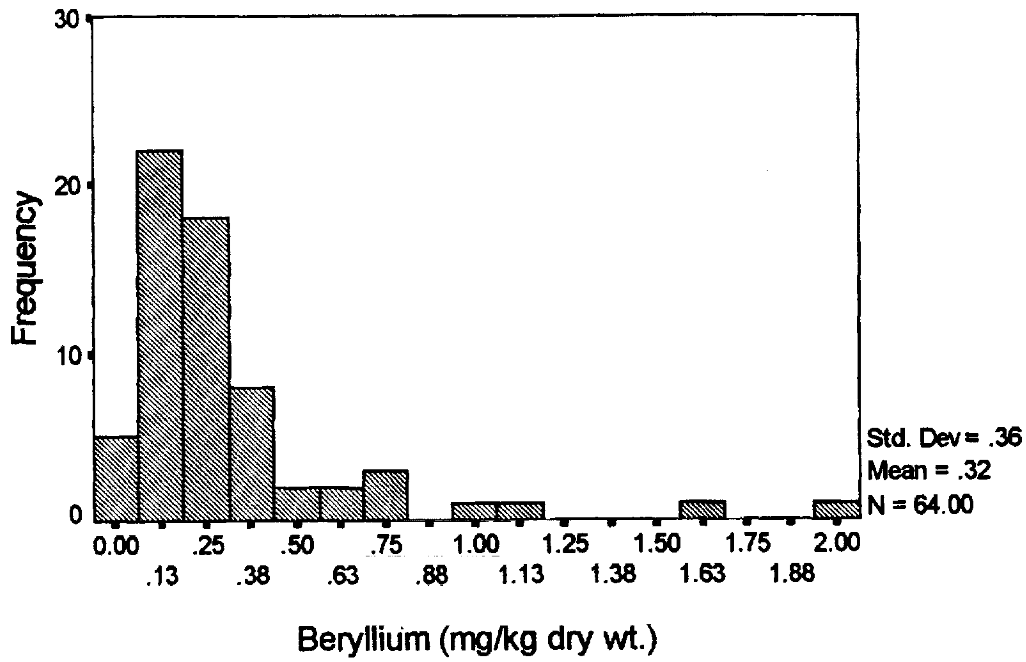


Figure A-72. Mean, standard deviation, and sample frequency distributions for aluminum and boron in Mosquito Lagoon sediment samples.



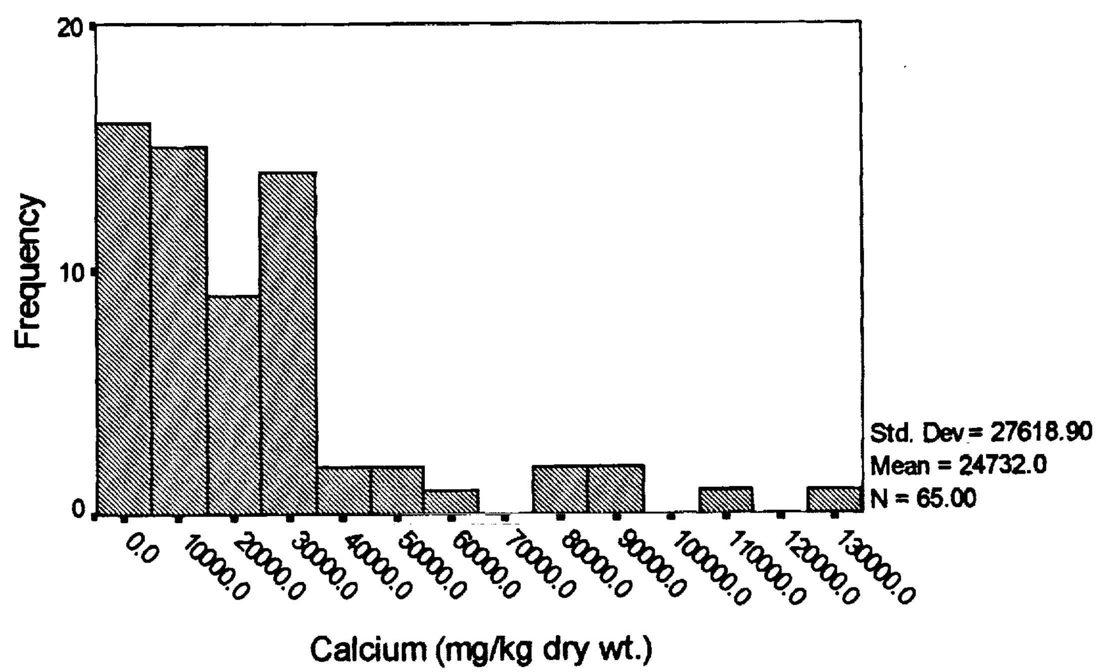
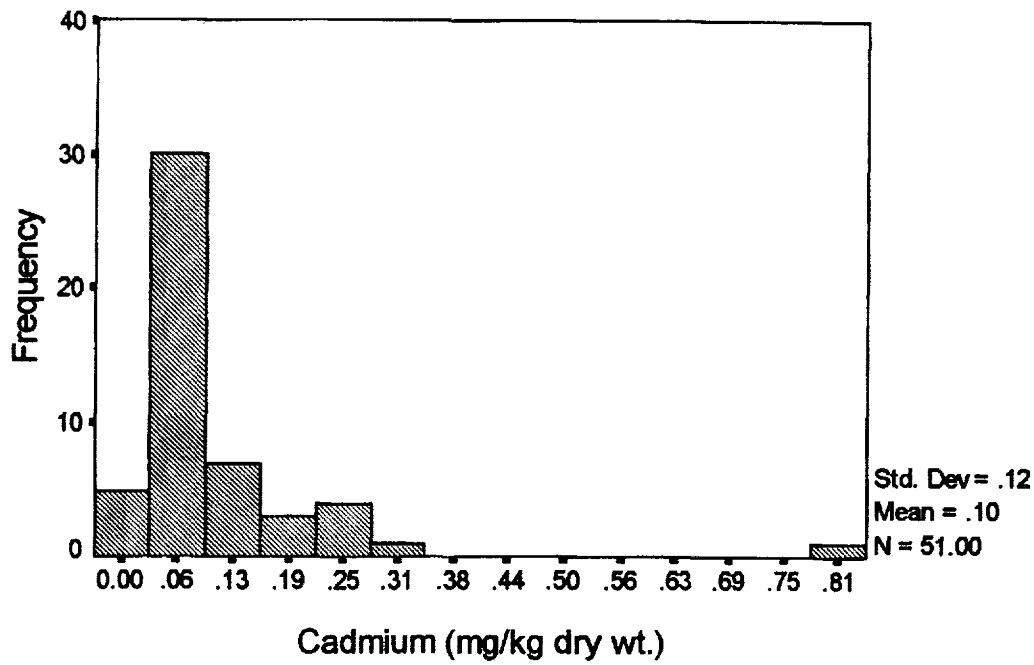


Figure A-73. Mean, standard deviations, and sample frequency distributions for beryllium and calcium in Mosquito Lagoon sediment samples.



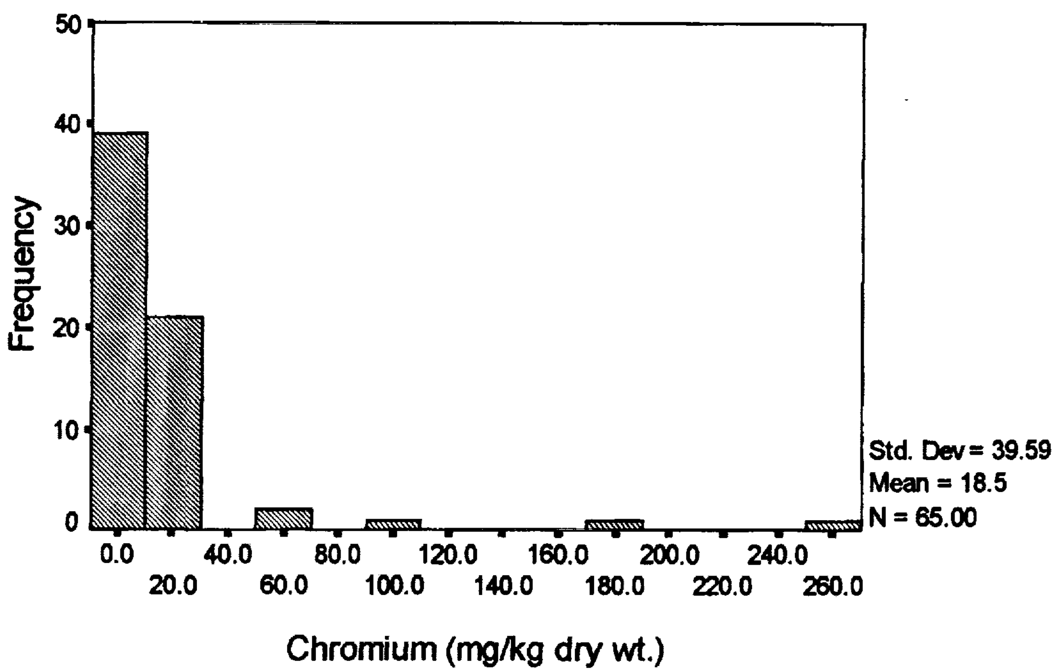
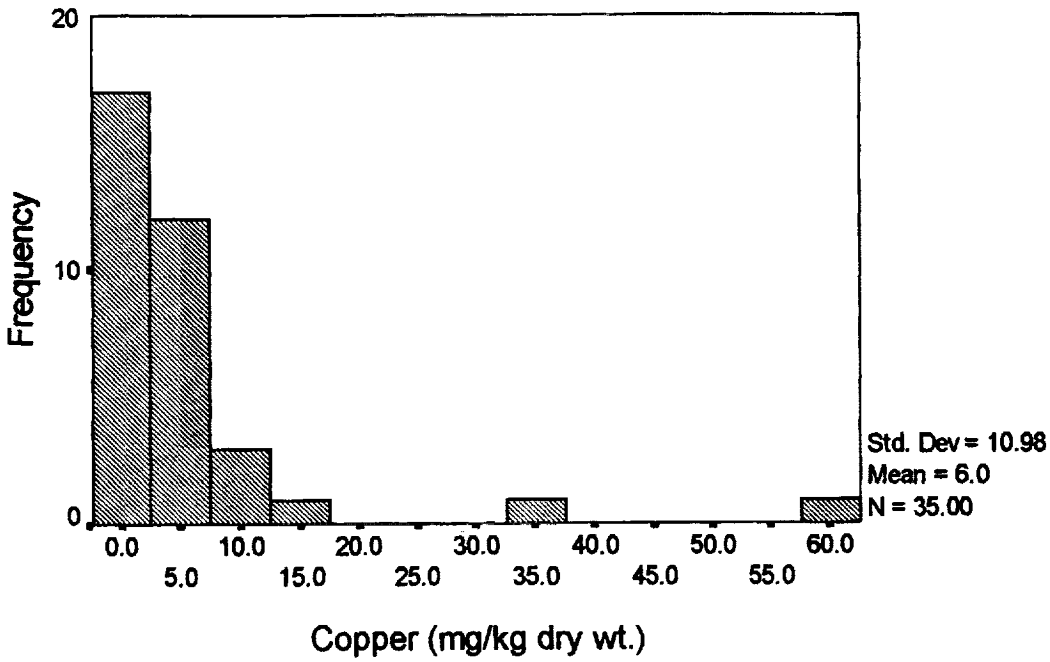


Figure A-74. . Mean, standard deviations, and sample frequency distributions for cadmium and chromium in Mosquito Lagoon sediment samples.



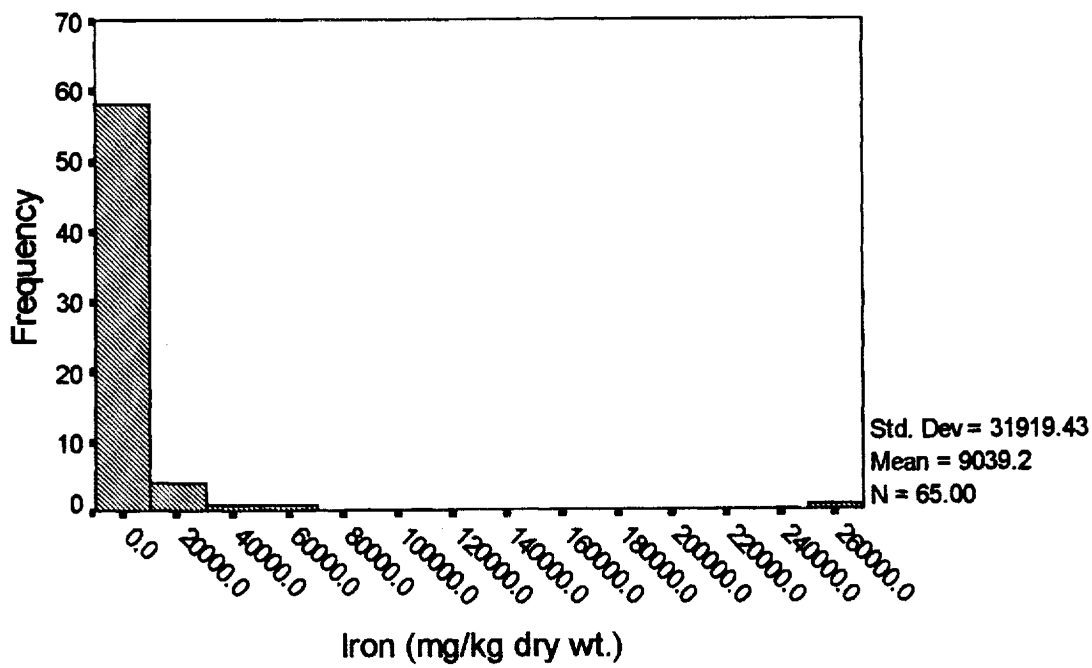
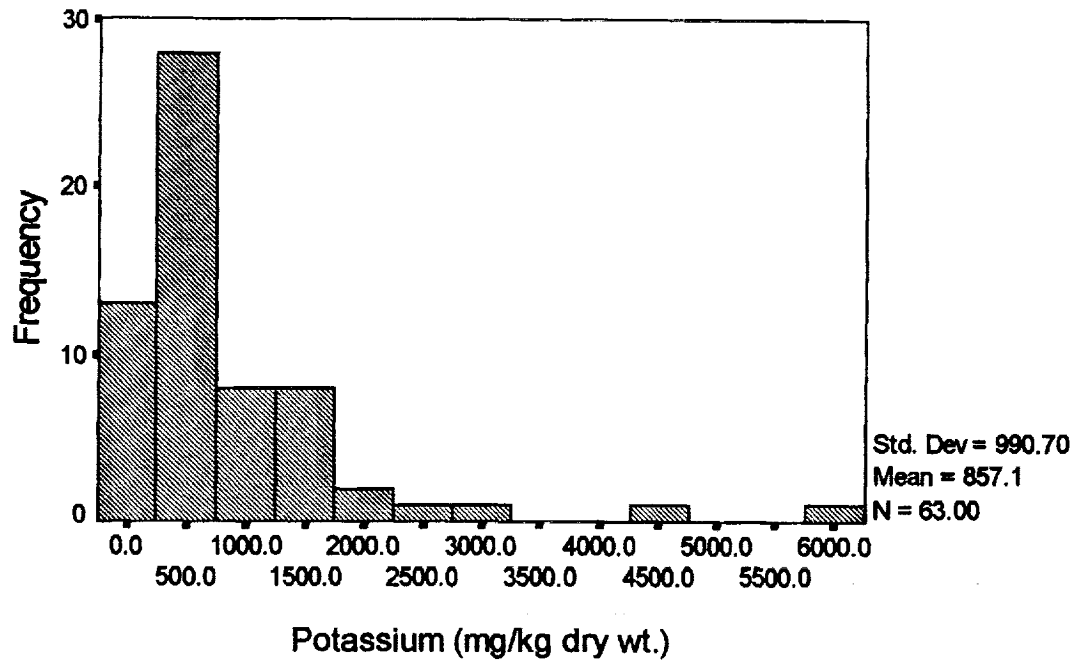


Figure A-75. Mean, standard deviation, and sample frequency distributions for copper and iron in Mosquito Lagoon sediment samples.



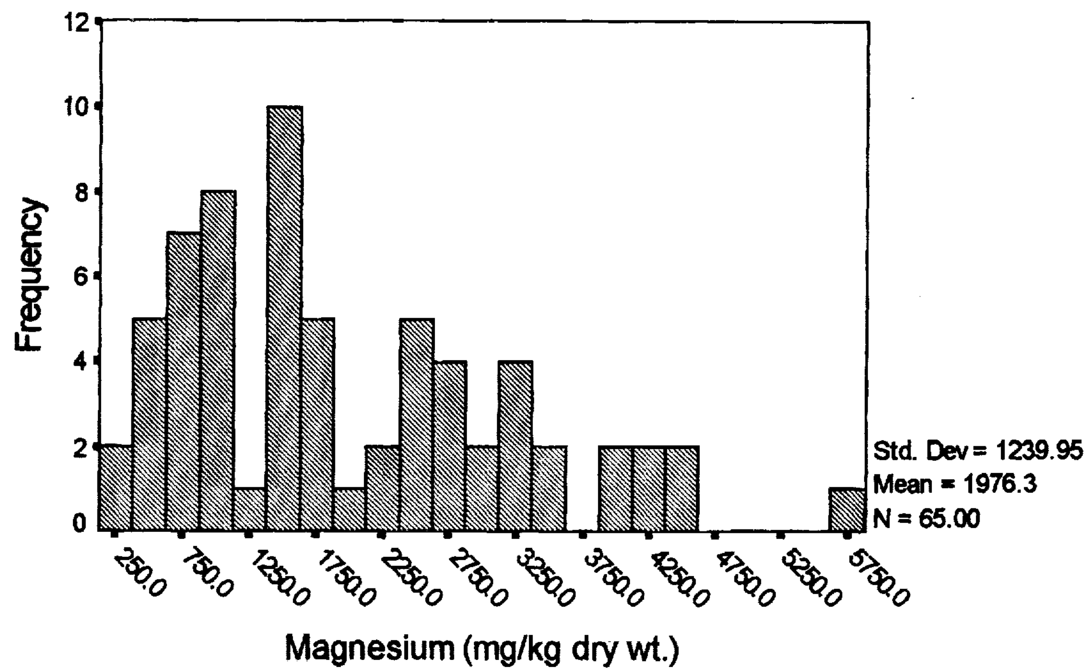
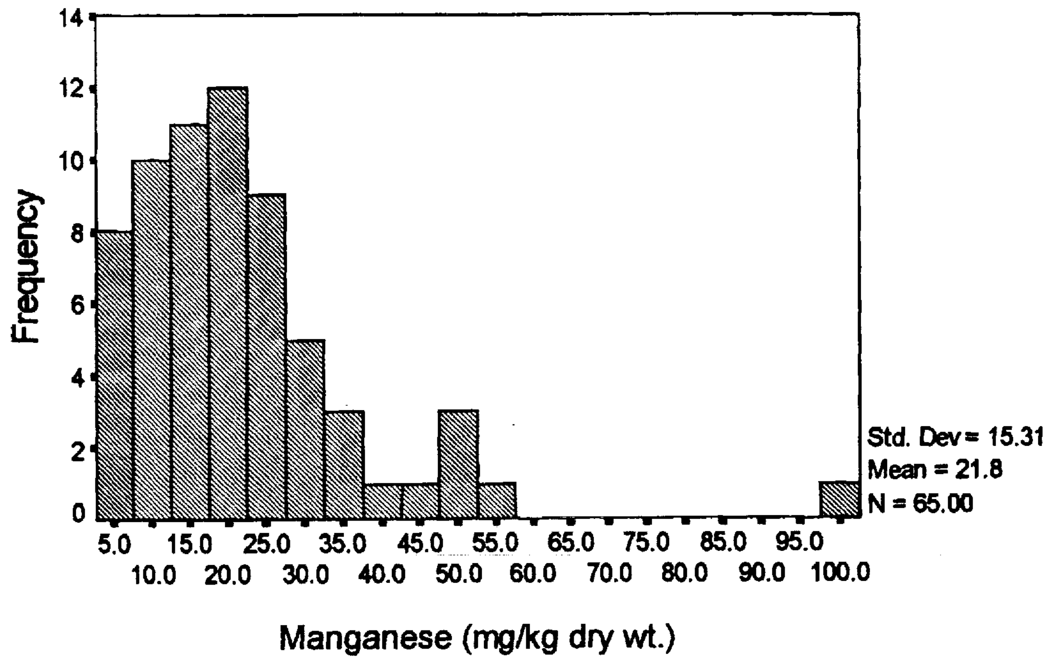


Figure A-76. Mean, standard deviation, and sample frequency distributions for potassium and magnesium in Mosquito Lagoon sediment samples.



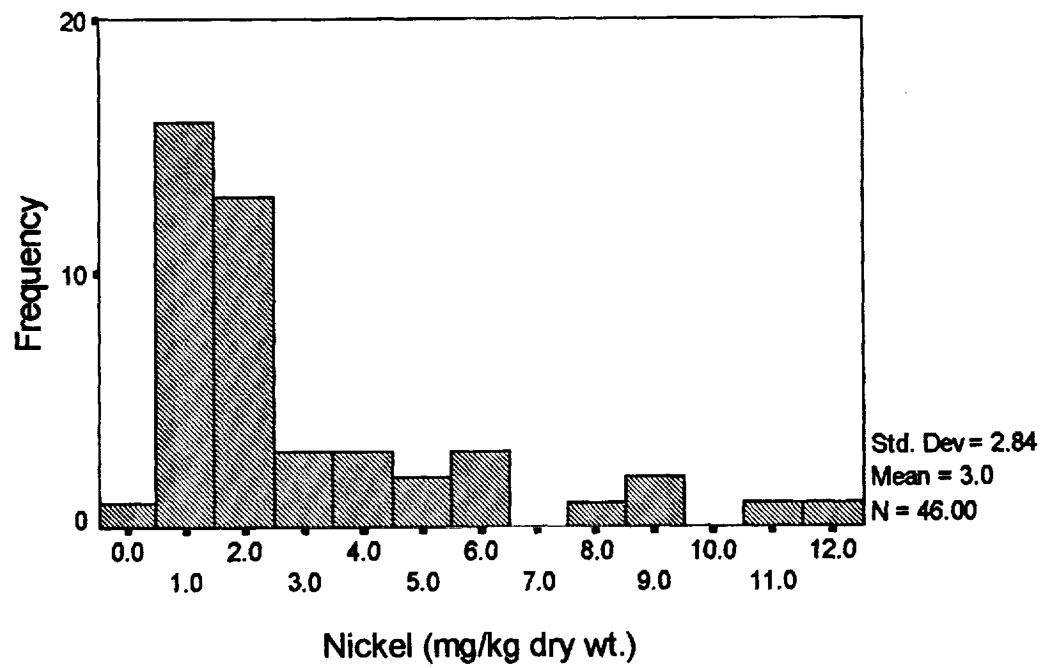


Figure A-77. Mean, standard deviation, and sample frequency distributions for manganese and nickel in Mosquito Lagoon sediment samples.

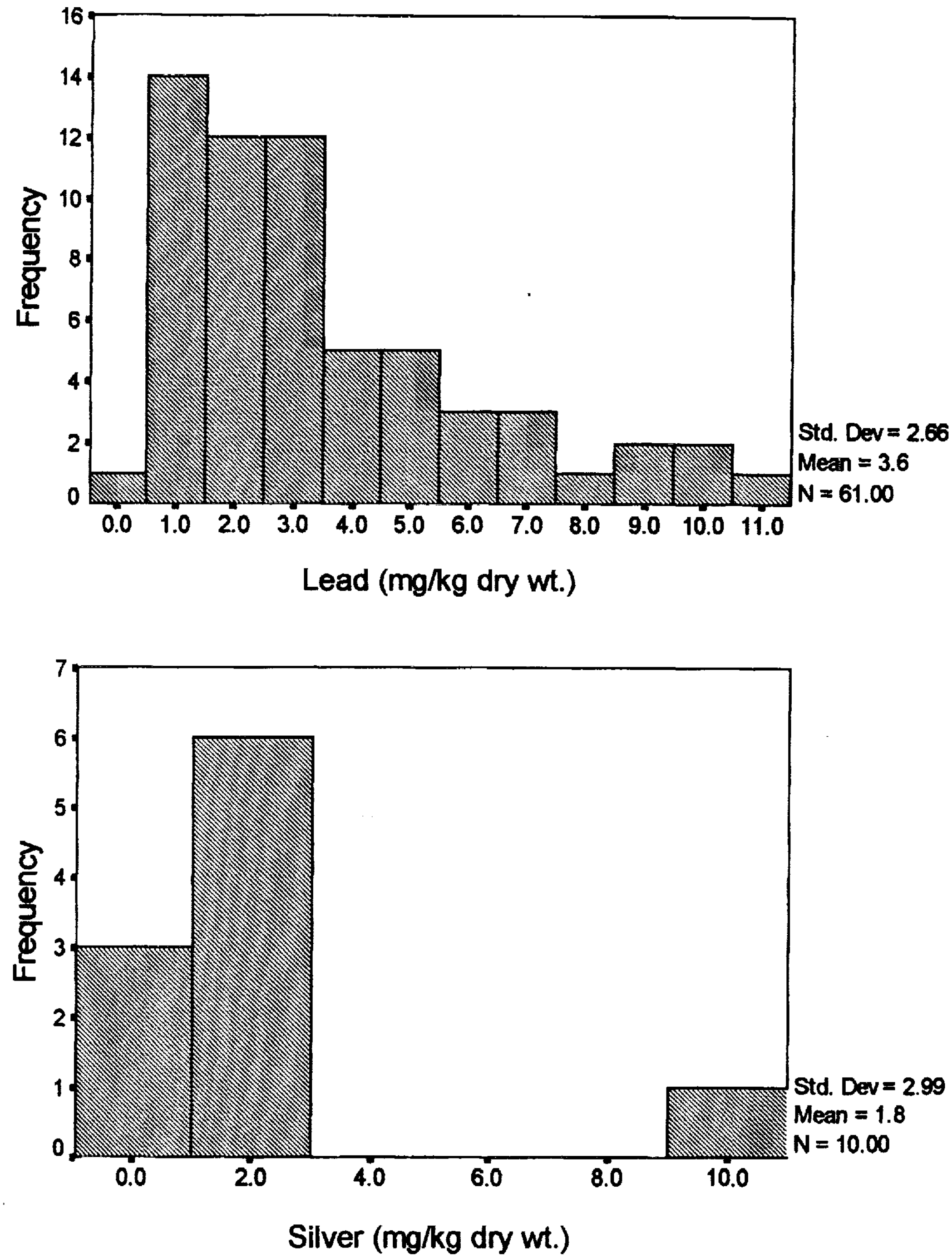
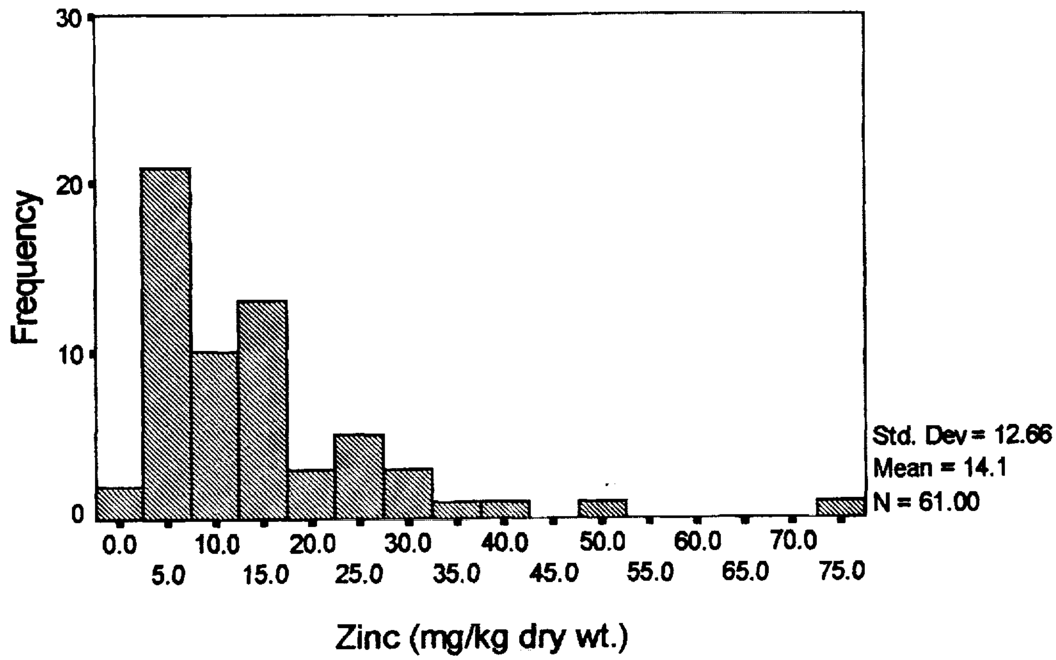


Figure A-78. Mean, standard deviation, and sample frequency distributions for lead and silver in Mosquito lagoon sediment samples.



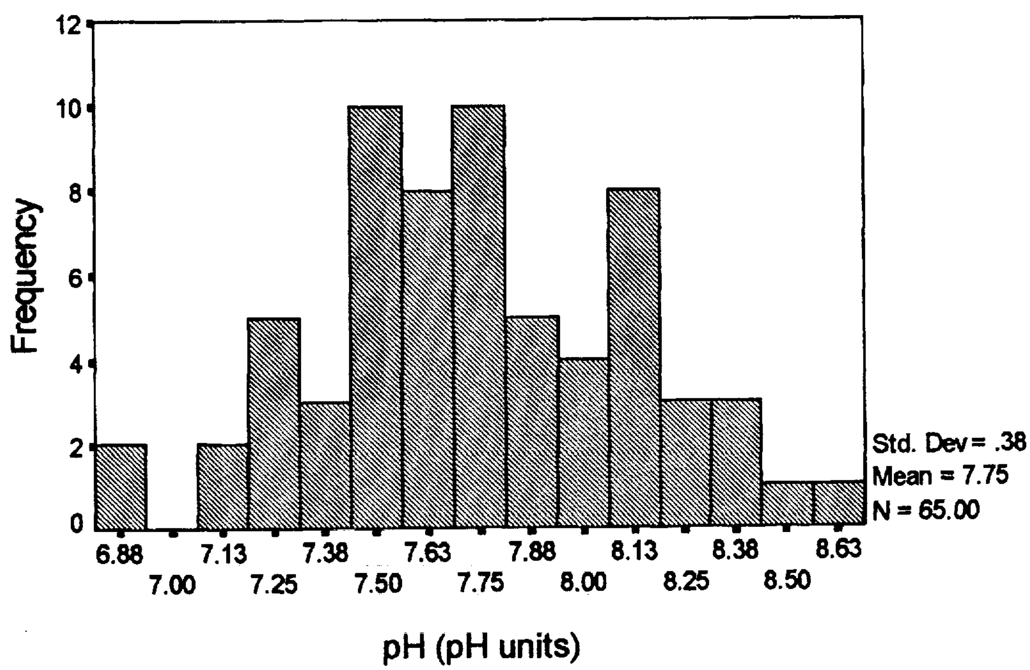
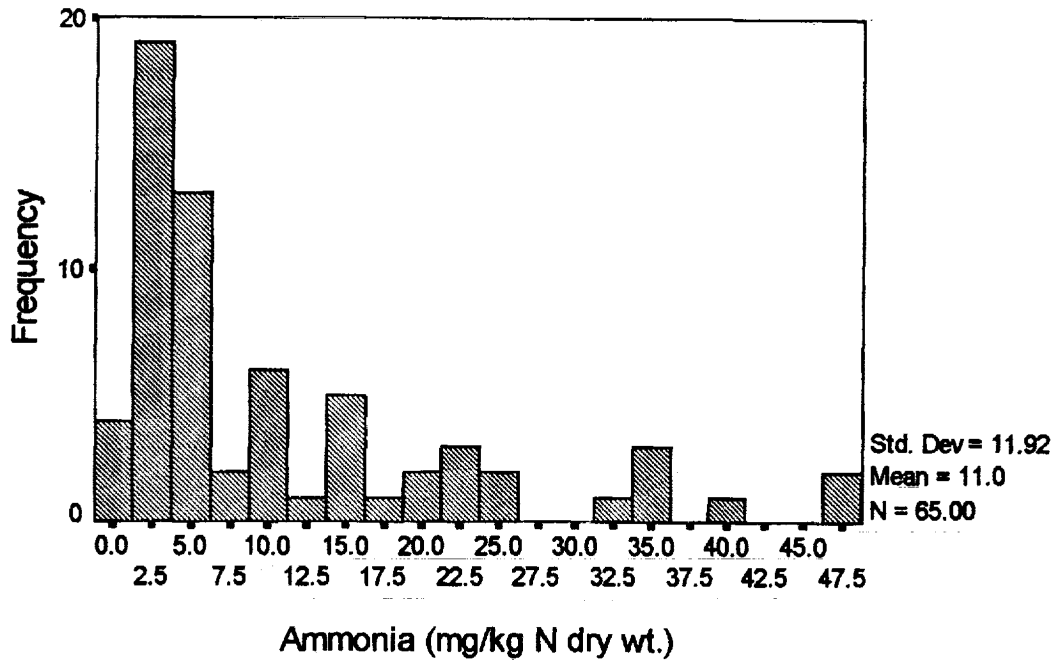


Figure A-79. Mean, standard deviation, and sample frequency distributions for zinc and pH in Mosquito lagoon sediment samples.



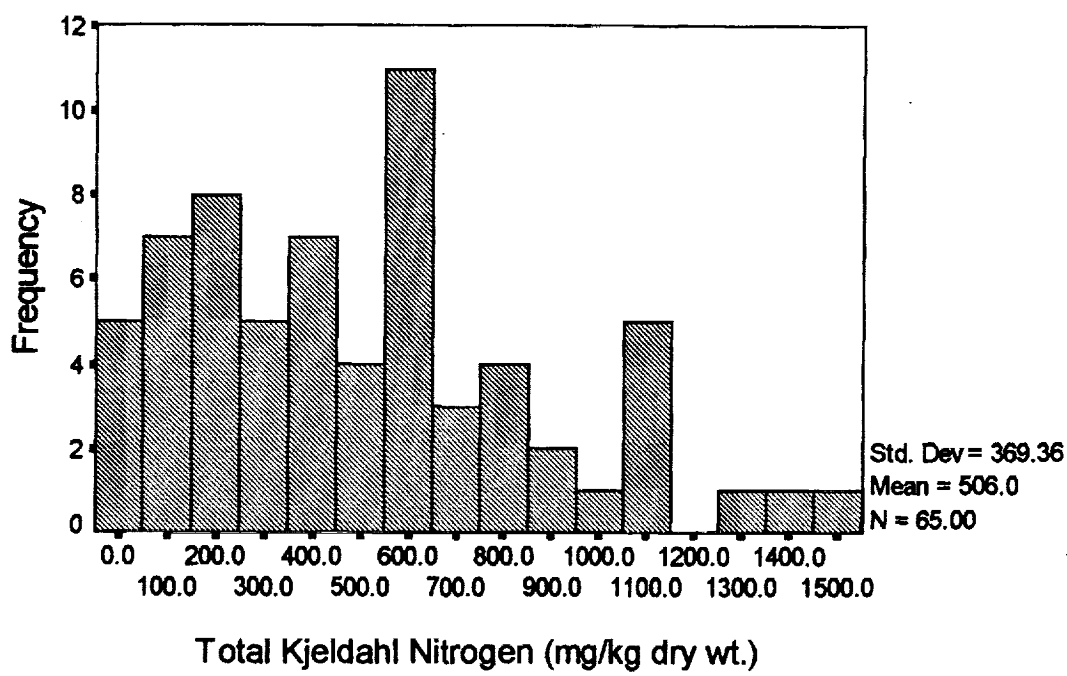
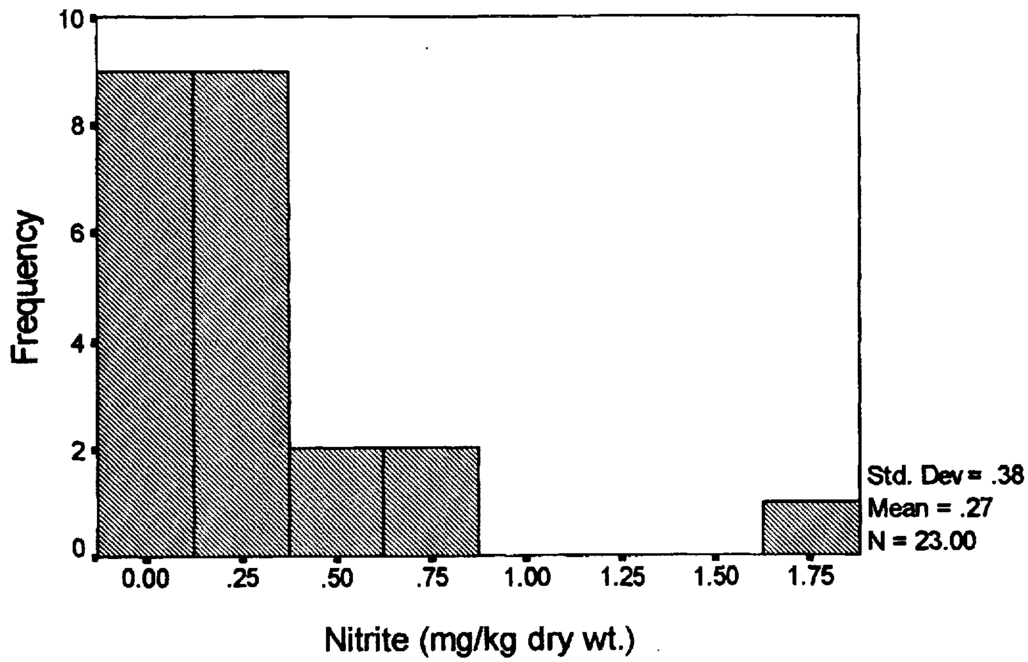


Figure A-80. Mean, standard deviation, and sample frequency distributions for ammonia and total kjeldahl nitrogen in Mosquito Lagoon sediment samples.



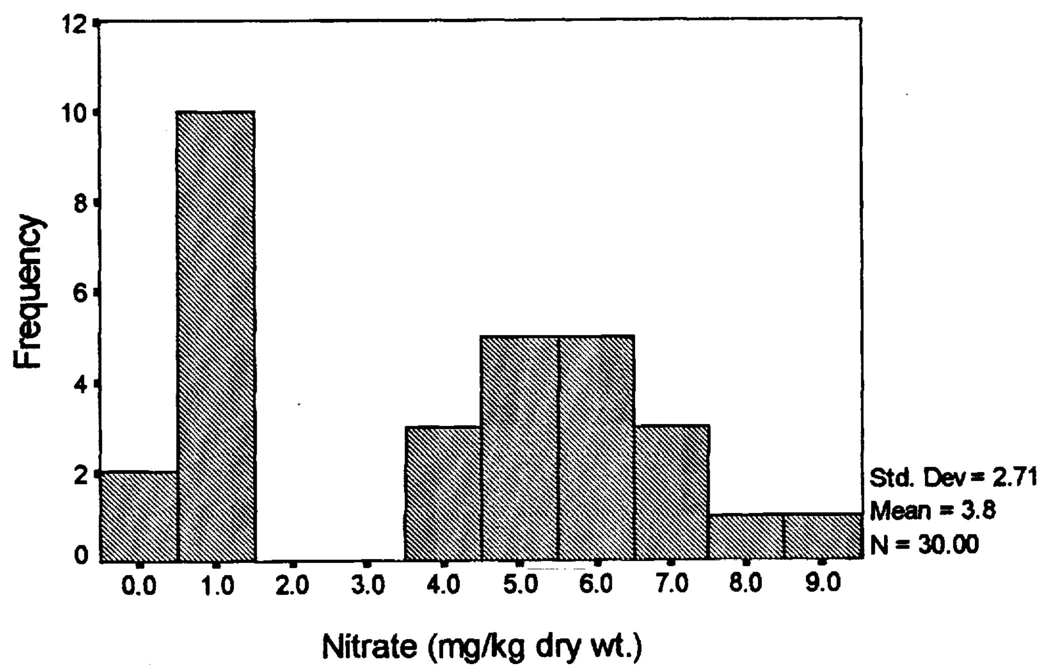
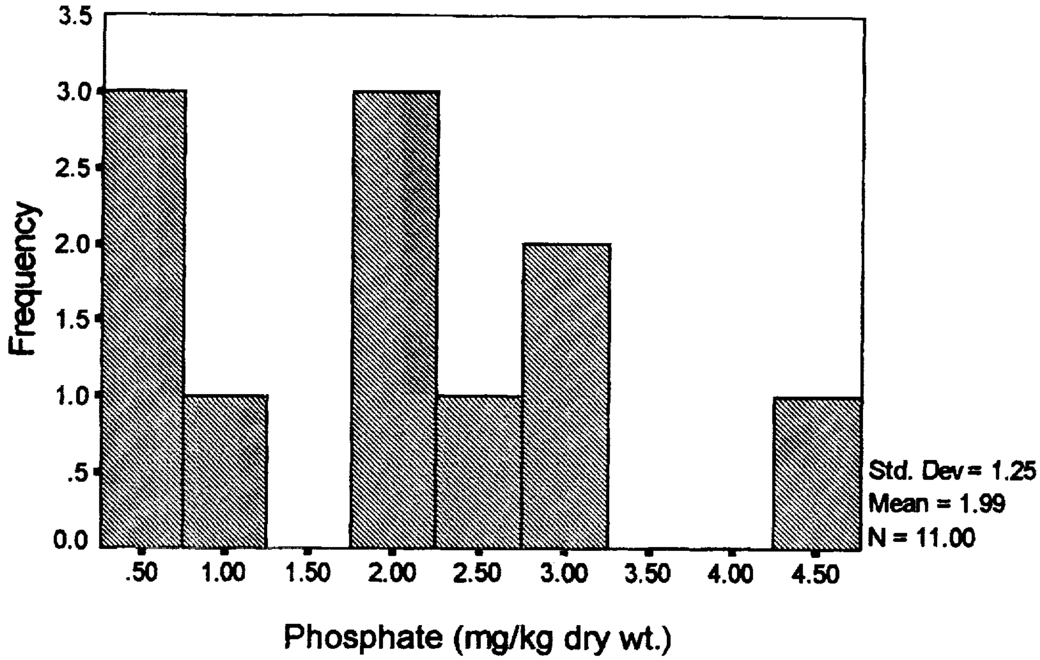


Figure A-81. Mean, standard deviation, and sample frequency distributions for nitrite and nitrate in Mosquito Lagoon sediment samples.



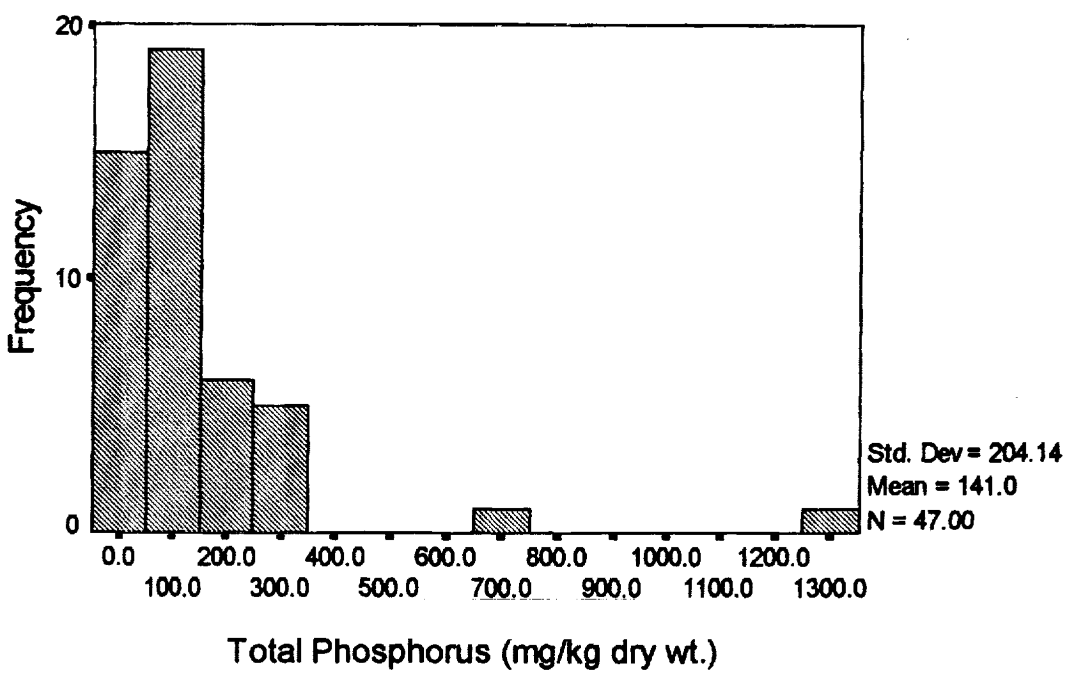
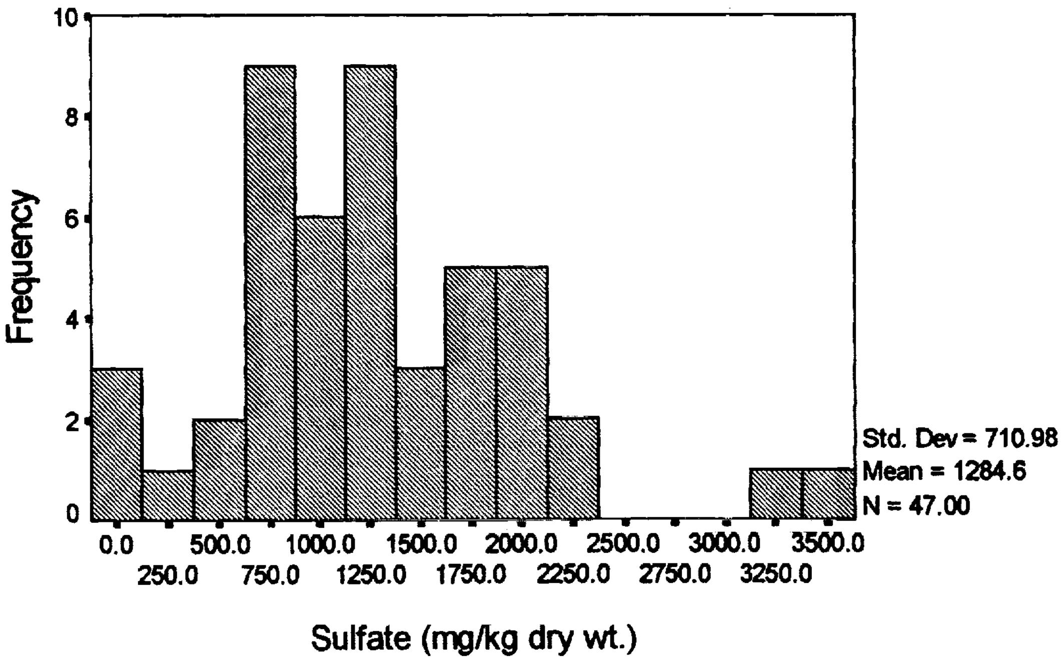


Figure A-82. Mean, standard deviation, and sample frequency distributions for phosphate and total phosphorus in Mosquito Lagoon sediment samples.



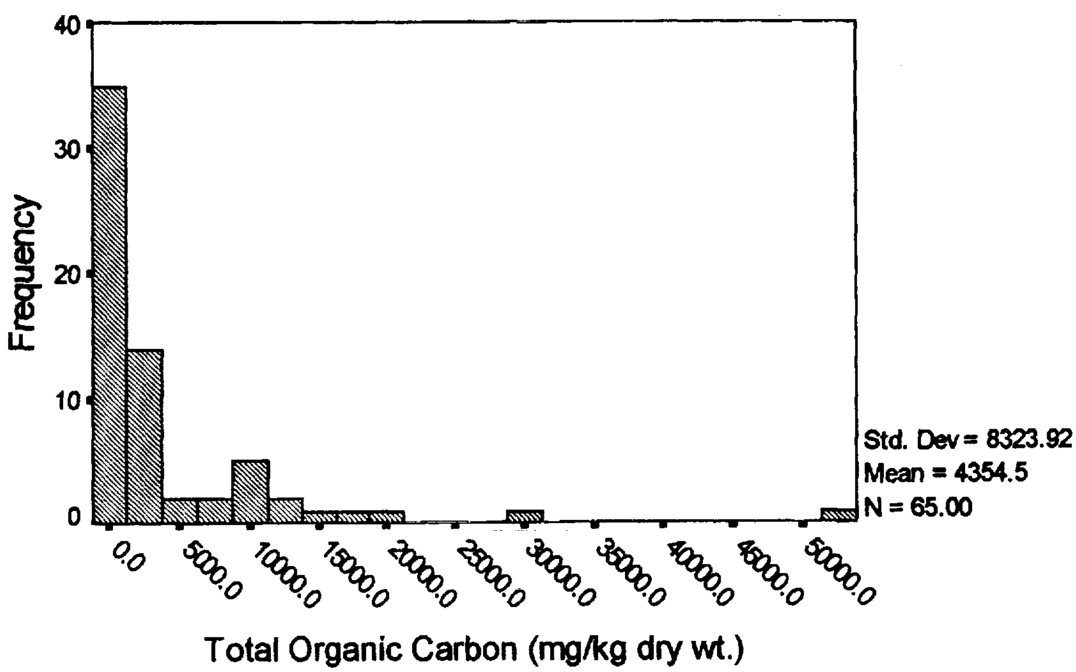
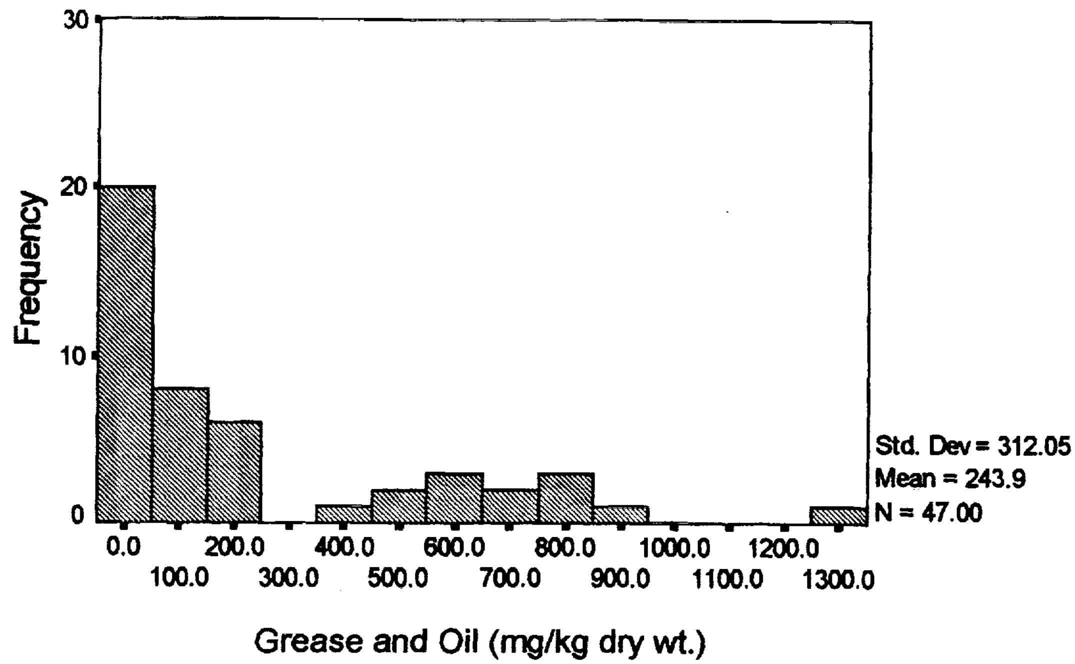


Figure A-83. Mean, standard deviation, and sample frequency distributions for sulfate and total organic carbon in Mosquito Lagoon sediment samples.



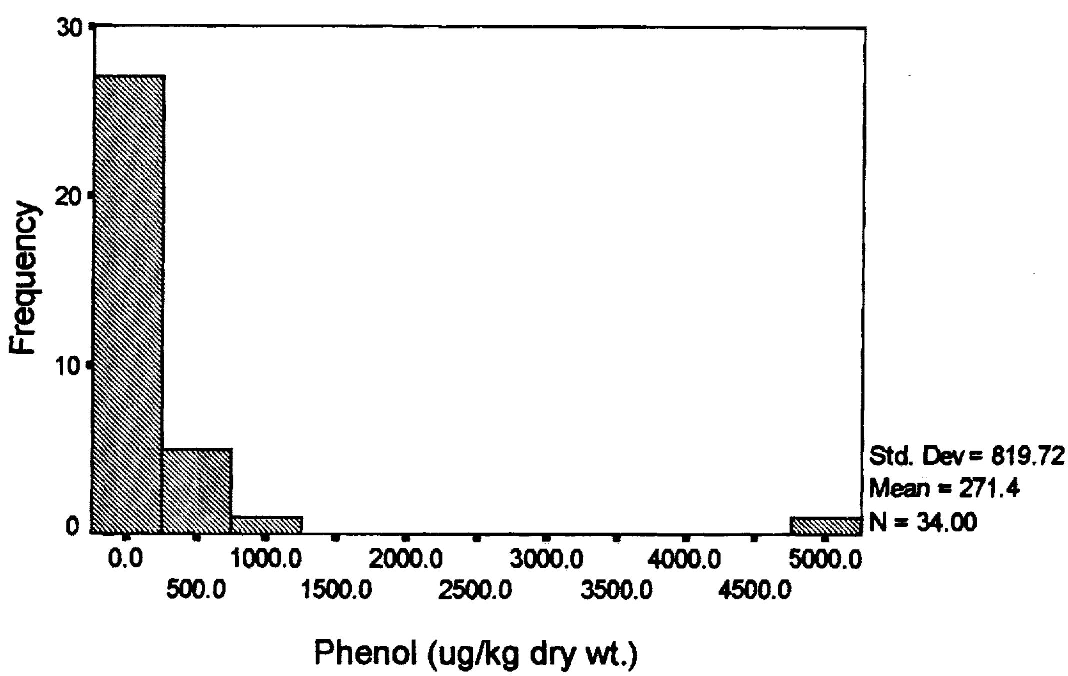


Figure A-84. Mean, standard deviation, and sample frequency distributions for grease and oil, and phenols in Mosquito Lagoon sediment samples.

Appendix B: Light Attenuation

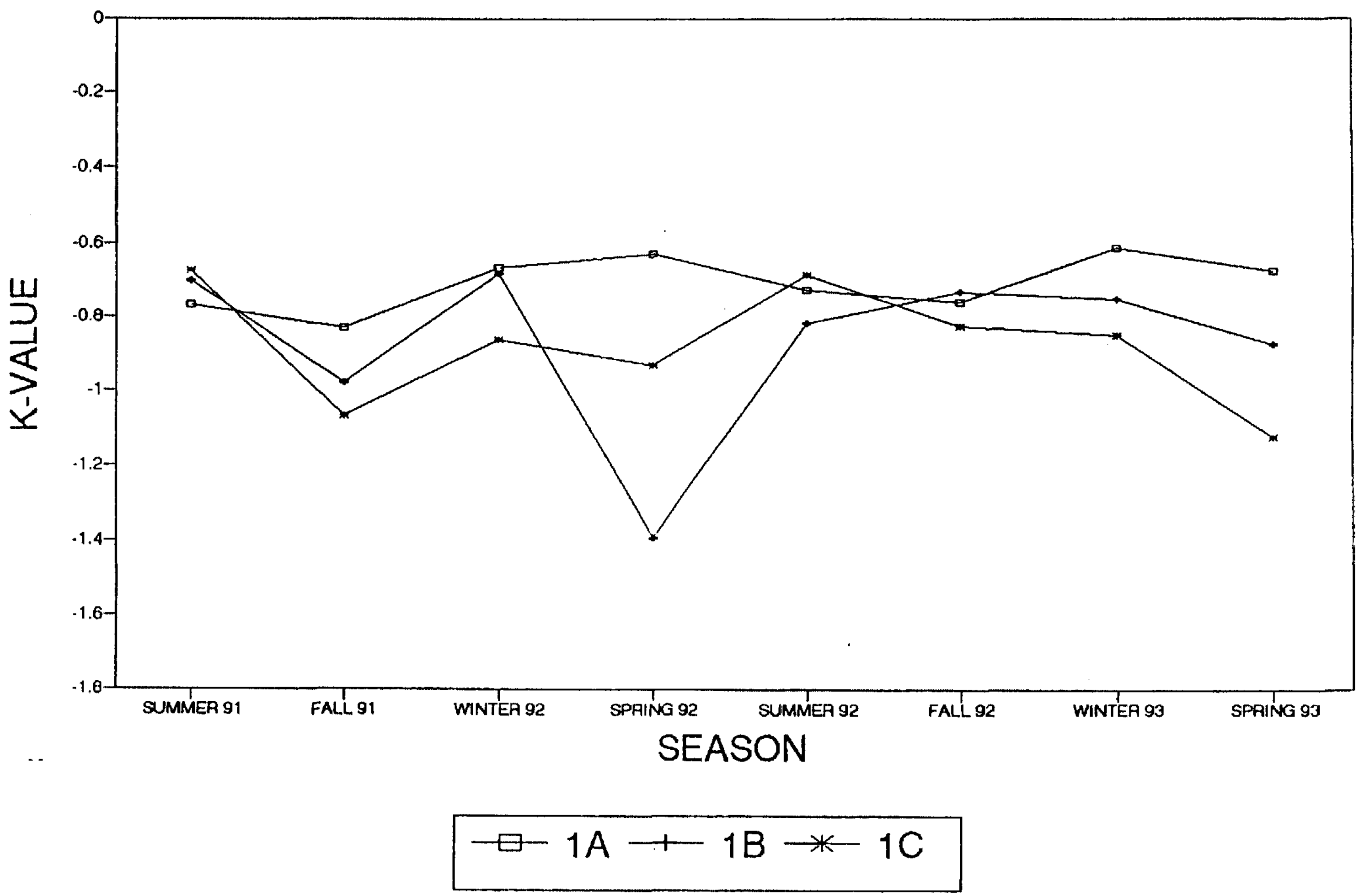


Figure B-1. Light attenuation coefficients (K m^{-1}) measured at Transect 1 in southern Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

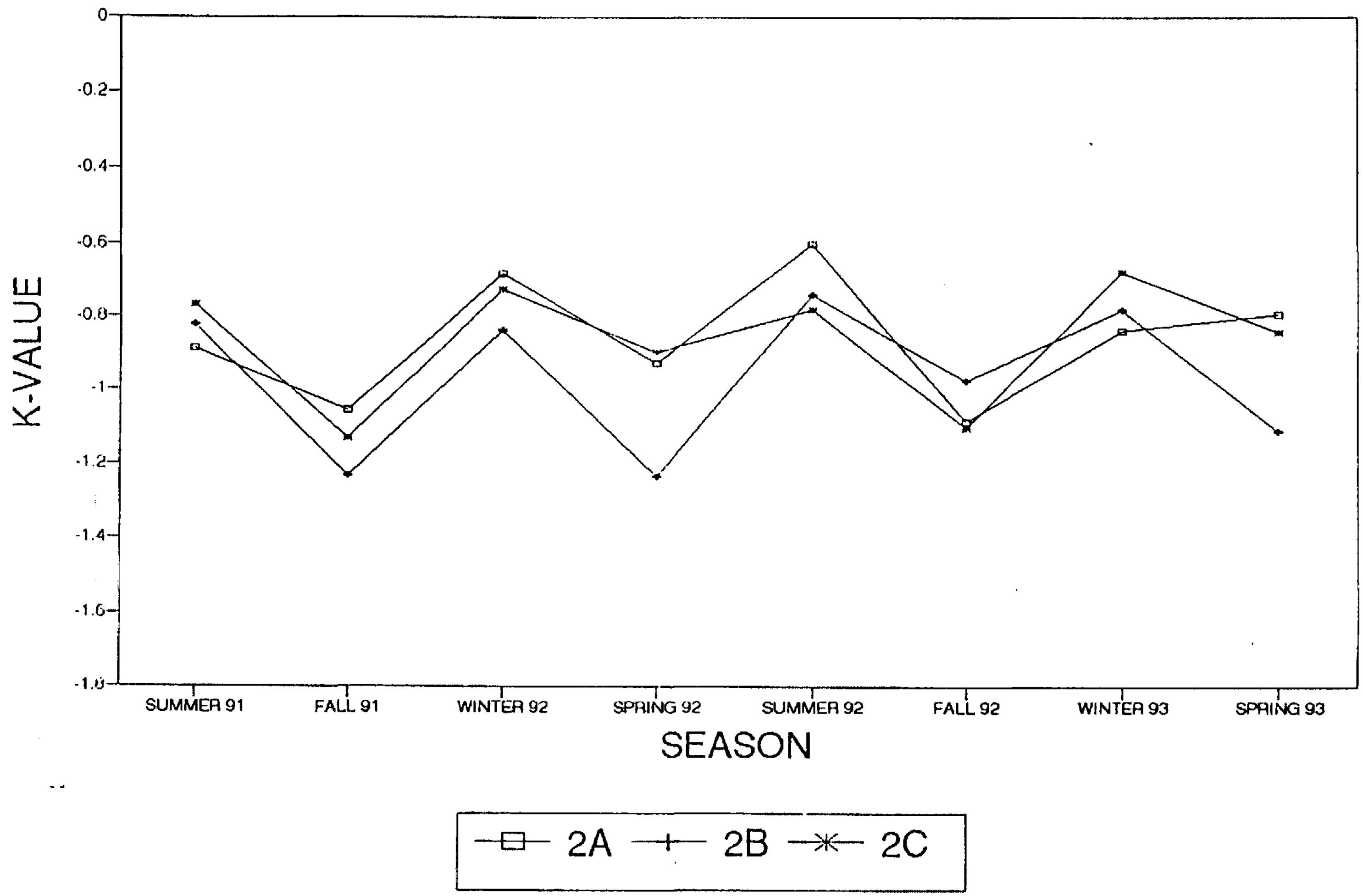


Figure B-2. Light attenuation coefficients (K m^{-1}) measured at Transect 2 in southern Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

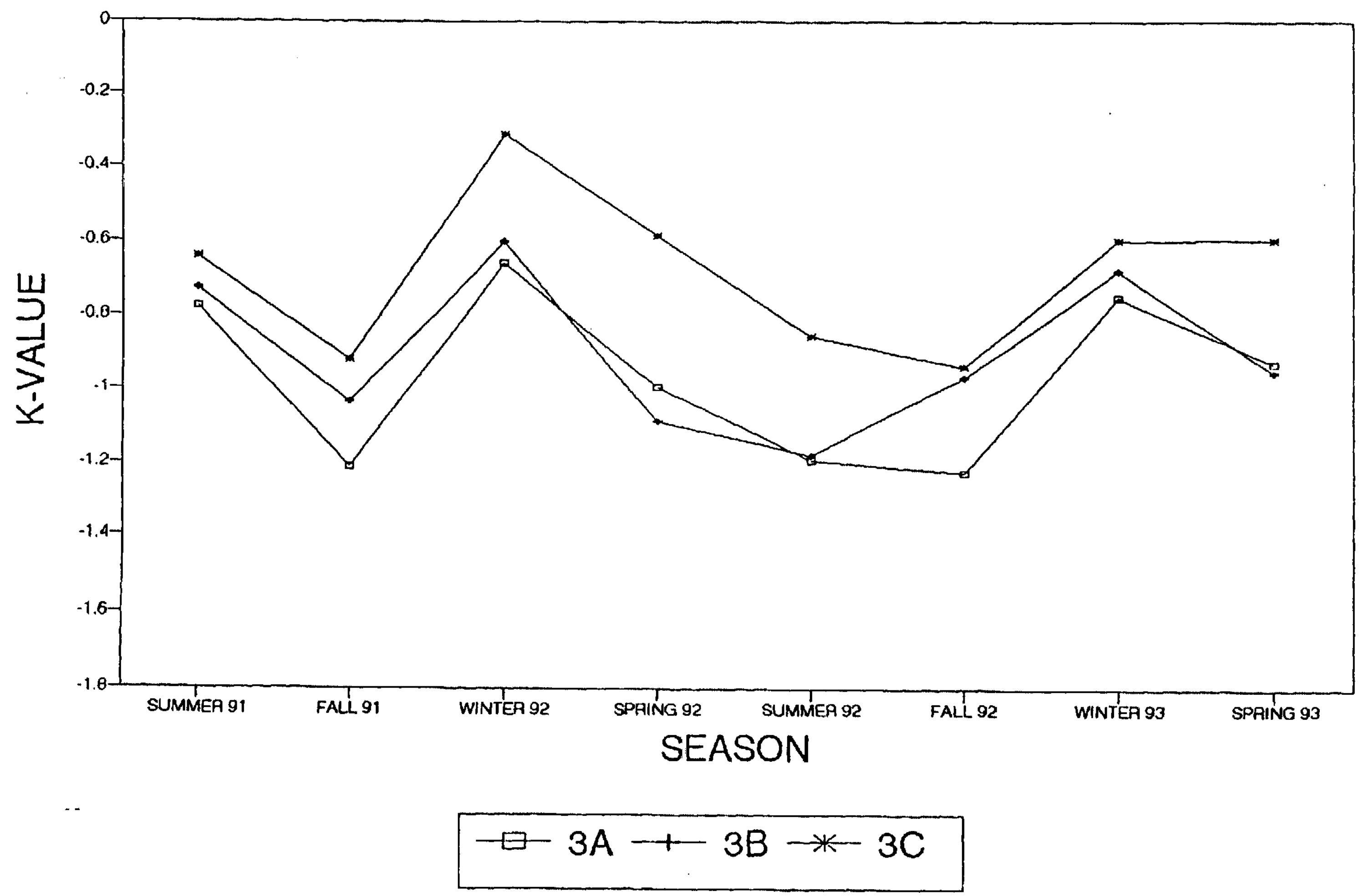


Figure B-3. Light attenuation coefficients (K m^{-1}) measured at Transect 3 in southern Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

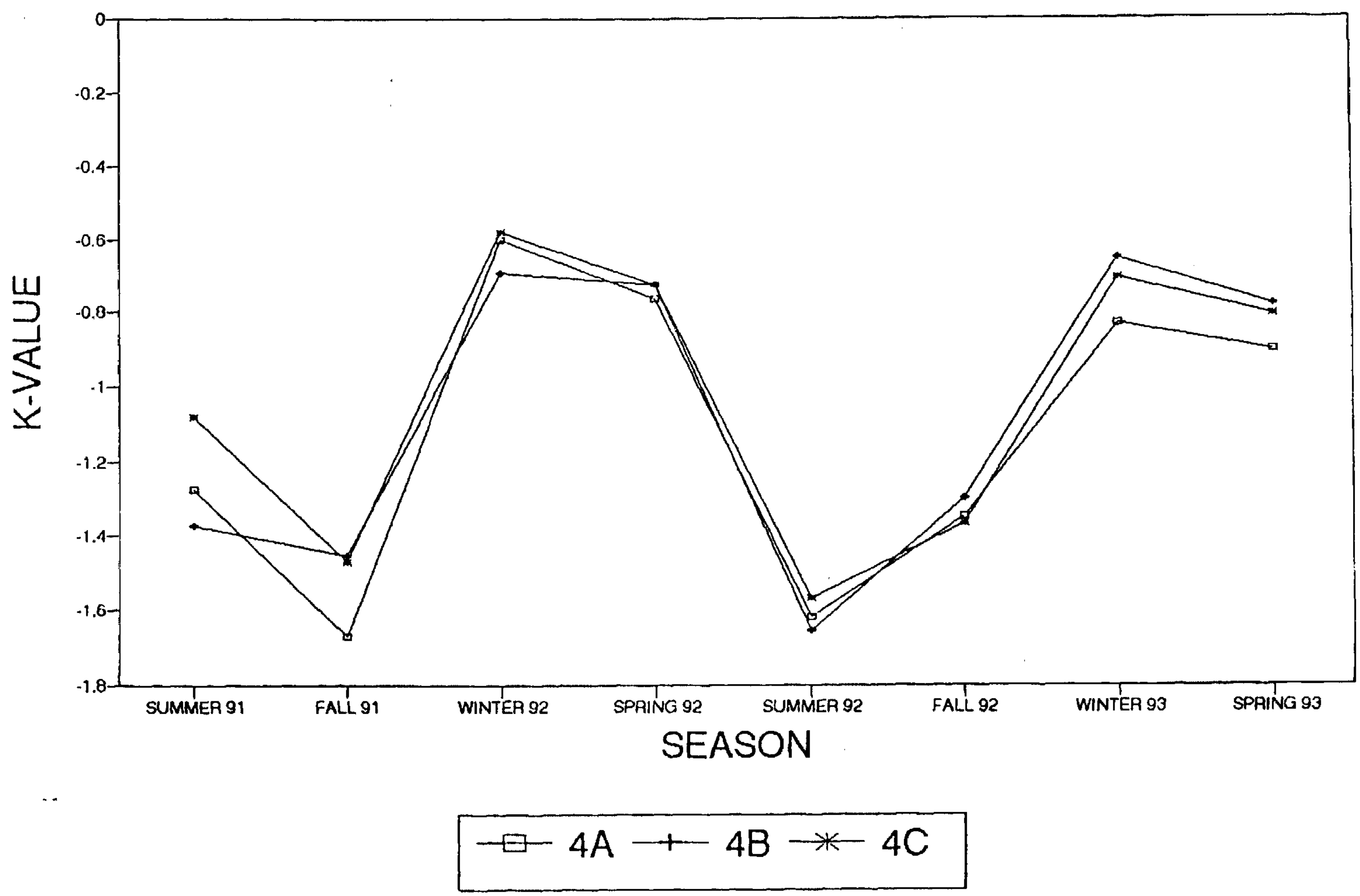


Figure B-4. Light attenuation coefficients (K m^{-1}) measured at Transect 4 in southern Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

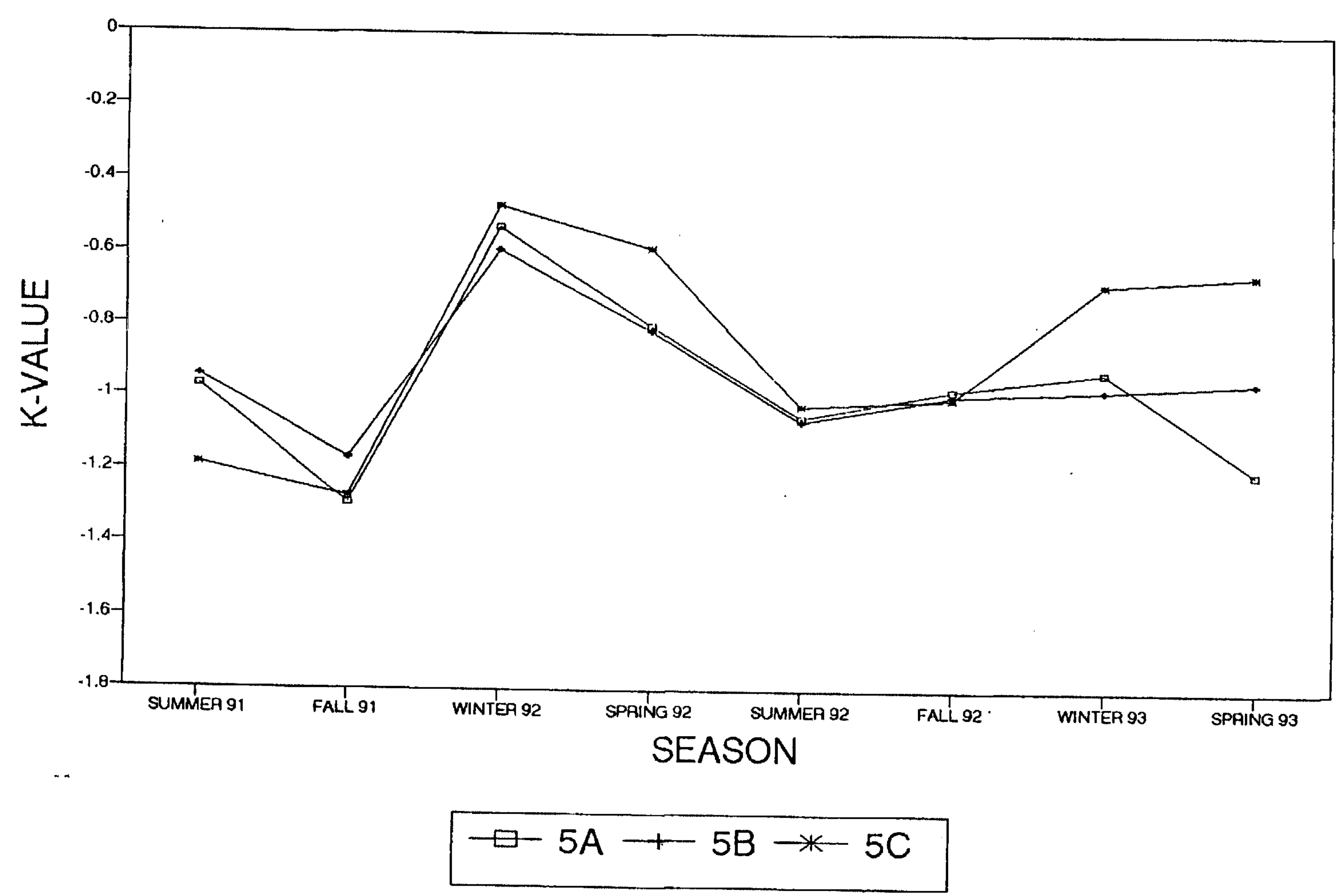


Figure B-5. Light attenuation coefficients (K m^{-1}) measured at Transect 5 in southern Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

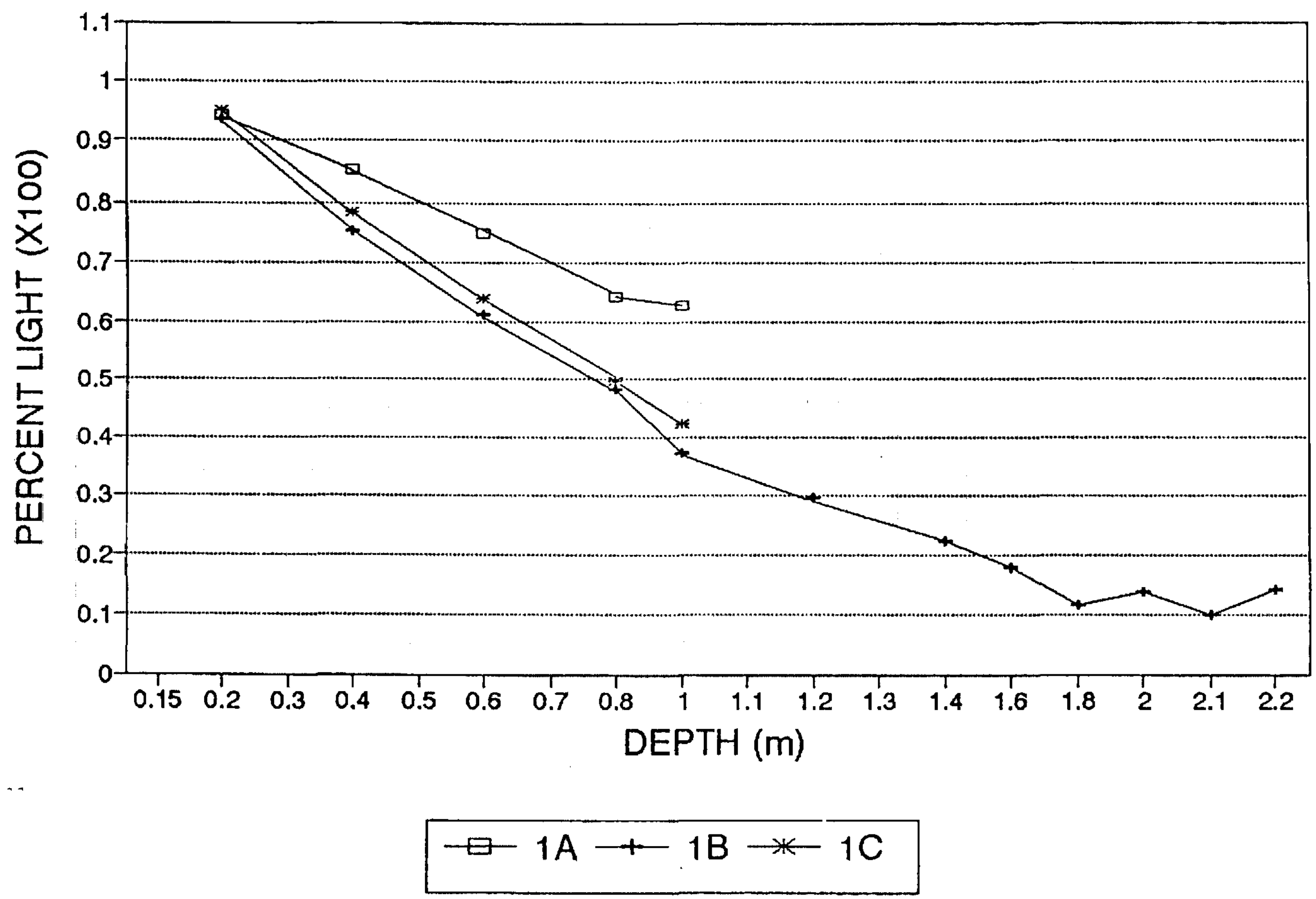


Figure B-6. Average percent light available at different depths measured at Transect 1 in southern Mosquito Lagoon between summer 1991 and spring 1993. Percent light was estimated using measures of scalar irradiance at varying depths below the water surface.

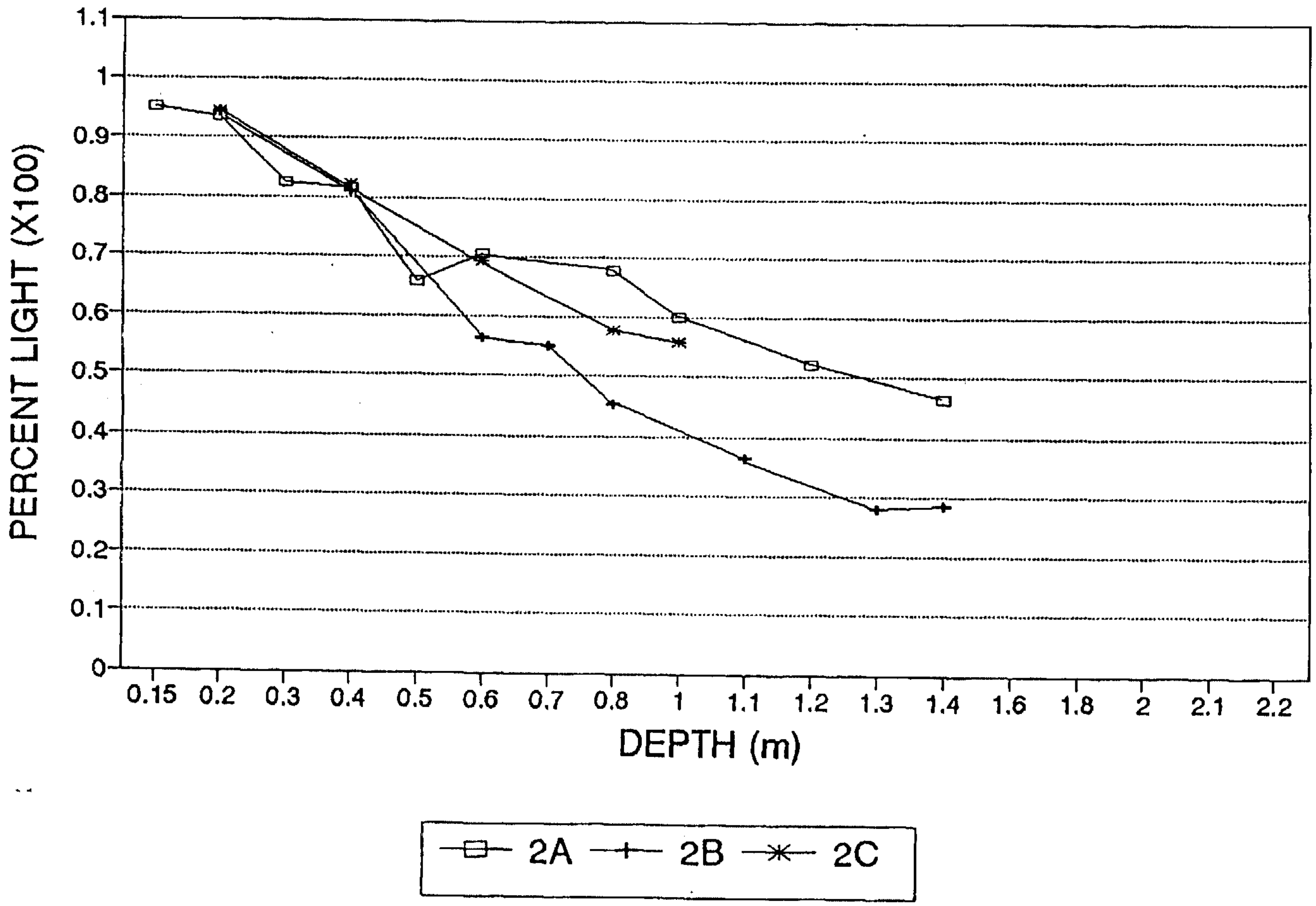


Figure B-7. Average percent light available at different depths measured at Transect 2 in southern Mosquito Lagoon between summer 1991 and spring 1993. Percent light was estimated using measures of scalar irradiance at varying depths below the water surface.

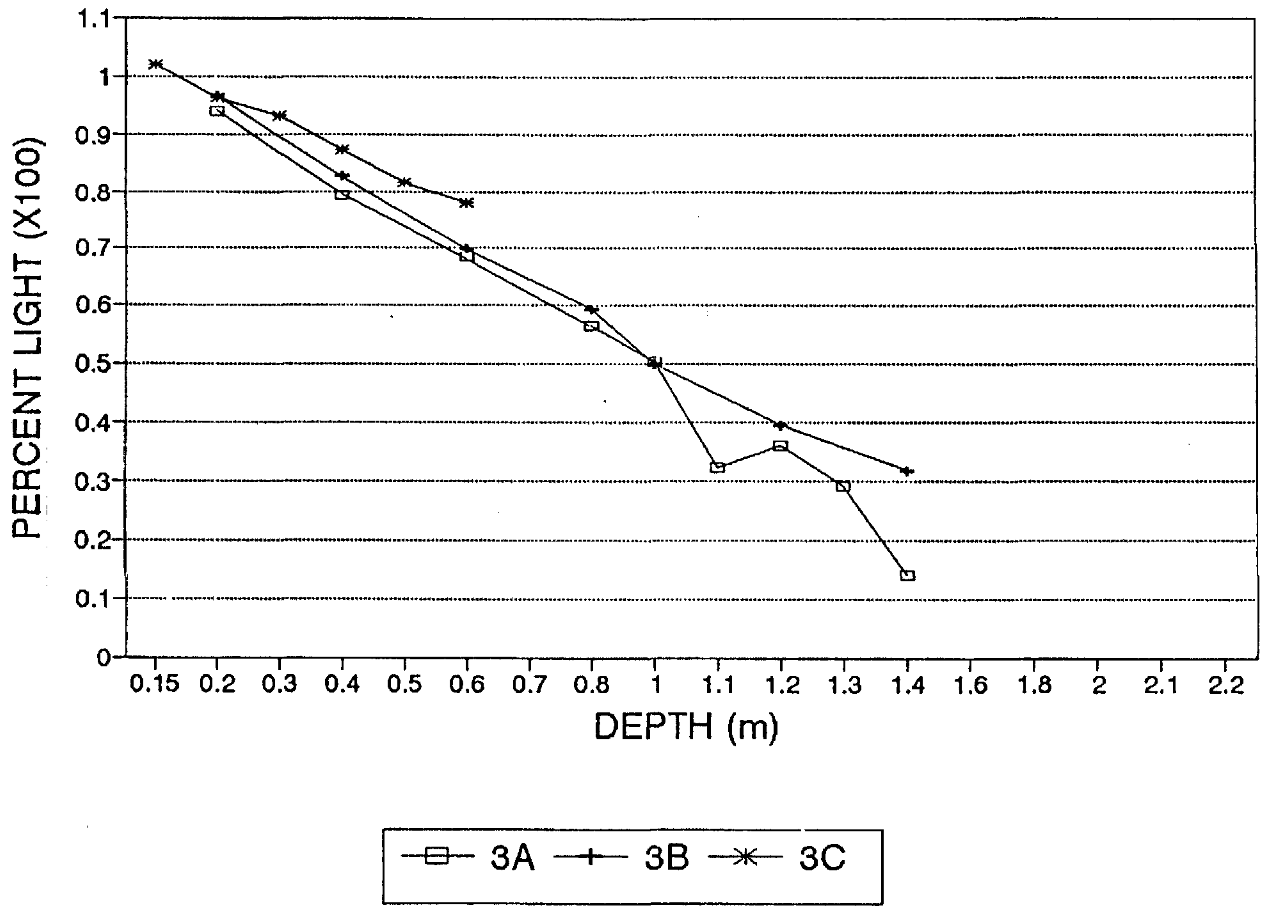


Figure B-8. Average percent light available at different depths measured at Transect 3 in southern Mosquito Lagoon between summer 1991 and spring 1993. Percent light was estimated using measures of scalar irradiance at varying depths below the water surface.

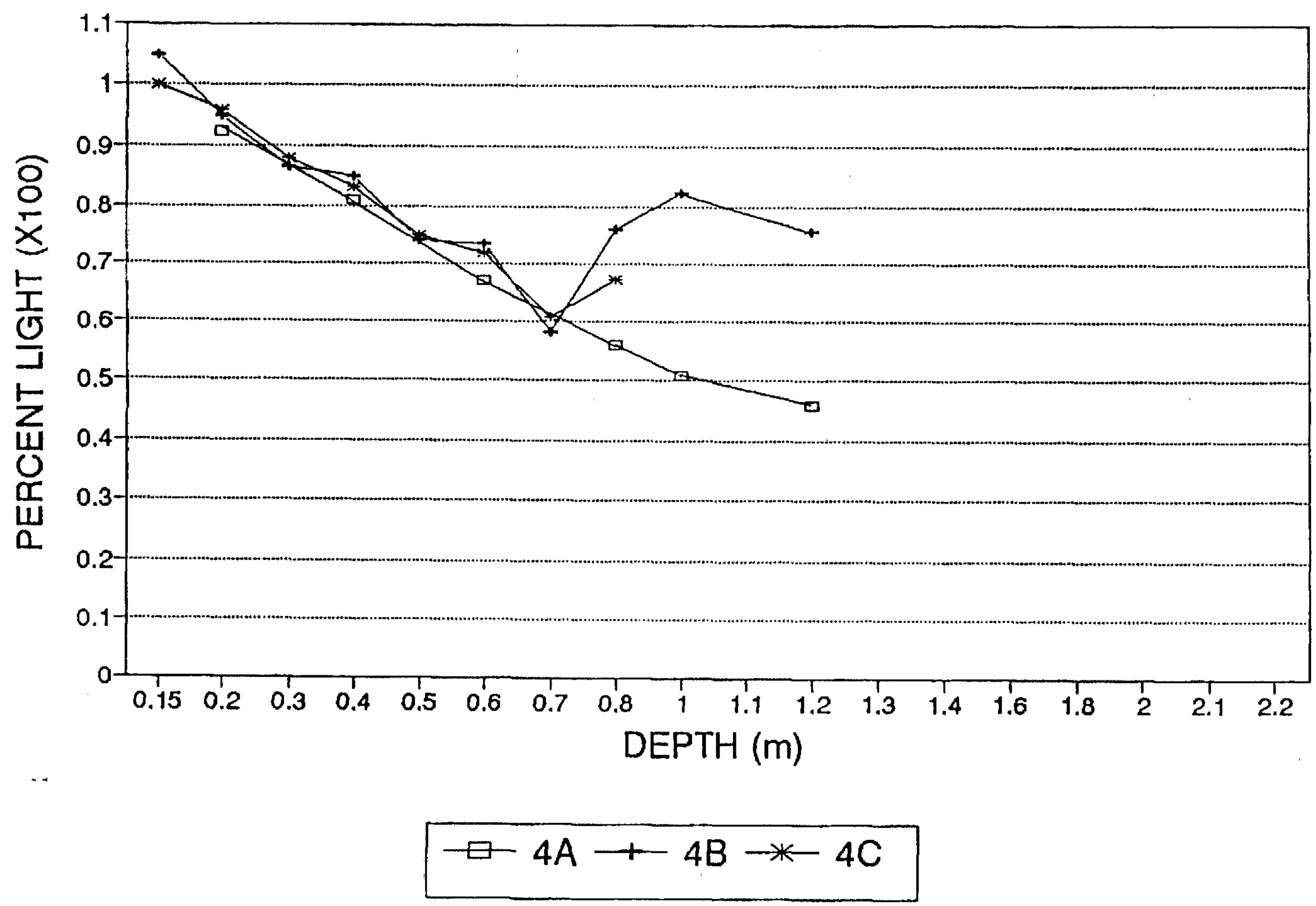


Figure B-9. Average percent light available at different depths measured at Transect 4 in southern Mosquito Lagoon between summer 1991 and spring 1993. Percent light was estimated using measures of scalar irradiance at varying depths below the water surface..

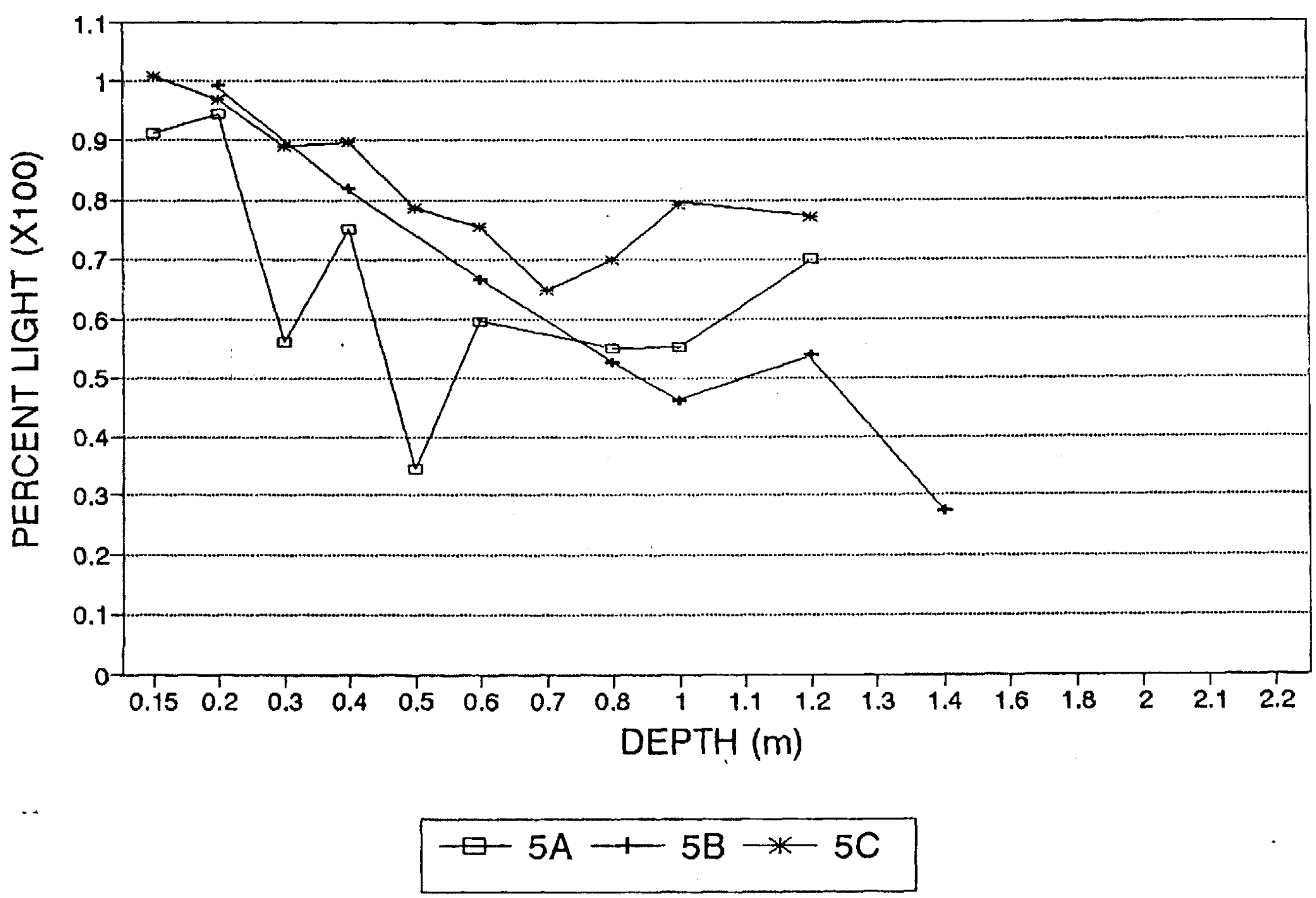
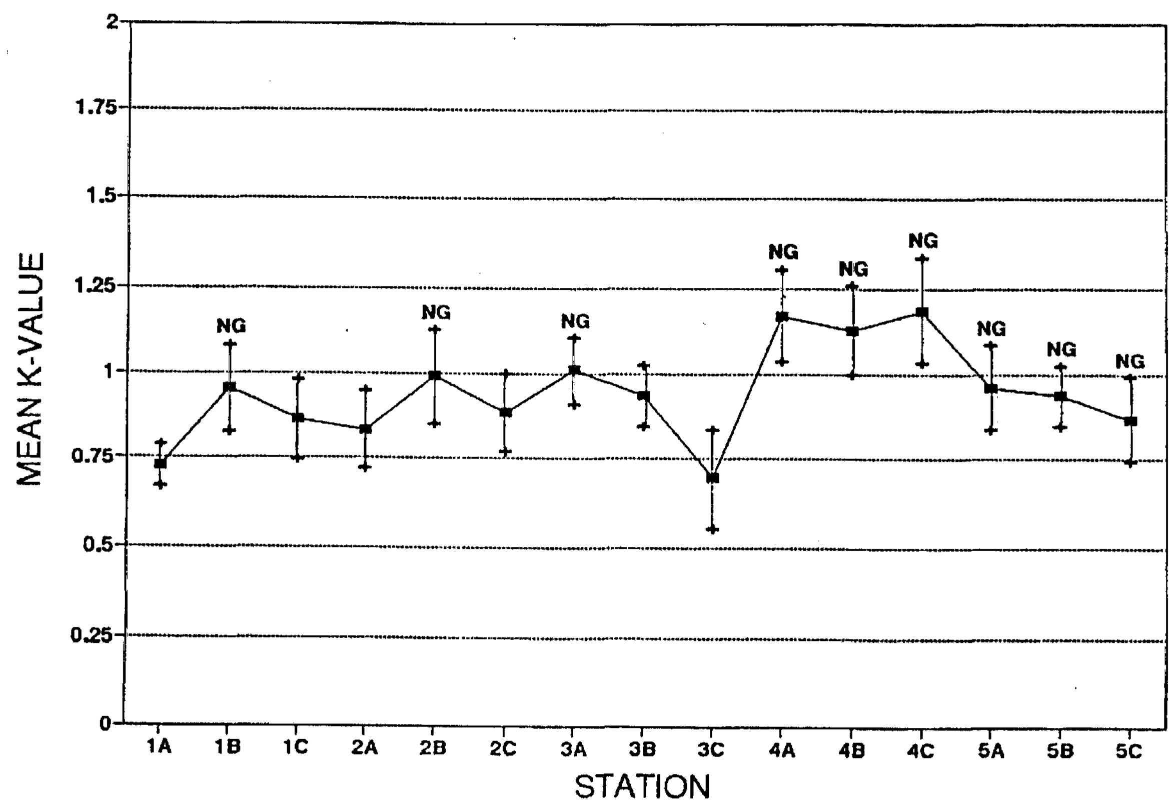


Figure B-10. Average percent light available at different depths measured at Transect 5 in southern Mosquito Lagoon between summer 1991 and spring 1993. Percent light was estimated using measures of scalar irradiance at varying depths below the water surface.



NG = no seagrass

Figure B-11. Average attenuation coefficient ($K\ m^{-1}$) and 95% confidence interval estimated for each sample station in Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

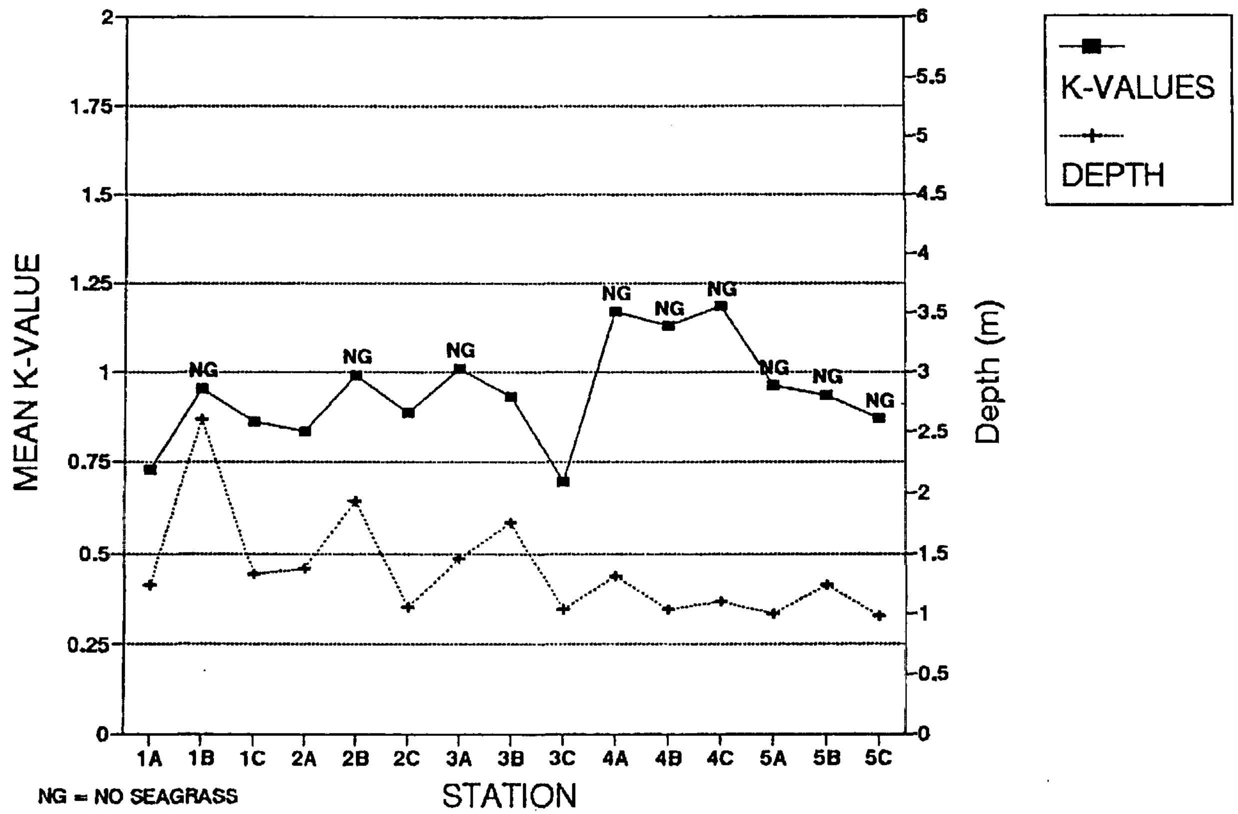


Figure B-12. Average attenuation coefficient (K m^{-1}) and depth estimated for each sample station in Mosquito Lagoon between summer 1991 and spring 1993. Attenuation was estimated using measures of scalar irradiance at varying depths below the water surface.

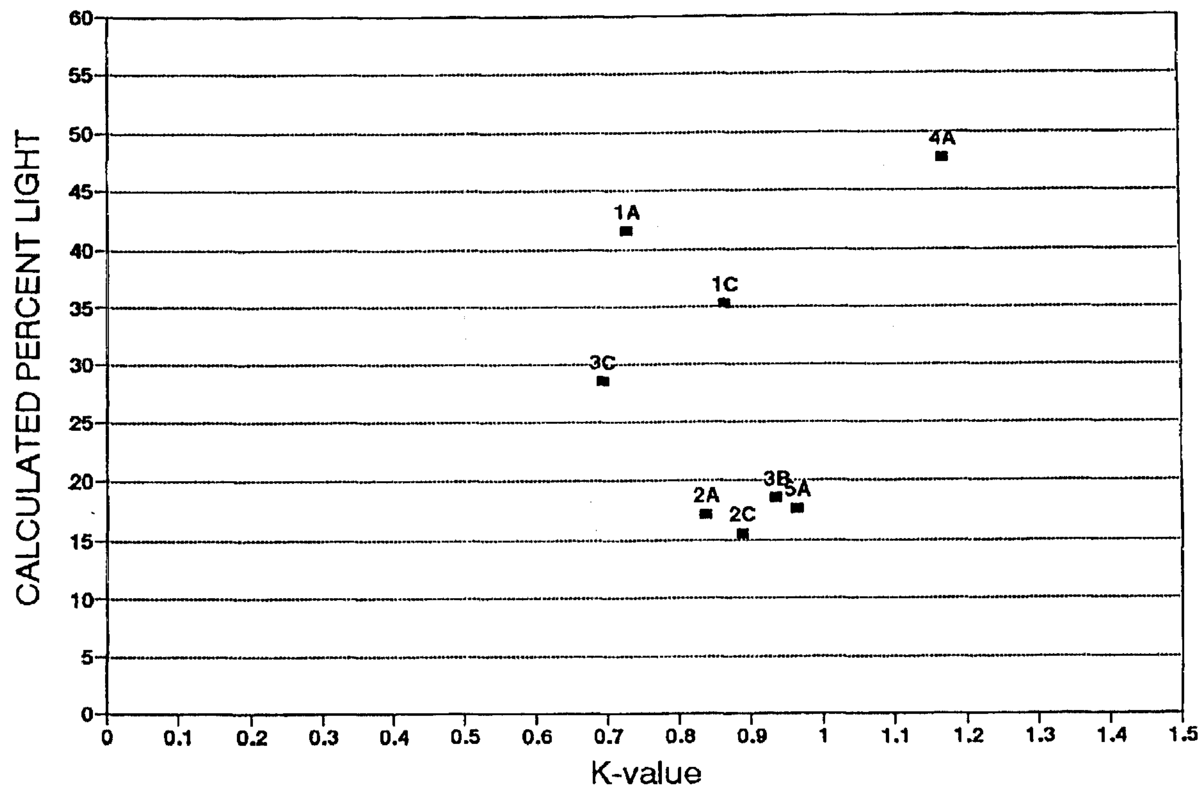


Figure B-13. Average attenuation coefficient (K m^{-1}) and estimated percent light and maximum depth of submerged aquatic vegetation on each sample transect in Mosquito Lagoon between summer 1991 and spring 1993. Attenuation and percent available light were estimated using measures of scalar irradiance at varying depths below the water surface.

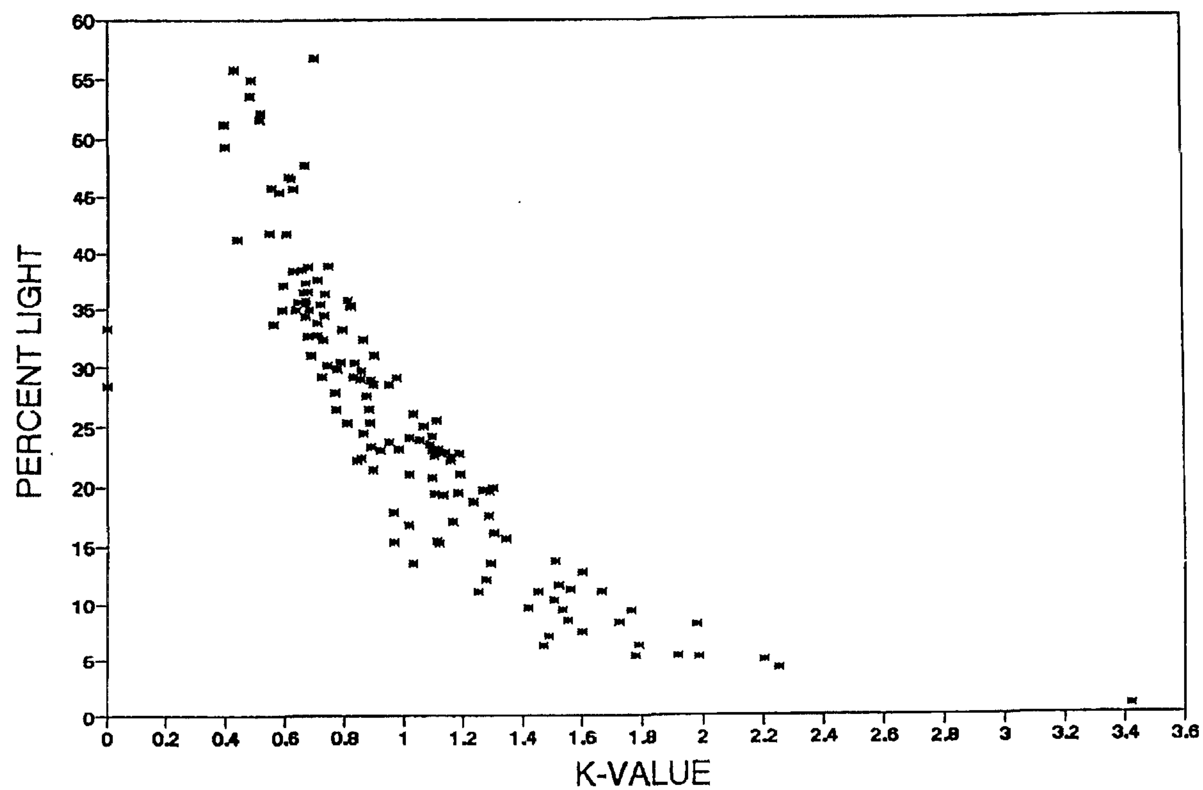


Figure B-14. Plot of relationship between percent light and attenuation (K m^{-1}) for sample stations having depths between 1.4 an d 1.9 m.

Appendix C: Submerged Aquatic Vegetation

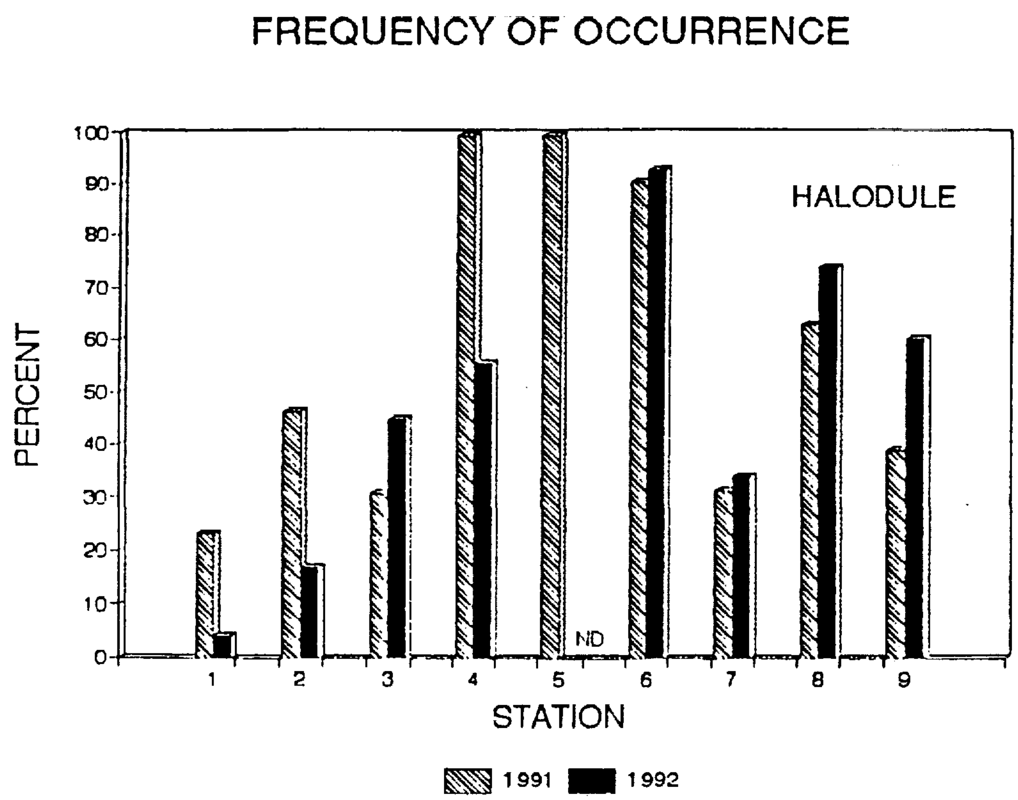


Figure C-1. Percent coverage of shoal grass, *Halodule wrightii*, along 9 transects in Mosquito Lagoon. Percent cover was estimated at 5 m intervals along a 50 m transect utilizing a 1 m^2 plot frame.

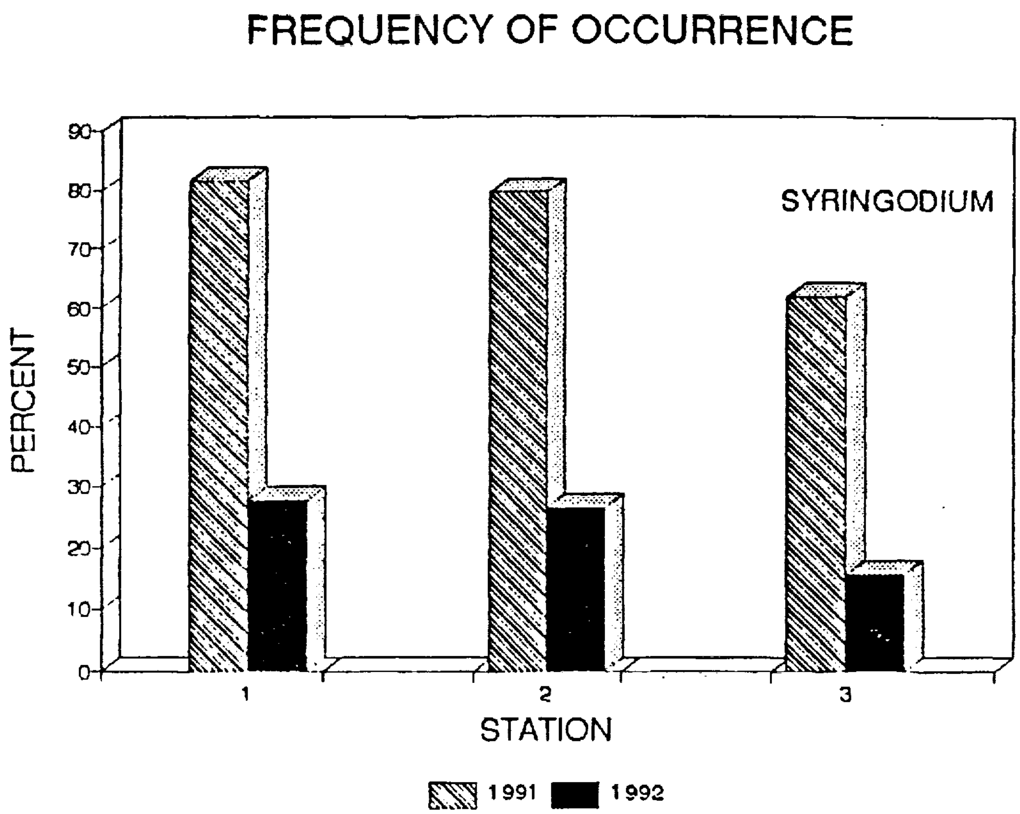
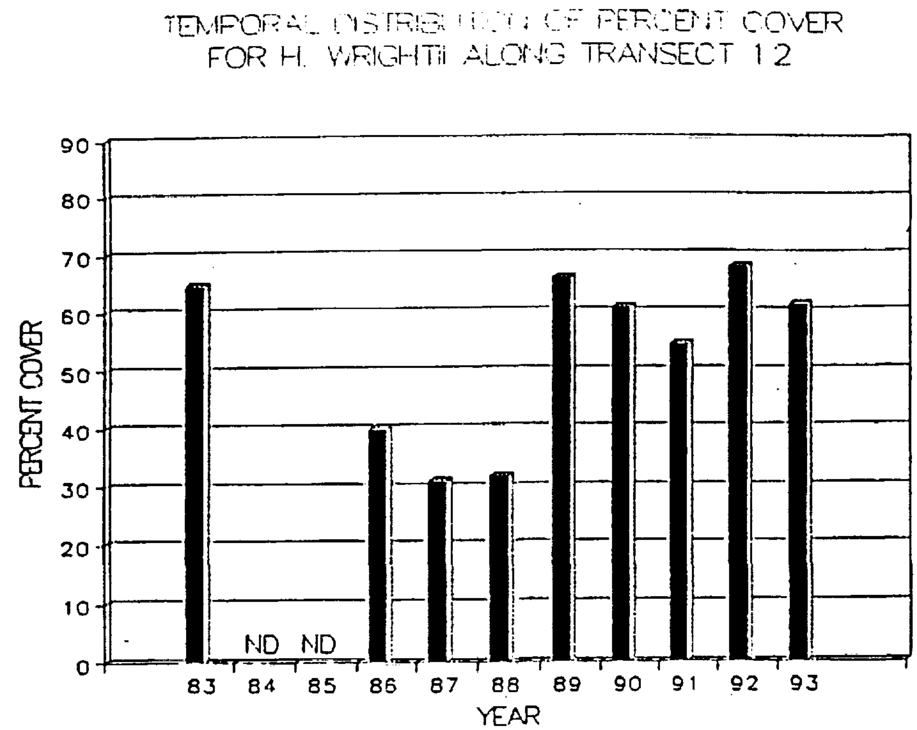


Figure C-2. Percent coverage of manatee grass, *Syringodium filiforme*, along 3 transects in Mosquito Lagoon. Percent cover was estimated at 5 m intervals along a 50 m transect utilizing a 1 m^2 plot frame.



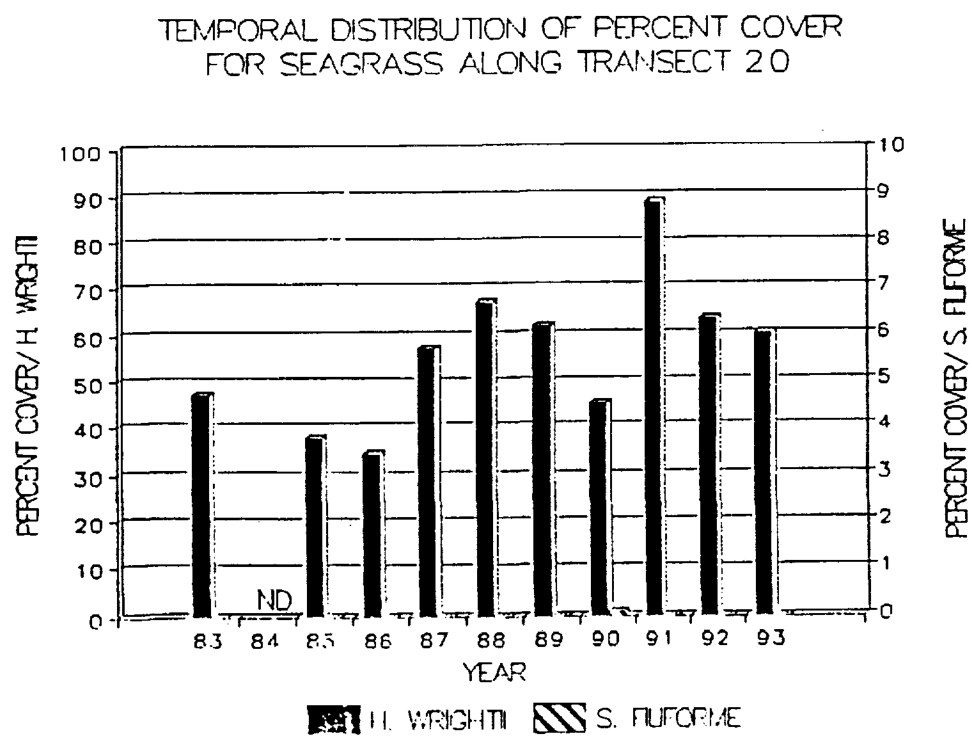
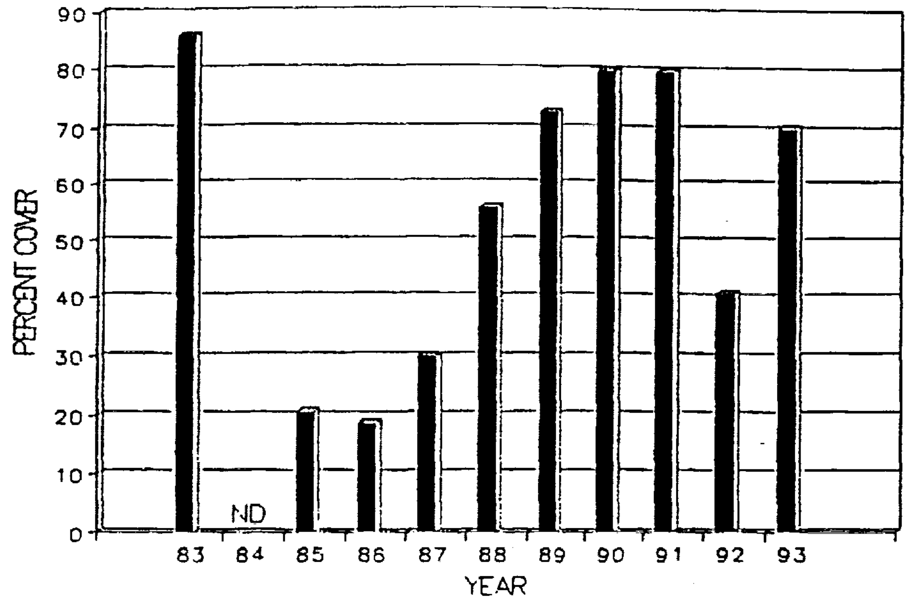


Figure C-3. Historic data on percent cover of submerged aquatic vegetation at Transects 12 and 20, monitored by the NASA Biomedical Office, in south Mosquito Lagoon between 1983 and 1993. Shoal grass, *Halodule wrightii*, is the dominate species in this region..

TEMPORAL DISTRIBUTION OF PERCENT COVER
FOR H. WRIGHTII ALONG TRANSECT 13



TEMPORAL DISTRIBUTION OF PERCENT COVER
FOR SEAGRASS ALONG TRANSECT 14

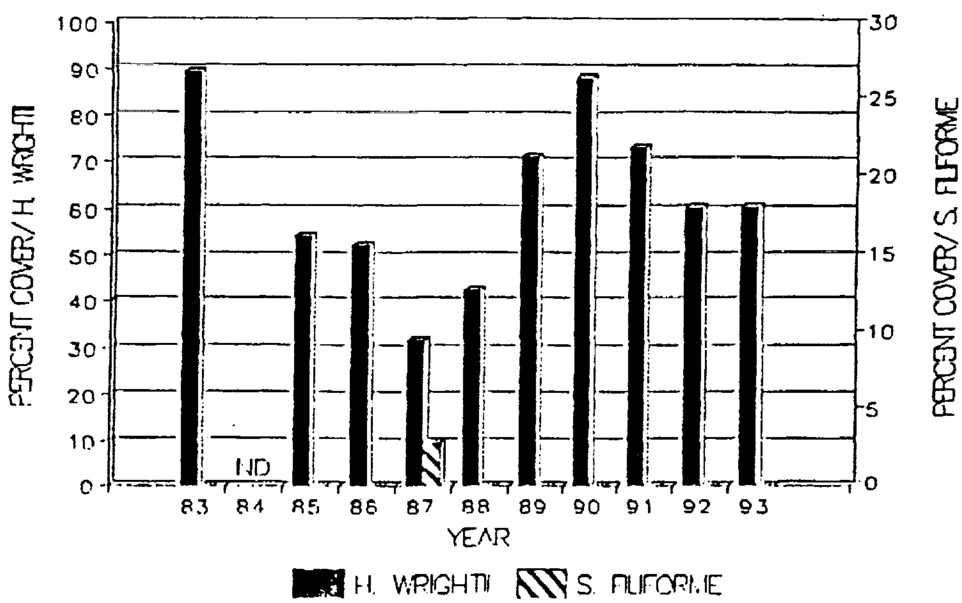
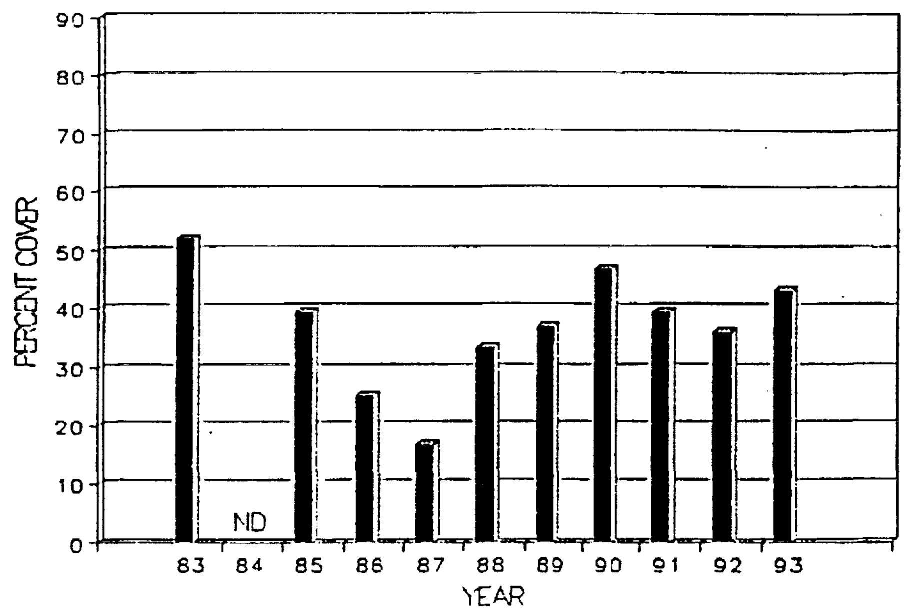


Figure C-4. Historic data on percent cover of submerged aquatic vegetation at Transects 13 and 14, monitored by the NASA Biomedical Office, in south Mosquito Lagoon between 1983 and 1993. Shoal grass, *Halodule wrightii*, is the dominate species in this region.

T[illegible] [illegible] [illegible] PERCENT COVER
FOR H. WRIGHTII [illegible] TRANSECT 2 1



TEMPORAL DISTRIBUTION OF PERCENT COVER
FOR SEAGRASS ALONG TRANSECT 22

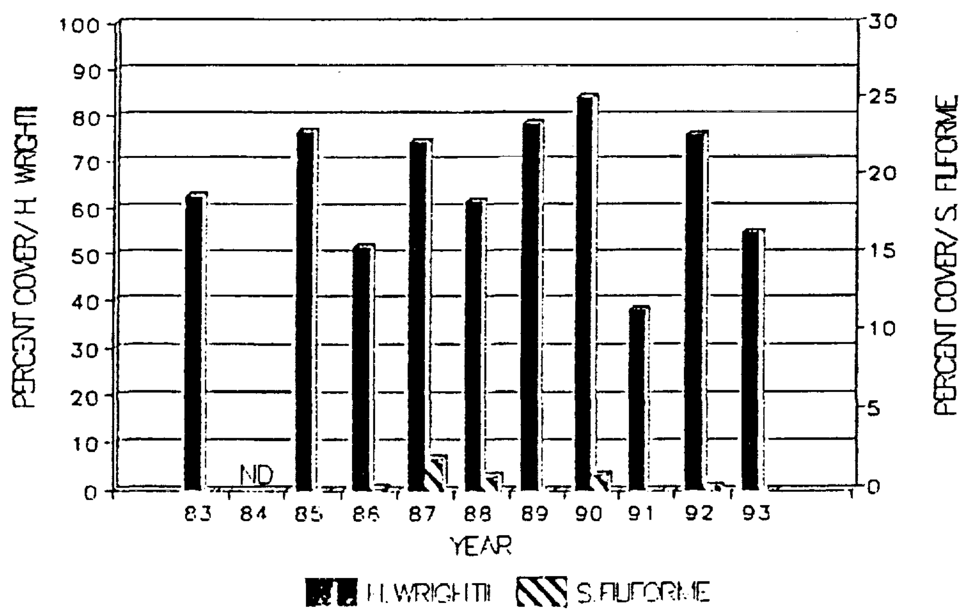


Figure C-5. Historic data on percent cover of submerged aquatic vegetation at Transects 21 and 22, monitored by the NASA Biomedical Office, in south Mosquito Lagoon between 1983 and 1993. Shoal grass, *Halodule wrightii*, is the dominate species in this region.

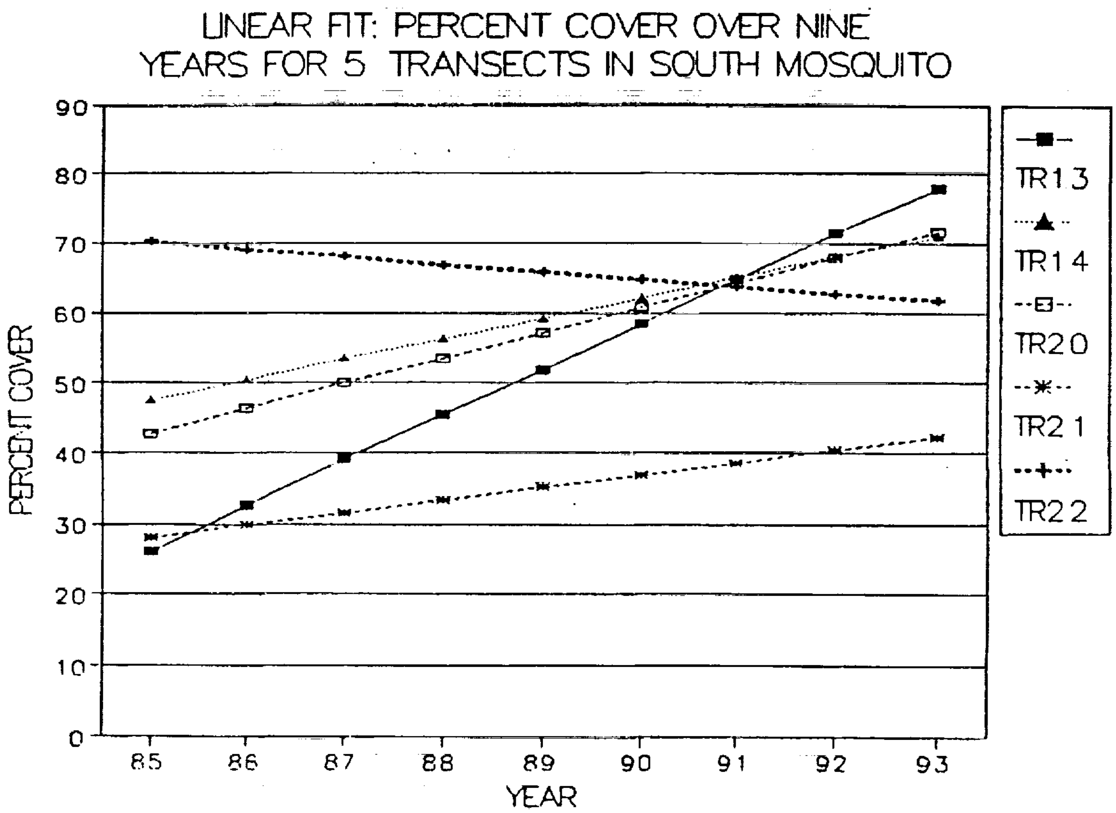


Figure C-6. Estimated trend lines for percent cover of submerged aquatic vegetation on 5 transects in south Mosquito Lagoon Transects monitored by the NASA Biomedical Office, in south Mosquito Lagoon between 1983 and 1993. Shoal grass, *Halodule wrightii*, is the dominate species in this region.

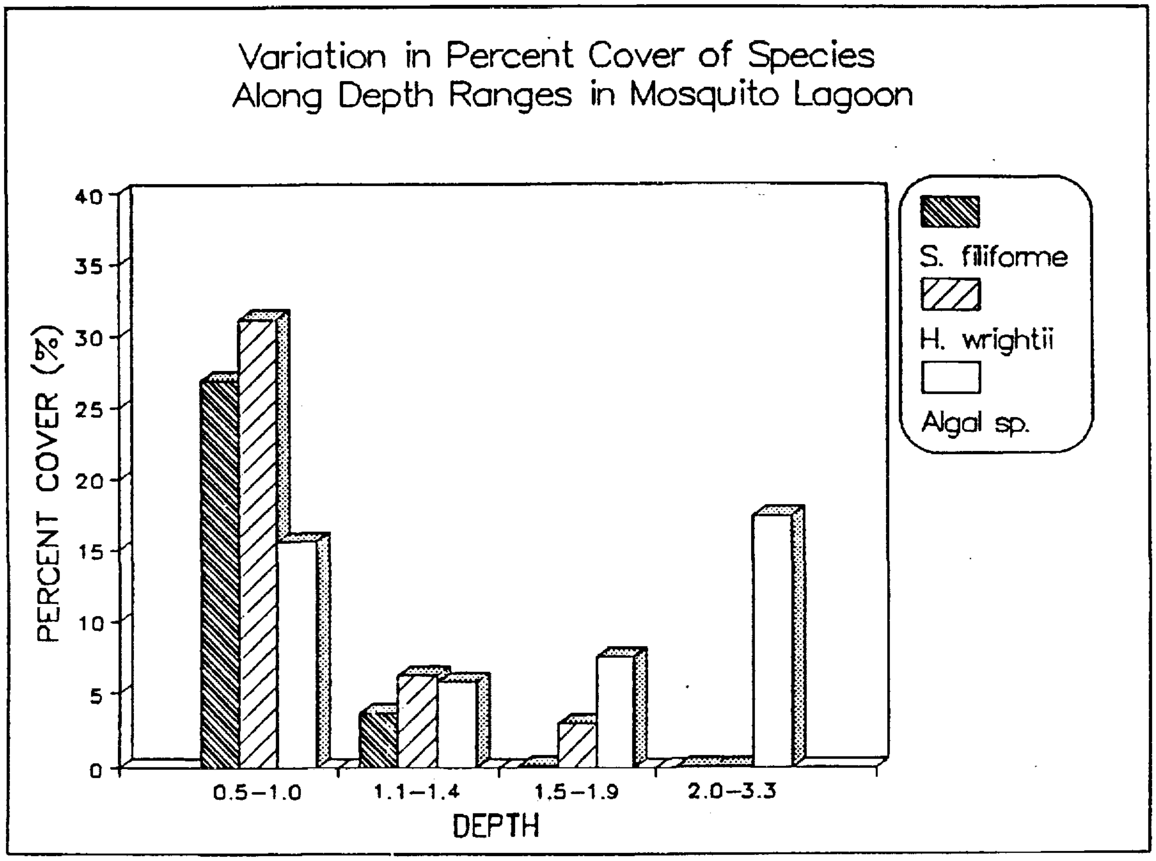


Figure C-7. Plot of relationship between percent cover of different types of submerged aquatic vegetation and depth in Mosquito Lagoon. Note the decrease in seagrass and increase in algae with depth.

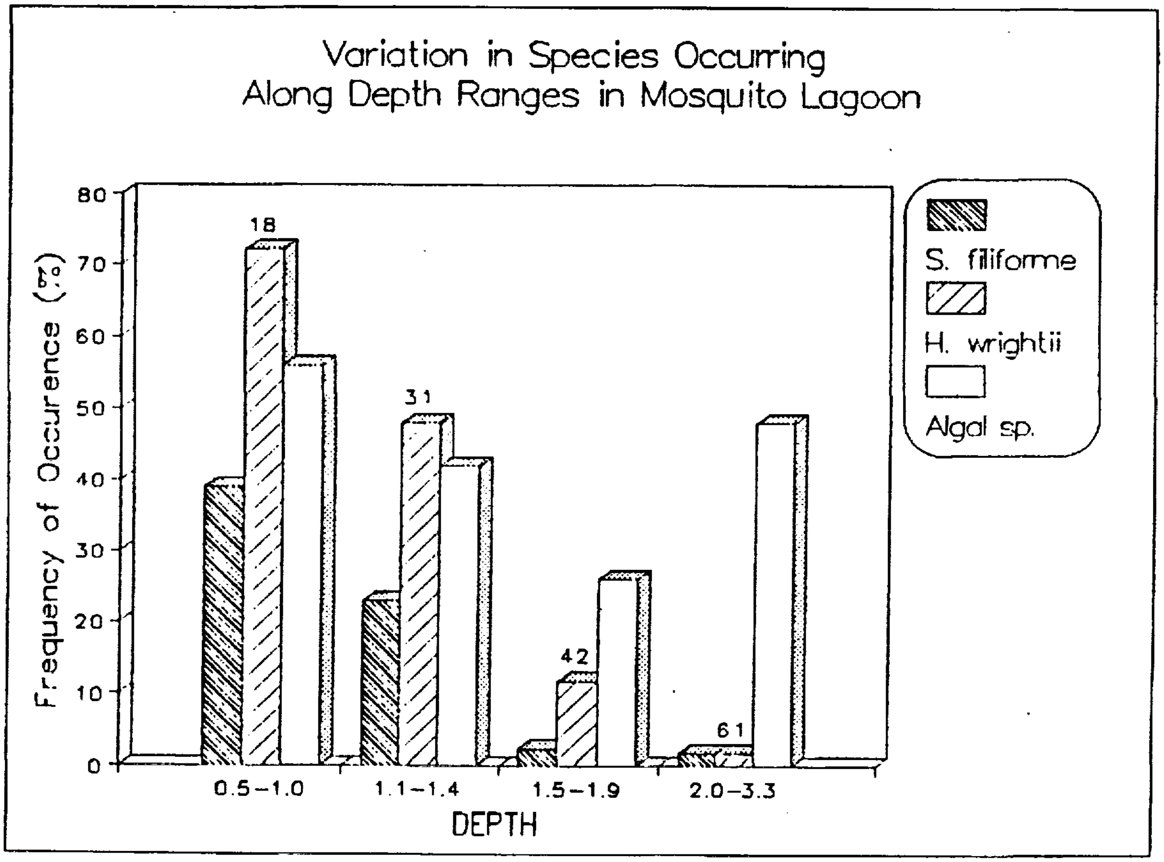


Figure C-8. Plot of relationship between frequency of encounter of different species types of submerged aquatic vegetation and depth in Mosquito Lagoon.

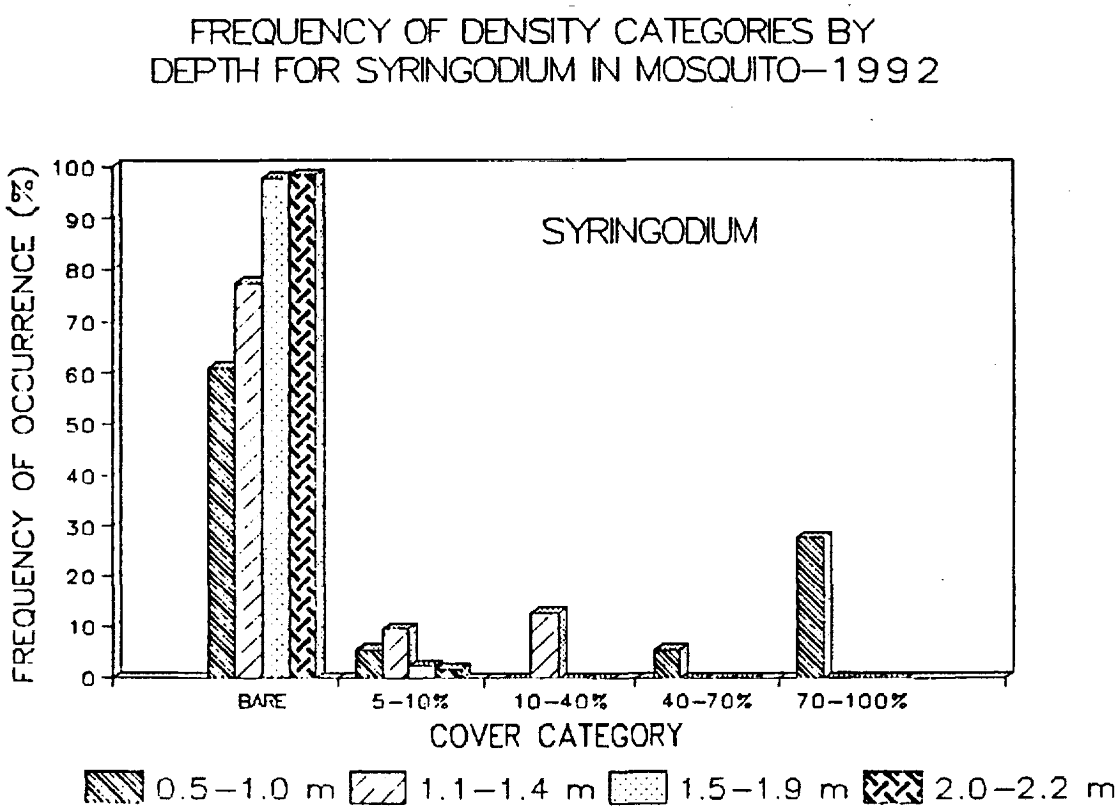


Figure C-9. Frequency of occurrence of different density categories by depth for manatee grass, *Syringodium filiforme*, collected at the Mosquito Lagoon transects in 1992.

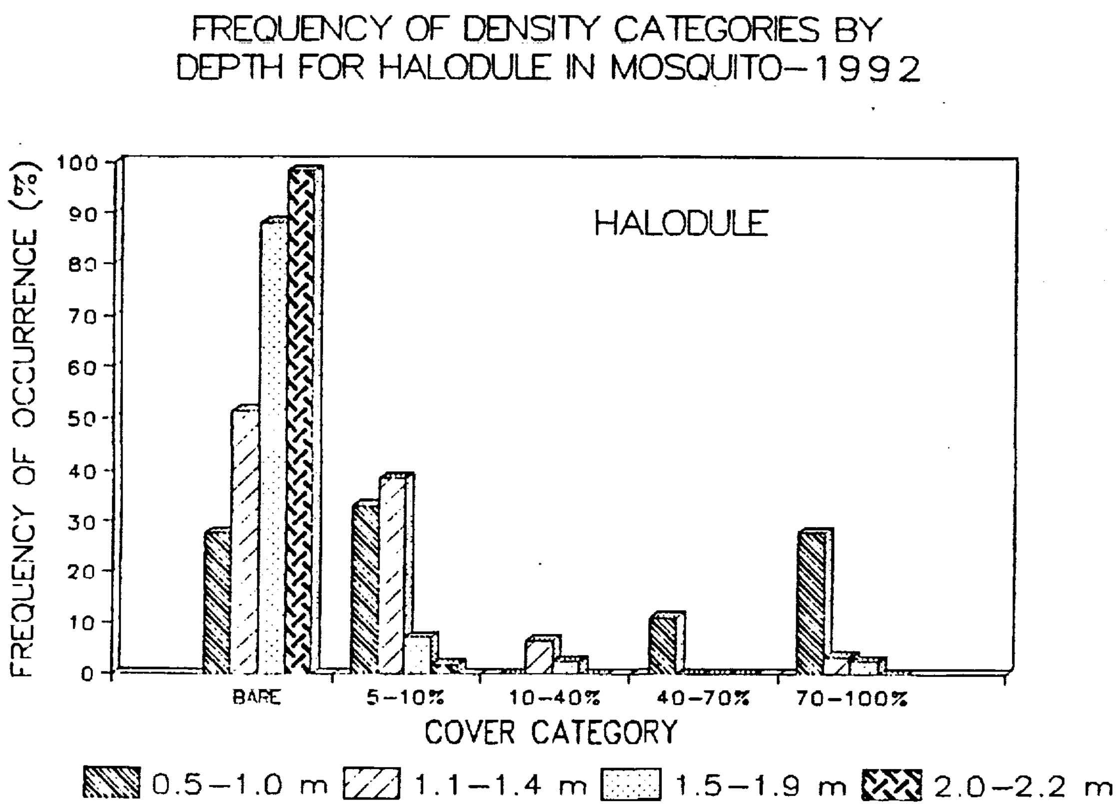


Figure C-10. Frequency of occurrence of different density categories by depth for shoale grass, *Halodule wrightii*, collected at the Mosquito Lagoon transects in 1992.

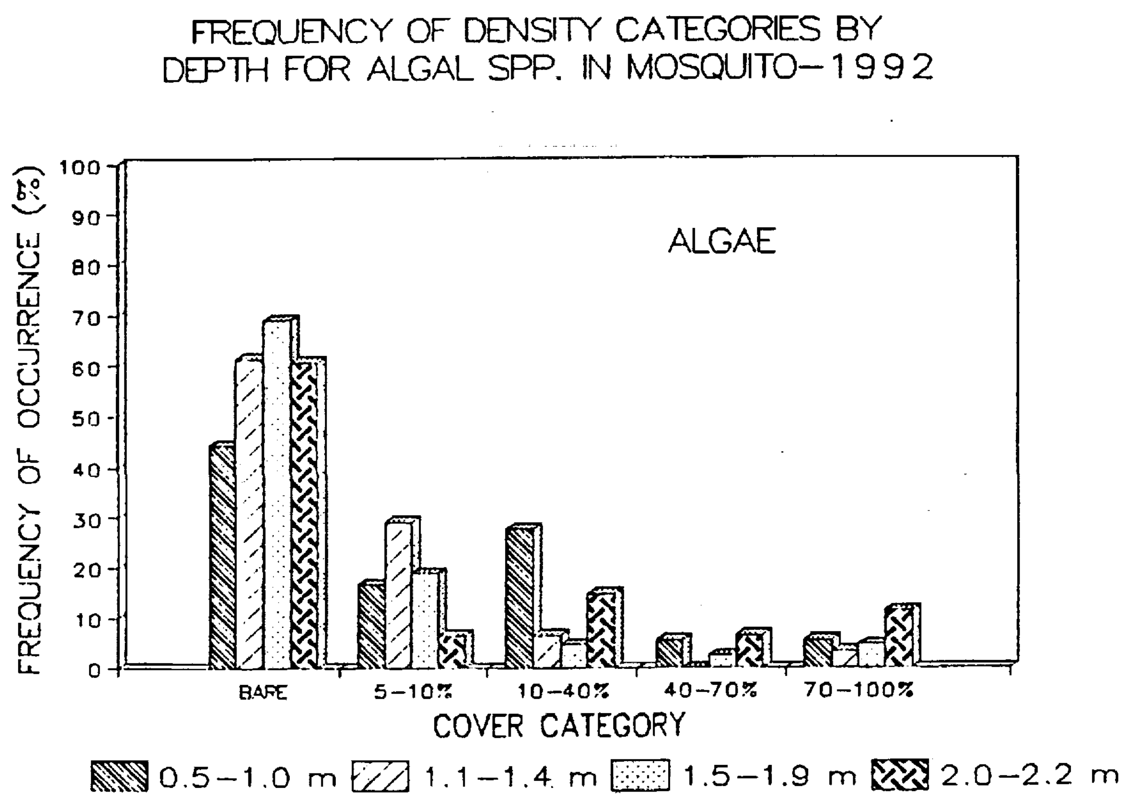


Figure C-11. Frequency of occurrence of different density categories by depth for all algae species combined collected at the Mosquito Lagoon transects in 1992.

Appendix D: Atmospheric Deposition

Table D-1. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1991 Third Quarter

Date	Amount (inches)	Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
7/01/91	0.24/.60	4.56	16.5	6.60
7/04/91	0.20	4.56	17.6	6.52
7/05/91	0.20			6.52
7/06/91	0.11			3.59
7/07/91	0.03			0.98
7/10/91	0.20	4.60	14.9	0.87
7/12/91	2.69			11.75
7/13/91	0.20			0.87
7/14/91	0.20			0.87
7/15/91	0.12			0.52
7/20/91	0.53	4.89	11.0	11.00
7/26/91	1.98	4.40	20.9	9.24
7/27/91	2.10			9.80
7/29/91	0.40			1.87
7/30/91	0.20	4.29	26.8	2.16
7/31/91	0.03			0.32
8/01/91	0.55			5.94
8/05/91	1.70			18.37
8/09/91	0.65	4.00	49.2	30.75
8/10/91	0.35			16.56
8/11/91	0.04			1.89
8/15/91	0.15	4.37	24.2	3.70
8/18/91	0.13			3.21
8/19/91	0.70			17.29
8/24/91	0.44	4.73	13.2	13.20
8/30/91	0.05	4.98	18.7	18.70
9/03/91	0.30	4.85	25.3	8.93
9/08/91	0.25	4.85	25.3	7.44
9/09/91	0.15			4.46
9/10/91	0.50			21.72
9/11/91	0.04/.39	4.70	24.2	2.48
9/20/91	1.45	4.45	20.9	13.78
9/21/91	0.14			1.33
9/22/91	0.58			5.51
9/23/91	0.03			0.29
9/28/91	0.10	6.03	16.5	0.50
9/29/91	2.95			14.66
9/30/91	0.27			1.34
Total	20.95			
Mean	0.55 (N=38)	4.65		7.51
Standard Deviation	0.75	1.10		7.28

Table D-2. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1991 Fourth Quarter

Date	Amount (inches)		Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
10/01/91	1.15		5.20	9.9	3.6
10/02/91	0.35				1.1
10/03/91	0.04				0.1
10/05/91	0.05				0.1
10/06/91	1.55				4.9
10/10/91	0.08		5.08	20.9	20.9
10/15/91	0.25		5.05	11.0	11.0
10/23/91	0.04		5.02	75.2	21.5
10/24/91	0.10				53.7
11/09/91	0.08		4.55	13.7	13.7
11/18/91	0.24		6.19	47.9	39.6
11/19/91	0.05				8.3
11/20/91	0.10		7.06	39.9	30.7
11/23/91	0.03				9.2
11/29/91	0.03				
12/04/91	0.30		4.91	7.7	7.7
12/10/91	0.05		5.40	14.8	4.1
12/12/91	0.13				10.7
Total	4.62				
Mean	0.26	(N=18)	5.34		15.06
Standard Deviation	0.42		1.14		14.96

Table D-3. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1992 First Quarter

Date	Amount (inches)	Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
1/01/92	1.02	4.72	19.4	11.05
1/02/92	0.77			8.35
1/14/92	0.14	4.94	16.8	16.80
1/17/92	0.04	4.77	9.7	3.23
1/18/92	0.08			6.47
1/23/92	0.08	5.66	23.9	23.90
2/05/92	0.90	4.81	11.6	9.24
2/07/92	0.04			0.41
2/09/92	0.15			1.54
2/10/92	0.04			0.41
2/23/92	0.30	4.30	43.9	29.27
2/24/92	0.15			14.63
2/25/92	0.44	4.72	13.8	13.80
3/05/92	0.10	4.69	16.3	0.60
3/06/92	2.29			13.72
3/07/92	0.33			4.76
3/11/92	0.25	4.90	9.0	7.50
3/12/92	0.05			1.50
3/19/92	0.03	4.43	38.7	6.45
3/22/92	0.15			32.25
3/25/92	2.10	4.70	16.3	16.30
Total	9.45			
Mean	0.45	4.77		10.58
Standard Deviation	0.65	1.07		9.26

Table D-4. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1992 Second Quarter

Date	Amount (inches)	Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
4/11/92	0.03	5.00	15.7	0.22
4/12/92	1.40	5.00	15.7	10.08
4/13/92	0.75	5.00	15.7	5.40
4/17/92	0.05	4.71	34.8	34.8
4/21/92	1.70	4.77	12.9	11.36
4/23/92	0.23	4.77	12.9	1.54
5/14/92	0.38	4.18	50.2	38.15
5/18/92	0.12	4.18	50.2	12.05
5/26/92	0.15	4.35	38.7	2.90
5/29/92	0.30	4.35	38.7	5.81
5/30/92	0.05	4.35	38.7	0.97
6/2/92	0.15	4.50	21.9	2.67
6/3/92	0.35	4.50	21.9	6.23
6/4/92	0.40	4.50	21.9	7.12
6/6/92	0.30	4.50	21.9	5.34
6/8/92	0.03	4.50	21.9	0.53
6/10/92	0.69	4.20	33.0	4.62
6/11/92	0.82	4.20	33.0	5.49
6/12/92	0.53	4.20	33.0	3.55
6/13/92	1.09	4.20	33.0	7.30
6/15/92	1.80	4.20	33.0	12.05
6/20/92	0.70	4.01	55.0	35.65
6/21/92	0.38			19.35
6/23/92	0.20	4.82	5.1	0.33
6/25/92	0.05	4.82	5.1	0.08
6/26/92	1.00	4.82	5.1	1.65
6/27/92	1.30	4.82	5.1	2.14
6/28/92	0.50	4.82	5.1	0.82
6/29/92	0.05	4.82	5.1	0.08
6/30/92	0.20	4.42	21.3	21.3
Total	15.70			
Mean	0.52	4.49		8.65
Standard Deviation	0.51	1.07		10.77

Table D-5. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1992 Third Quarter

Date	Amount (inches)	Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
7/13/92	0.35	4.34	27.1	27.1
7/14/92	0.44	4.51	21.9	14.2
7/17/92	0.06			1.9
7/19/92	0.03			1.0
7/20/92	0.15			4.8
7/21/92	0.18	4.76	11.0	7.3
7/23/92	0.09			3.6
7/30/92	0.53	3.85	72.5	72.5
8/04/92	0.90	4.25	27.9	23.9
8/08/92	0.15			4.0
8/12/92	0.60	4.80	10.2	2.2
8/14/92	1.40			5.1
8/15/92	0.23			0.8
8/16/92	0.14			0.5
8/17/92	0.45			1.6
8/18/92	0.07	4.42	19.1	0.4
8/19/92	0.11			0.7
8/20/92	1.54			9.9
8/22/92	0.62			4.0
8/23/92	0.55			3.5
8/24/92	0.07			0.4
8/29/92	0.70	4.26	28.8	28.8
9/02/92	0.20	4.66	15.0	9.7
9/03/92	0.03			1.5
9/04/92	0.05			2.3
9/07/92	0.03			1.5
9/10/92	0.95	4.42	21.3	7.7
9/13/92	1.35			10.9
9/14/92	0.34			2.7
9/16/92	0.01			
9/18/92	0.01			
9/24/92	0.08	4.98	12.7	0.7
9/27/92	0.20			1.6
9/28/92	1.28			10.4
9/29/92	2.10	4.93	14.0	8.6
9/30/92	0.09			0.4
Total	16.08			
Mean	0.45	4.50		8.1
Standard Deviation	0.51	1.07		13.4

Table D-6. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1992 Fourth Quarter

Date	Amount (inches)	Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
10/02/92	0.14	4.93	17.8	2.0
10/03/92	0.65			9.6
10/04/92	0.42			6.2
10/06/92	0.85	4.83	37.4	14.5
10/07/92	0.65			11.1
10/09/92	0.02			0.3
10/11/92	0.68			11.6
10/23/92	0.19	4.06	80.0	42.2
10/24/92	0.17			37.8
10/31/92	0.07	4.40	27.1	27.1
11/08/92	0.25	4.23	80.0	57.1
11/09/92	0.10			22.9
11/12/92	0.40	4.62	36.3	29.6
11/16/92	0.06			4.4
11/17/92	0.03			2.3
11/18/92	0.11	4.76	20.3	0.9
11/20/92	0.02			0.2
11/21/92	0.12			1.0
11/22/92	1.67			14.0
11/23/92	0.50			4.2
11/28/92	0.09	4.33	25.8	25.8
12/10/92	0.60	4.81	7.7	7.7
12/16/92	0.02	4.58	50.3	25.2
12/20/92	0.02			25.1
12/27/92	0.05	4.44	47.7	47.7
12/29/92	0.40	4.72	19.4	3.5
12/30/92	1.02			9.0
12/31/92	0.77			6.8
Total (N=28)	10.07			
Mean	0.36	4.27		16.06
Standard Deviation	0.39	1.27		15.67

Table D-7. John F. Kennedy Space Center Rainfall Totals, pH, and Conductivity

1993 First Quarter

Date	Amount (inches)	Field pH Weekly Sample	Field Conductivity(umho/cm) Weekly Sample	Volume Weighted
1/02/93	0.23	4.93	27.1	6.2
1/03/93	0.25			6.7
1/04/93	0.53			14.2
1/08/93	0.54	4.88	9.0	6.7
1/09/93	0.07			0.9
1/11/93	0.12			1.5
1/13/93	0.03	4.30	10.3	0.4
1/14/93	0.90			4.7
1/15/93	0.60			3.1
1/16/93	0.45			2.3
1/20/93	0.23	5.06	9.0	0.9
1/23/93	0.03			0.1
1/25/93	1.10			4.3
1/26/93	0.93			3.7
1/26/93	0.20	4.45	39.9	16.0
1/27/93	0.30			23.9
2/09/93	0.55	5.00	7.7	3.9
2/10/93	0.05			0.3
2/11/93	0.50			3.5
2/17/93	0.09	4.67	15.5	1.3
2/21/93	0.03			0.4
2/22/93	0.95			13.8
2/26/93	0.40	4.70	20.6	20.6
3/03/93	0.05	5.02	20.6	3.4
3/04/93	0.20			13.7
3/07/93	0.05			3.4
3/13/93	2.10	5.02	6.5	6.5
3/16/93	0.09	4.93	36.1	2.8
3/17/93	0.15			4.7
3/18/93	0.18			5.7
3/20/93	0.05			1.6
3/21/93	0.68			21.3
3/23/93	0.10	4.38	30.9	11.4
3/24/93	0.14			16.0
3/26/93	0.03			3.5
3/31/93	0.85	4.90	9.0	7.3
Total	13.75			
Mean (N=36)	0.38	4.78		6.41
Standard Deviation (N=1)	0.43	1.06		6.32

Table D-8. John F. Kennedy Space Center Rainfall Totals (inches) from 1983 through 1992.

Year	July	August	September	October	November	December
1983				4.71	1.63	7.54
1984	7.02	5.85	7.28	1.01	7.31	0.20
1985	5.57	5.59	6.37	2.54	3.54	4.53
1986	4.45	4.93	2.04	3.42	2.23	7.59
1987	4.85	3.39	15.71	5.24	9.44	0.55
1988	5.99	3.67	0.44	1.78	5.71	1.19
1989	4.52	2.24	1.39*	7.15	1.53	5.03
1990	1.39	7.52	3.01	8.58	5.79	0.65
1991	9.43	4.76	6.76	3.61	0.53	0.48
1992	1.83	7.53	6.72	3.84	3.35	2.88
KSC (1983-1992) Mean	5.40	4.74	5.38	4.23	4.19	3.08
Standard Deviation	2.16	1.54	4.61	2.47	3.03	3.10
Titusville (86-yr record)	7.52	6.69	7.96	5.41	2.52	2.32
Merritt Island (75-yr Record)	5.99	5.52	7.76	6.14	2.52	2.30

*One week's data missing

Table D-9. John F. Kennedy Space Center Rainfall Totals (inches) from 1984 through 1993.

Year	January	February	March	April	May	June
1984	1.53	3.75	0.63	4.40	6.61	2.03
1985	0.56	0.61	4.18	3.82	3.40	6.26
1986	6.65	1.93	1.55	0.61	1.57	3.61
1987	0.78	2.03	8.36	1.65	1.57	3.90
1988	2.51	1.54	5.06	0.65	2.56	6.37
1989	4.95	0.55	2.77	3.96	1.70	5.02
1990	0.06	3.73	0.67	0.42	1.70	6.23
1991	0.90	1.61	7.92	5.93	7.05	3.29
1992	2.13	2.02	5.30	4.16	1.00	10.54
1993	6.51	2.57	4.67			
KSC (1984-1993) Mean	2.23	1.97	4.05	2.68	3.27	4.59
Standard Deviation	2.20	1.14	2.90	2.11	2.29	1.63
Titusville (86-yr record)	2.22	2.80	3.06	2.53	4.09	7.12
Merritt Island (75-yr Record)	2.68	2.56	2.79	2.77	3.70	6.65

Table D-10. John F. Kennedy Space Center Rainfall Totals (inches) from 1984 through 1992.

	Annual Rain				
Year	First Quarter	Second Quarter	Third Quarter	Fourth Quarter	Annual Total
1984	5.91	13.04	20.15	8.52	47.62
1985	5.35	13.48	17.53	10.61	49.67
1986	10.13	5.79	11.42	13.24	40.58
1987	11.17	7.12	23.95	15.23	57.47
1988	9.11	9.58	10.10	8.68	37.47
1989	8.27	10.68	8.15	13.71	40.81
1990	4.46	8.35	11.92	15.02	39.75
1991	10.43	16.27	20.95	4.62	52.27
1992	9.45	15.70	16.08	10.07	51.30
KSC (1984-1992) Mean	8.10	10.54	15.52	11.20	45.37
Standard Deviation	7.55	3.54	5.85	3.75	6.96
Titusville (86-yr record)	8.08	13.74	22.17	10.25	54.24
Merritt Island (75-yr Record)	8.03	13.12	19.27	10.96	51.38

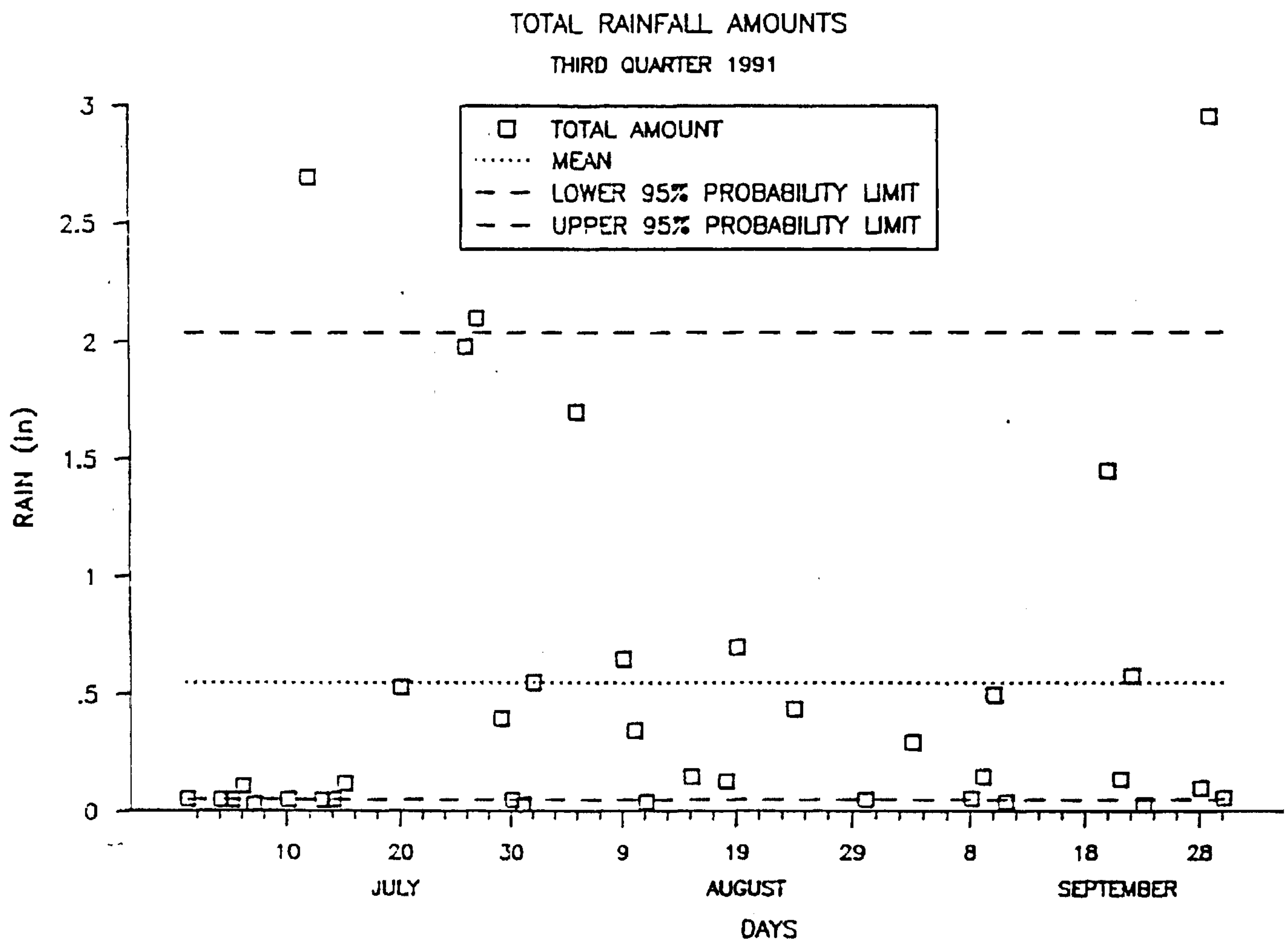


Figure D-1. Temporal rainfall volumes, average rainfall, and 95% probability limits for the third quarter of 1991. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon

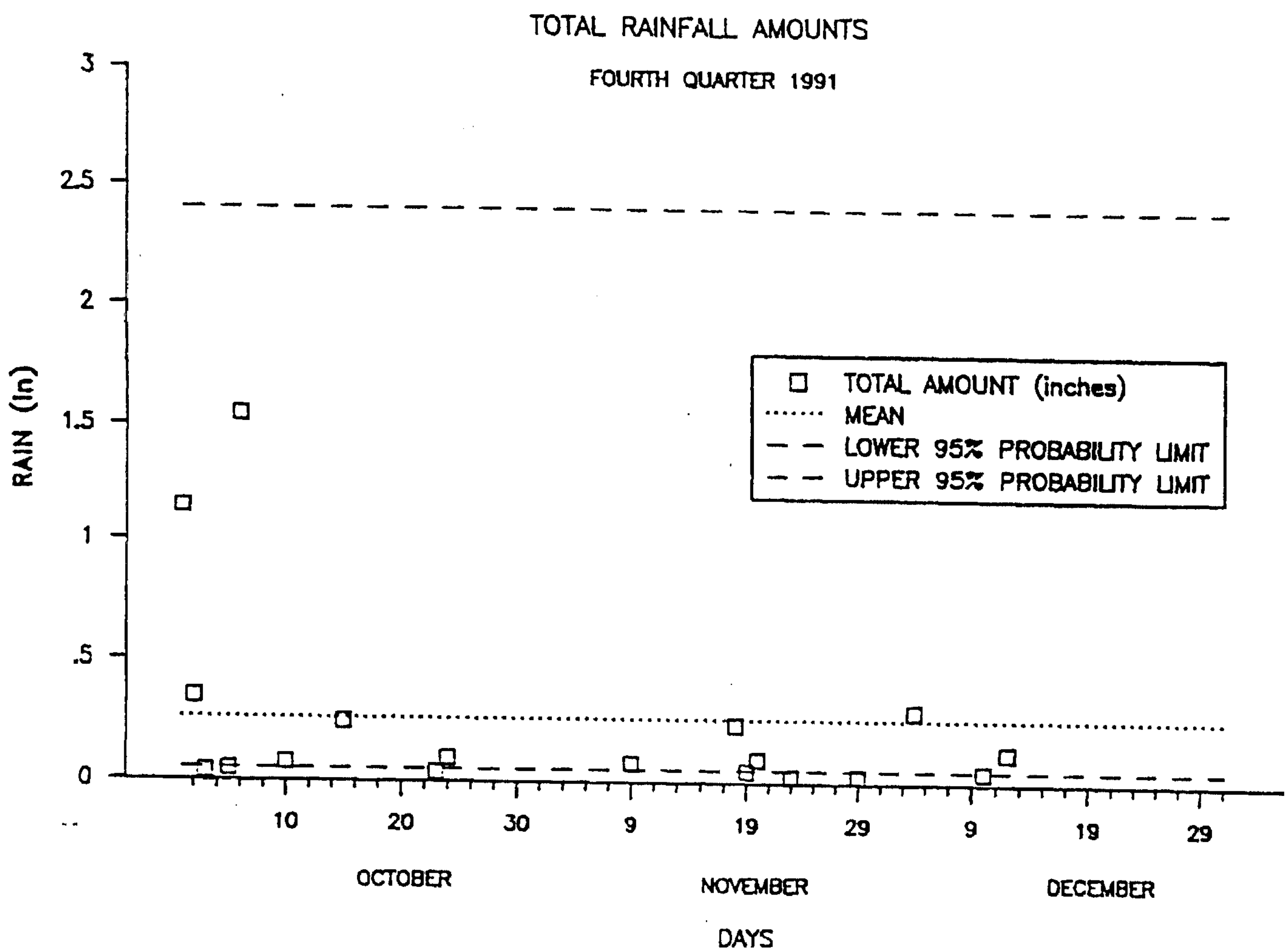


Figure D-2. Temporal rainfall volumes, average rainfall, and 95% probability limits for the fourth quarter of 1991. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon

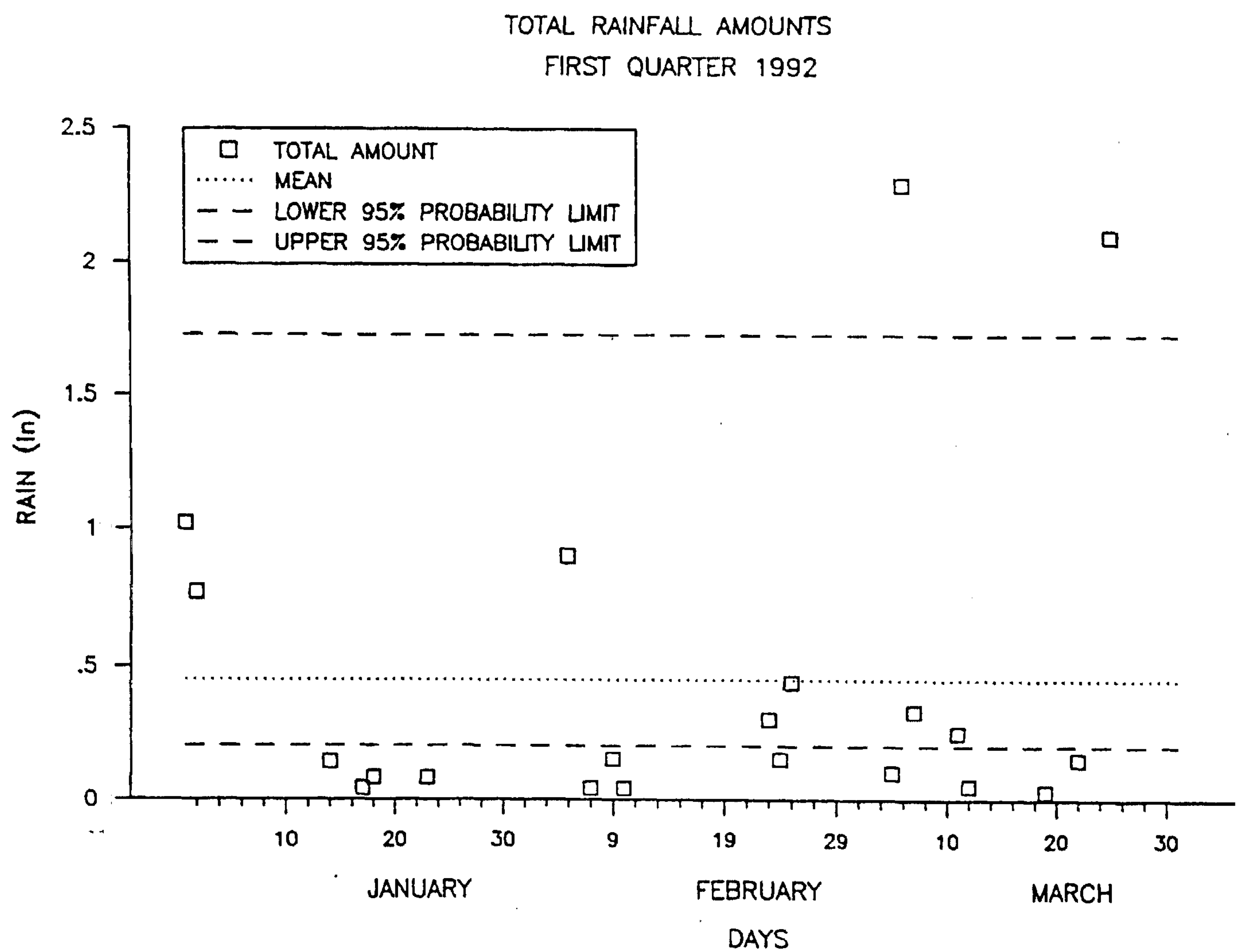


Figure D-3. Temporal rainfall volumes, average rainfall, and 95% probability limits for the first quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon

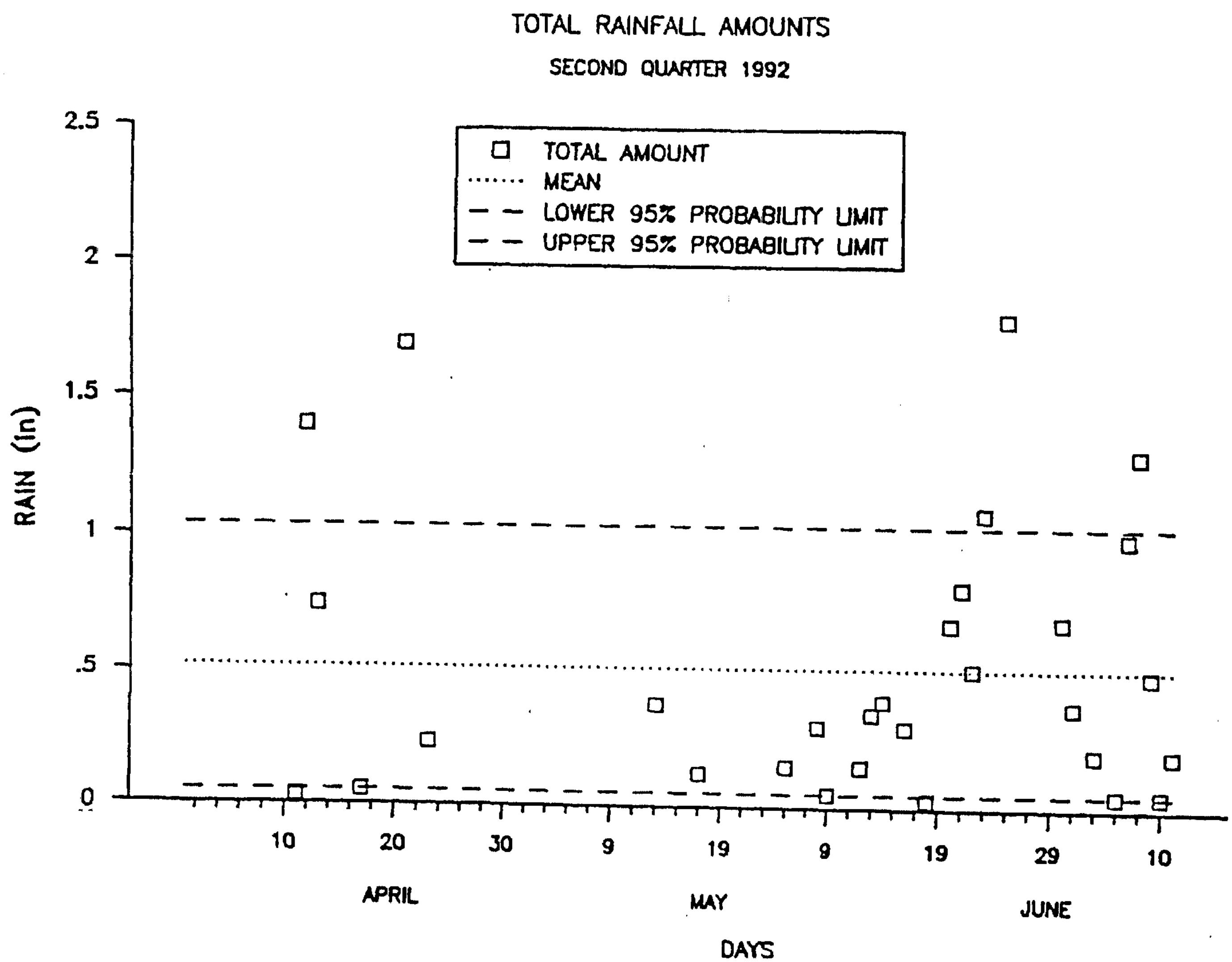


Figure D-4. Temporal rainfall volumes, average rainfall, and 95% probability limits for the second quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon

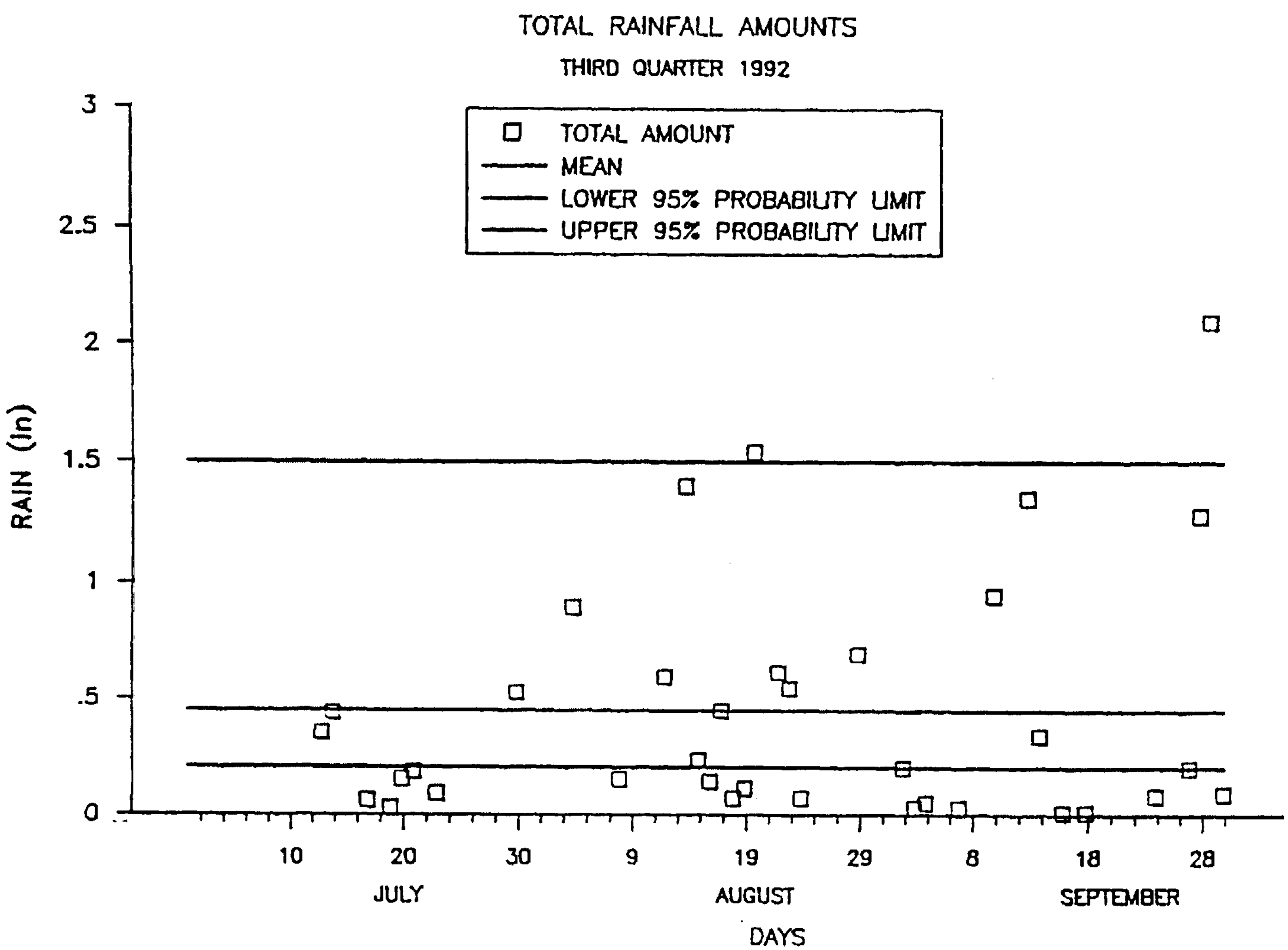


Figure D-5. Temporal rainfall volumes, average rainfall, and 95% probability limits for the third quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

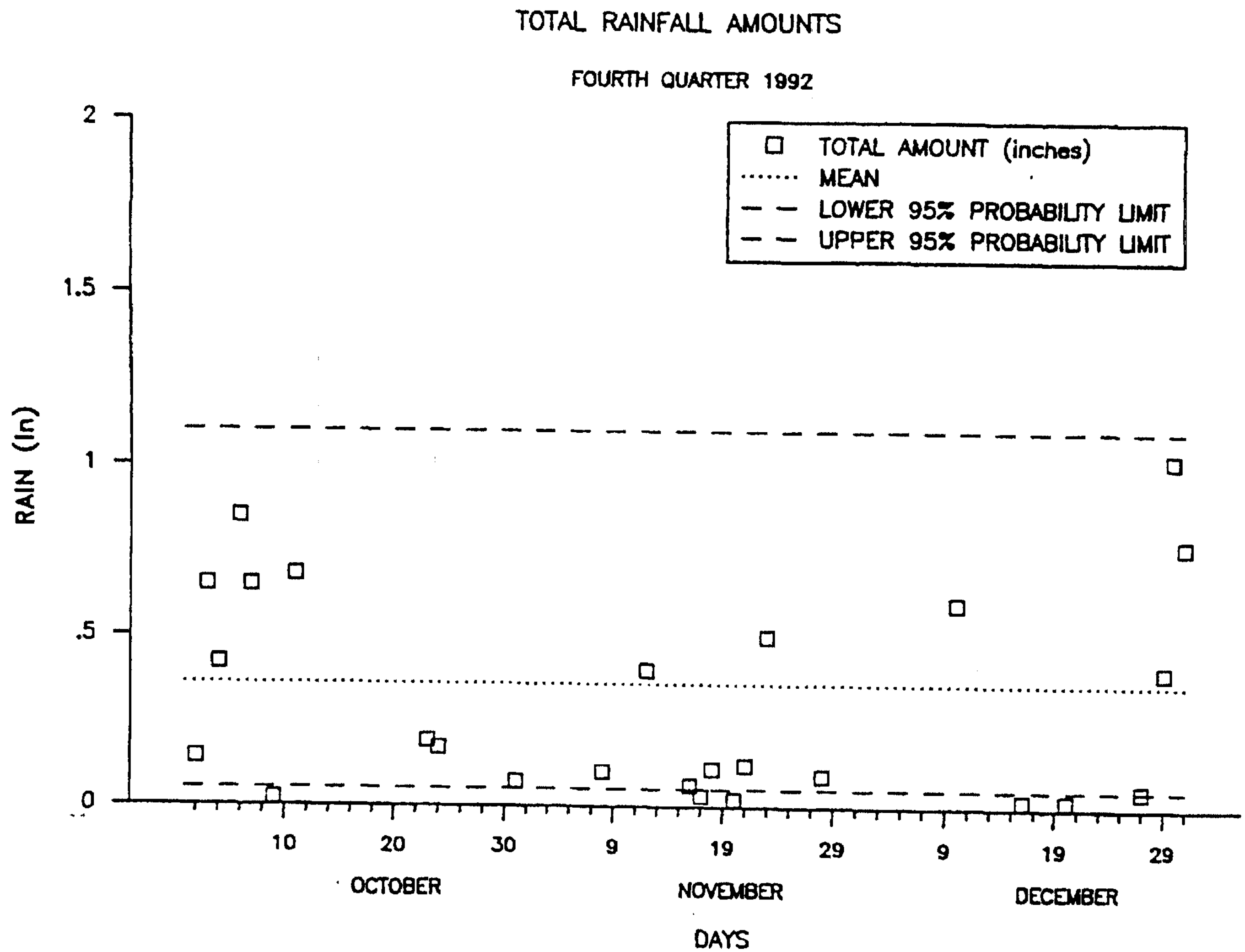


Figure D-6. Temporal rainfall volumes, average rainfall, and 95% probability limits for the fourth quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

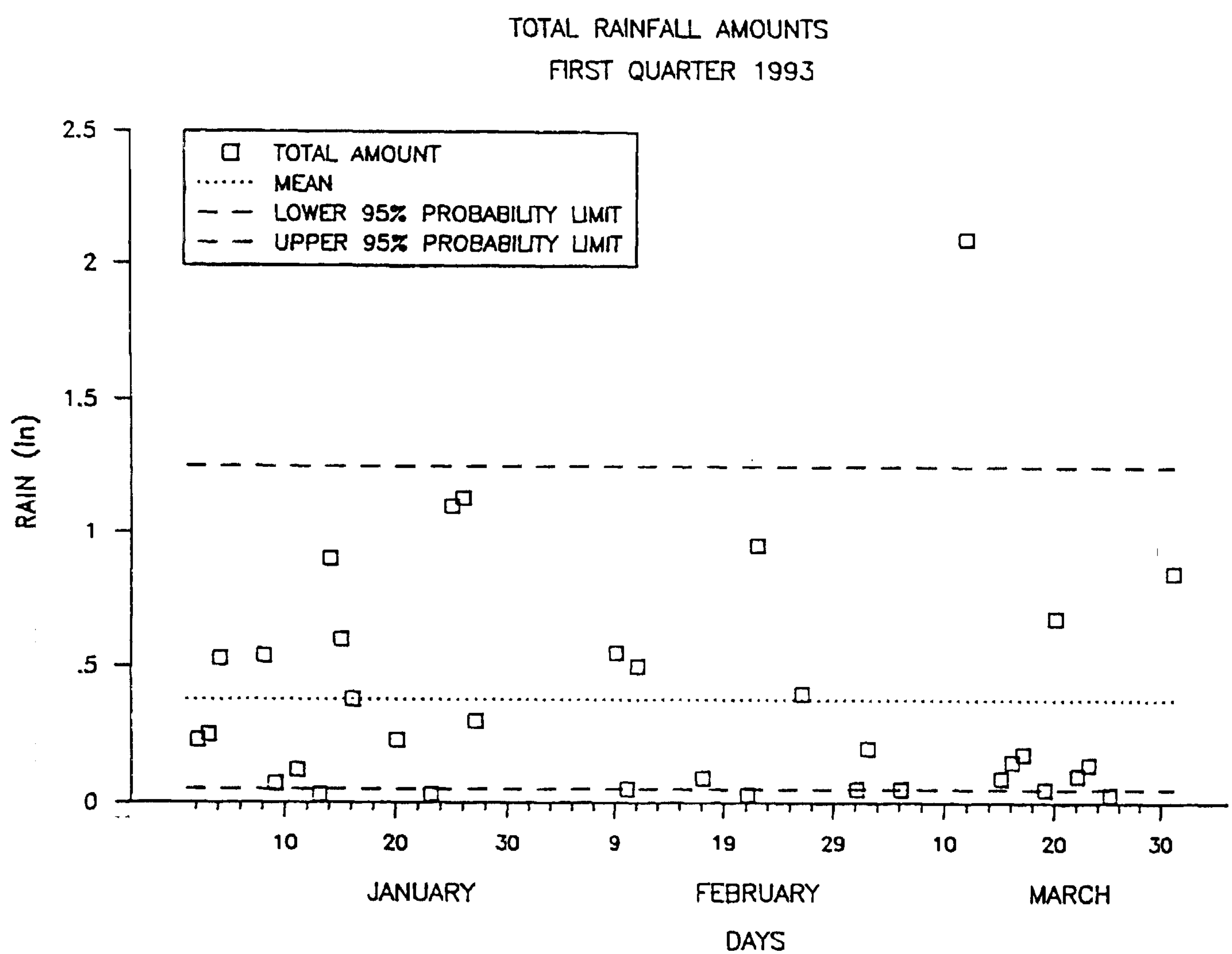


Figure D-7. Temporal rainfall volumes, average rainfall, and 95% probability limits for the first quarter of 1993. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

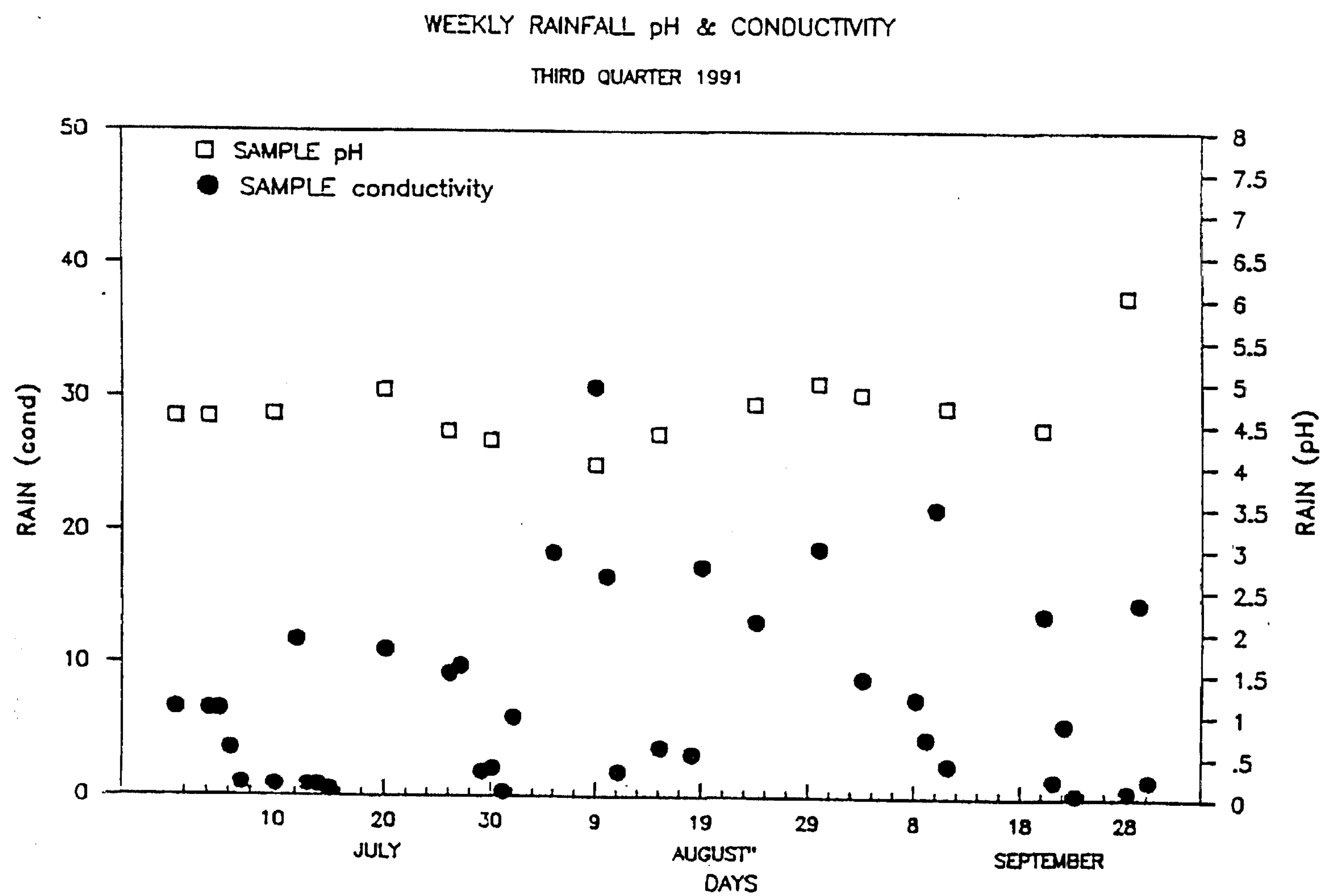


Figure D-8. Temporal rainfall pH and conductivity for the third quarter of 1991. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

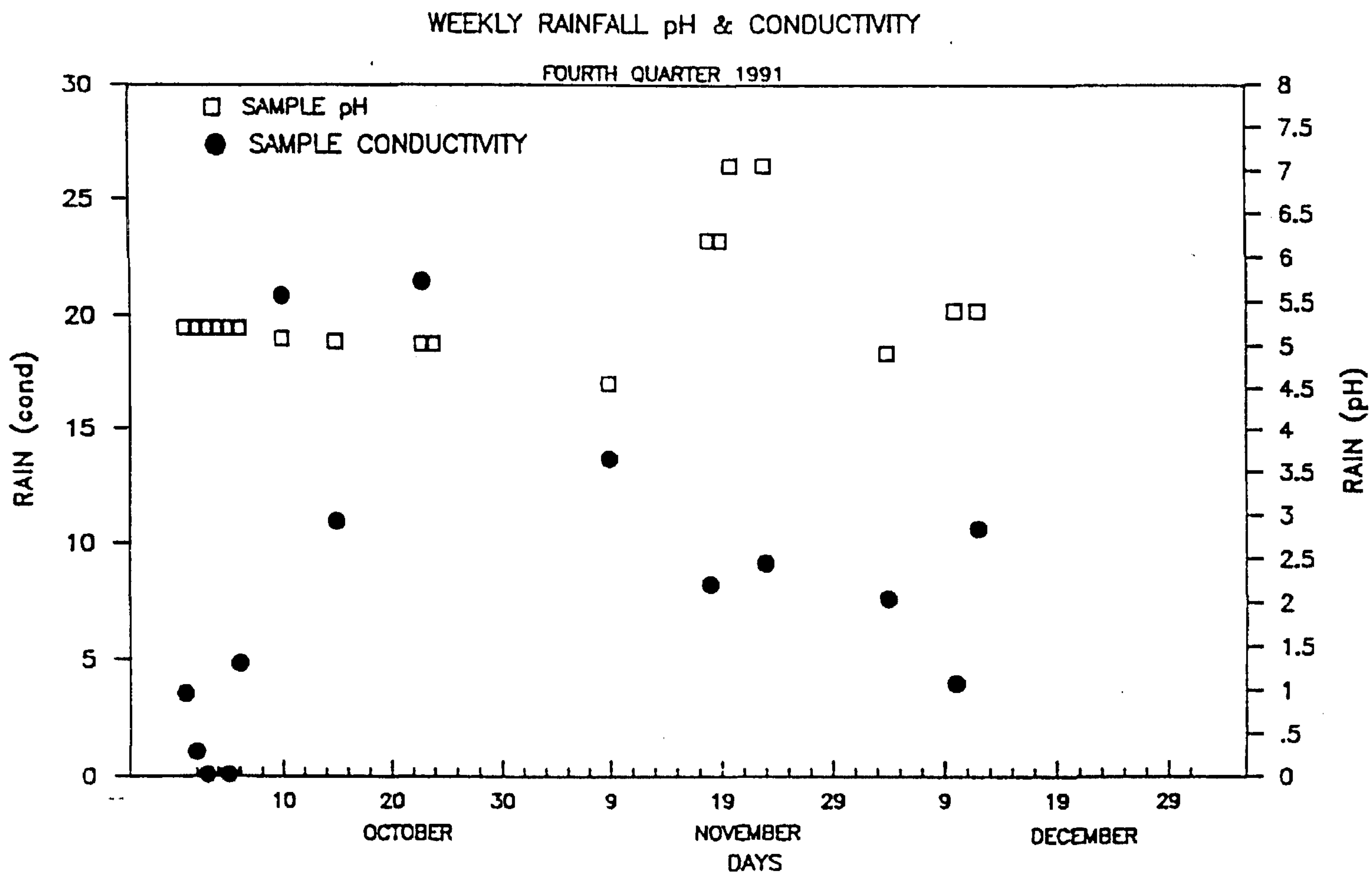


Figure D-9. Temporal rainfall pH and conductivity for the fourth quarter of 1991. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

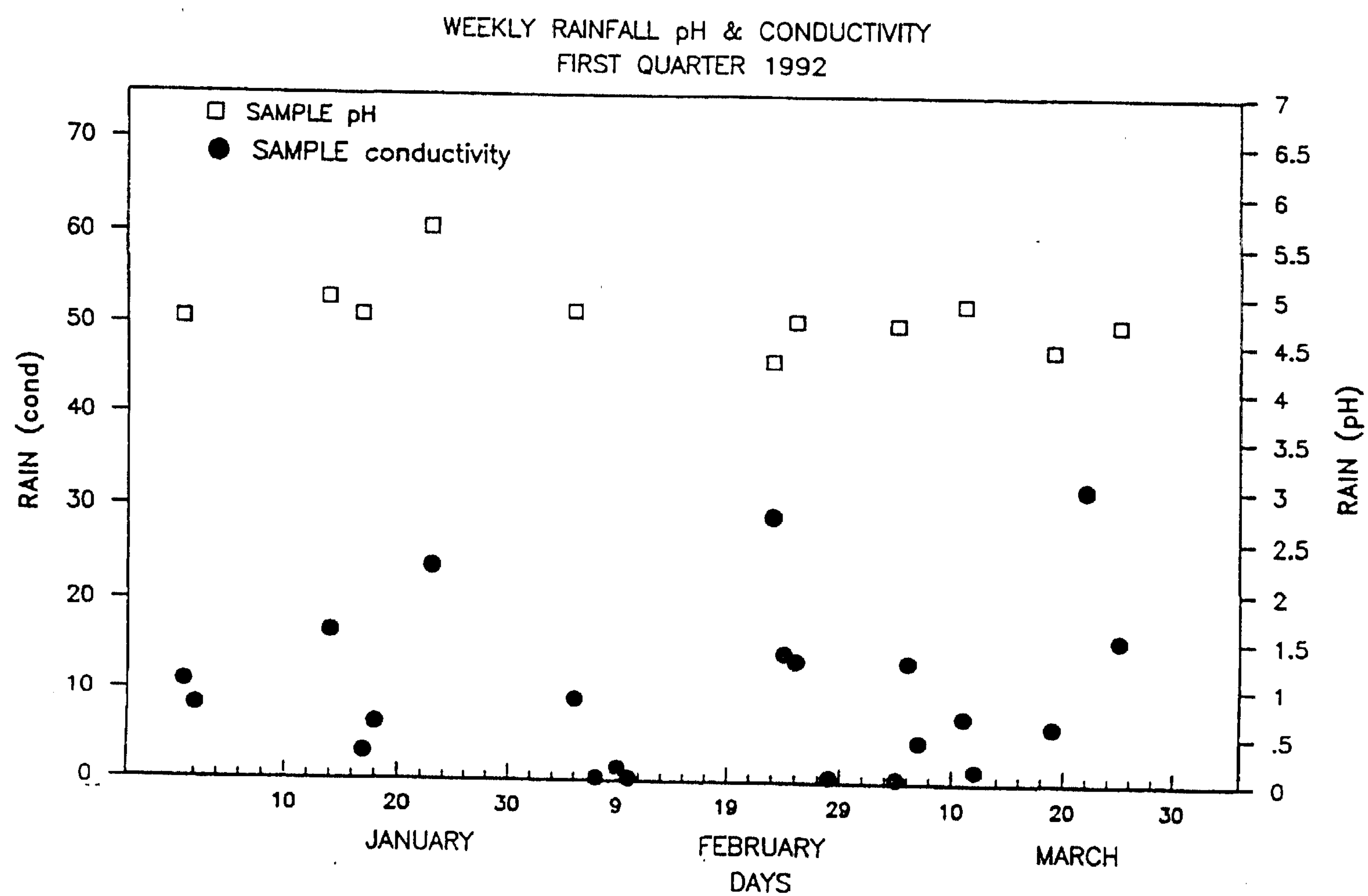


Figure D-10. Temporal rainfall pH and conductivity for the first quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

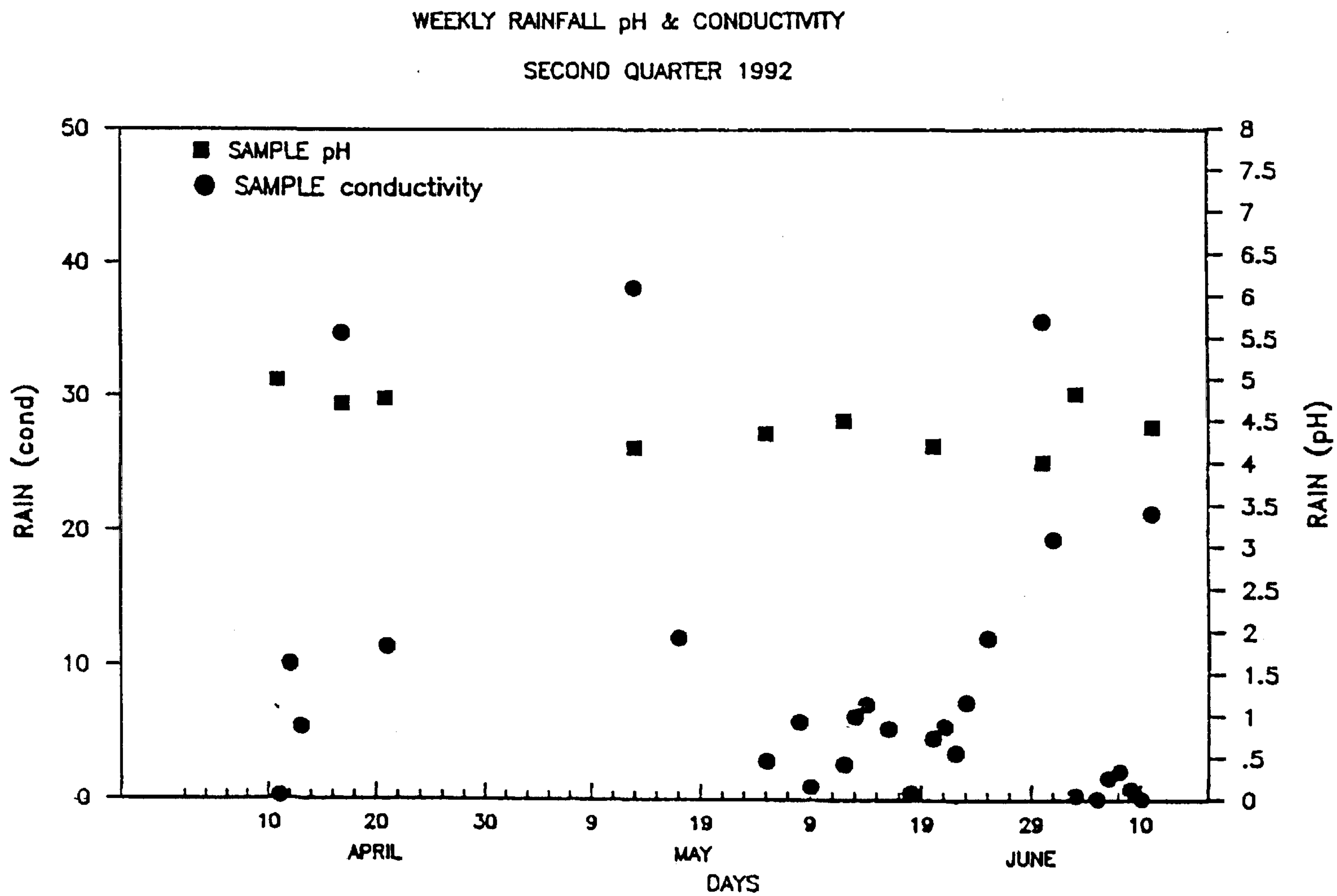


Figure D-11. Temporal rainfall pH and conductivity for the second quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

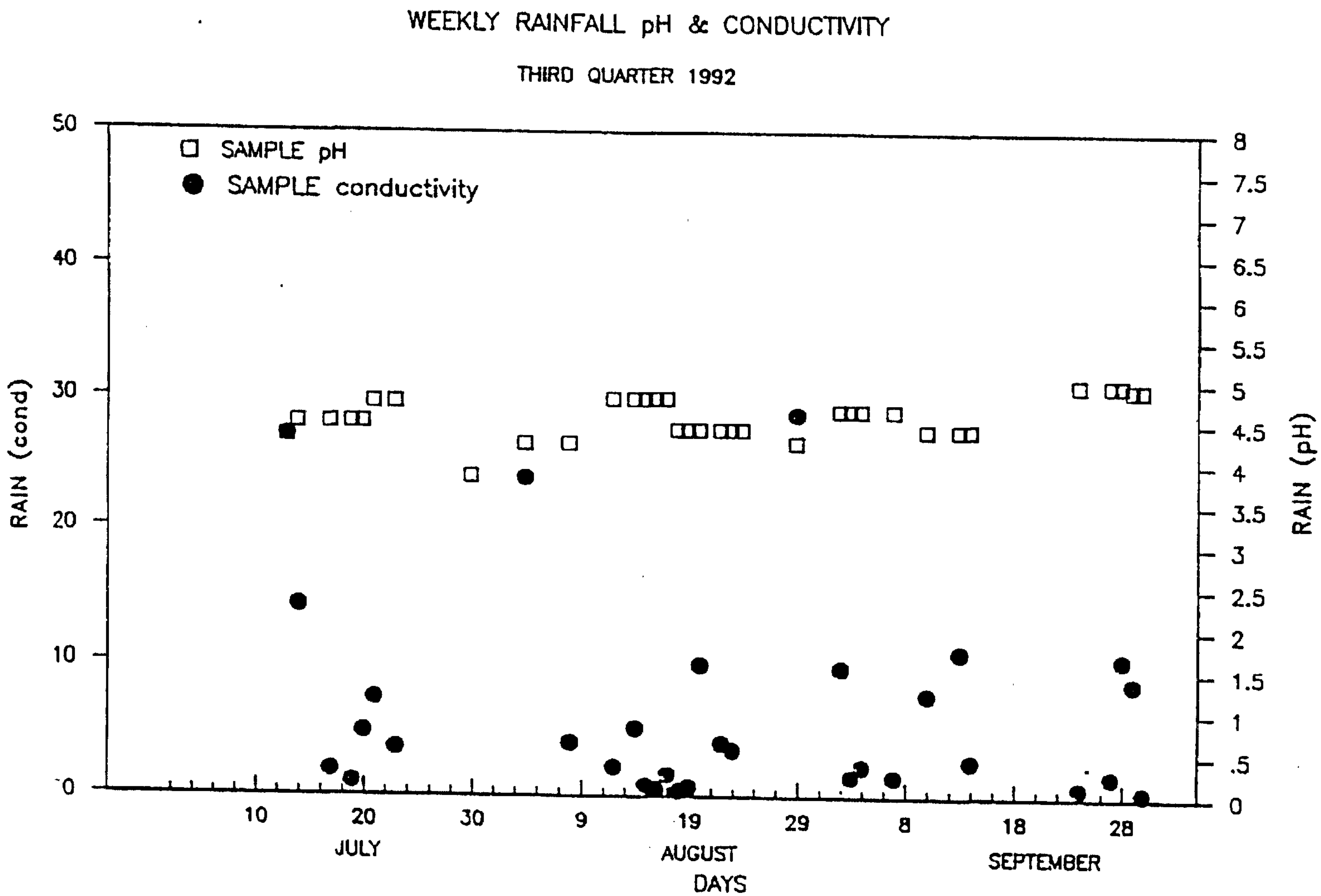


Figure D-12. Temporal rainfall pH and conductivity for the third quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

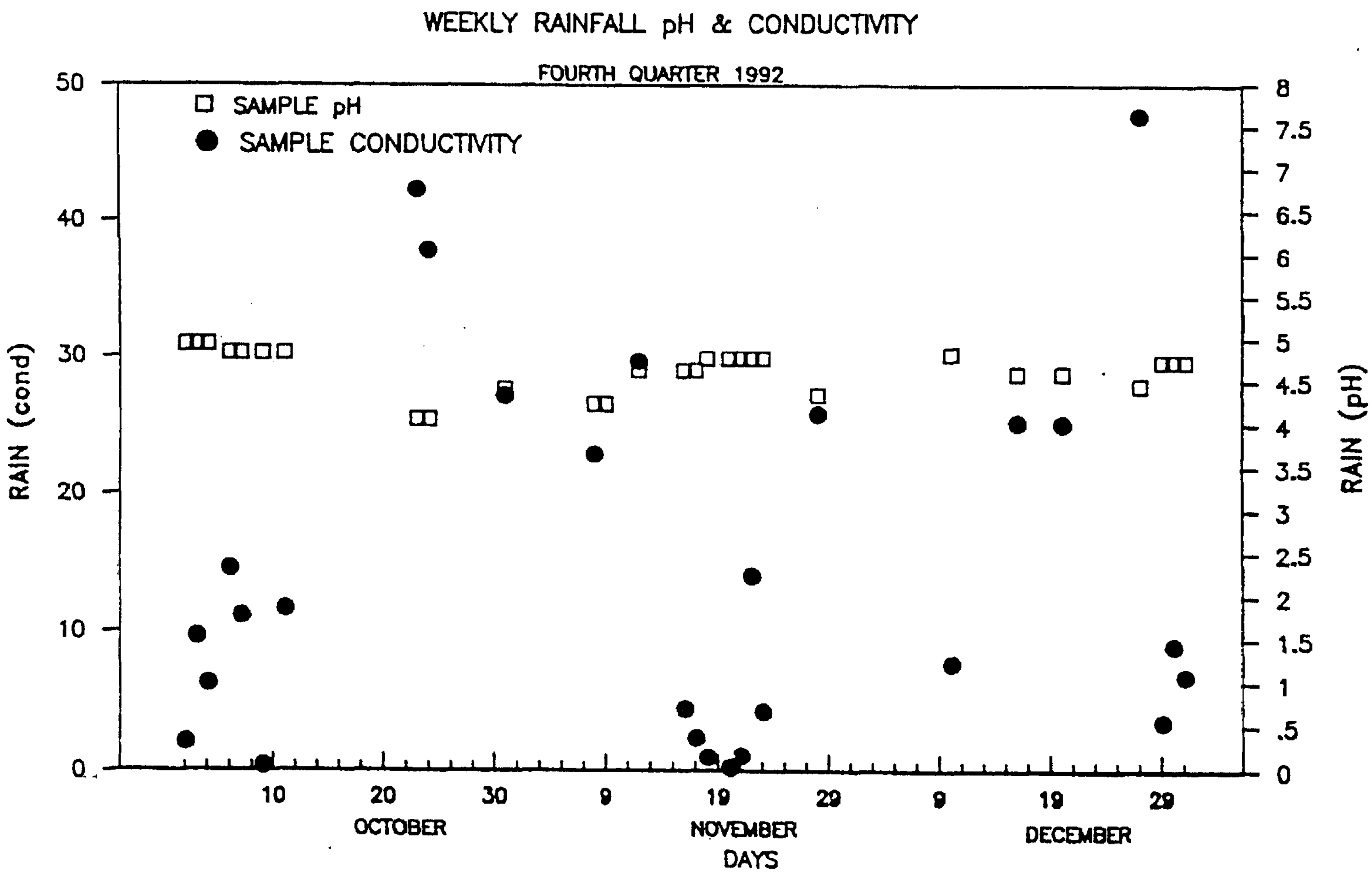


Figure D-13. Temporal rainfall pH and conductivity for the fourth quarter of 1992. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

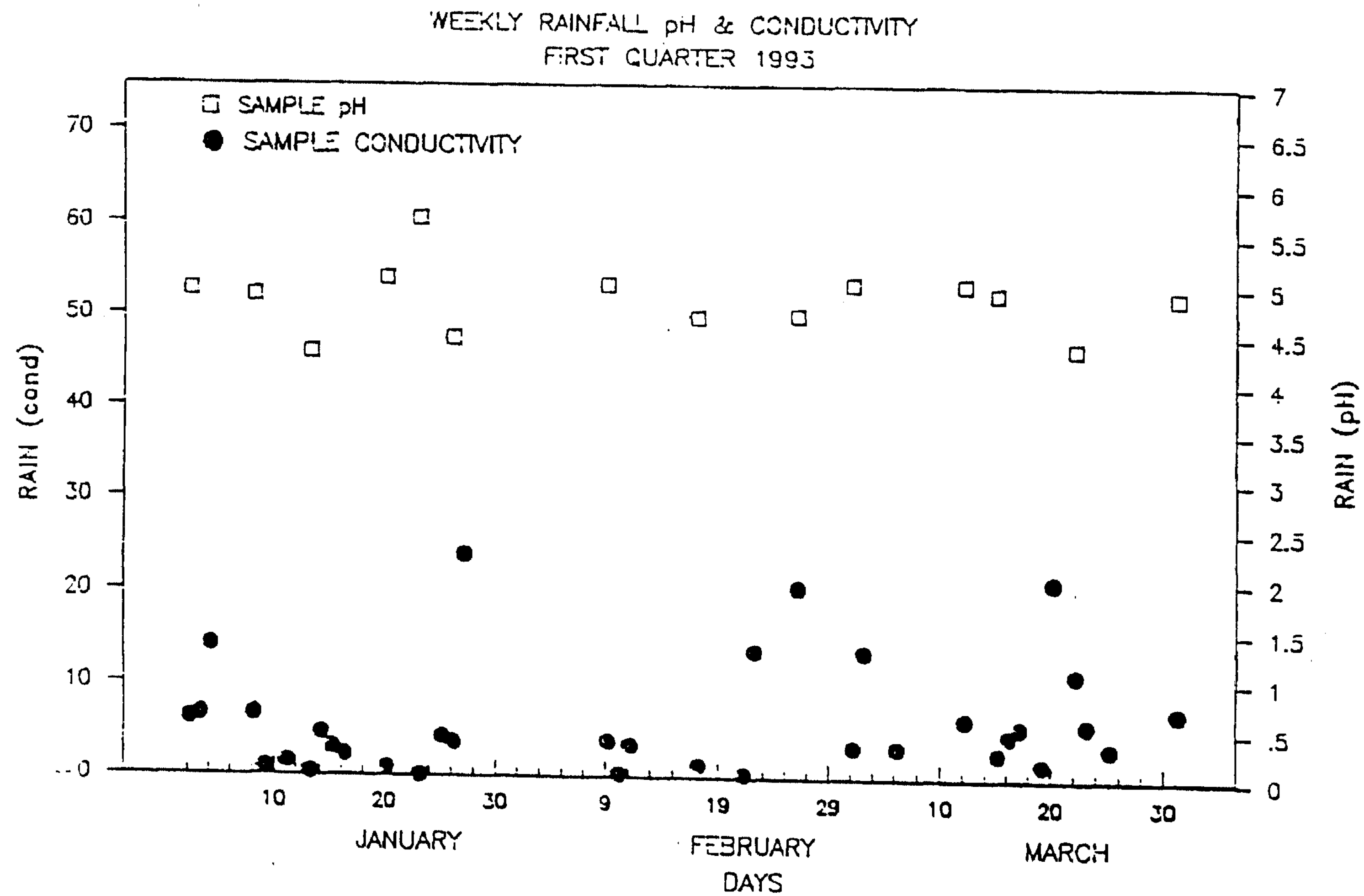
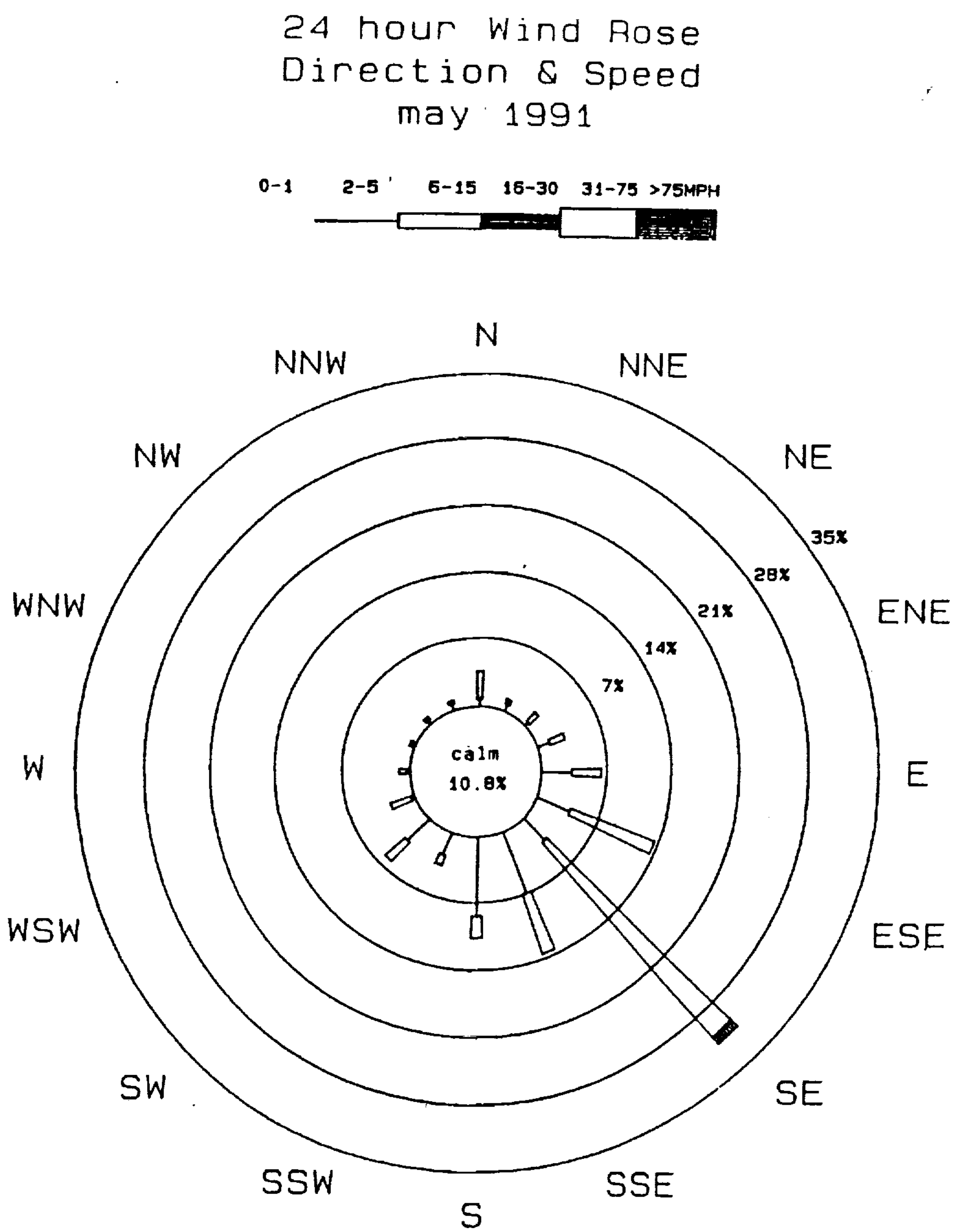


Figure D-14. Temporal rainfall pH and conductivity for the first quarter of 1993. Samples were collected at the National Atmospheric Deposition site on Kennedy Space Center approximately 5 miles southwest of Mosquito Lagoon.

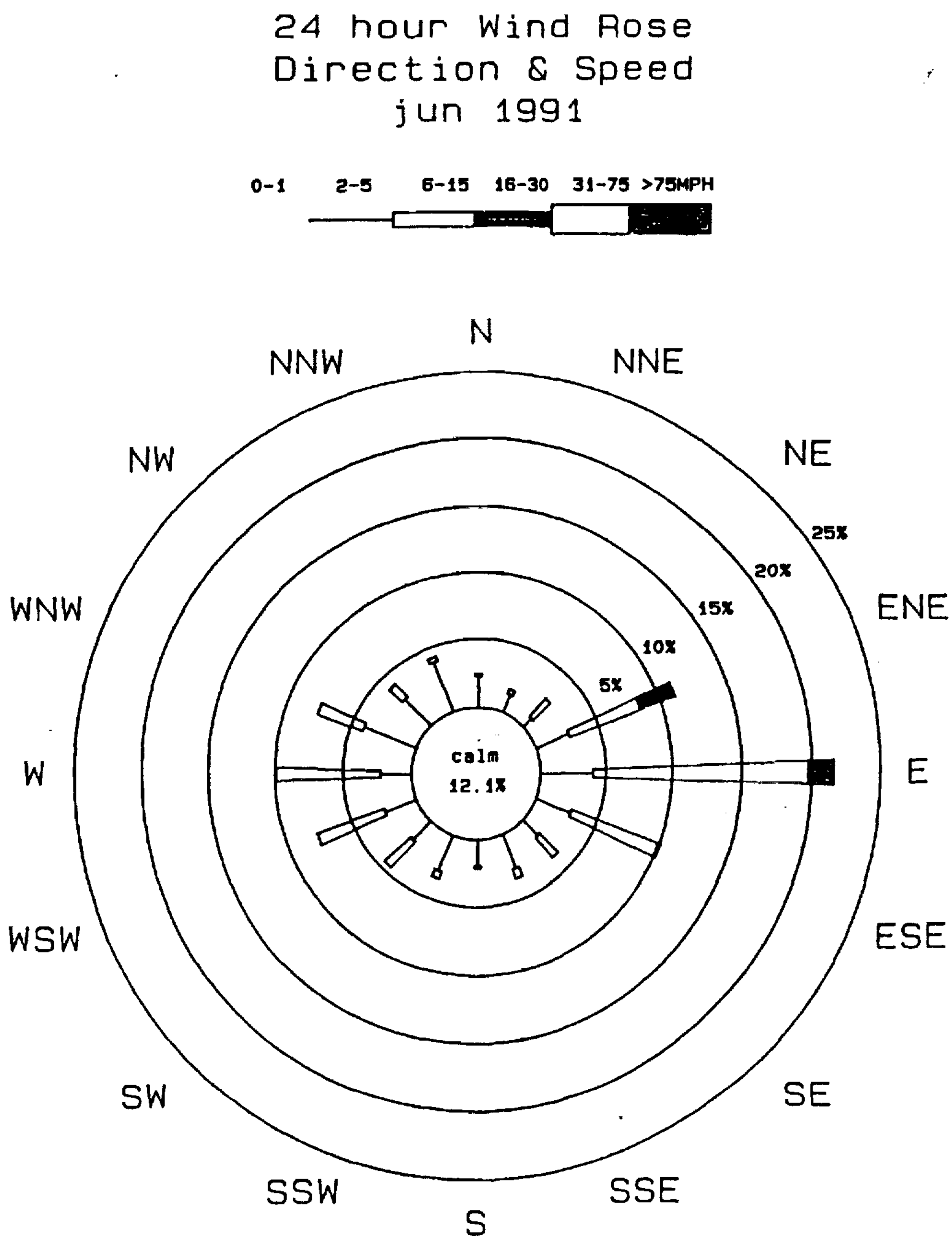
Appendix E: Wind Tower Data Summaries



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	68.6	12.5	0.0	10.0	4.9	2.3	.5	0.0	8.5	0.0	2.6	11.1	12.5	50.0	37.5	25.0	10.8
2-5	5.7	50.0	20.0	35.0	46.3	26.7	9.6	50.6	71.8	68.2	52.6	11.1	25.0	25.0	37.5	50.0	31.4
6-15	25.7	37.5	80.0	55.0	48.8	70.9	86.9	49.4	19.7	31.8	44.7	77.8	62.5	25.0	12.5	25.0	56.8
16-30	0.0	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	1.0
% of total (excluding calm winds)	3.5	1.1	1.6	2.9	6.3	13.5	31.7	13.3	10.5	3.5	5.9	2.6	1.1	.6	.8	1.0	

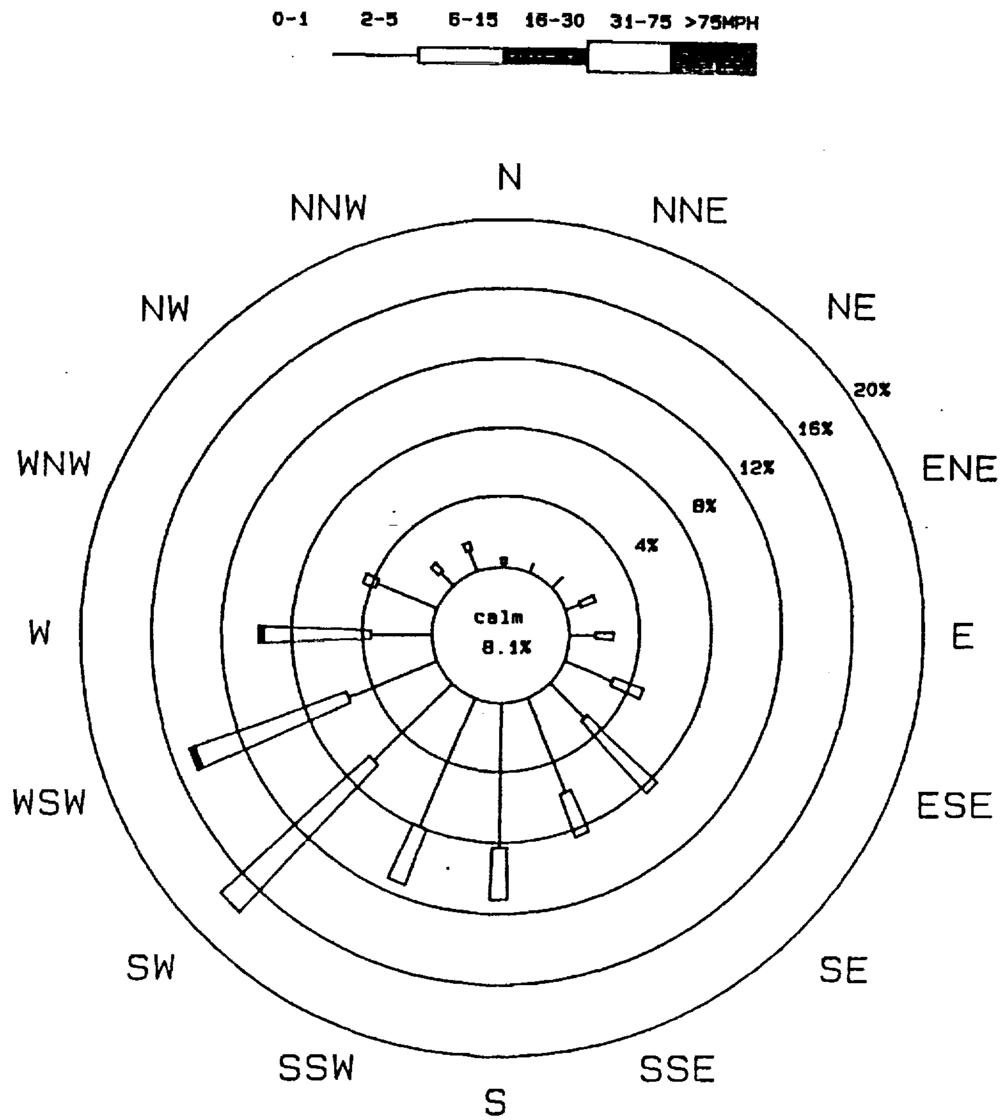
Figure E-1. Wind direction and speed measured at Haulover Canal bridge during May 1991.



ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	74.0	18.2	22.2	1.6	.9	3.6	9.5	14.3	15.4	14.3	7.7	12.8	7.0	6.8	0.0	8.0	12.1
2-5	24.0	63.6	22.2	23.0	17.9	26.8	38.1	66.7	76.9	71.4	38.5	27.7	21.1	50.0	68.2	84.0	34.9
6-15	2.0	18.2	55.6	50.8	72.6	67.9	52.4	19.0	7.7	14.3	53.8	59.6	71.9	43.2	31.8	8.0	48.7
16-30	0.0	0.0	0.0	24.6	8.5	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3
% of total	excluding calm winds																
	2.4	1.7	2.6	11.2	21.6	10.1	3.5	3.4	2.1	3.4	4.5	7.6	9.9	7.6	4.1	4.3	

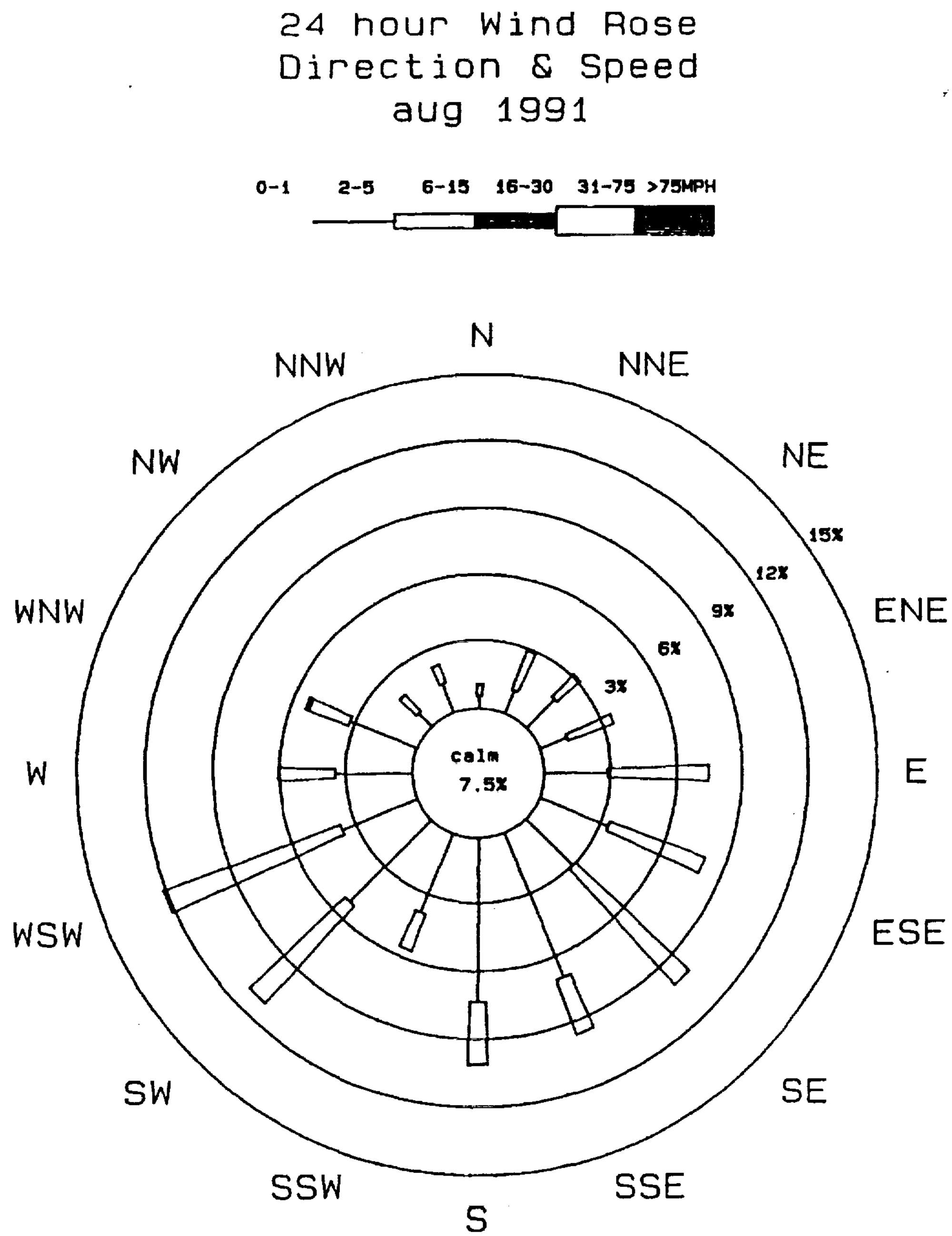
Figure E-2. Wind direction and speed measured at Haulover Canal bridge during June 1991.

24 hour Wind Rose
Direction & Speed
jul 1991



ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	81.3	40.0	16.7	26.7	23.8	3.1	0.0	9.8	3.9	7.5	3.3	3.0	4.4	9.1	21.4	8.3	8.1
2-5	6.3	60.0	83.3	33.3	42.9	59.4	32.7	62.3	71.1	65.0	34.2	35.6	33.8	75.8	50.0	66.7	48.1
6-15	12.5	0.0	0.0	40.0	33.3	37.5	67.3	27.9	25.0	27.5	62.5	59.4	58.8	15.2	28.6	25.0	43.2
16-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.9	0.0	0.0	0.0	.6
% of total (excluding calm winds)	.5	.5	.8	1.7	2.4	4.7	8.4	8.4	11.1	11.3	17.7	14.9	9.9	4.6	1.7	1.7	

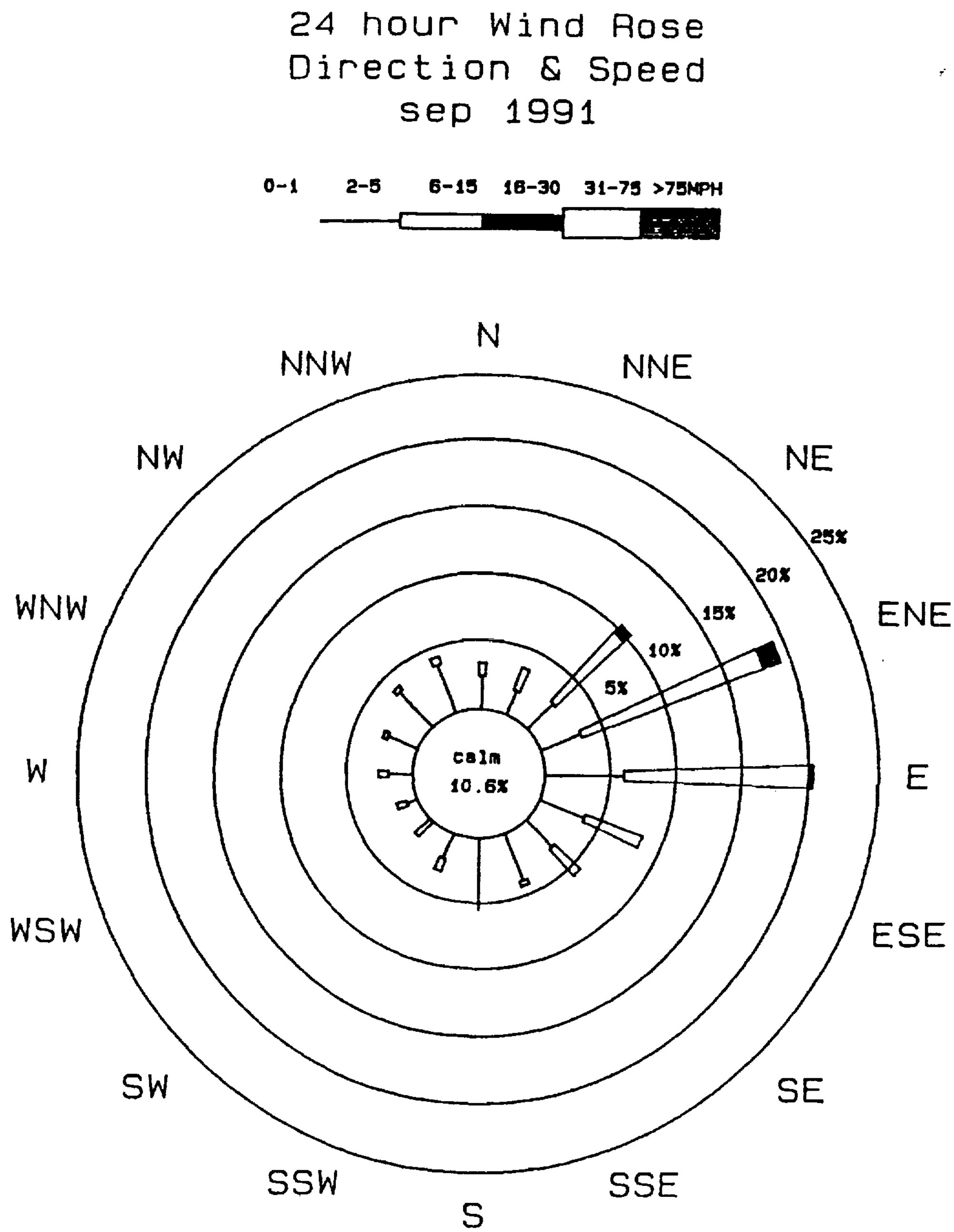
Figure E-3. Wind direction and speed measured at Haulover Canal bridge during July 1991.



% of each direction for hourly averages

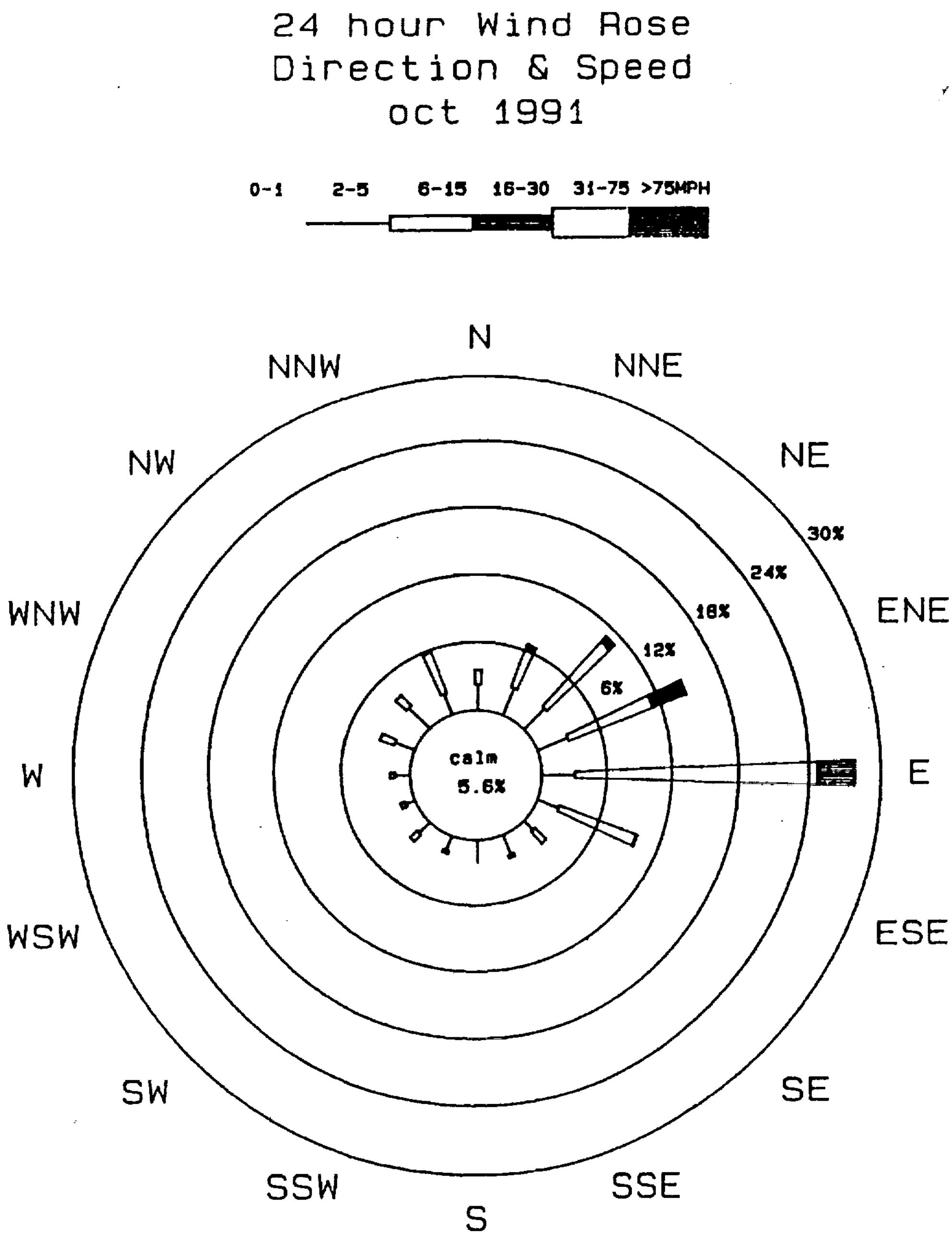
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	60.0	5.6	10.0	9.1	6.5	0.0	1.7	6.8	7.9	3.0	5.9	9.1	12.5	3.1	0.0	13.3	7.5
2-5	20.0	33.3	50.0	31.8	34.8	41.3	28.8	67.8	66.7	66.7	44.1	27.3	50.0	59.4	45.5	53.3	45.7
6-15	20.0	61.1	40.0	59.1	58.7	58.7	69.5	25.4	25.4	30.3	50.0	63.6	37.5	34.4	54.5	33.3	46.6
16-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.1	0.0	0.0	.2
% of total (excluding calm winds)	1.0	2.9	3.1	3.5	7.5	8.0	10.1	9.5	10.1	5.5	11.1	12.1	6.1	5.4	1.9	2.3	

Figure E-4. Wind direction and speed measured at Haulover Canal bridge during August 1991.



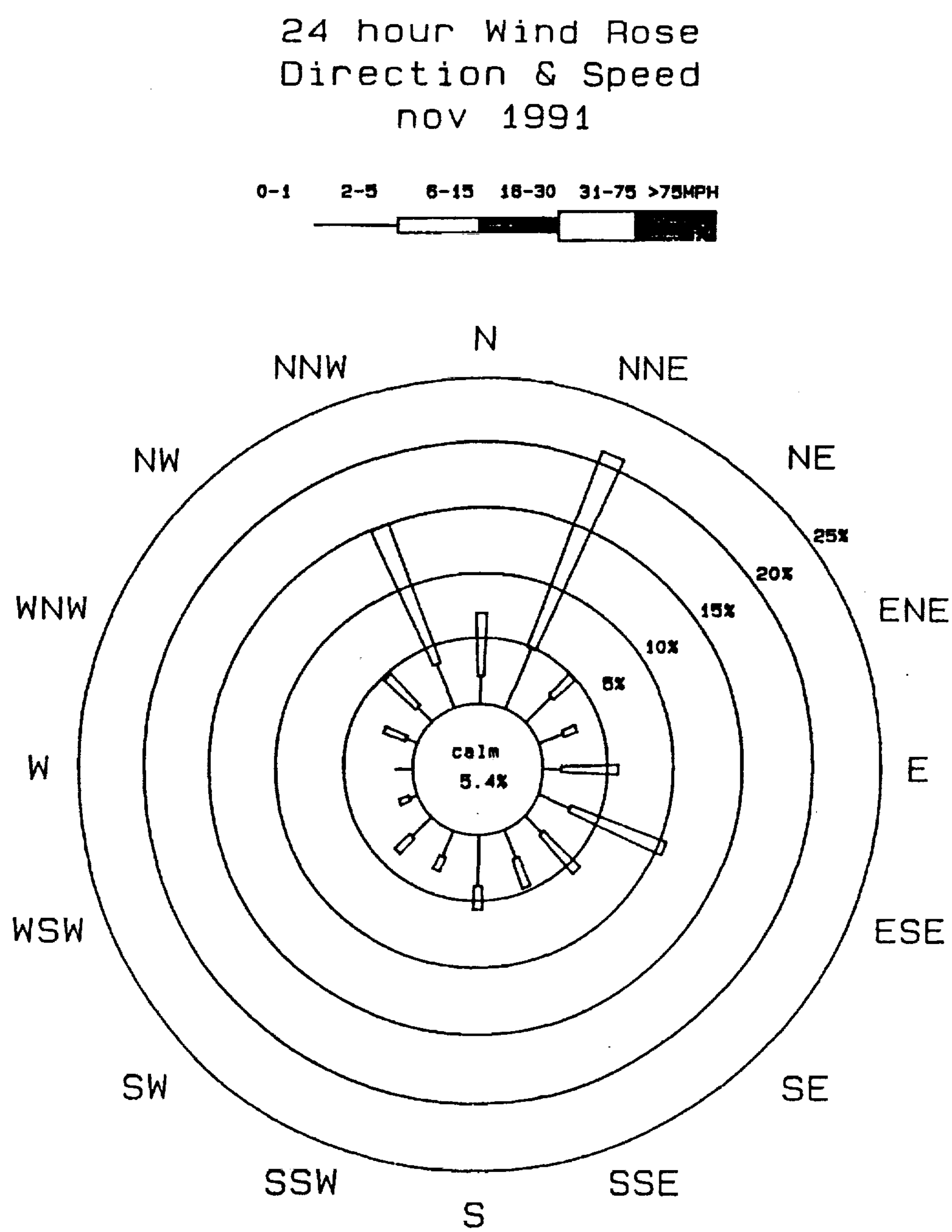
	% of each direction for hourly averages																% of
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	total
0-1	64.6	10.0	7.0	3.0	1.9	4.5	0.0	0.0	15.6	11.8	11.1	0.0	0.0	26.3	4.8	8.3	10.6
2-5	25.0	45.0	22.8	15.8	28.6	40.9	50.0	90.5	84.4	58.8	0.0	50.0	69.2	63.2	85.7	79.2	40.6
6-15	10.4	45.0	63.2	74.3	68.6	54.5	50.0	9.5	0.0	29.4	88.9	50.0	30.8	10.5	9.5	12.5	46.7
16-30	0.0	0.0	7.0	6.9	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.1
% of								excluding calm winds									
total	3.4	3.6	10.5	19.3	20.3	8.3	5.5	4.1	5.3	3.0	1.6	1.6	2.6	2.8	3.9	4.3	

Figure E-5. Wind direction and speed measured at Haulover Canal bridge during September 1991.



ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	27.3	2.2	1.3	4.8	.5	2.9	10.5	0.0	13.3	8.3	0.0	25.0	20.0	15.4	12.9	4.8	5.6
2-5	45.5	37.0	22.1	18.3	9.9	19.1	36.8	85.7	86.7	75.0	60.0	50.0	60.0	50.0	58.1	31.0	29.0
6-15	27.3	52.2	70.1	54.8	78.0	76.5	52.6	14.3	0.0	16.7	40.0	25.0	20.0	34.6	29.0	64.3	57.8
16-30	0.0	8.7	6.5	22.1	11.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.6
% of total	excluding calm winds																
	3.5	6.6	11.2	14.6	27.9	9.7	2.5	2.1	1.9	1.6	2.2	1.3	1.8	3.2	4.0	5.9	

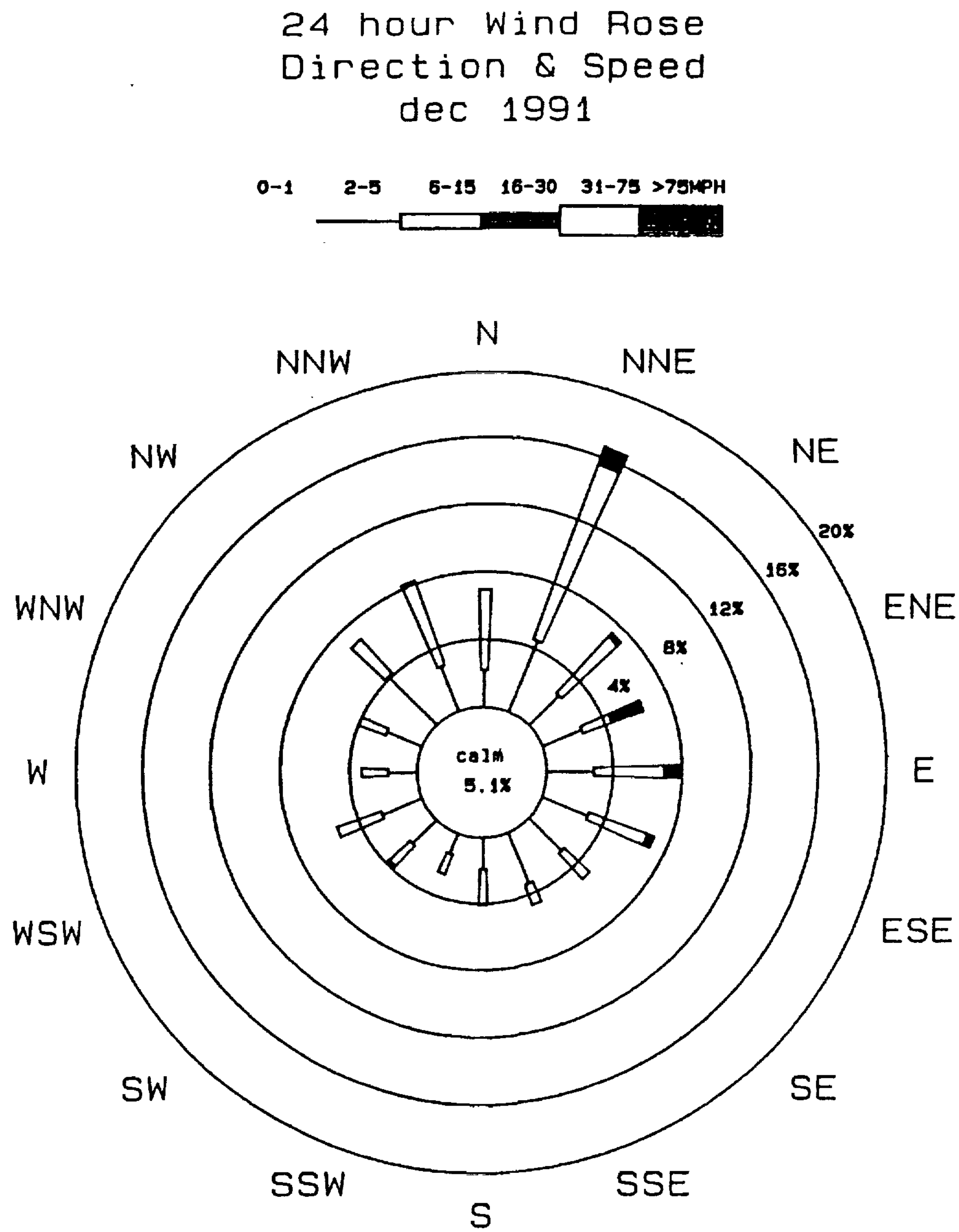
Figure E-6. Wind direction and speed measured at Haulover Canal bridge during October 1991.



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	21.4	2.2	3.1	5.0	5.3	1.5	7.7	3.3	7.9	13.0	14.8	0.0	11.1	0.0	0.0	1.0	5.4
2-5	23.2	22.8	53.1	60.0	21.1	23.9	28.2	46.7	63.2	56.5	48.1	44.4	88.9	35.3	32.3	24.0	33.4
6-15	55.4	75.0	43.8	35.0	73.7	74.6	64.1	50.0	28.9	30.4	37.0	55.6	0.0	64.7	67.7	75.0	61.2
% of total (excluding calm winds)	7.0	21.0	4.9	3.0	5.7	10.4	5.7	4.6	5.5	3.2	3.6	1.4	1.3	2.7	4.9	15.0	

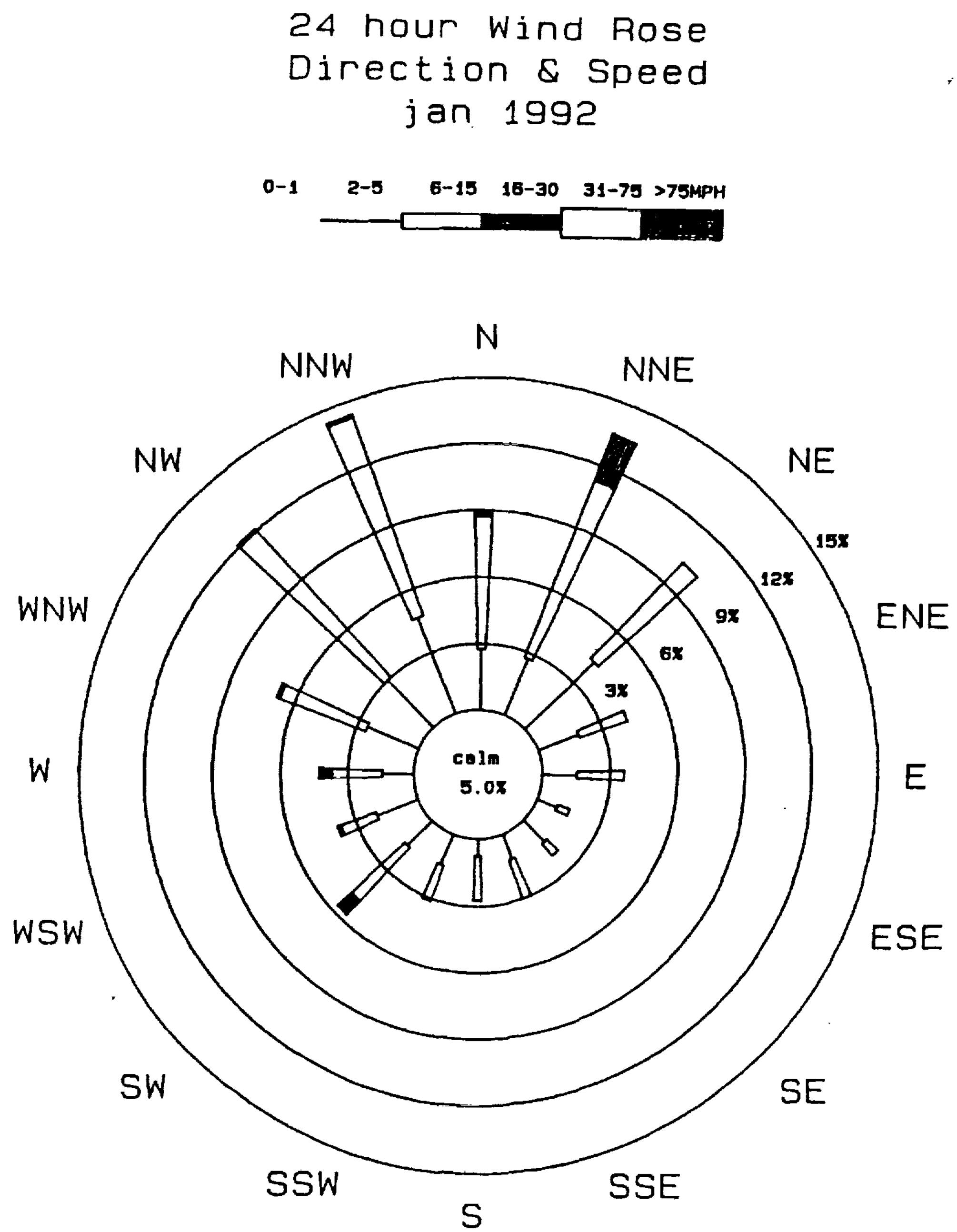
Figure E-7. Wind direction and speed measured at Haulover Canal bridge during November 1991.



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	11.1	1.7	7.3	4.3	3.6	5.8	5.6	3.0	9.7	0.0	0.0	2.6	14.8	3.4	5.9	5.0	5.1
2-5	27.8	26.3	30.9	37.0	33.9	38.5	52.8	69.7	41.9	50.0	51.9	47.4	44.4	55.2	56.9	33.3	39.9
6-15	61.1	65.3	58.2	28.3	51.8	50.0	41.7	27.3	48.4	50.0	44.4	50.0	40.7	41.4	37.3	61.7	50.3
16-30	0.0	6.8	3.6	30.4	10.7	5.8	0.0	0.0	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	4.7
% of total (excluding calm winds)	6.9	16.7	7.3	6.3	7.8	7.1	4.9	4.6	4.0	2.6	3.9	5.3	3.3	4.0	6.9	8.2	

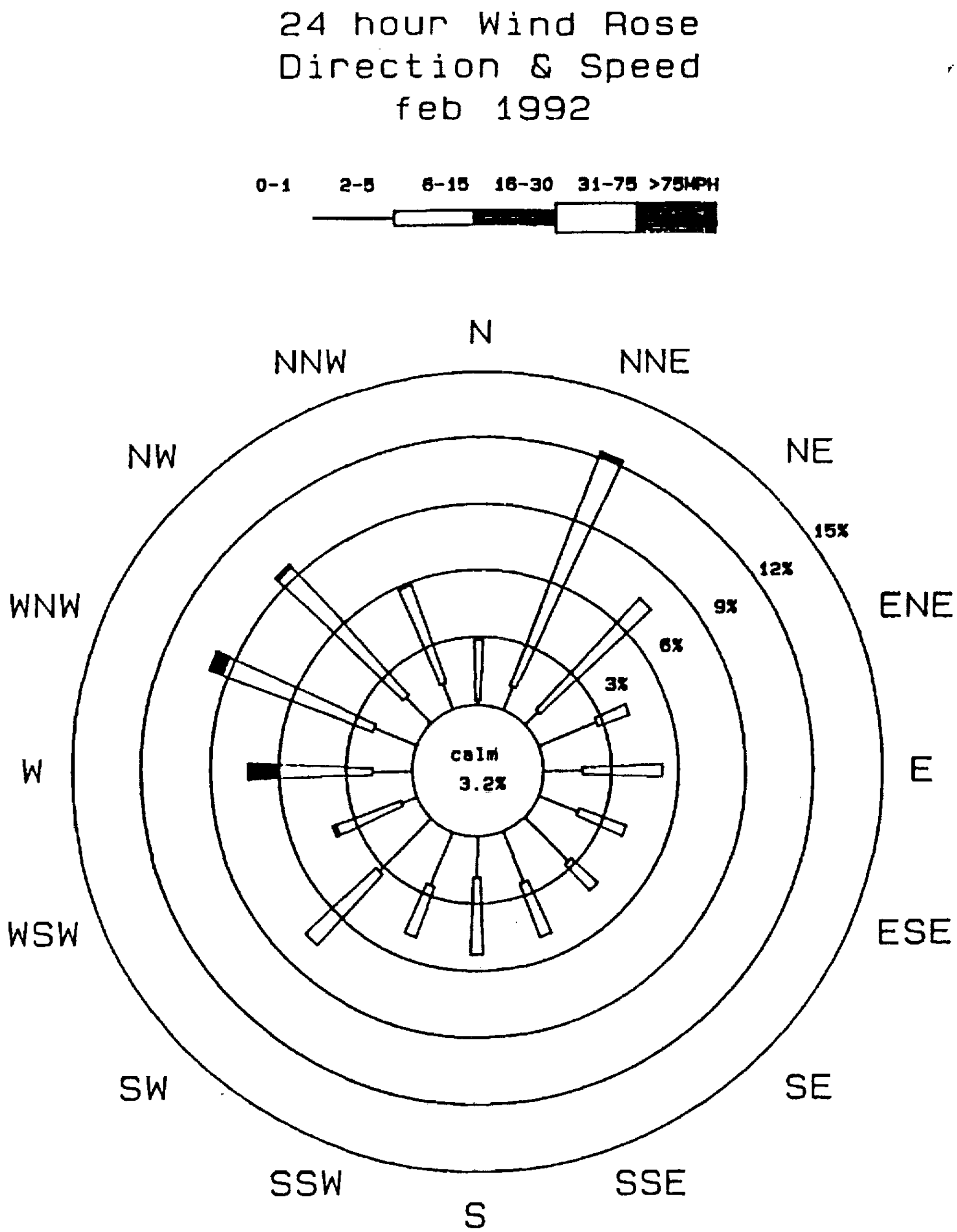
Figure E-8. Wind direction and speed measured at Haulover Canal bridge during December 1991.



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	16.0	3.1	5.3	6.5	3.8	16.7	6.7	8.7	0.0	0.0	7.0	0.0	3.2	0.0	4.5	1.9	5.0
2-5	25.3	19.4	39.5	41.9	38.5	50.0	60.0	34.8	26.3	45.5	25.6	51.9	32.3	37.5	23.6	32.0	32.0
6-15	56.0	61.2	55.3	51.6	57.7	33.3	33.3	56.5	73.7	54.5	53.5	44.4	51.6	60.4	70.8	65.0	58.7
16-30	2.7	16.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	14.0	3.7	12.9	2.1	1.1	1.0	4.3
% of total (excluding calm winds)	9.0	13.6	10.3	4.1	3.6	1.4	2.0	3.0	2.7	3.1	5.7	3.9	4.3	6.8	12.1	14.4	

Figure E-9. Wind direction and speed measured at Haulover Canal bridge during January 1992.

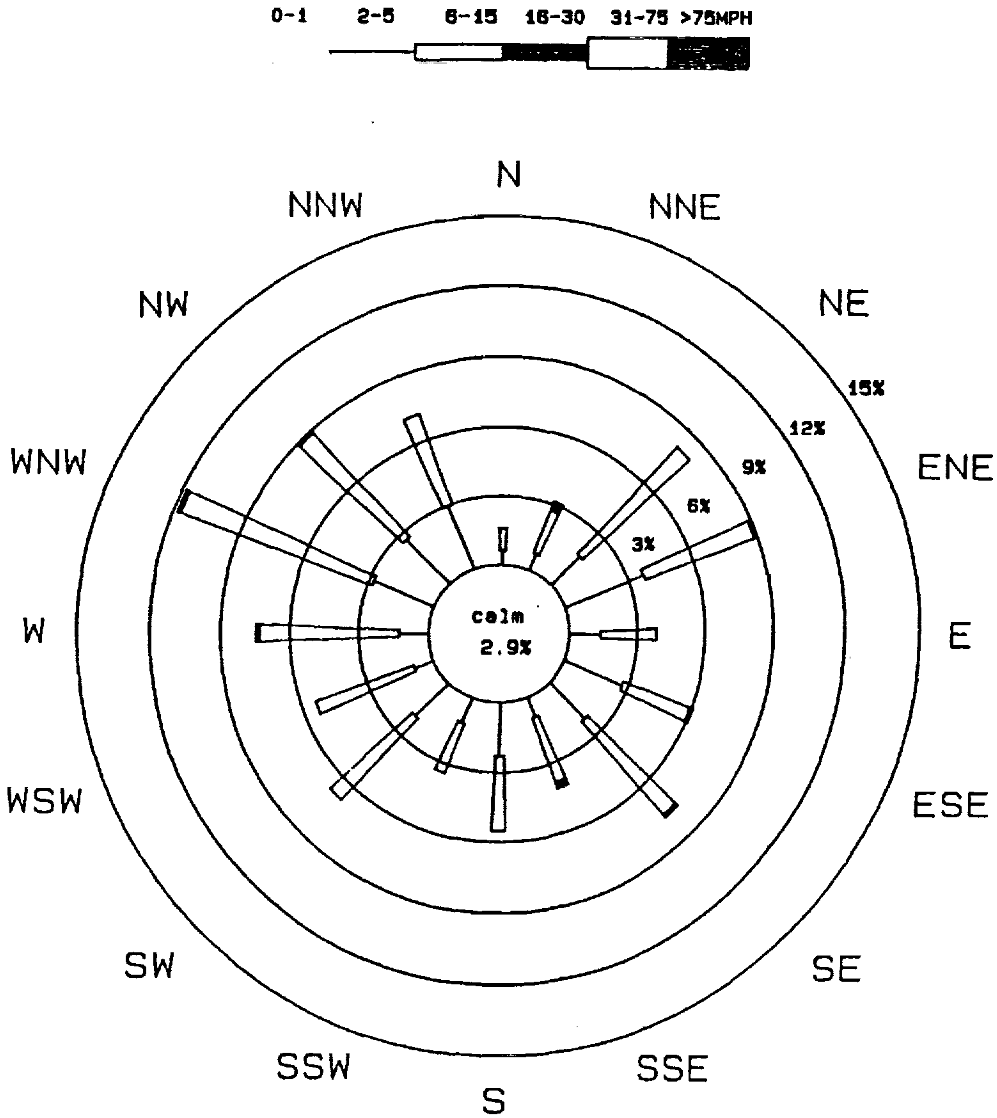


% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	9.5	1.2	3.8	9.7	2.8	0.0	6.5	2.9	0.0	0.0	5.6	3.6	0.0	1.5	4.5	4.9	3.2
2-5	4.8	8.4	9.6	58.1	30.6	44.4	58.1	47.1	34.3	51.5	40.7	17.9	24.5	20.9	16.4	19.5	27.4
6-15	85.7	89.2	86.5	32.3	66.7	55.6	35.5	50.0	65.7	48.5	53.7	75.0	59.2	71.6	77.6	75.6	67.2
16-30	0.0	1.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	16.3	6.0	1.5	0.0	2.2
% of total (excluding calm winds)	2.8	12.3	7.5	4.2	5.2	4.0	4.3	4.9	5.2	4.9	7.6	4.0	7.3	9.9	9.6	5.8	

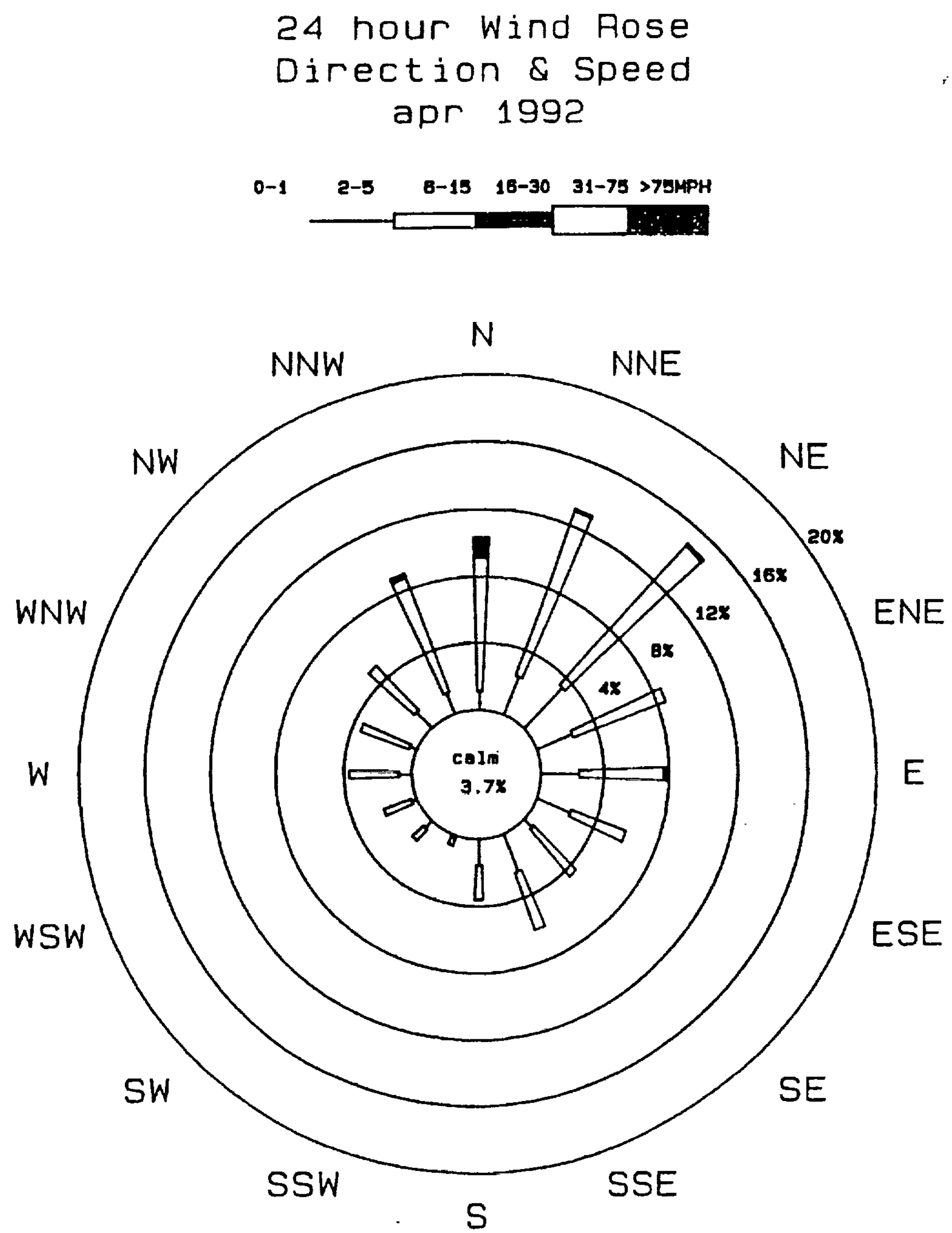
Figure E-10. Wind direction and speed measured at Haulover Canal bridge during February 1992.

24 hour Wind Rose
Direction & Speed
mar 1992



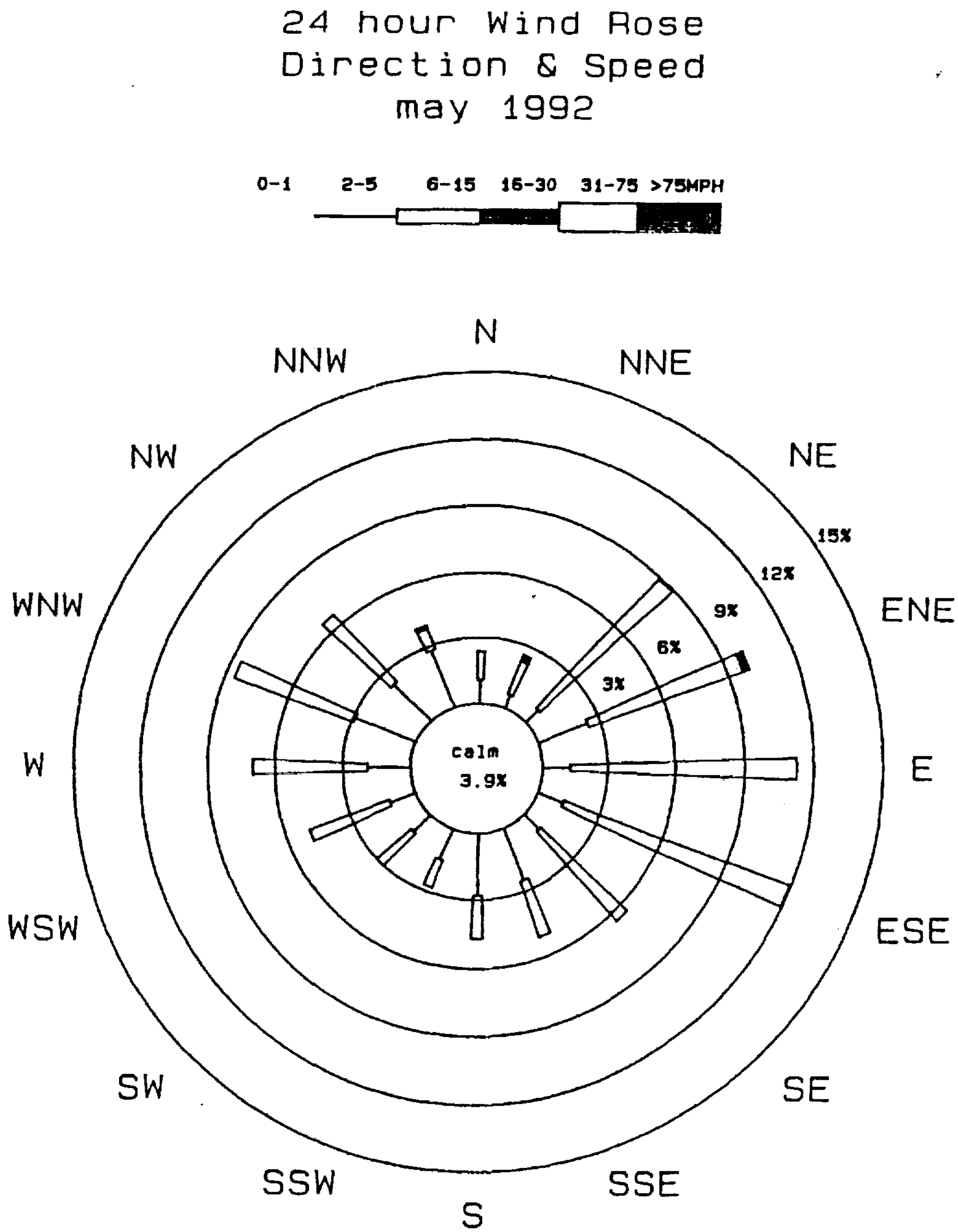
	% of each direction for hourly averages																% of
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	total
0-1	21.4	8.3	1.7	0.0	3.6	0.0	1.8	6.5	2.5	4.0	4.0	5.0	0.0	2.3	0.0	5.6	2.9
2-5	28.6	20.8	20.3	40.6	32.1	44.2	26.8	19.4	40.0	32.0	28.0	15.0	17.0	23.3	29.7	38.9	28.8
6-15	50.0	58.3	78.0	57.8	64.3	53.5	69.6	67.7	57.5	64.0	68.0	80.0	81.1	73.3	68.8	55.6	67.0
16-30	0.0	12.5	0.0	1.6	0.0	2.3	1.8	6.5	0.0	0.0	0.0	0.0	1.9	1.2	1.6	0.0	1.5
% of	excluding calm winds																
total	1.5	3.1	8.2	9.0	3.8	6.1	7.7	4.1	5.5	3.4	6.8	5.4	7.5	11.8	9.0	7.2	

Figure E-11. Wind direction and speed measured at Haulover Canal bridge during March 1992.



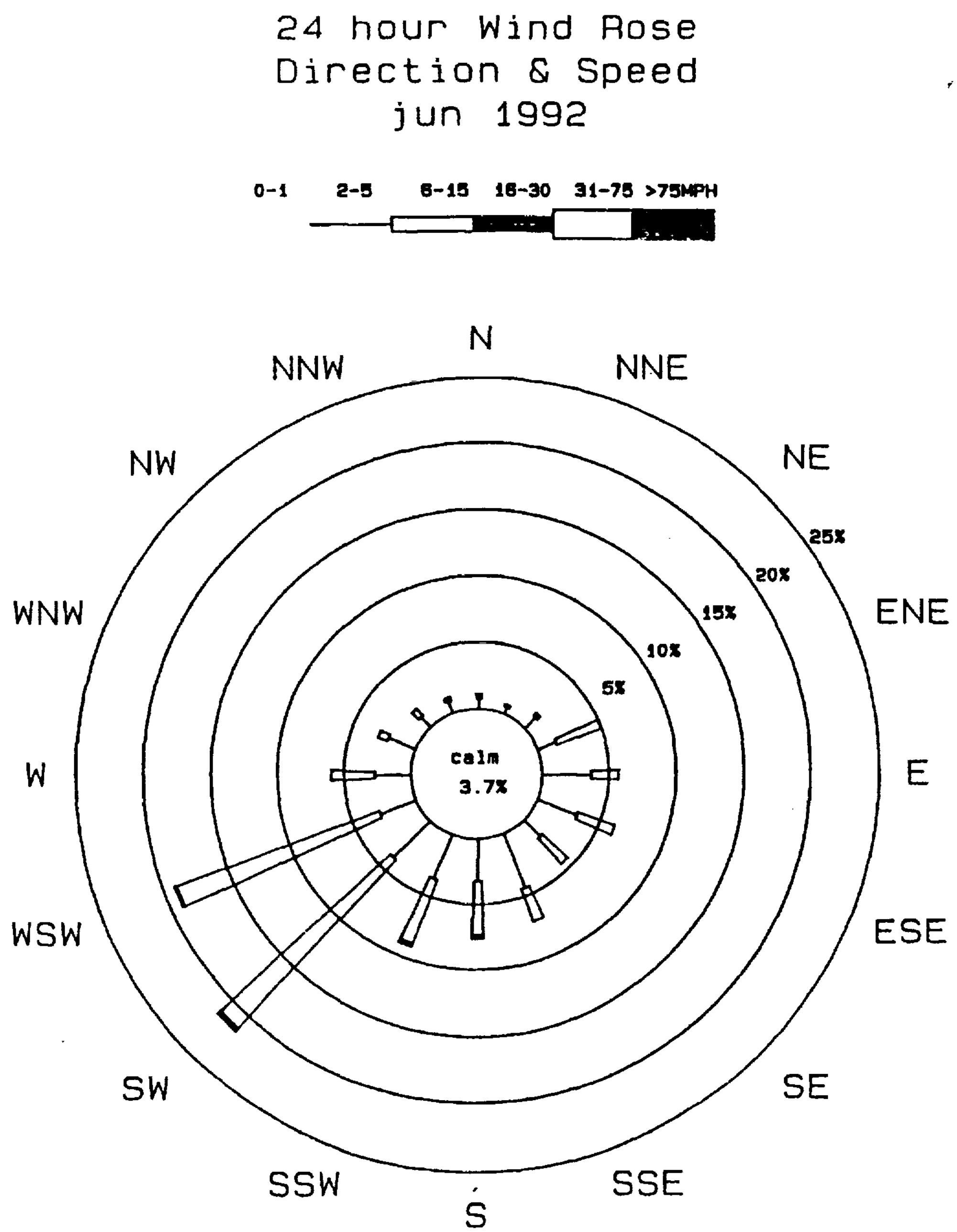
	% of each direction for hourly averages																% of
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	total
0-1	9.1	0.0	5.6	1.7	6.9	0.0	3.2	2.4	4.0	33.3	9.1	0.0	0.0	4.0	0.0	1.6	3.7
2-5	9.1	18.0	21.3	27.1	27.6	37.5	12.9	38.1	40.0	16.7	36.4	14.3	20.0	12.0	26.5	14.5	22.1
6-15	71.4	80.9	72.2	71.2	62.1	62.5	83.9	59.5	56.0	50.0	54.5	85.7	80.0	84.0	73.5	80.6	72.2
16-30	10.4	1.1	.9	0.0	3.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.2	2.0
% of								excluding calm winds									
total	10.3	13.1	15.0	8.5	7.9	5.9	4.4	6.0	3.5	.6	1.5	2.1	3.7	3.5	5.0	9.0	

Figure E-12. Wind direction and speed measured at Haulover Canal bridge during April 1992.



ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	33.3	10.5	0.0	2.9	1.3	2.4	2.2	2.8	3.0	0.0	0.0	5.6	5.9	1.7	6.3	3.6	3.9
2-5	29.2	21.1	8.2	22.9	10.3	9.5	13.3	47.2	57.6	52.6	33.3	22.2	25.5	33.3	33.3	67.9	25.7
6-15	37.5	57.9	91.8	71.4	88.5	88.1	84.4	50.0	39.4	47.4	66.7	72.2	68.6	65.0	60.4	25.0	69.7
16-30	0.0	10.5	0.0	2.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	.7
% of total	excluding calm winds																
	2.3	2.5	8.9	9.9	11.2	12.0	6.4	5.1	4.7	2.8	3.1	5.0	7.0	8.6	6.6	3.9	

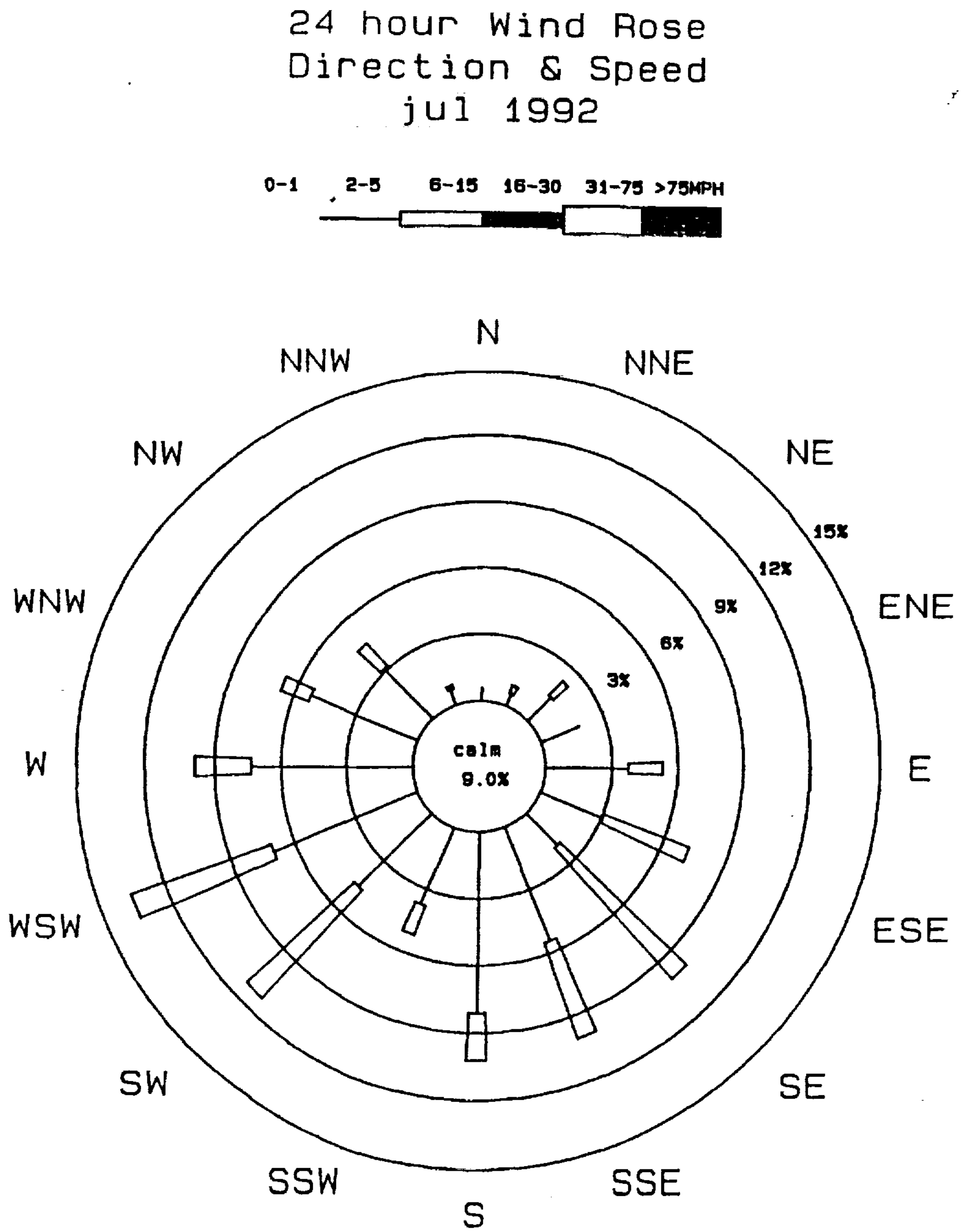
Figure E-13. Wind direction and speed measured at Haulover Canal bridge during May 1992.



% of each direction for hourly averages

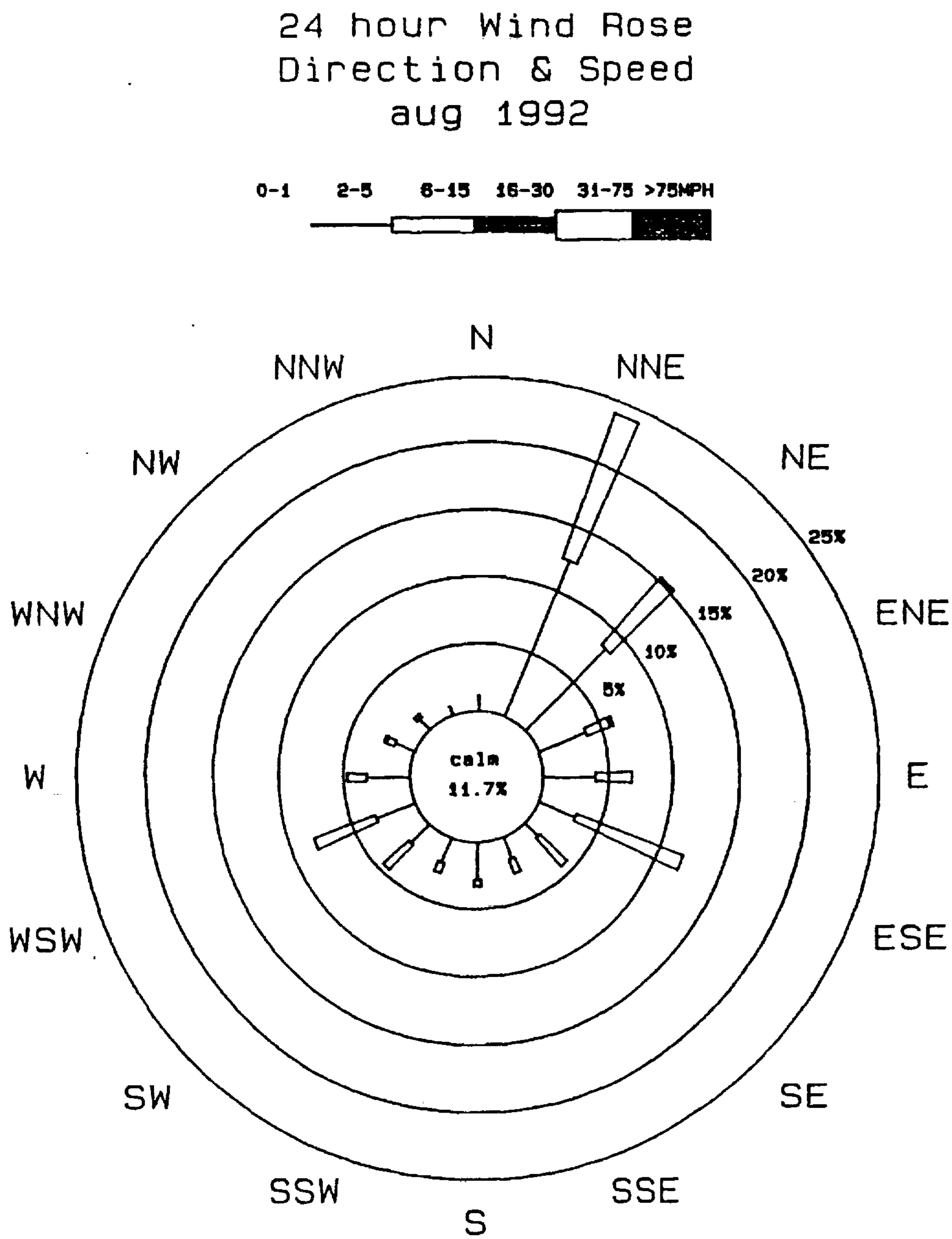
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	53.3	33.3	0.0	0.0	2.6	0.0	3.3	0.0	3.8	3.2	.7	4.4	2.4	9.1	0.0	0.0	3.7
2-5	33.3	50.0	77.8	27.3	61.5	51.2	36.7	61.7	39.6	38.1	17.8	14.1	43.9	68.2	58.3	75.0	35.0
6-15	13.3	16.7	22.2	72.7	35.9	48.8	60.0	38.3	52.8	55.6	80.1	80.7	53.7	22.7	41.7	12.5	60.1
16-30	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	3.2	1.4	.7	0.0	0.0	0.0	12.5	1.1
% of total (excluding calm winds)	1.0	.6	1.3	4.9	5.6	6.1	4.3	7.0	7.6	9.1	21.5	19.1	5.9	3.0	1.8	1.2	

Figure E-14. Wind direction and speed measured at Haulover Canal bridge during June 1992.



ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	88.0	28.6	7.1	9.1	9.1	2.4	1.7	3.4	3.3	9.4	4.5	3.8	5.1	11.6	7.1	28.6	9.0
2-5	12.0	42.9	57.1	90.9	63.6	40.5	19.0	52.5	76.7	65.6	38.8	50.0	71.2	69.8	64.3	57.1	53.0
6-15	0.0	28.6	35.7	0.0	27.3	57.1	79.3	44.1	20.0	25.0	56.7	46.3	23.7	18.6	28.6	14.3	38.1
% of total (excluding calm winds)	.5	.9	2.3	1.8	5.3	7.2	10.0	10.0	10.2	5.1	11.2	13.5	9.8	6.7	4.6	.9	

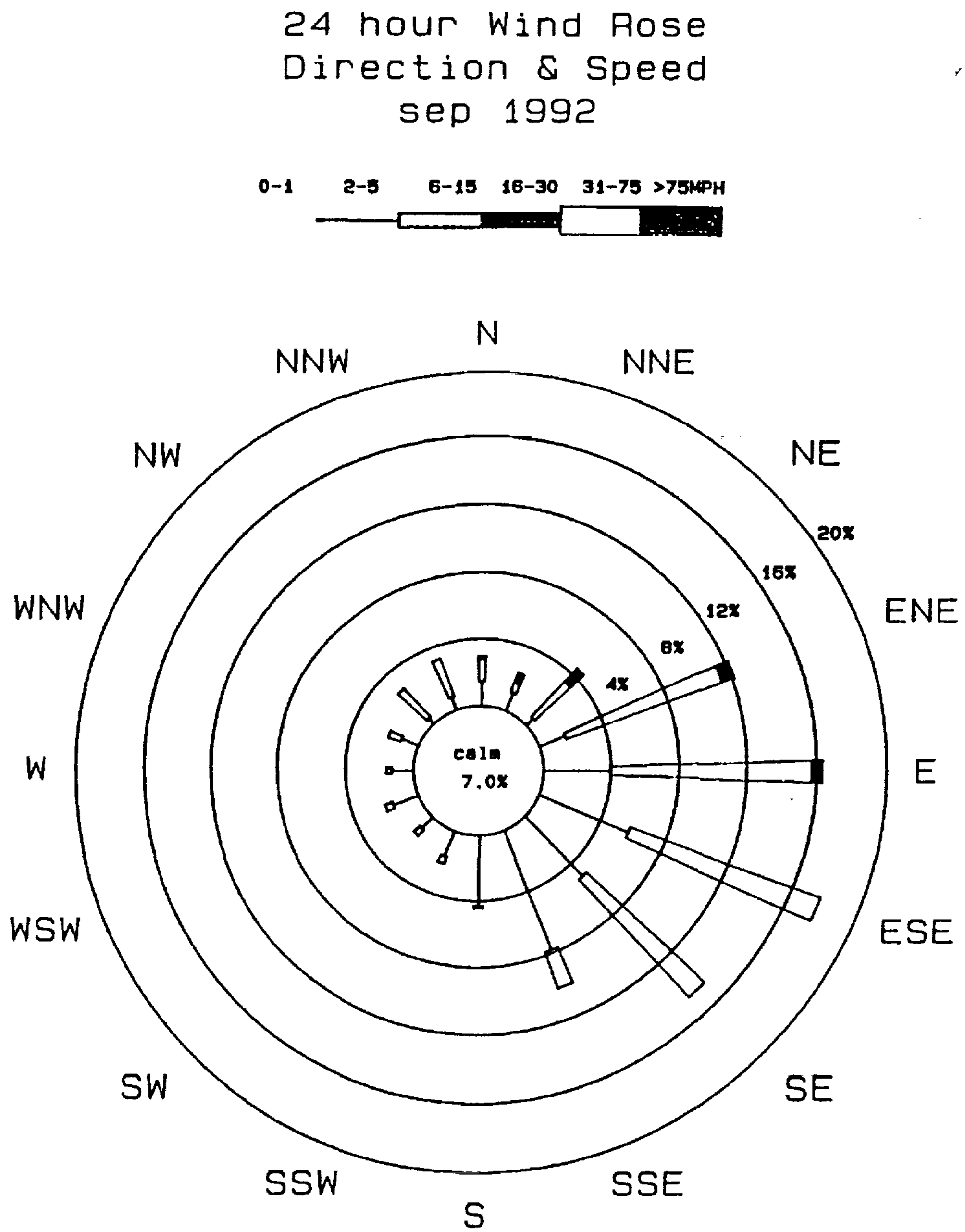
Figure E-15. Wind direction and speed measured at Haulover Canal bridge during July 1992.



% of each direction for hourly averages

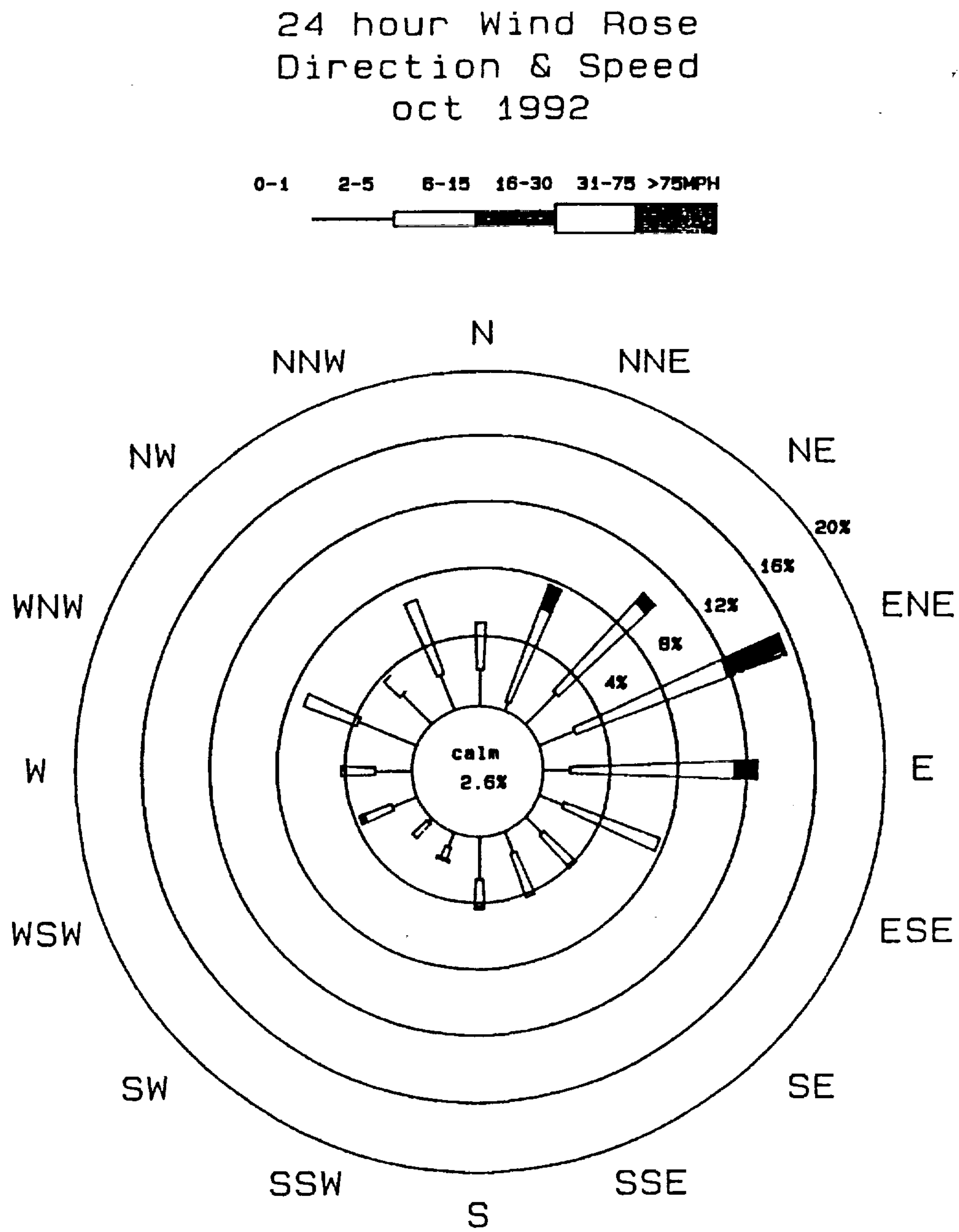
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	69.6	7.4	11.1	17.8	8.7	1.3	3.7	15.0	13.0	5.6	3.4	5.7	14.7	28.6	18.2	50.0	11.7
2-5	30.4	48.1	49.1	51.1	52.2	24.0	29.6	50.0	73.9	66.7	41.4	35.8	58.8	47.6	63.6	50.0	45.8
6-15	0.0	44.4	38.0	26.7	39.1	74.7	68.7	35.0	13.0	27.8	55.2	58.5	26.5	19.0	18.2	0.0	41.8
16-30	0.0	0.0	1.9	4.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8	0.0	0.0	.7
% of total (excluding calm winds)	1.1	24.2	15.5	6.0	6.8	11.9	4.2	2.7	3.2	2.7	4.5	8.1	4.7	2.4	1.4	.6	

Figure E-16. Wind direction and speed measured at Haulover Canal bridge during August 1992.



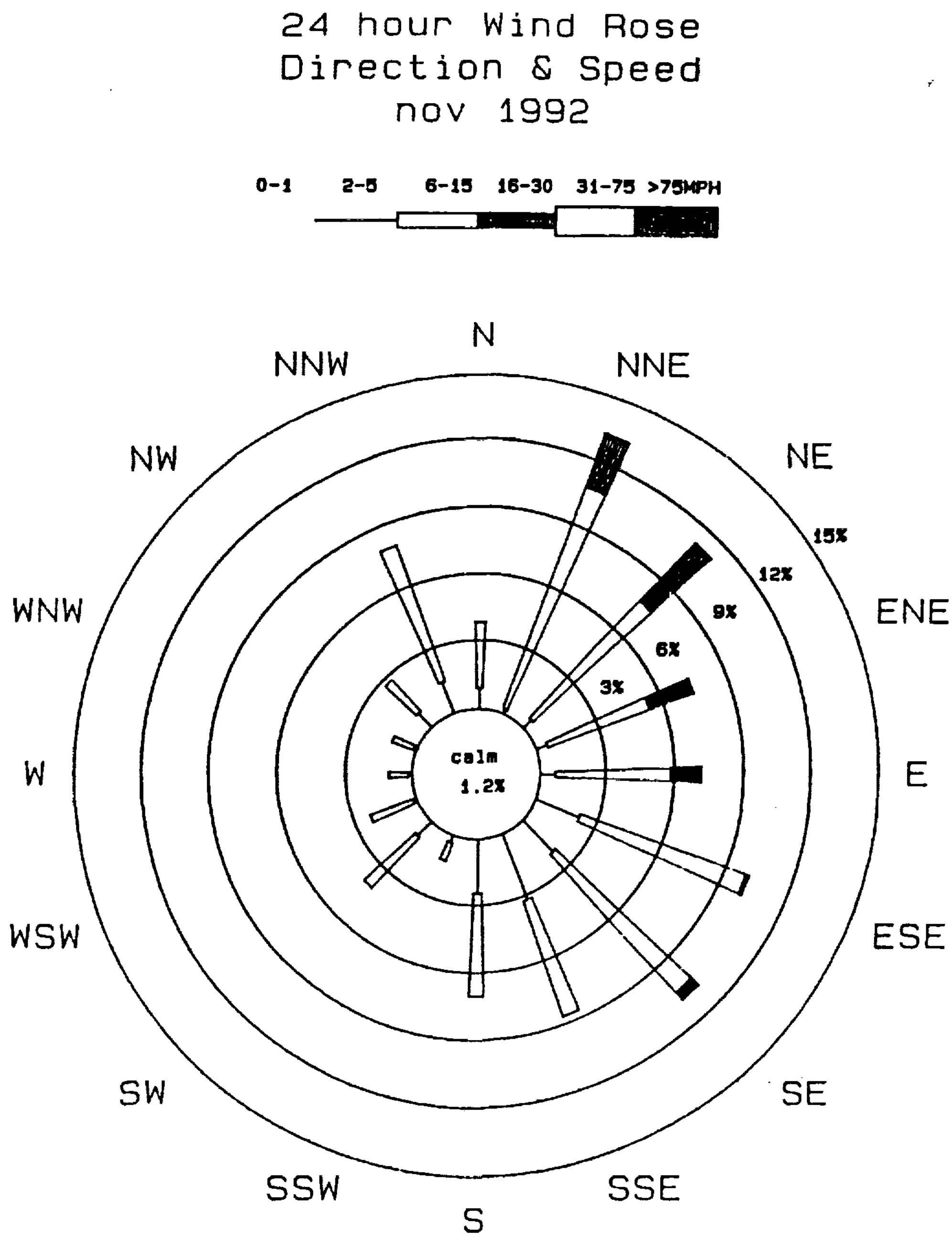
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	36.7	11.8	6.5	2.5	3.6	.9	1.0	7.1	3.4	31.6	10.0	18.8	23.1	29.4	10.0	0.0	7.0
2-5	30.0	41.2	9.7	12.3	22.7	31.9	33.3	71.4	93.1	52.6	60.0	62.5	61.5	41.2	15.0	23.8	35.8
6-15	30.0	23.5	61.3	79.0	70.0	67.2	65.6	21.4	3.4	15.8	30.0	18.8	15.4	29.4	75.0	76.2	54.2
16-30	3.3	23.5	22.6	6.2	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.0
% of total	excluding calm winds																
	2.9	2.3	4.5	12.2	16.4	17.8	14.7	10.0	4.3	2.0	1.4	2.0	1.5	1.9	2.8	3.2	

Figure E-17. Wind direction and speed measured at Haulover Canal bridge during September 1992.



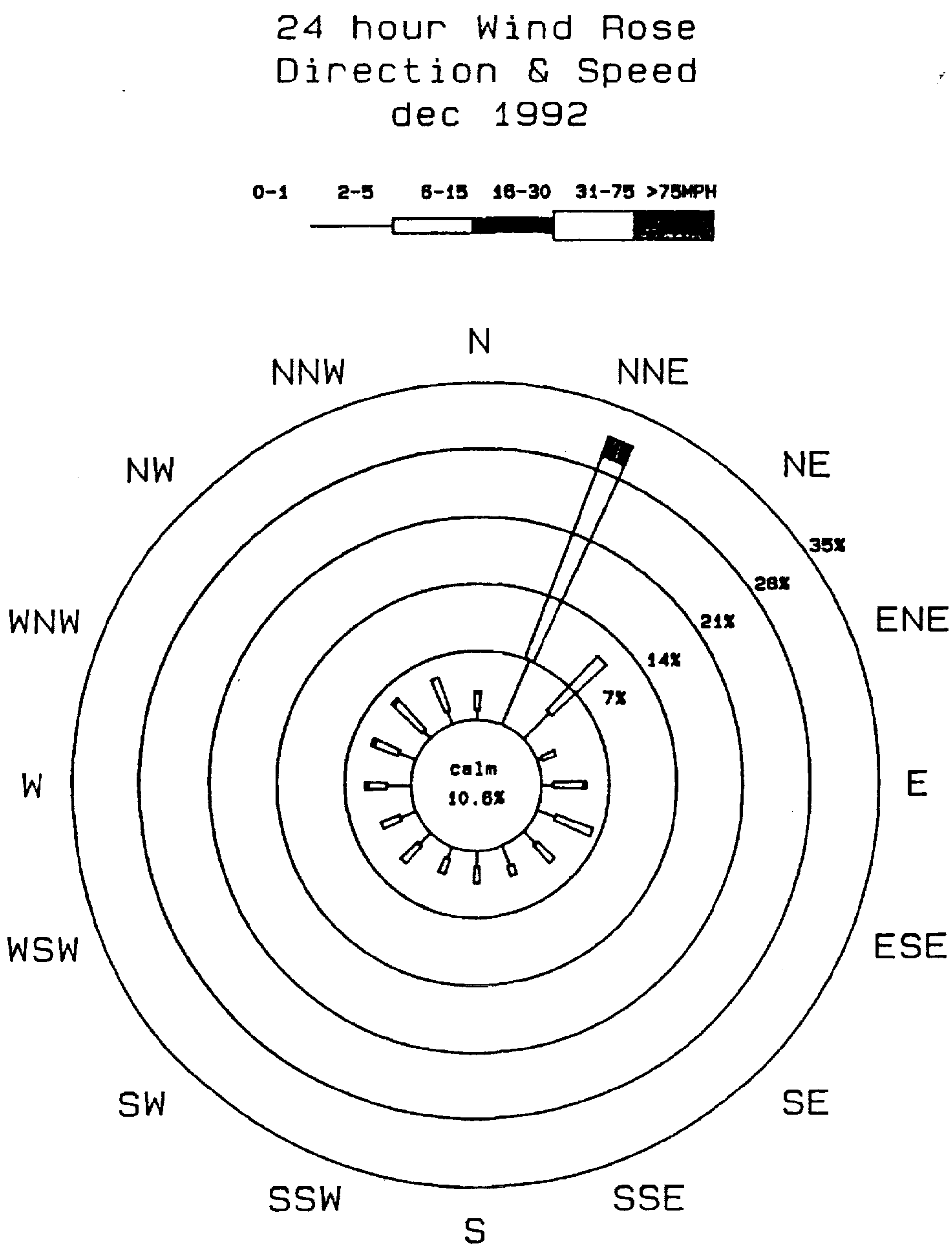
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
	% of each direction for hourly averages																
0-1	15.4	0.0	0.0	0.0	0.0	0.0	3.6	0.0	3.3	0.0	0.0	0.0	12.1	0.0	10.3	6.0	2.6
2-5	35.9	5.7	23.9	14.2	11.6	19.2	32.1	32.1	56.7	50.0	20.0	44.0	45.5	53.1	58.6	30.0	28.0
6-15	48.7	75.5	69.0	62.3	77.9	80.8	60.7	67.9	36.7	41.7	80.0	48.0	42.4	46.9	31.0	64.0	61.8
16-30	0.0	18.9	7.0	23.6	10.5	0.0	3.6	0.0	3.3	0.0	0.0	8.0	0.0	0.0	0.0	0.0	7.6
31-75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.3	0.0	0.0	0.0	0.0	0.0	0.0	.1
% of	excluding calm winds																
total	4.8	7.8	10.4	15.5	12.6	7.6	4.0	4.1	4.2	1.8	1.5	3.7	4.2	7.2	3.8	6.9	

Figure E-18. Wind direction and speed measured at Haulover Canal bridge during October 1992.



ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
					% of each direction for hourly averages												
0-1	13.3	0.0	0.0	0.0	0.0	1.4	0.0	1.7	0.0	0.0	3.6	0.0	12.5	0.0	0.0	0.0	1.2
2-5	20.0	1.1	3.9	6.0	8.3	20.3	17.8	35.6	34.0	25.0	21.4	6.7	12.5	12.5	31.6	18.5	15.8
6-15	66.7	80.0	64.5	66.0	72.9	76.8	78.1	62.7	66.0	75.0	75.0	93.3	75.0	87.5	68.4	81.5	73.0
16-30	0.0	18.9	31.6	28.0	18.8	1.4	4.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	10.0
% of total							excluding calm winds										
	3.9	13.4	11.3	7.4	7.1	10.1	10.8	8.6	7.0	1.2	4.0	2.2	1.0	1.2	2.8	8.0	

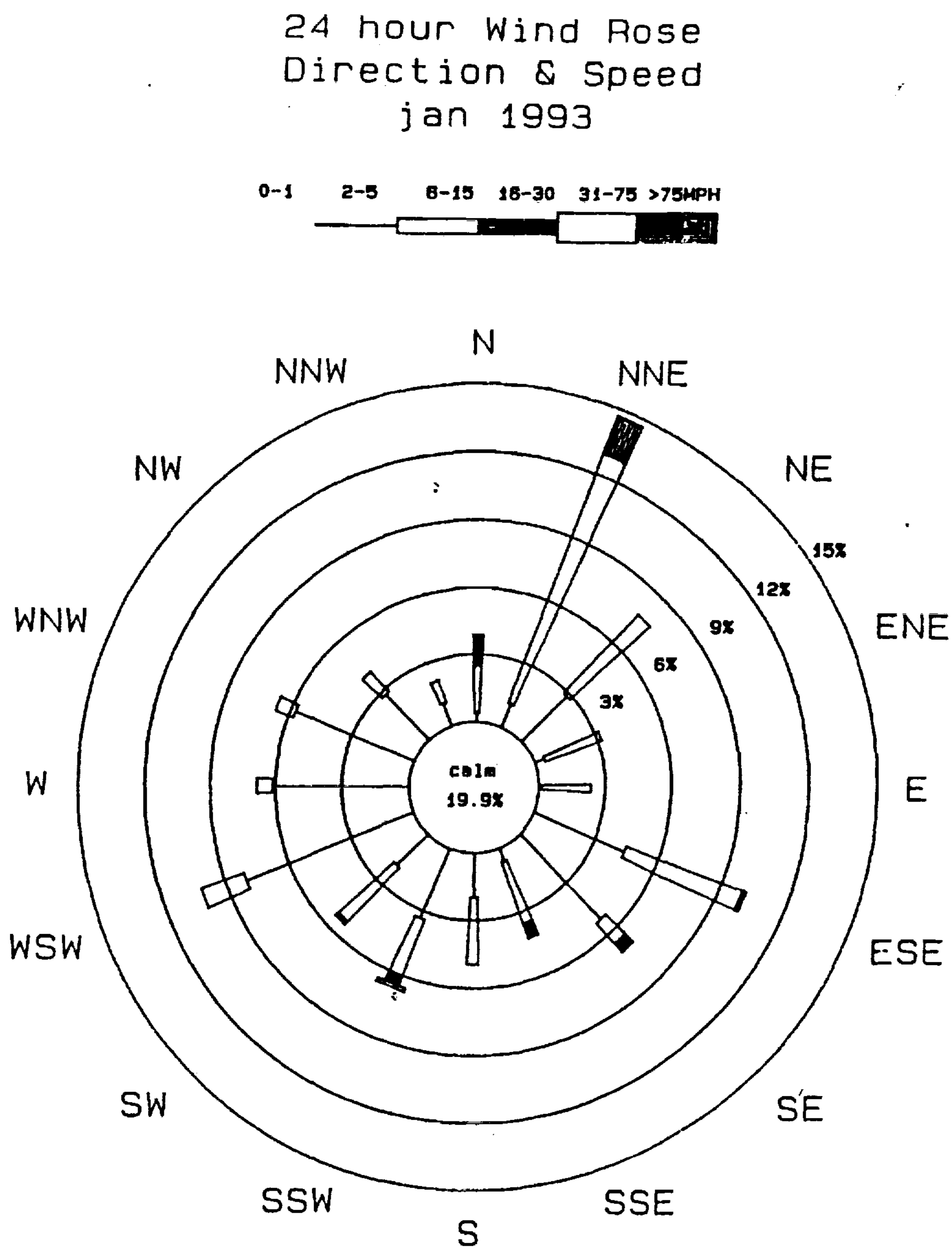
Figure E-19. Wind direction and speed measured at Haulover Canal bridge during November 1992.



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	61.7	7.9	11.8	42.9	3.3	0.0	0.0	8.7	0.0	17.4	6.9	0.0	0.0	8.3	0.0	0.0	10.6
2-5	12.8	20.7	28.2	9.5	20.0	30.8	40.7	60.9	47.6	34.8	37.9	46.2	53.1	36.1	19.4	27.3	28.4
6-15	23.4	65.2	60.0	47.6	70.0	69.2	59.3	30.4	52.4	47.8	55.2	53.8	40.6	50.0	75.0	72.7	57.8
16-30	2.1	6.2	0.0	0.0	6.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.3	5.6	5.6	0.0	3.1
% of total (excluding calm winds)	2.7	31.8	11.4	1.6	4.4	5.9	4.1	3.2	3.2	2.9	4.1	4.0	4.9	5.0	5.5	5.0	

Figure E-20. Wind direction and speed measured at Haulover Canal bridge during December 1992.

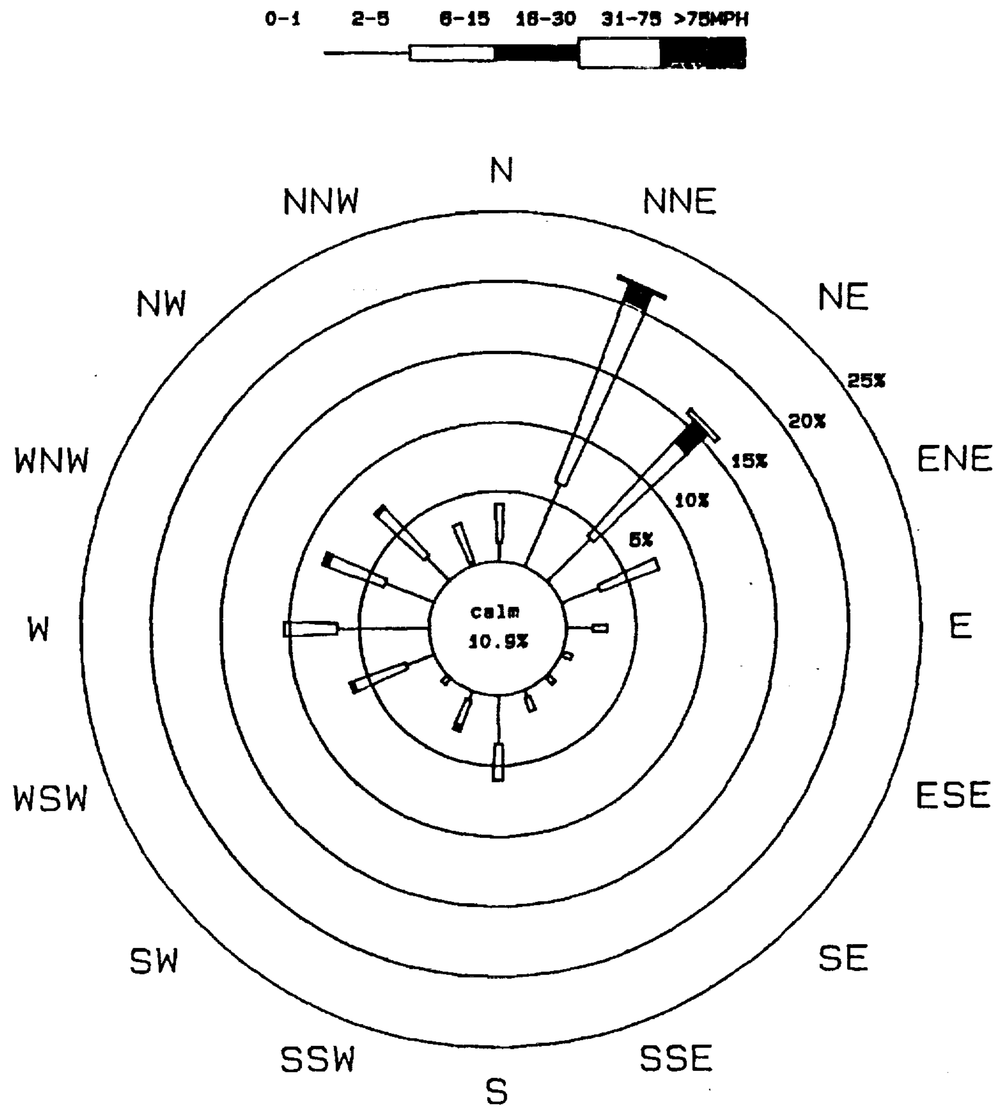


% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	45.0	0.0	6.4	5.3	0.0	21.6	28.5	4.0	26.3	25.5	8.8	25.6	17.0	29.6	42.5	0.0	19.9
2-5	5.0	7.1	34.0	10.5	0.0	33.8	53.6	12.0	28.9	37.3	32.4	59.0	74.5	61.1	40.0	50.0	36.7
6-15	30.0	81.0	59.6	84.2	99.9	43.2	12.5	68.0	44.7	31.4	55.9	15.4	8.5	9.3	17.5	50.0	39.2
16-30	20.0	11.9	0.0	0.0	0.0	1.4	5.4	16.0	0.0	3.9	2.9	0.0	0.0	0.0	0.0	0.0	4.1
31-75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
% of total (excluding calm winds)	3.9	14.7	7.7	3.2	2.3	10.2	7.0	4.2	4.9	6.7	5.4	10.2	6.8	6.7	4.0	2.1	

Figure E-21. Wind direction and speed measured at Haulover Canal bridge during January 1993.

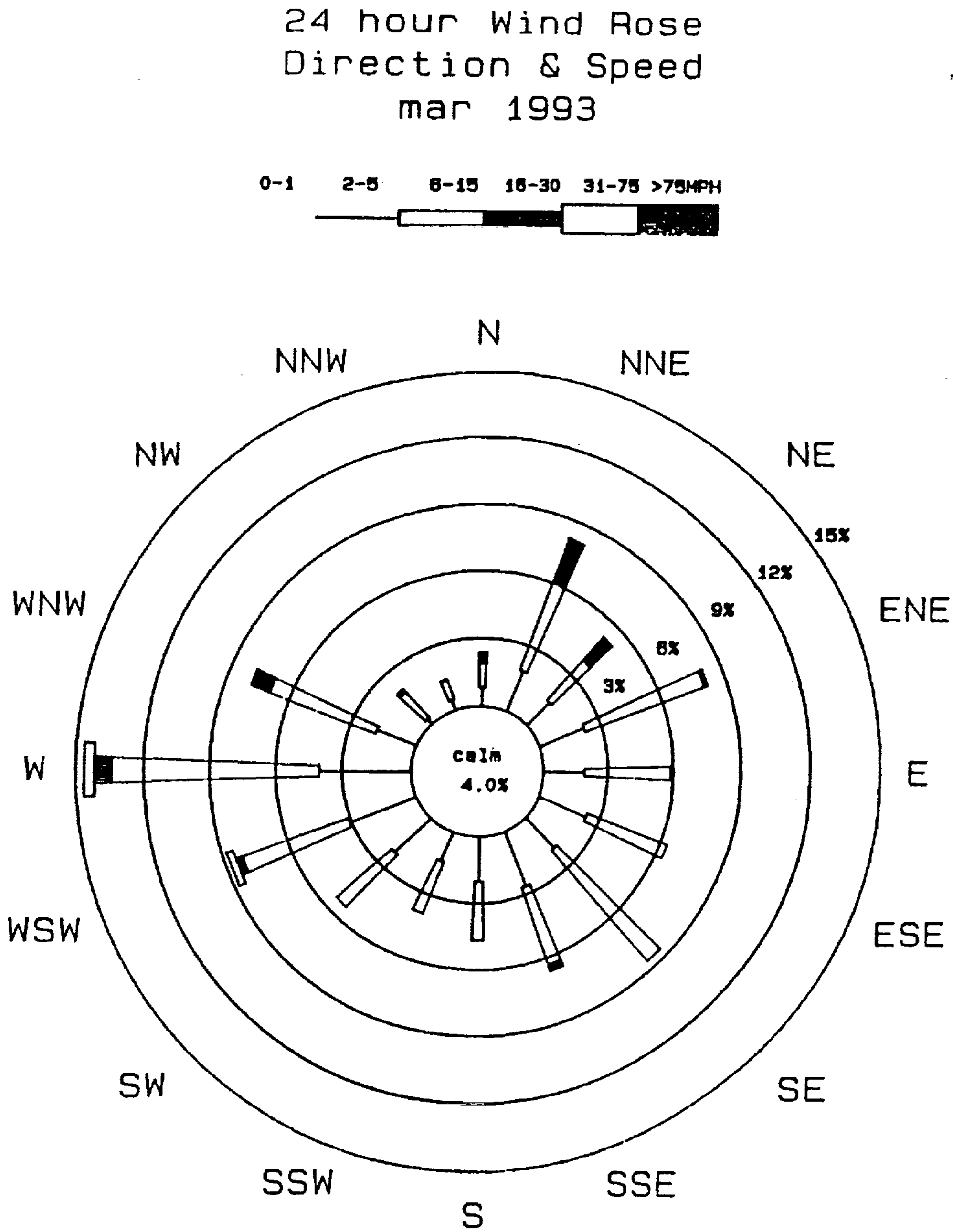
24 hour Wind Rose
Direction & Speed
feb 1993



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	32.1	4.6	5.0	14.6	13.3	0.0	25.0	0.0	12.5	17.6	0.0	25.0	10.9	4.8	12.8	6.3	10.9
2-5	21.4	27.8	25.0	31.7	53.3	0.0	0.0	28.6	50.0	17.6	0.0	25.0	56.4	42.9	28.2	6.3	31.9
6-15	46.4	61.1	55.0	53.7	33.3	99.9	75.0	71.4	37.5	52.9	99.9	47.5	32.7	47.6	56.4	87.5	52.5
16-30	0.0	5.6	12.5	0.0	0.0	0.0	0.0	0.0	0.0	11.8	0.0	2.5	0.0	4.8	2.6	0.0	4.2
31-75	0.0	.9	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.6
% of total (excluding calm winds)	4.0	21.8	16.1	7.4	2.8	.6	.6	1.5	5.9	3.0	.6	6.4	10.4	8.5	7.2	3.2	

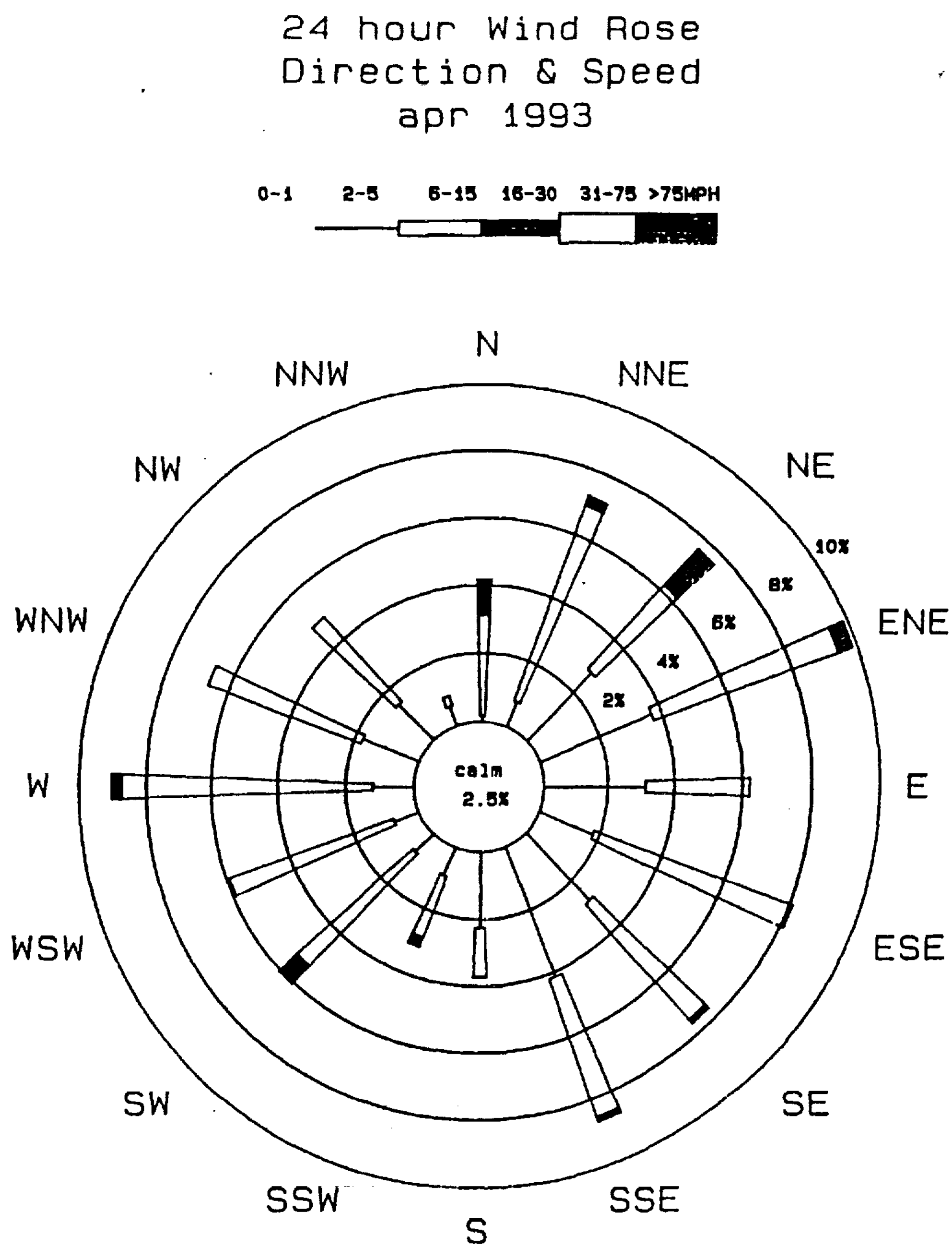
Figure E-22. Wind direction and speed measured at Haulover Canal bridge during February 1993.



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	25.0	1.9	2.9	0.0	2.6	0.0	6.7	8.5	6.3	0.0	2.8	6.6	3.1	1.9	0.0	0.0	4.0
2-5	25.0	22.2	25.7	26.4	30.8	36.6	20.0	36.2	40.6	36.0	38.9	32.8	26.5	23.1	15.4	33.3	28.9
6-15	35.0	50.0	45.7	71.7	66.7	63.4	73.3	51.1	53.1	64.0	58.3	54.1	62.2	63.5	76.9	66.7	60.0
16-30	15.0	25.9	25.7	1.9	0.0	0.0	0.0	4.3	0.0	0.0	0.0	3.3	5.1	11.5	7.7	0.0	6.4
31-75	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.3	3.1	0.0	0.0	0.0	.7
% of total (excluding calm winds)	2.3	8.2	5.2	8.2	5.9	6.3	8.6	6.6	4.6	3.9	5.4	8.8	14.7	7.9	2.0	1.4	

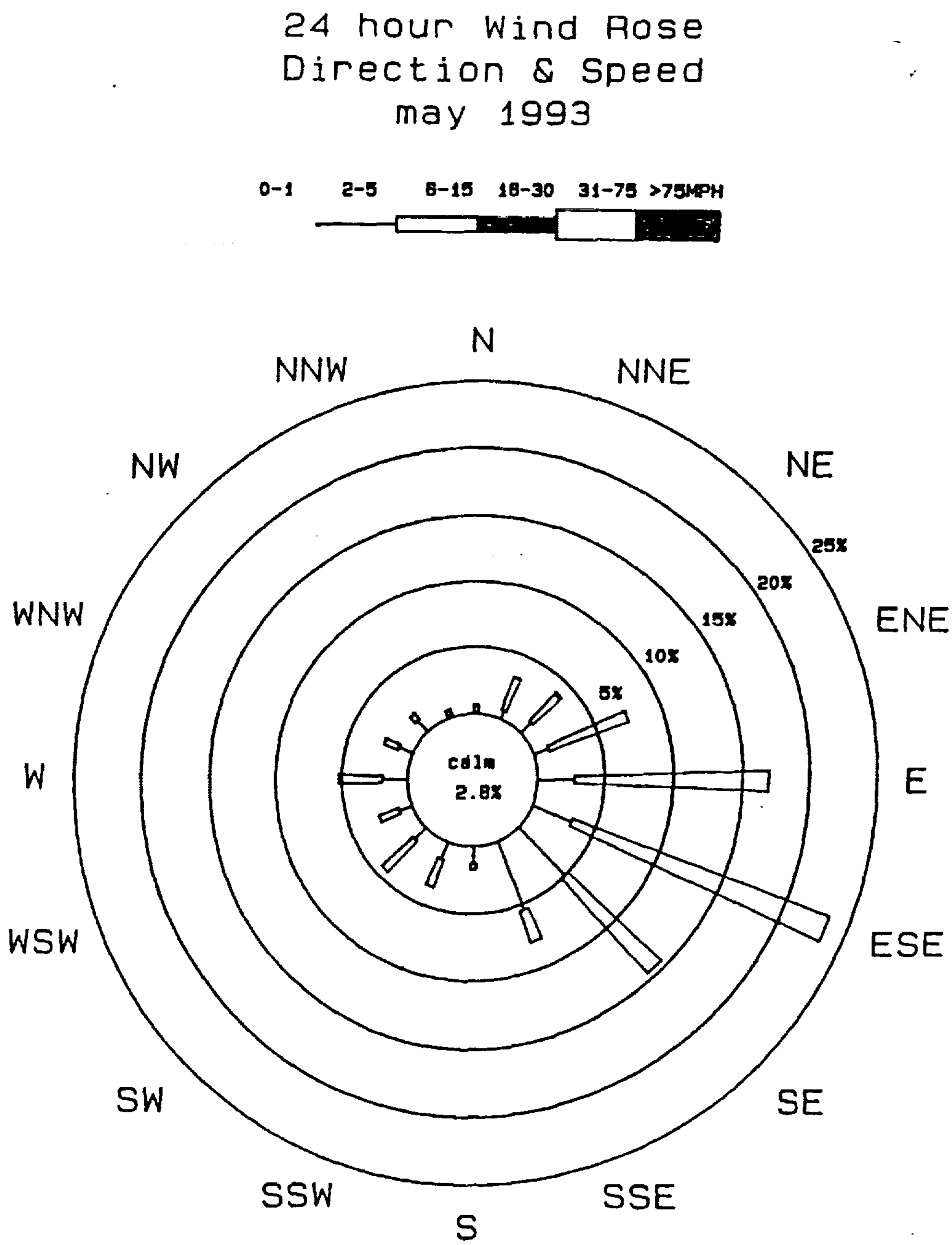
Figure E-23. Wind direction and speed measured at Haulover Canal bridge during March 1993.



% of each direction for hourly averages

ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	% of total
0-1	3.4	0.0	1.9	2.9	0.0	1.8	0.0	4.8	13.8	12.5	2.4	0.0	0.0	2.2	0.0	0.0	2.5
2-5	3.4	10.2	35.8	36.2	50.0	21.4	36.5	45.2	51.7	25.0	11.9	12.5	13.1	26.1	30.3	66.7	28.1
6-15	69.0	85.7	43.4	56.5	50.0	76.8	61.5	48.4	34.5	54.2	73.8	87.5	83.6	71.7	69.7	33.3	64.6
16-30	24.1	4.1	18.9	4.3	0.0	0.0	1.9	1.6	0.0	8.3	11.9	0.0	3.3	0.0	0.0	0.0	4.8
% of total (excluding calm winds)	4.1	7.2	7.7	9.9	6.2	8.1	7.7	8.7	3.7	3.1	6.1	5.9	9.0	6.7	4.9	.9	

Figure E-24. Wind direction and speed measured at Haulover Canal bridge during April 1993.



	% of each direction for hourly averages																% of
ranges	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW	total
0-1	42.9	4.3	0.0	0.0	.8	1.2	2.0	11.5	0.0	4.0	0.0	5.3	0.0	0.0	0.0	33.3	2.8
2-5	0.0	17.4	25.9	13.7	15.3	12.8	33.3	60.7	72.7	36.0	26.7	36.8	36.1	50.0	66.7	16.7	26.8
6-15	57.1	78.3	70.4	86.3	83.9	86.0	64.7	27.9	27.3	60.0	73.3	57.9	63.9	50.0	33.3	50.0	70.2
16-30	0.0	0.0	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	.1
% of	excluding calm winds																
total	.6	3.2	3.9	7.4	17.0	23.5	14.5	7.8	1.6	3.5	4.4	2.6	5.2	2.3	1.7	.6	

Figure E-25. Wind direction and speed measured at Haulover Canal bridge during May 1993.

Appendix F: Total Metals in Clams from Mosquito Lagoon

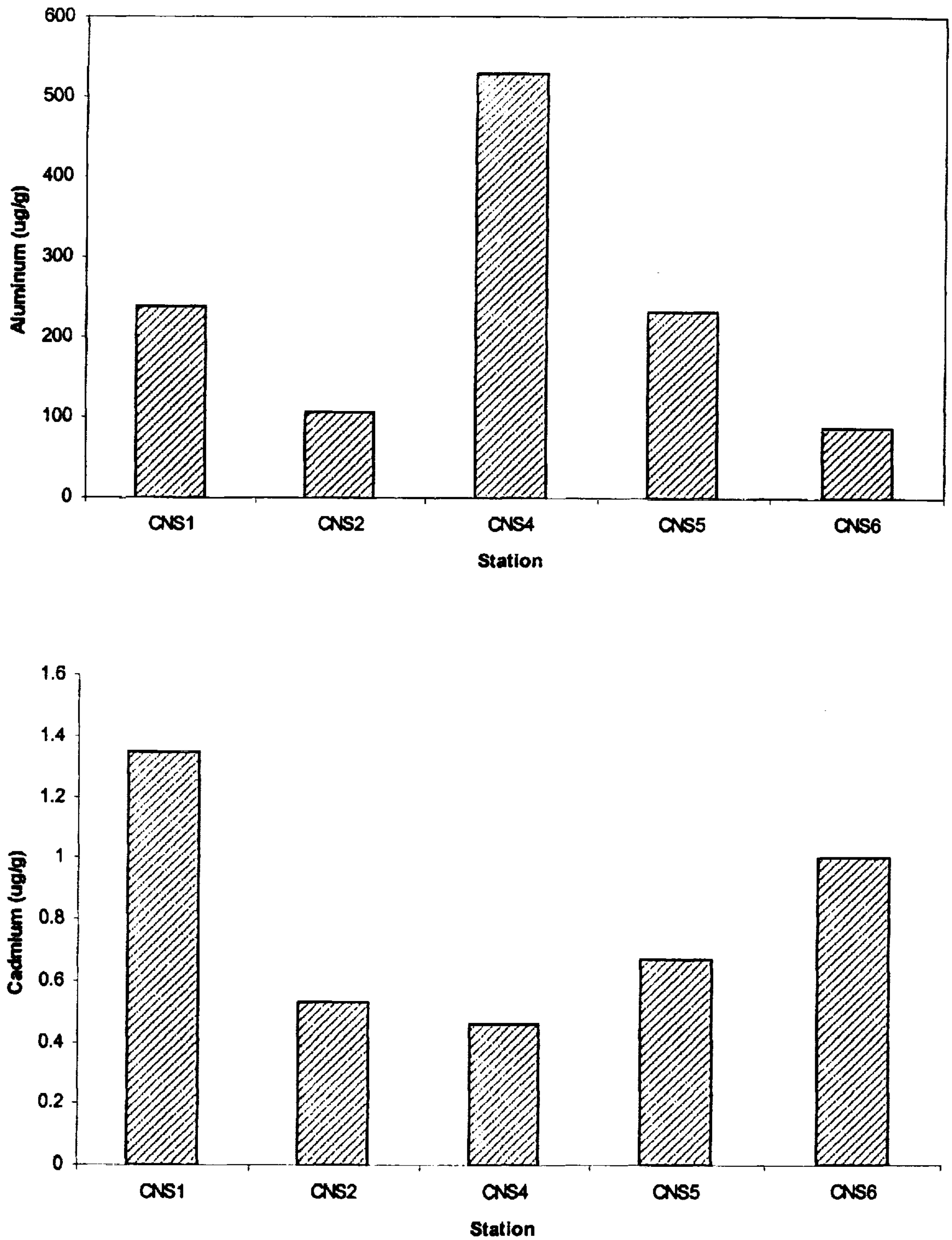


Figure F-1. Concentrations of aluminum and cadmium in whole clams collected at the Mosquito Lagoon surface water and sediment chemistry stations.

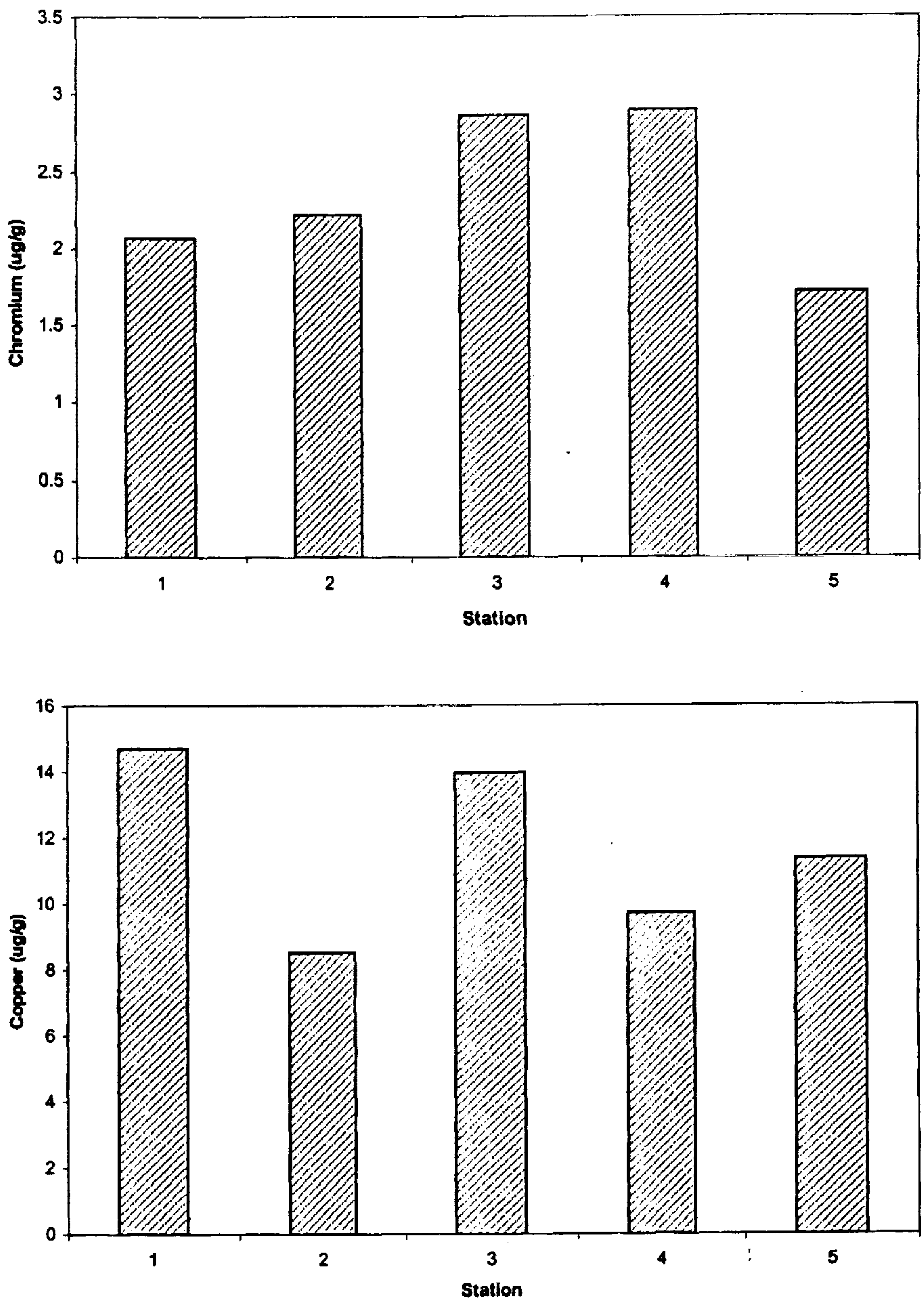


Figure F-2. Concentrations of chromium and copper in whole clams collected at the Mosquito Lagoon surface water and sediment chemistry stations.

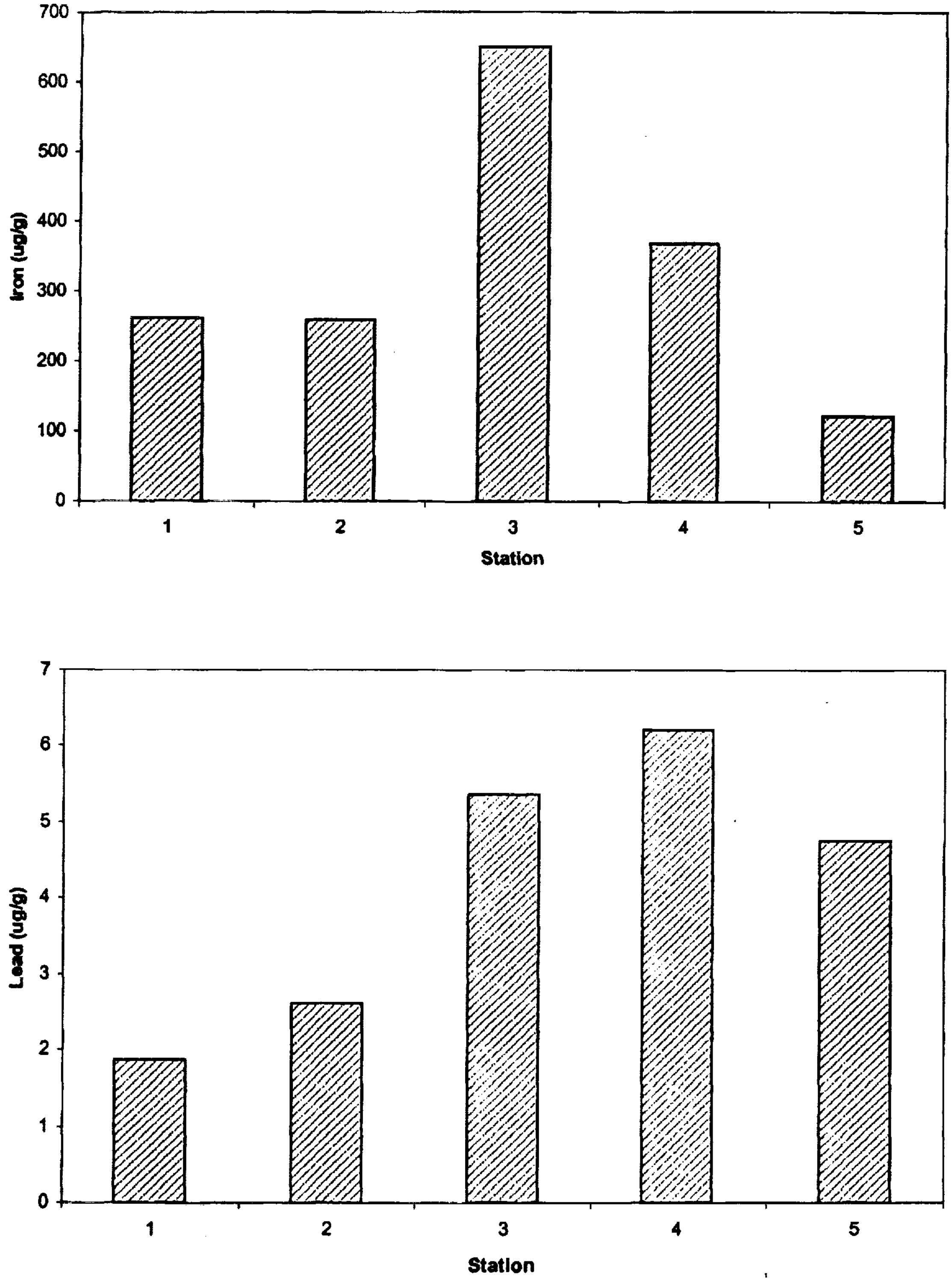


Figure F-3. Concentrations of iron and lead in whole clams collected at the Mosquito Lagoon surface water and sediment chemistry stations.

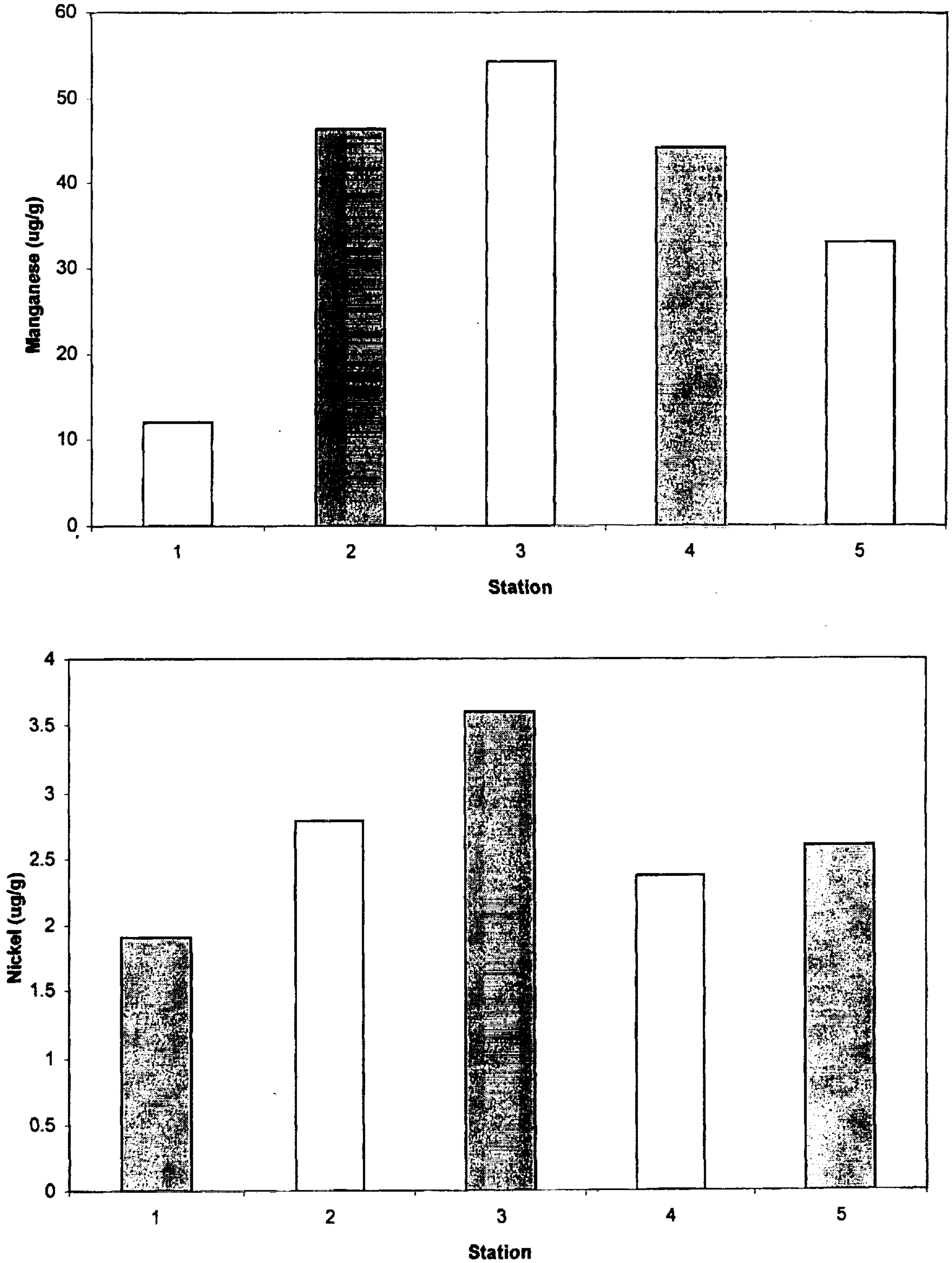
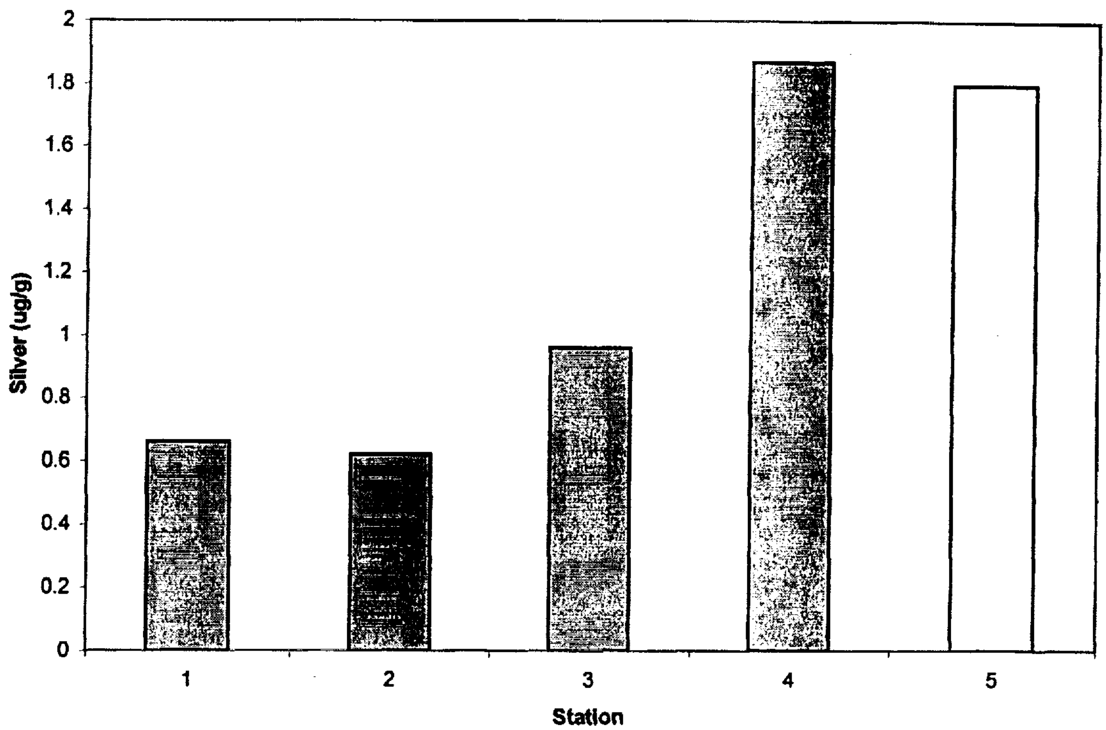


Figure F-4. Concentrations of manganese and nickel in whole clams collected at the Mosquito Lagoon surface water and sediment chemistry stations.



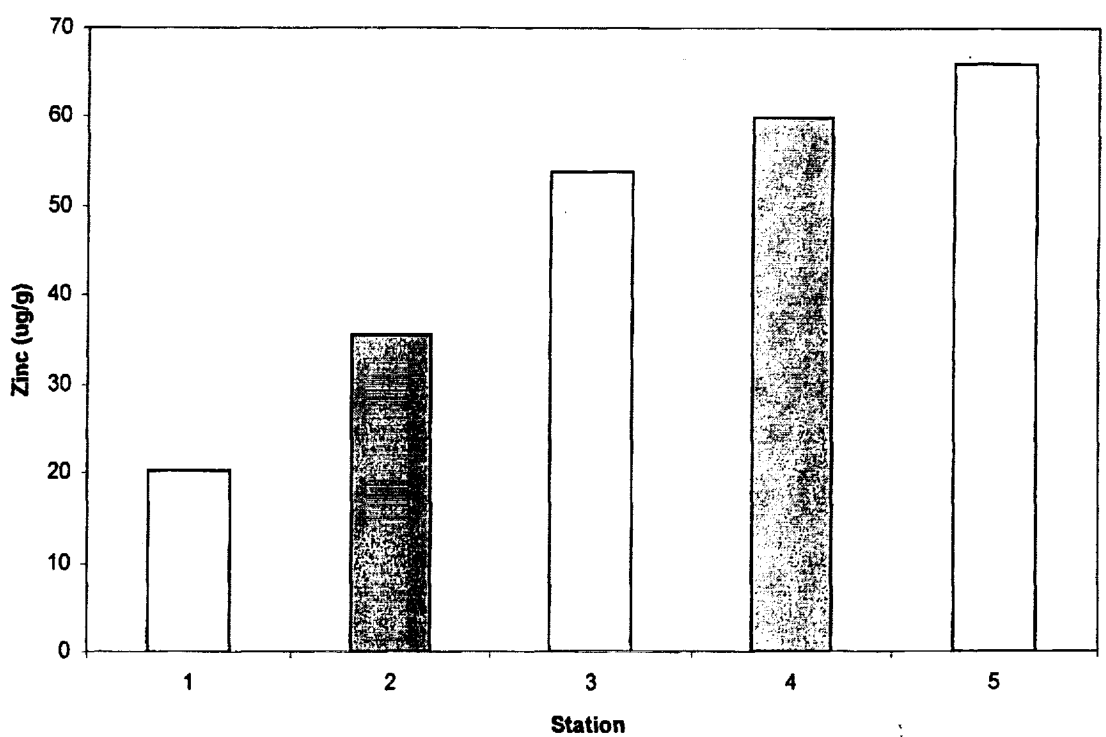


Figure F-5. Concentrations of silver and zinc in whole clams collected at the Mosquito Lagoon surface water and sediment chemistry stations.

Appendix G: Results From Impoundment Monitoring

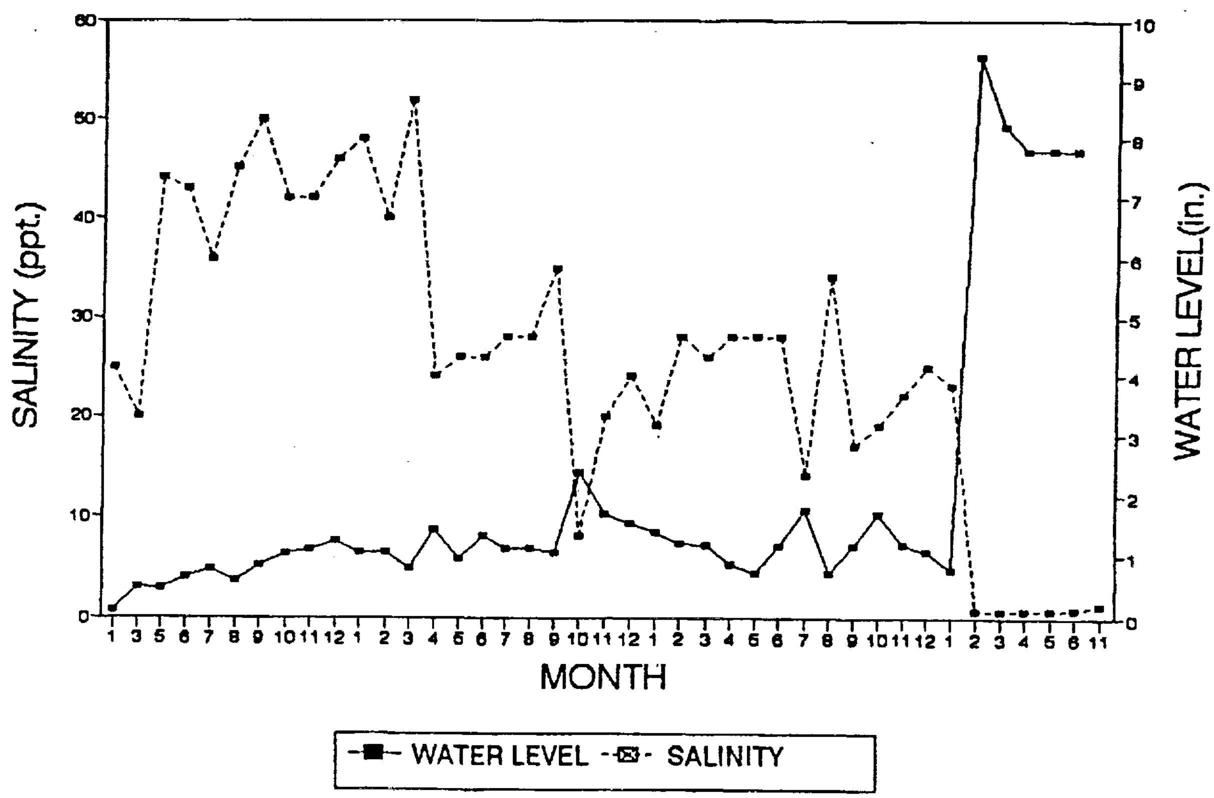


Figure G-1. Monthly water level and salinity measurements for Impoundment V-1 on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

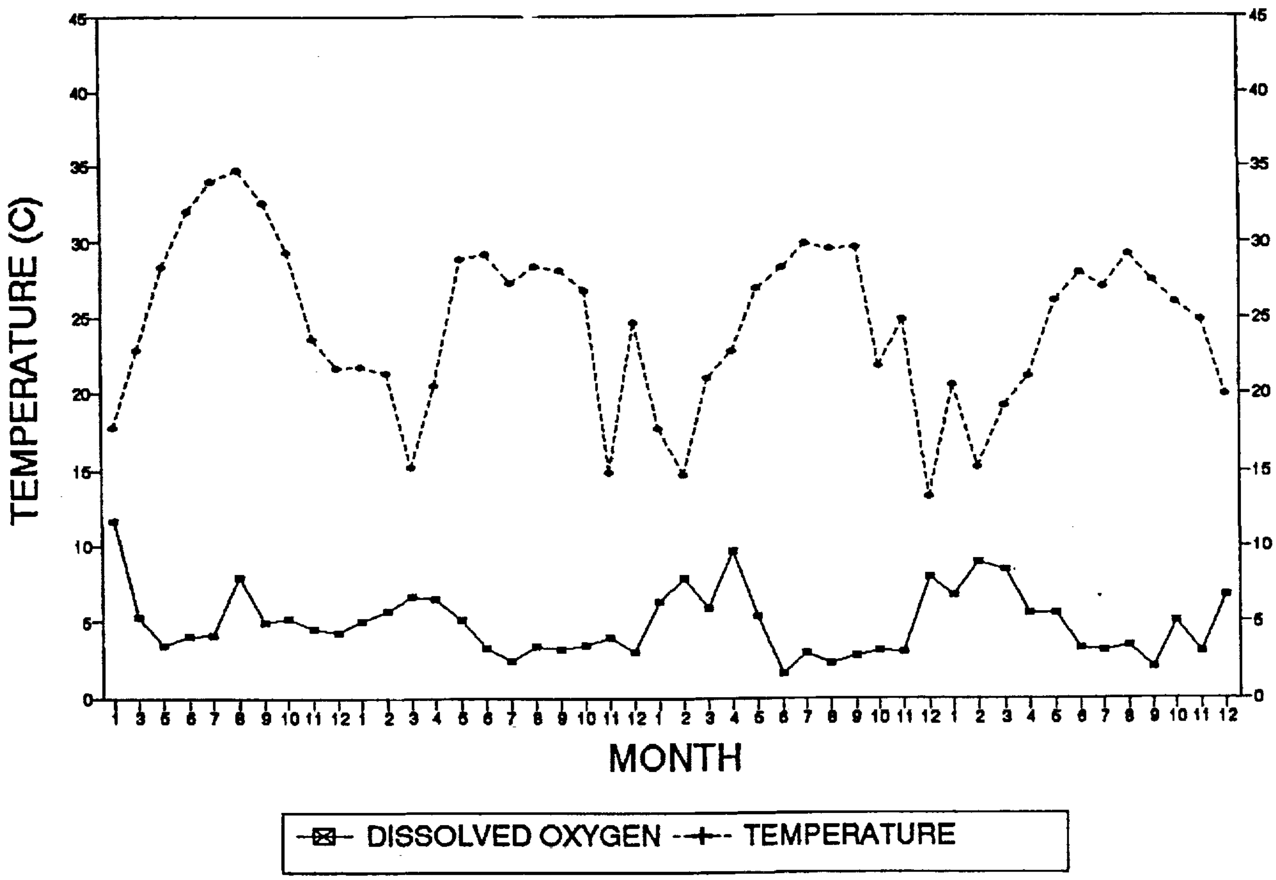


Figure G-2. Monthly dissolved oxygen and temperature measurements for Impoundment V-1 on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

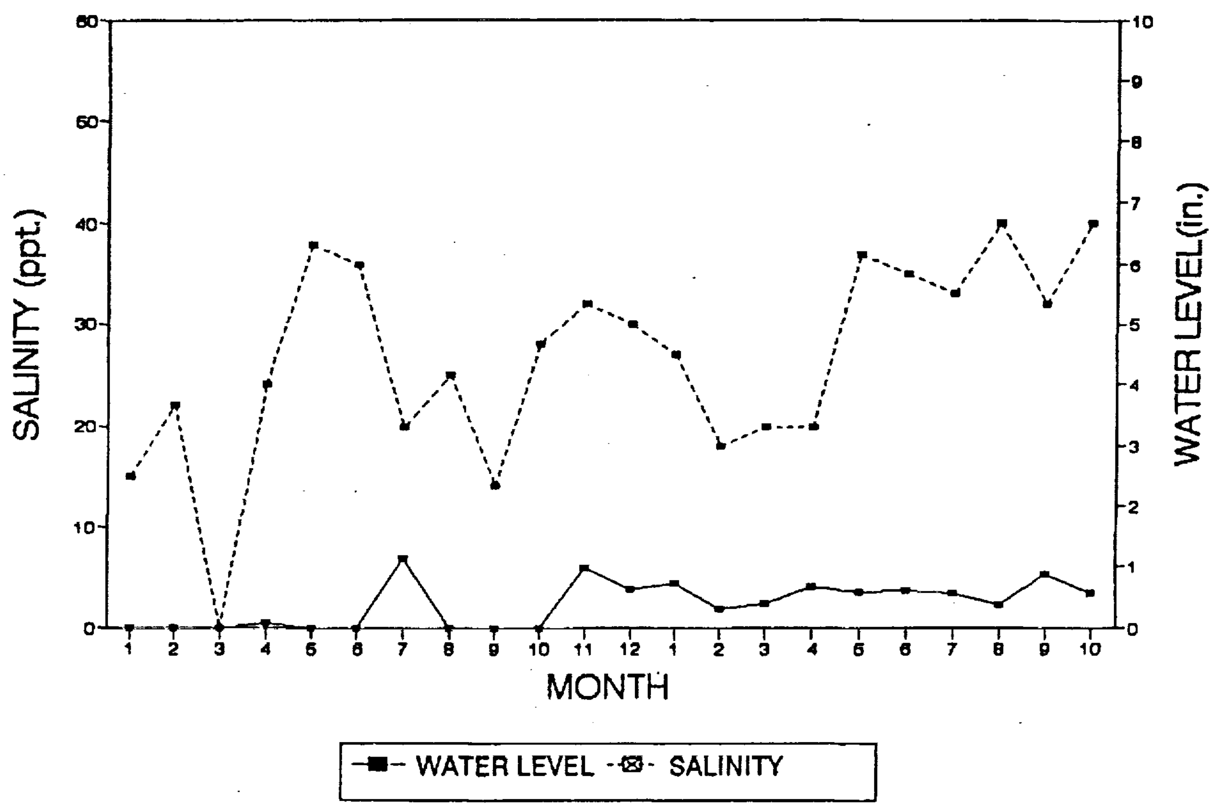


Figure G-3. Monthly water level and salinity measurements for Impoundment County Line on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

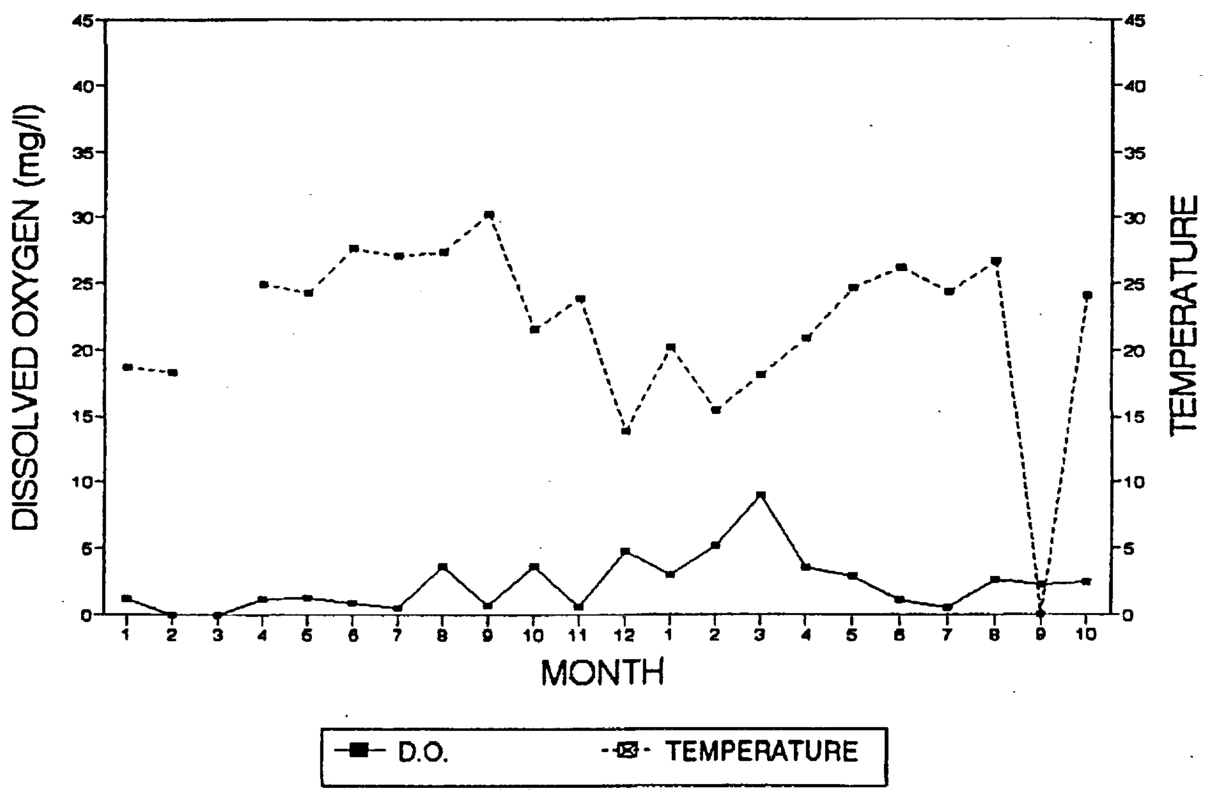


Figure G-4. Monthly dissolved oxygen and temperature measurements for Impoundment County Line on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

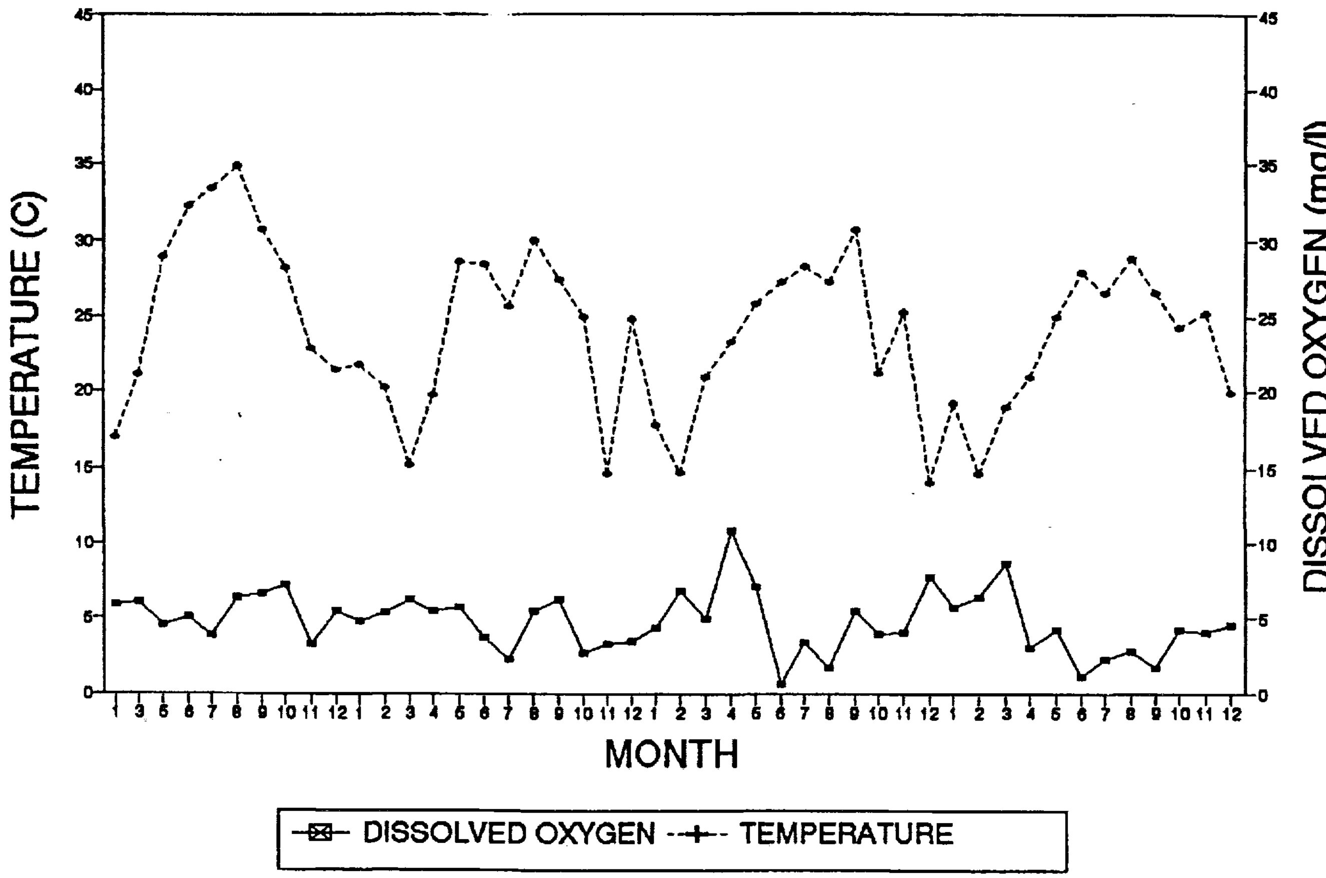


Figure G-5. Monthly water level and salinity measurements for Impoundment T-44 on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

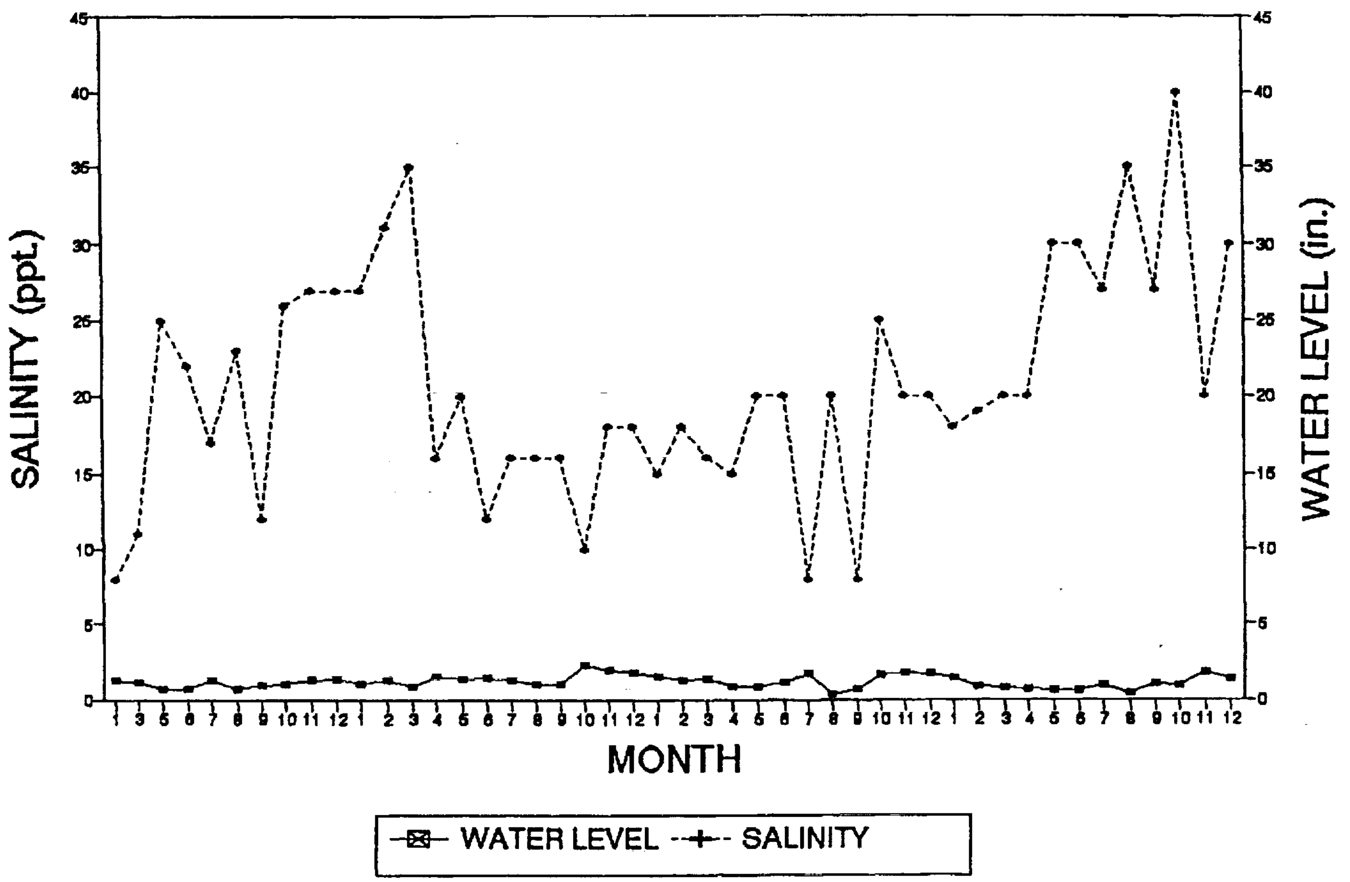


Figure G-6. Monthly dissolved oxygen and temperature measurements for Impoundment T-44 on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

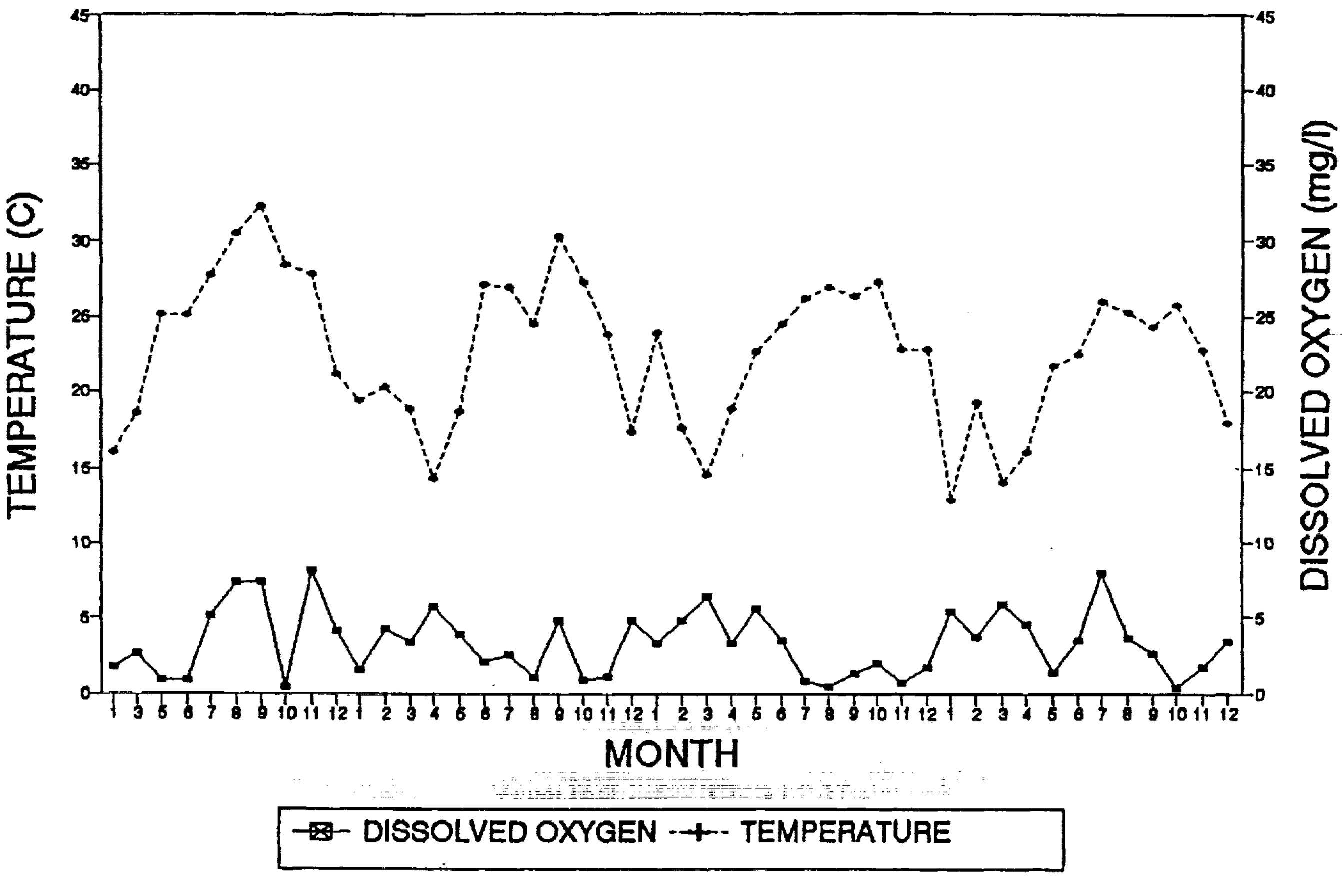


Figure G-7. Monthly water level and salinity measurements for Impoundment T-38 on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

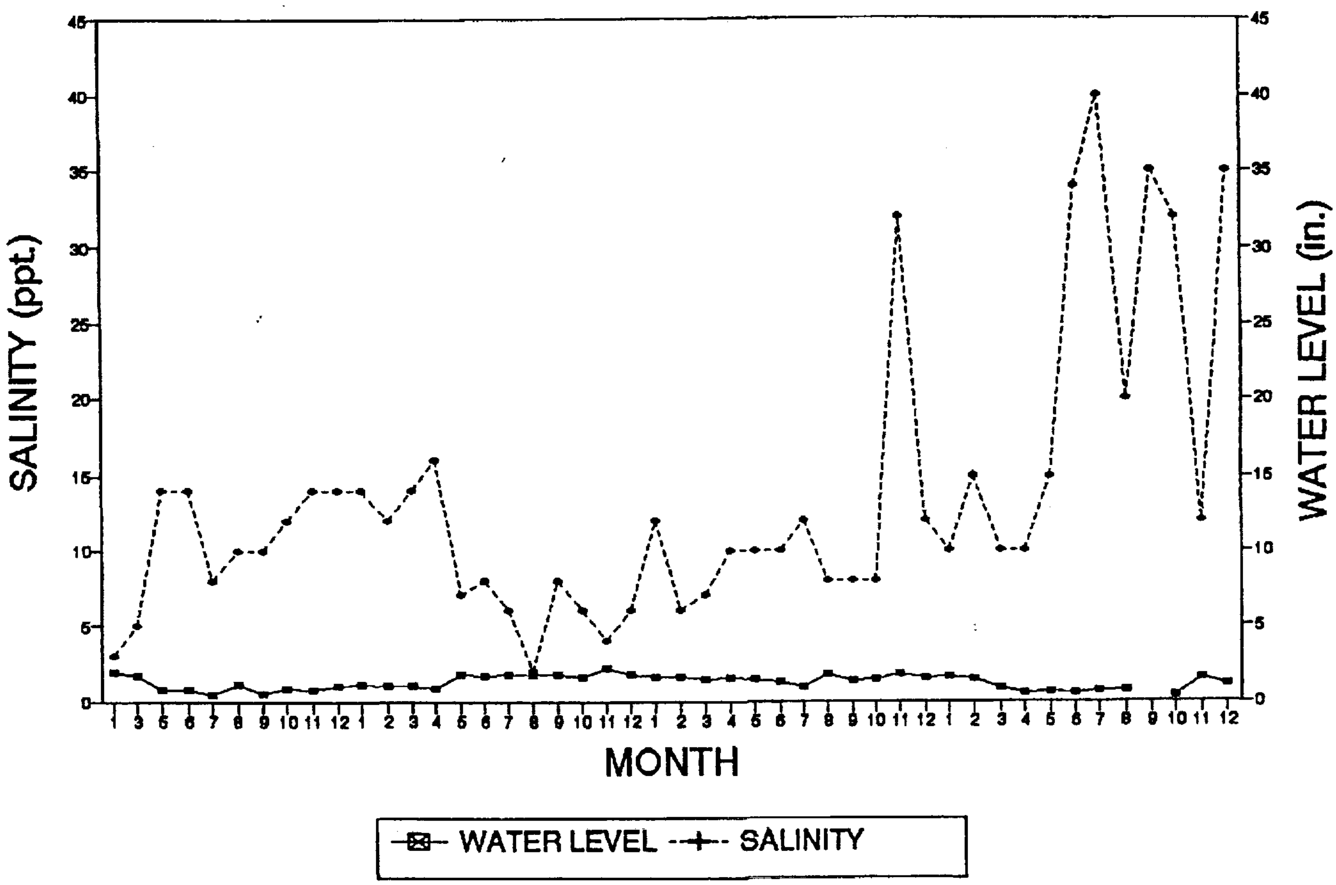


Figure G-8. Monthly dissolved oxygen and temperature measurements for Impoundment T-38 on the east side of Mosquito Lagoon. Data were collected between 1990 and 1993.

REPORT DOCUMENTATION PAGE

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13. ABSTRACT *(Maximum 200 words)*

Mosquito Lagoon is a shallow, bar-built estuary located on the east central Florida Coast, primarily within the KSC boundary. The lagoon and watershed cover approximately 327 km^2 (79422 acres). The lagoon occupies 159 km^2 (37853 acres). Water depths average approximately 1 m. The lagoon volume is approximately $1.6x10^8 m^3$. Water quality in Mosquito Lagoon is good. Salinity data typically range between 20 ppt and 35 ppt. The lowest value recorded was 4.5 ppt and the highest value was 37 ppt. Water temperatures fluctuate 2-3°C over a 24 h period. Cold front passage can rapidly alter water temperatures by 5-10°C or more in a short period of time. The highest temperature was 33.4°C and the lowest temperature was 8.8°C after a winter storm. Dissolved oxygen concentrations ranged from a low of 0.4 mg/l to a high of 15.3 mg/l. Extended periods of measurements below the Florida Department of Environmental Protection criteria of 4.0 mg/l were observed in fall and spring months suggesting high system respiration and oxygen demand. Metals such as antimony, arsenic, molybdenum and mercury were report as below detection limits for all samples. Cadmium, copper, chromium, silver, and zinc were found to be periodically above the Florida Department of Environmental Protection criteria for Class II and Class III surface waters.

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