MISSISSIPPI SOUND

TEMPORAL AND SPACIAL DISTRIBUTION OF NUTRIENTS

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MISSISSIPPI-ALABAMA
SEA GRANT CONSORTIUM
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by

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Lastly, I wish to thank Mrs. Joyce Randall Edwards for her expert handling of the numerous tasks that burden her position. The results of her efforts are always of the highest calibre.

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INTRODUCTION

Mississippi Sound (Figure 1), located on the northeastern Gulf of Mexico, is an elongate water body with its major axis oriented parallel to the Gulf. A series of barrier islands mark the seaward boundary of the Sound. Some of these islands: Dauphin, Petit Bois, Horn and Ship, are a part of the Gulf Islands National Seashore. The western boundary bisects Halfmoon Island, formerly known as Grand Island. Narrow peninsulas and shallow shell reefs connecting Dauphin Island to the mainland separate the Sound from Mobile Bay on the east.

The tides of Mississippi Sound are diurnal with an average range of 1.8 feet at Biloxi Bay. The two principal diurnal components of the tide are K_1 and O_1 with periods of 23.93 and 25.84 hours, respectively. The tides are modified by the bathymetry, geometry of the basin, river discharge and winds. Sustained south and southeast winds push water into the Sound piling it against the mainland. North winds have the opposite effect, driving the water out.

The Sound is a relatively shallow basin with an average depth of 9.9 feet. The greater depths, caused by tidal scouring action, are located at the immediate western tips of the islands. A second, shallower cut is found about midway of the pass between Horn and Ship islands. With the exception of these deep cuts, the passes are predominantly shoal areas. In the Sound west of Cat Island is an extensive area of both live and dead oyster reefs.

Three channels traverse Mississippi Sound from the Gulf to the mainland. The ports at Pascagoula and Gulfport have deep water access by two of these channels with authorized depths of 40 and 32 feet, respectively. The third, Biloxi Channel, used primarily by barge, commercial fishing fleet and pleasure craft, has an authorized depth of 12 feet. A fourth channel, the Intracoastal Waterway, spans the east-west length of the Sound. Since the natural bathymetry along the waterway is greater than the authorized depth of 12 feet except in the area west of Cat Island and east of the west tip of Dauphin Island, dredging is necessary only in these shallower areas. The customary practice of disposal of dredge spoil from maintenance dredging operations in this area has been placement of the spoil alongside the channel.

Pascagoula River empties directly into the Sound with an average flow of 13,369.4 cubic feet per second. The Biloxi and Tchoutacabouffa rivers with average flows of 493.5 CFS and 436.6 CFS, respectively, reach the Sound via Biloxi Bay. The Jourdan and Wolf rivers empty into St. Louis Bay with average flows, respectively, of 1,535.4 CFS and 705.9 CFS. The mouth of the Pearl River is located on Lake Borgne approximately 3.5 miles west of the boundary where the lake and Sound waters merge indistinguishably. Pearl River has an average flow of 11,580.3 CFS. It has been estimated (Austin 1954) that one-fifth of the discharge from Mobile Bay is diverted into Mississippi Sound mainly via Grants Pass. Besides rainfall and direct runoff, additional fresh water is contributed to the Sound by numerous tidal bayous.

Mississippi Sound, an estuarine system, is an integral part of what Gunter (1963) described as the "Fertile Fisheries Crescent." This name refers to the area encompassed by a figurative arc extending into the Gulf of Mexico from Pascagoula, Mississippi, to Port Arthur, Texas. Since the area inscribed produced over 20 percent of the total fishery landings of the United States in 1961 and 1962, the name is appropriate. The same area now produces an even larger percentage of landings. A recent look at the State of Mississippi mainland coastline (Gunter 1976) shows "that this state lands more commercial fishery products per mile of shoreline than any other state in the nation."

The Mississippi coast became well established as a resort area in the latter part of the nineteenth century. Tourism has continued to flourish and represents a notable portion of the economy. The development of the Mississippi coastal area has been rapid and largely confined to a band approximately five miles wide spanning almost the entire shoreline. This concentration of population and industry has had associated with it many of the well-known environmental problems of pollution, dredging, coastal construction, conflicting uses of resources, alteration, and in some instances, destruction of the marine environment.

The Sound is the eventual recipient of the accumulative effluents from activities throughout the drainage basin and is further altered by other direct actions such as dredging and construction. In order to assess the effect of present and future development on the water quality of the Sound, it is necessary to ascertain the existing regime of nutrients through determination of descriptive norms and causal relationships. A "baseline" thus established serves as a reference to which perturbations in the nutrient levels can be compared to evaluate whether the level is a normal variation or an abnormality.

The importance of nutrients to primary productivity in the oceans, seas and estuaries has been addressed by many authors. Ketchum (1967) lists three ways that an estuary may be fertilized: "(1) river waters leach plant nutrients from the soil and carry a constant supply through the estuary; (2) pollution, either locally within the estuary or indirectly through the river, may enrich the waters and increase productivity; and (3) the subsurface counter current, which is a unique characteristic of many estuarine circulations, may enrich the estuary when the sea water is drawn from below the euphotic zone where nutrient concentrations are higher than at the surface."

The estuarine waters are the principal sources of the major elementary components of estuarine organisms: carbonate, phosphate and nitrate ions. While added amounts of phosphates and nitrates serve to increase the fertility of the estuary, excessive amounts result in algae blooms and accompanying anoxic conditions. Excessive nutrient levels result in degradation of water quality and are therefore used as indicators of pollution.

Only two investigations prior to this study attempted to address the nutrient levels in Mississippi Sound. McIlwain (1970) obtained data on nutrient levels in the lower reaches of the rivers, bayous, bays and Mississippi Sound near the mainland. Christmas and Eleuterius (1973), in reporting the results of the hydrographic phase of an environmental inventory of Mississippi Sound and its subsystems, discussed the seasonal and areal trends of the nutrients: nitrite-nitrogen, nitrate-nitrogen, orthophosphate and total phosphate. The nutrient determinations in these two investigations were made in connection with and limited to biological sampling efforts. While this information made a valuable contribution in describing annual cycles, the station sitings dictated by the areal and temporal constraints of the study's objectives limited spatial resolution.

On 1 January 1973 the Physical Oceanography Section of Gulf Coast Research Laboratory initiated a three-year investigation of the hydrography of Mississippi Sound funded by the National Oceanic and Atmospheric Administration's Sea Grant Program and administered through Mississippi's Universities Marine Center (Mississippi-Alabama Sea Grant Consortium). The primary objectives of the Mississippi Sound research effort were to provide a description of flow patterns; determine the salinity and temperature characteristics; and to ascertain the temporal and spatial distribution of nutrients. The results, due to the scope of the project, will be reported in several technical reports and scientific journals.

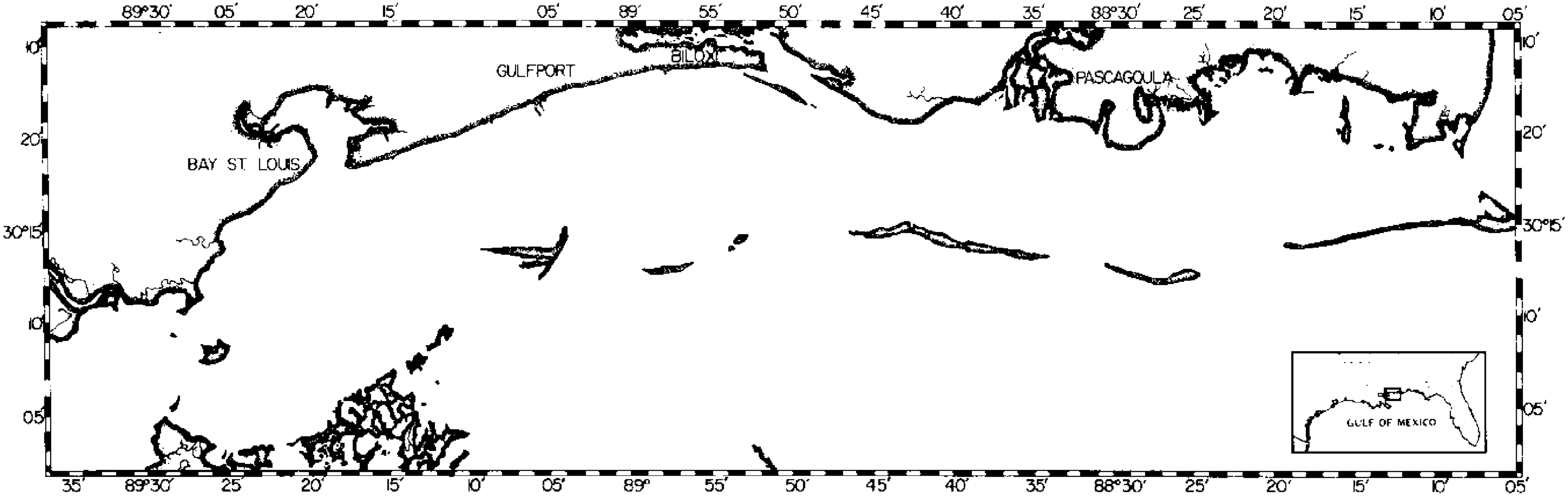

Figure 1. Map of Study Area: Mississippi Sound.

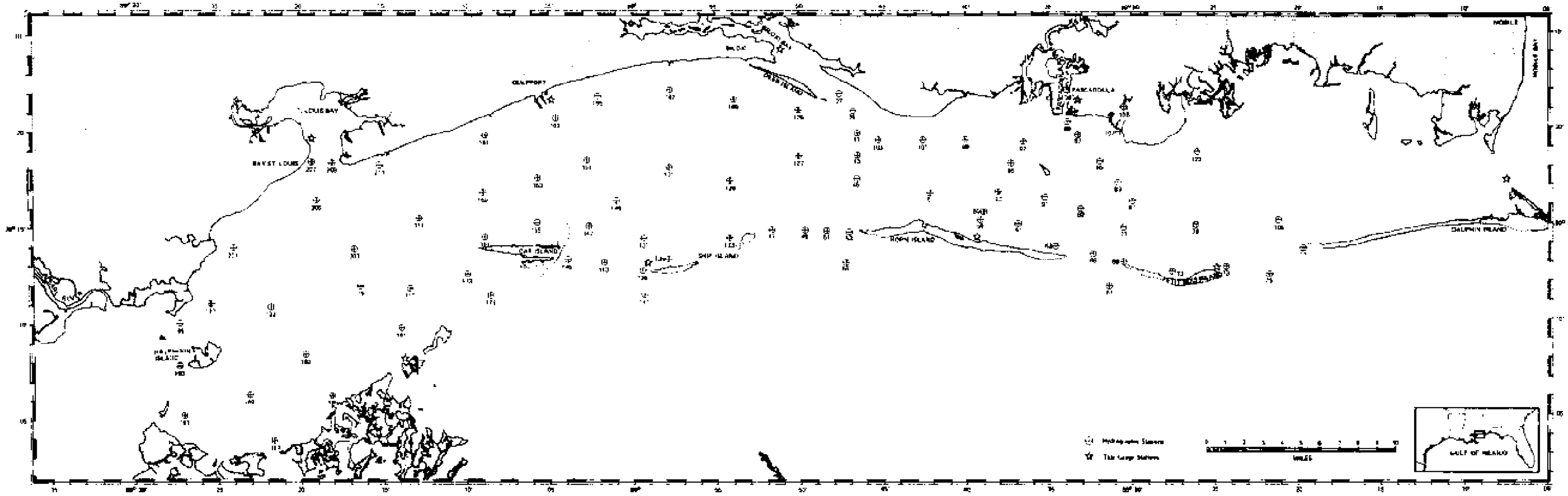

Figure 2. Locations of Hydrographic and Tide Gauge Stations.

METHODS

Sampling stations were established throughout Mississippi Sound (Figure 2) with their locations being determined, first, on the basis of the probable value of the hydrographic information they would provide; and second, on the ability to reoccupy those sites under various weather conditions. With the accuracy of Loran-A within the Sound being unacceptable and use of alternate navigation systems too costly, it was necessary to locate stations by means of landmarks, buoys and day markers. Station sitings constrained by the second criterion precluded an arrangement of stations that would have yielded more definitive information.

Initially, eighty-five station sites were selected and numbered using the odd integers not assigned to sites in previous investigations. When preliminary analysis indicated the need for additional stations to clarify circulation patterns in an area, they were established and assigned even integer numbers.

The number of stations and the vastness of the area precluded the possibility of covering the entire Sound in a single cruise. The Sound was divided into three overlapping segments that can best be described by their east-west linear extents as follows: the eastern segment extended from the west tip of Dauphin Island to the east tip of Ship Island; the middle section covered the area from the west end of Horn Island to near the west end of Cat Island; the western section extended from near the west end of Cat Island to just west of Half Moon Island. The three sections were overlapping in that stations on boundaries common to adjacent sections were occupied when cruises were conducted in either of the adjacent areas. Cruises rotated among the three areas except during the first year when work was confined to the eastern section on recommendation of the local Sea Grant office.

The research vessel, Seiche, is a twenty-nine foot, aluminum alloy, single-screw offshore survey boat powered by a 6v-53 General Motors diesel engine. The boat, specially designed to satisfy the requirements of the oil industry's offshore operations, proved to be ideally suited for the demands of hydrographic research. The boat was equipped with a Johnson citizen's band radio, Ray Jefferson VHF radio, Decca model 050 radar and an Apelco depth recorder.

A Martek, model II, water quality analyzer, modified by a member of the Laboratory staff, was used in obtaining measurements of temperature, conductivity, pH and dissolved oxygen through the water column. Readings were taken near the surface (< 1 foot) and descending depths at multiples of the interval of five feet with respect to the surface. If the distance between the bottom and the last reading taken was greater than one-half of the standard interval (5 feet), a reading was obtained for that depth. The accuracy of the instrument is reported to be: temperature, ±0.5C; conductivity, ±0.2 mmho/cm; pH, ±0.1; dissolved oxygen, ±0.5 ppm. The instrument was tested and recalibrated, if necessary, before each cruise. The reason for adopting this particular interval (5 feet) was to enable the comparison with and utilize data formerly collected using this procedure.

A Bendix psychrometer was used to obtain air temperature and dew point. A GM precision bucket thermometer was employed to verify water temperature readings from the Martek by comparison of near-surface values. A salinity determination of surface water was also made, post cruise, by means of a Plessey precision salinometer and using Copenhagen standard seawater to confirm the validity of the Martek conductivity readings.

Samples of surface waters were collected at each station and from near-bottom at selected stations. Surface water was taken by bucket while a Van Dorn sampler was used to obtain bottom water. Each water sample was transferred to three prelabeled Whirl Pak sample bags of approximately 150 ml each and immediately placed on ice. The separated portions of the water sample were labeled for the following quantitative chemical analyses: nitrite-nitrogen, nitrate-nitrogen, orthophosphate and total phosphate. A single bag was used for holding the portion of the sample for the nitrite and nitrate determinations. After returning to the Laboratory, the sample portion indicated for determination of total phosphate was "pickled" with 3 drops of concentrated hydrochloric acid. All samples were then frozen until the tests could be run.

All samples were processed using procedures as outlined by Strickland and Parsons (1965). The results for all nutrient samples were obtained from a Coleman model 124D, double-beam spectrophotometer, using a 1 cm cell. Stated wavelength accuracy of this instrument is ±0.5 nm with reproduciability of ±0.2 nm. A correction factor for turbidity was obtained for each sample by making a reading prior to processing. Perchloric acid was added to each sample according to its level of salinity.

Measurements of orthophosphate were made at a wavelength of 670 nm. The final corrected calculations in μga/ℓ were recorded to the nearest one-hundredth. Levels of total phosphate were determined using the same wavelength as orthophosphate. The results were also recorded to the nearest one-hundredth μga/ℓ.

For nitrite-nitrogen determinations a wavelength of 543 nm was used. The corrected calculations were carried out to three decimal places and recorded in μga/ℓ. After running the nitrate-nitrogen samples through a cadmium reduction column, they were read at the same wavelength stipulated for nitrite. The calculations were to the nearest thousandth μga/ℓ.

The results of the chemical analyses were entered onto specially designed computer coding forms along with other hydrographic data. Coded data were submitted to the GCRL Computer Center for keypunching. The encoded data were verified and processed.

Several computer programs to process the data were written for the Laboratory's IBM 1130, model 2B, computer by the principal investigator. Programs employing the on-line Houston Electronics incremental plotter generated trend charts and isopleth work sheets. Descriptive statistics for each station for each nutrient were also computed. These nutrient statistics appear in an Appendix to this report.

Isopleth charts were constructed for surface waters for the mean and extreme values of each of the nutrients. The computer-generated isopleth work sheets consisted of the positions of specified nutrient levels arrived at by linear interpolation between stations. The charts were completed by hand. The convention of uniform intervals between isopleths was not adhered to here due to the great range, variability and complex patterns. This relaxed approach permitted the configuration of horizontal distribution while avoiding too great a density of isopleths which makes the charts illegible.

Flow rates of rivers affecting Mississippi Sound hydrography and for which data were available for the period of the study are shown in Figures 3, 4, 5 and 6. Daily extremes of air temperature at Biloxi, Mississippi, for the study period are plotted in Figure 7. The time period on all trend charts is for the period 1 May 1973 through 31 March 1975.

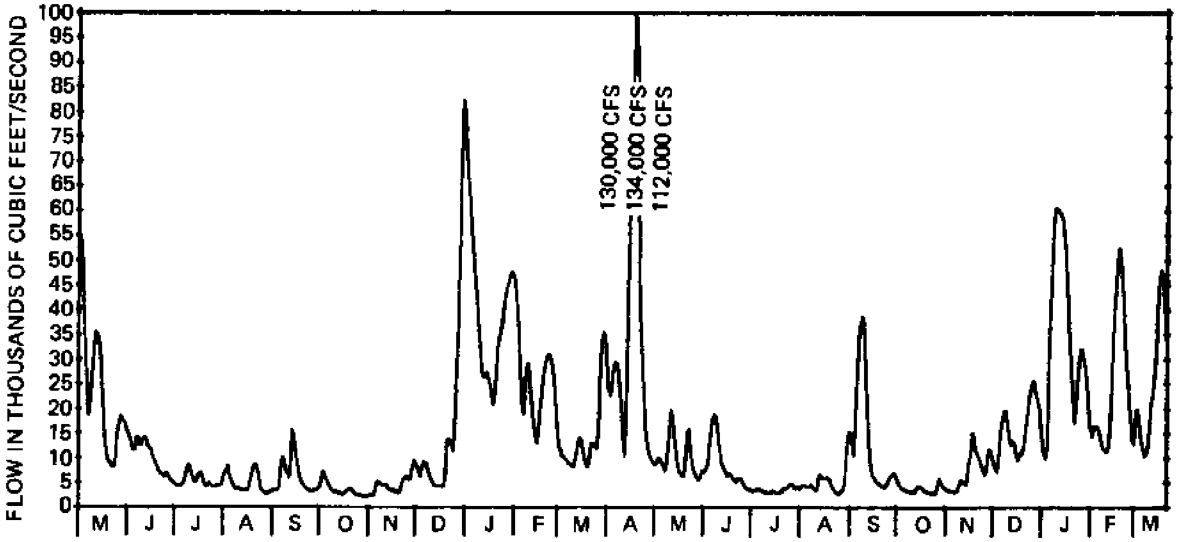

Figure 3. Flow of Pascagoula River at Merrill, Mississippi from 1 May 1973 through March 1975.

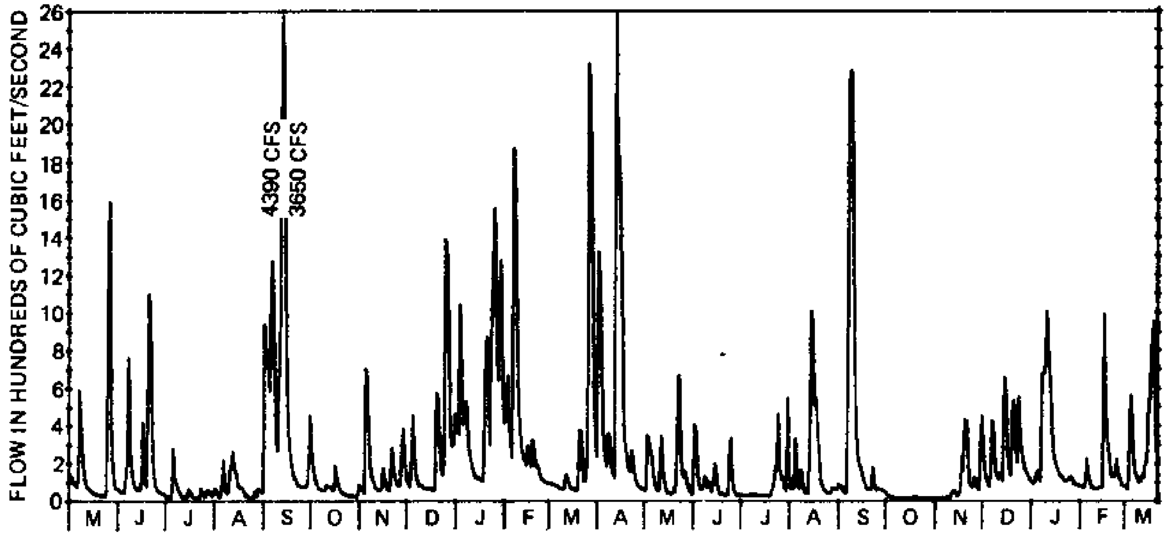

Figure 4. Flow of Biloxi River at Wortham, Mississippi from 1 May 1973 through March 1975.

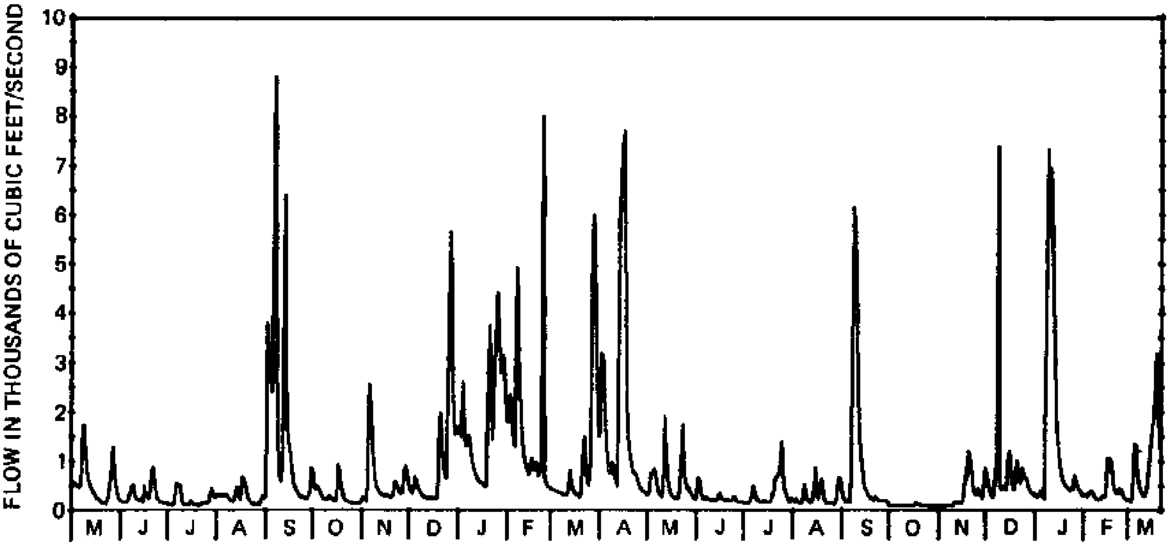

Figure 5. Flow of Wolf River at Landon, Mississippi from 1 May 1973 through March 1975.

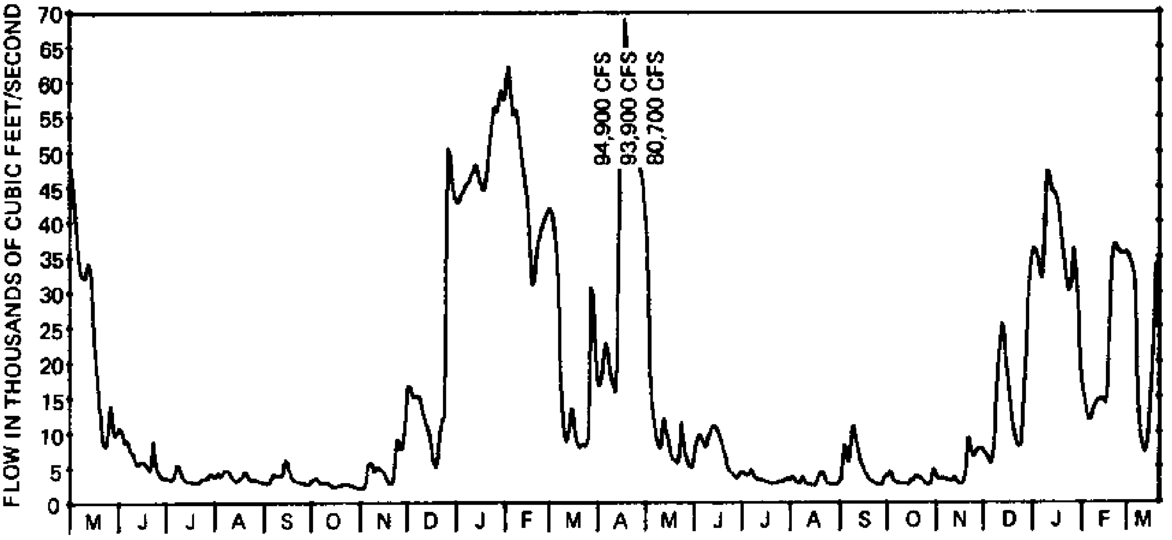

Figure 6. Flow of Pearl River near Bogalusa, Louisiana from 1 May 1973 through March 1975.

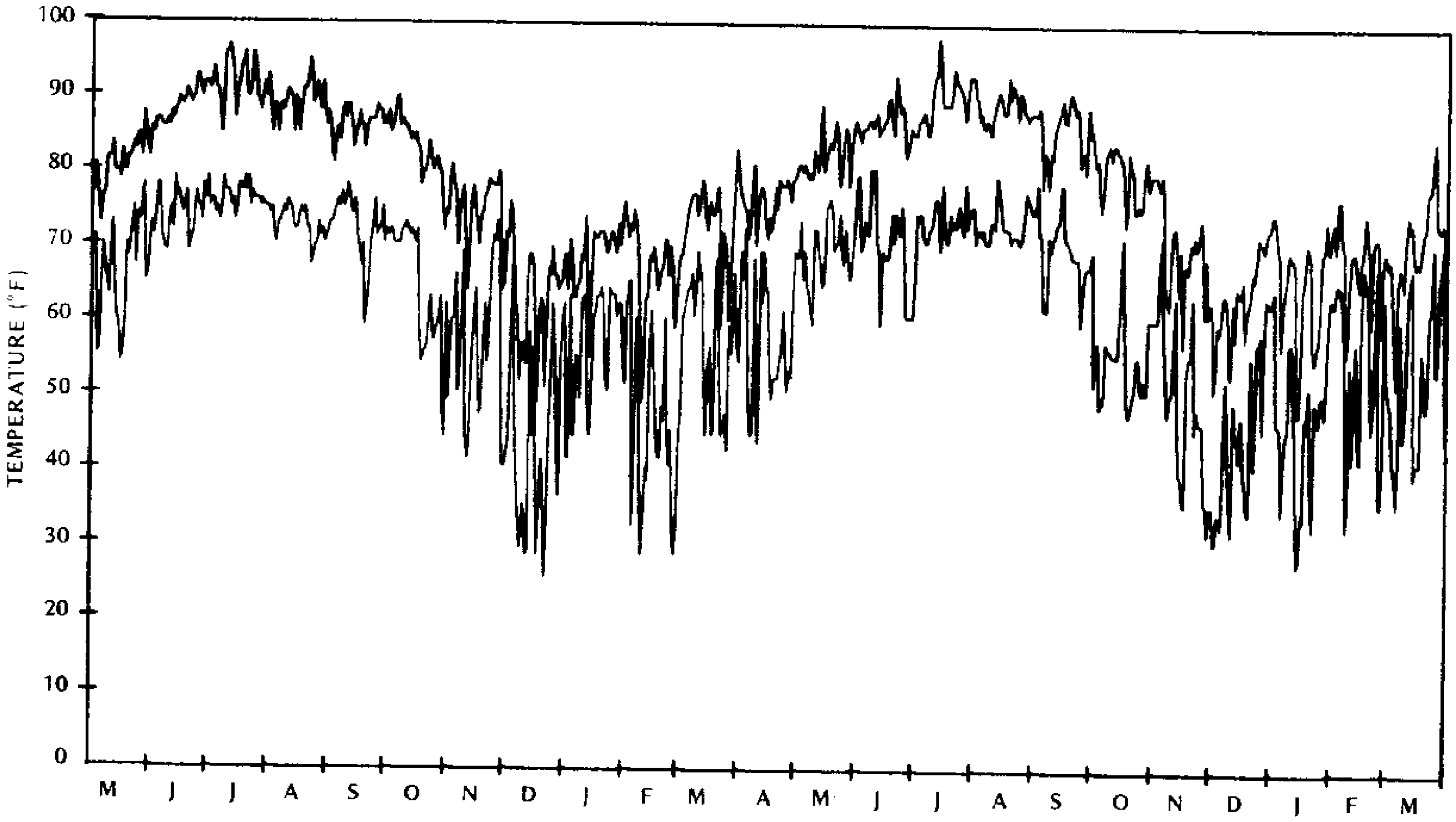

Figure 7. Daily Minimum-Maximum Air Temperatures (°F) During Period of Study.

RESULTS

Located approximately one-half mile up from the mouth of Pascagoula River was station 109. At this point and further upstream, fish processing plants discharge waste waters into the river. Other industrial and domestic effluent sources also are emptied into the river in this area. While both the physical/chemical variables (Figure 8) and the level of nutrients (Figure 9) show great variability, certain tendencies are still apparent. Both total phosphate and orthophosphate reached peak levels during late summer and held until December. The lowest levels of phosphorus occurred during the period from December through April. This corresponds to the low-flow period for the river.

Nitrogen showed an almost inverse relationship to phosphorus and salinity. Comparison of Figure 9 with Figure 3 clearly shows the direct relationship between rate of river flow and nitrogen levels. Nitrite levels, while still expressing seasonal trends, were highly variable probably reflecting the aperiodic introduction of effluent into the river.

Station 89 (Figures 10 and 11) was located at the mouth of Pascagoula River. The general relationship between river flow and levels of phosphorus and nitrogen held. On the average, levels of nitrite were higher than at station 109 but levels of nitrate were lower. This is probably explained by the presence of an outfall between the two stations. The inorganic-phosphate level was lower on the average than at the upstream station. In the surface waters, total phosphate appears to diminish downstream; however, the reverse appears to be the case with near-bottom waters (Table IV). In addition, total phosphate is higher at the surface than at the bottom and with greater variability at the upstream station 109. The inverse is true at station 89. This could be explained if one considers that the organic-phosphate load is being introduced at the surface near the upstream station and, acted on by gravity, sinks as it moves downstream.

At the juncture of the Pascagoula Ship and the Bayou Casotte channels in Mississippi Sound was station 83 (Figures 12 and 13). This site is approximately five miles from the Pascagoula River. While still influenced by the river flow, the salinity and temperature changes are more gradual. With the exception of nitrite, there is a marked decline in the average levels of all nutrients, the decline in nitrite being very slight. (The trend line for nitrate in Figure 13 has inadvertently been left off.) The negative correlation between river flow and phosphorus levels is apparent from the charts.

Ten miles southeast of the river mouth station 79 was established (Figures 14 and 15). The influence of the river is evidenced by the response of the surface salinity to fluctuations in stream flow. The levels of all nutrients; on the average, are consistently much lower and less variable than the more landward stations.

Station 73 (Figures 16 and 17) is situated just offshore and northeast of the east tip of Petit Bois Island. With the exception of nitrate, the nutrients are even lower than at station 79. The physical/chemical parameters in the surface waters of these latter two stations as a whole seem to express about the same degree of variability.

Two stations, 107 and 108, (Figures 18, 19, 20 and 21) were located in the Bayou Casotte Industrial "canal." The "canal" resulted from deepening and widening an existing bayou whose upper reaches still exist in a somewhat altered form. Several chemical plants and a refinery are in the industrial park contiguous to the canal. One station is located at the canal entrance, station 107; and the other, station 108, is at head of the canal. All nutrient levels were extremely high at the two sites. The reason the graphs have a sparsity of lines is that most of the values were simply off scale. The statistics on the nutrient levels for the two stations can be found in the Appendix.

The transect across Mississippi Sound from outer Biloxi Bay to two miles seaward of Horn Island is represented here by stations 27, 41, 45 and 55 (Figures 22, 23, 24, 25, 26, 27, 28 and 29). The relation of phosphorus to salinity level appears, generally, to be in accord. However, there does not exist a consistent decline in nutrient levels across the Sound but instead, increases to mid-Sound then diminishes seaward.

A third transect across Mississippi Sound from east of Gulfport to mid-Sound north of Ship Island then along Gulfport Ship Channel to 1 1/2 miles seaward of Ship Island is represented by stations 165, 131, 137 and 141 (Figures 30, 31, 32, 33, 34, 35, 36 and 37). After studying these charts, several facts become apparent. There is a greater similarity between these stations than along the other transects discussed so far. The changes in the trend lines of the physical/chemical parameters are much less erratic and the salinities were consistently higher. The nutrient levels were consistently lower with the highest values detected at the most seaward station. This situation is supported by the flow patterns in this area (Eleuterius 1976).

It seemed to be of particular importance to discuss the nutrient levels recorded for station 195. This station is located almost due south of Light House Point in St. Joe Pass approximately four miles from the mouth of Pearl River. Since the major portion of the river outflow passes through St. Joe Pass, it appears reasonable to expect it to reveal the influence of Pearl River on the fertility of west Mississippi Sound.

As Figure 38 shows, the level of salinity never exceeded 17.0 ppt during the study and dissolved oxygen never fell below 7.0 ppm. Generally, the other physical/chemical parameters changed in a gradual manner. Compared with the stations similarly situated in the vicinity of Pascagoula River, the nutrient levels at station 195 (Figure 39) are low. The inverse relationship between total phosphate and stream flow so apparent in the east Sound did not hold.

A fourth transect across the Sound is represented by stations 211, 171 and 175. Station 211 (Figures 40 and 41), located near the mainland southwest of the City of Pass Christian, shows less variability in both the physical/chemical variables and the nutrient levels than station 171 (Figures 42 and 43) situated mid-Sound. There existed a greater fluctuation in salinity at this mid-Sound station than near the mainland. The author explained the reason for this occurrence in a previous publication (Eleuterius 1976).

The third station comprising the transect was located in the passage between Cat Island and the Isle of Pitre (Louisiana marshlands). Waters exchanged through this passage are largely estuarine and exclusively so at the surface. The presence of Chandeleur Sound to the south of the passage restricts the water exchange between west Mississippi Sound and the Gulf of Mexico. The surface salinity measurements recorded for station 175 (Figure 44) never exceeded 27.0 ppt.

The nutrients for this site (Figure 45) were lower than mid-Sound station 171. Since the single high nitrate value of 9.039 μga/ℓ occurring in early June 1975 was not supported by similar readings at any of the surrounding stations, the author is led to believe that the water sample was not representative.

Because nitrite was not detectable at least once in the surface waters at most stations during the study, the discussion of the areal distribution of nitrite will be limited to the average and maximum levels. Bayou Casotte, located east of Pascagoula, shows it averaged the highest nitrite level in Mississippi Sound (Figure 46). Another area whose average was high due to a single anomalous reading was located southeast of Half Moon Island. The effect of Biloxi Bay waters is clearly shown.

The maximum levels of nitrite (Figure 47) occurred in Bayou Casotte followed by Biloxi Bay. It is interesting to note that a large segment of the Sound from Deer Island to west of Bay St. Louis never revealed nitrite levels in excess of 0.2 μga/ℓ.

Bayou Casotte is also attributed with showing, on the average, the highest levels of nitrate (Figure 48). The area to the leeward of Cat Island also expressed levels in excess of 4.0 μga/ℓ. The contribution of Pearl River to the nitrate levels of Mississippi Sound is defined by a configuration of isopleths that closely resembles the normal surface flow patterns in this area.

Among the areas with the greatest maximum levels of nitrate (Figure 49) were Bayou Casotte, Pascagoula River, Biloxi Bay and the far west Sound (influenced by Pearl River). In addition, the chart indicates that the waters outside the Sound, in general, attained higher levels of nitrate than those within.

The highest average level of orthophosphate (Figure 50) occurred in Bayou Casotte. West of Biloxi the levels averaged less than 0.5 μga/ℓ. The primary sources of orthophosphate in the Sound are clearly evident from the distribution of maximum levels (Figure 51).

Only three areas (Figure 52) consistently showed levels of total phosphate greater than 1.0 μga/ℓ: an area east of the entrance to St. Louis Bay; Bayou Casotte and the lower Pascagoula River; and the leeward side of Horn Island. Biloxi Bay (Figure 53) outflow showed average levels in excess of 2.0 μga/ℓ. The average levels (Table IV) in Pascagoula River and outer Bayou Casotte areas were 4.47 μga/ℓ and 51.32 μga/ℓ, respectively. Obviously, an attempt to show this gradient with isopleths would have resulted in complete obliteration of that area of the chart. The same would have been true in depicting the distribution of maximum levels of this nutrient (Figure 54). The Biloxi and Gulfport areas are indicated as major sources of total phosphate to Sound waters. The highest values were recorded in the lower Pascagoula River, station 109, and the upper reach of the Bayou Casotte canal, station 108. The maximum values observed at these two locations were 32.23 μga/ℓ and 91.38 μga/ℓ, respectively. The records show that the majority of this phosphorus was inorganic.

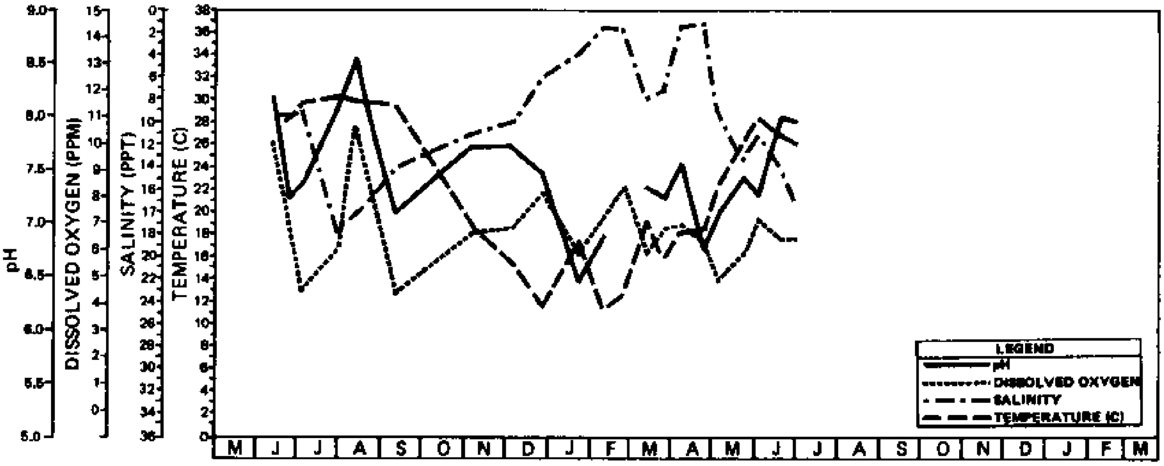

Figure 8. Station 109 Physical-Chemical Trends.

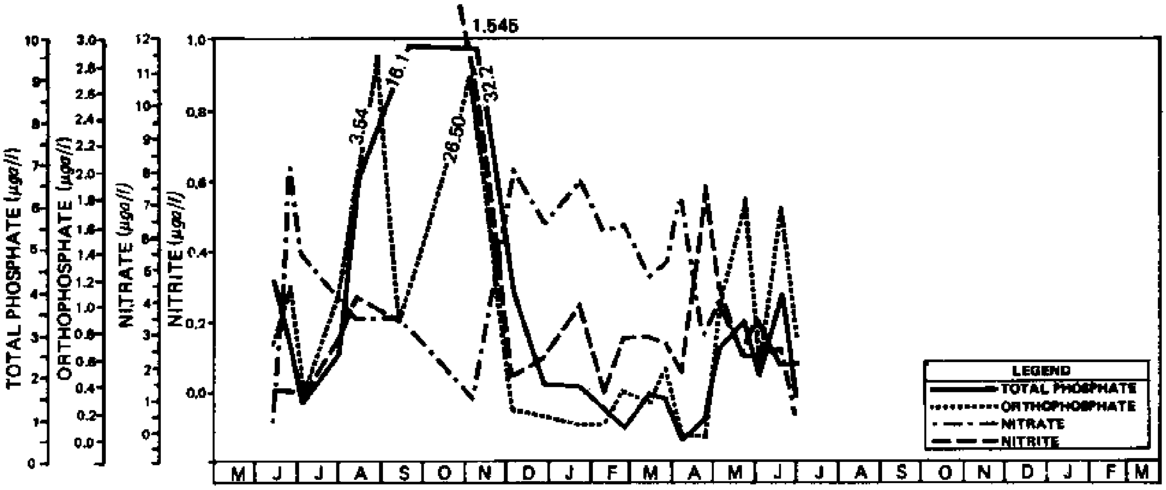

Figure 9. Station 109 Nutrient Trends.

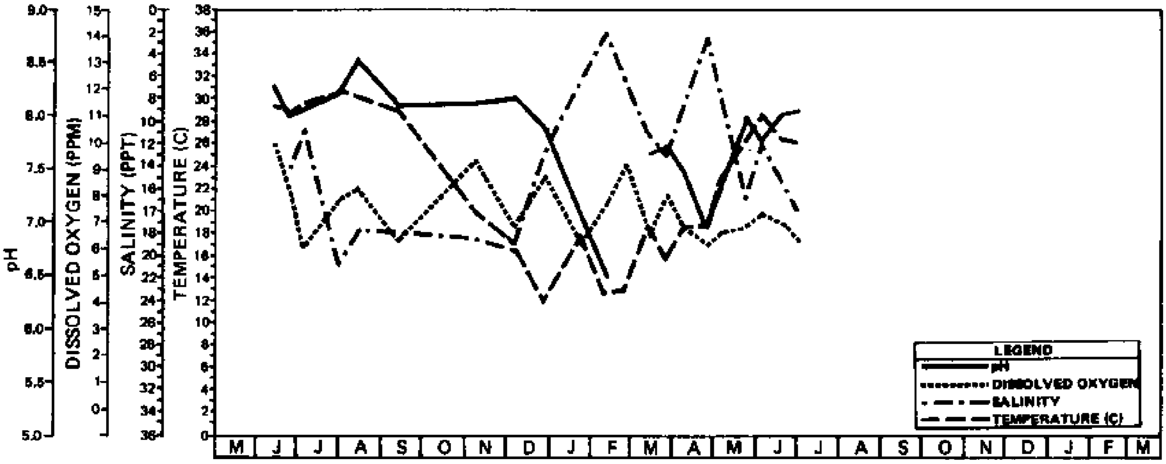

Figure 10. Station 89 Physical-Chemical Trends.

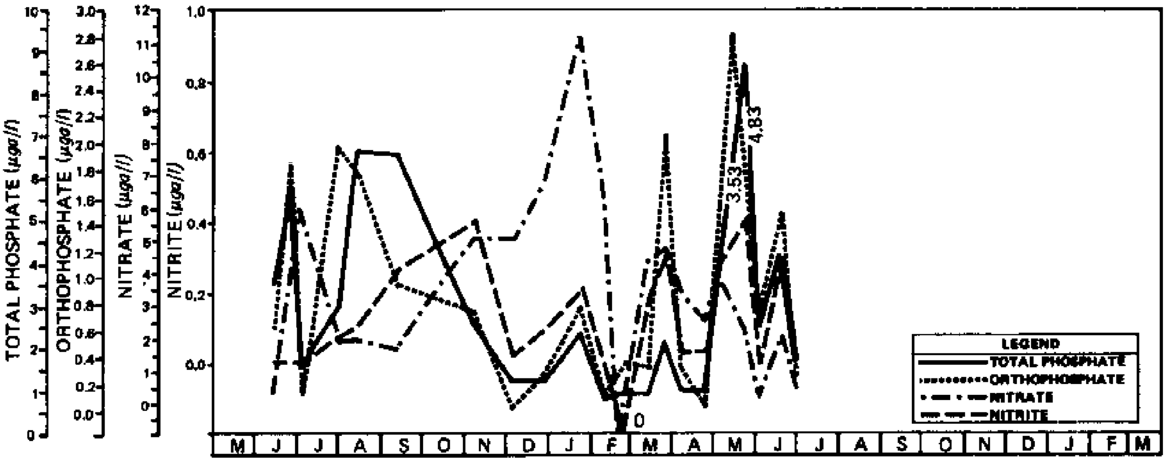

Figure 11. Station 89 Nutrient Trends.

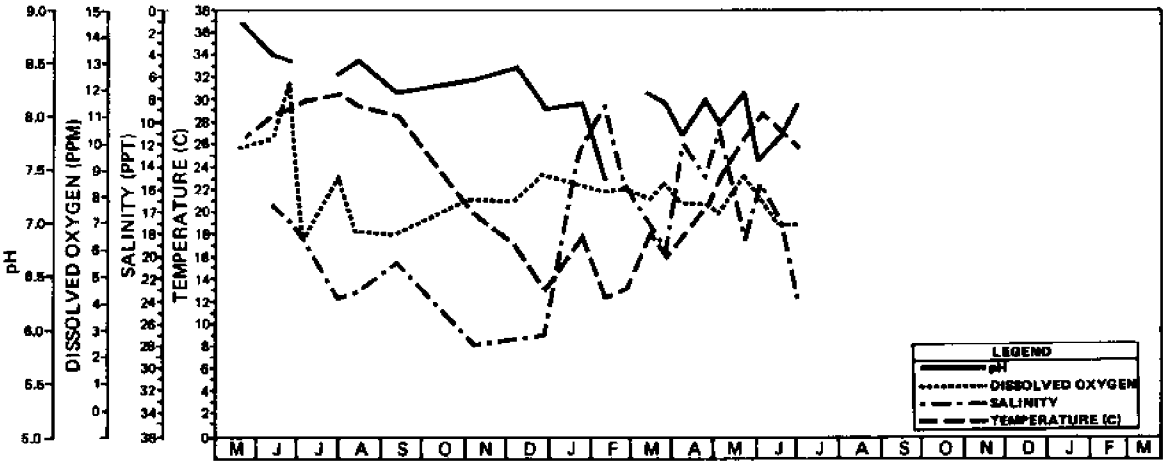

Figure 12. Station 83 Physical-Chemical Trends.

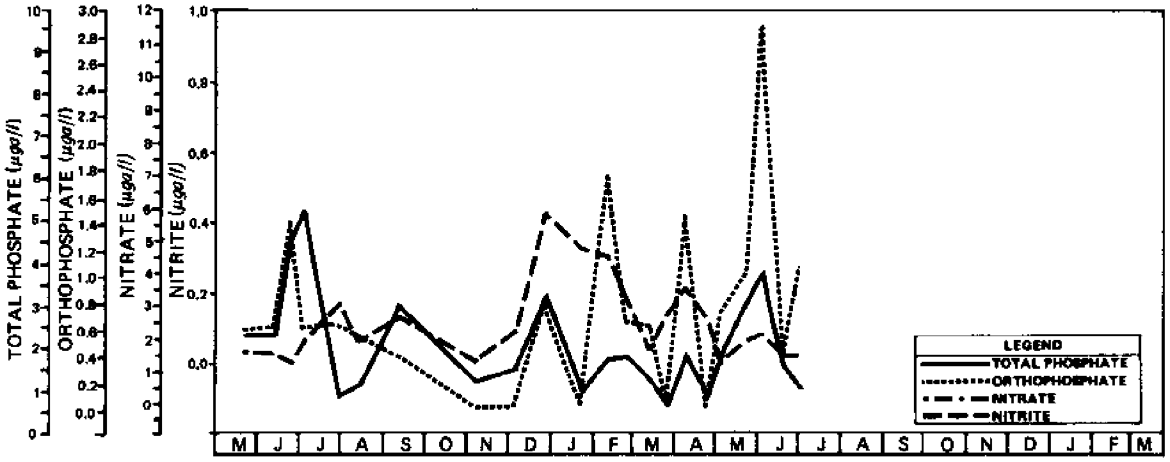

Figure 13. Station 83 Nutrient Trends.

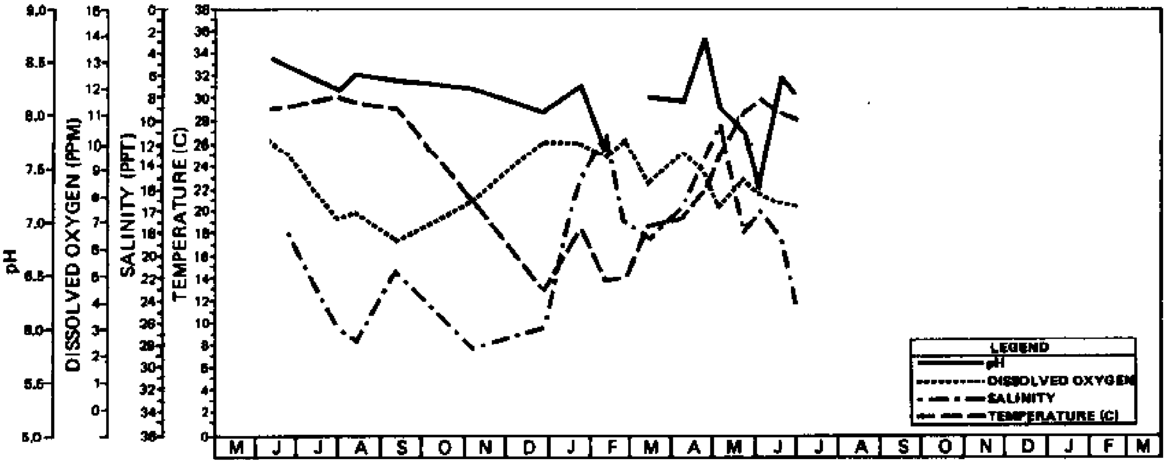

Figure 14. Station 79 Physical-Chemical Trends.

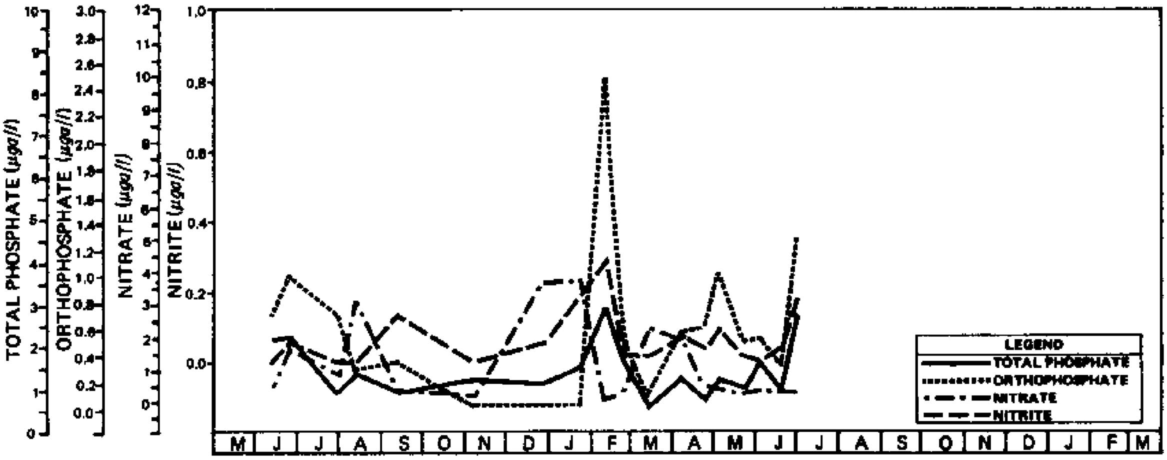

Figure 15. Station 79 Nutrient Trends.

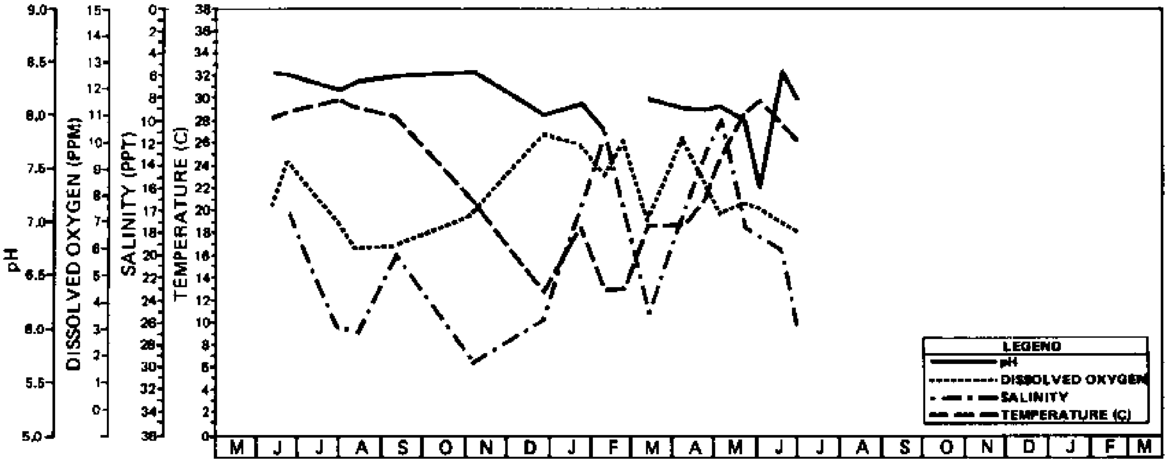

Figure 16. Station 73 Physical-Chemical Trends.

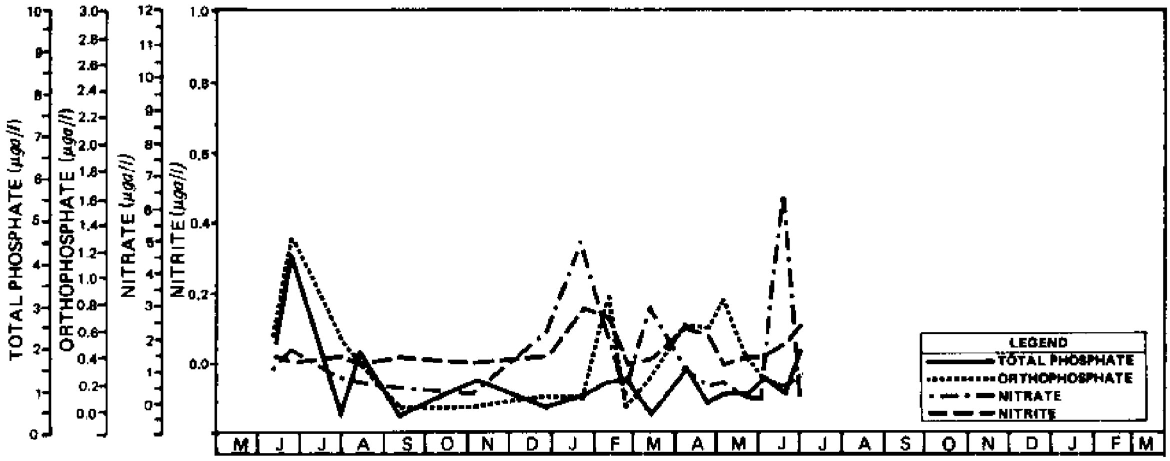

Figure 17. Station 73 Nutrient Trends.

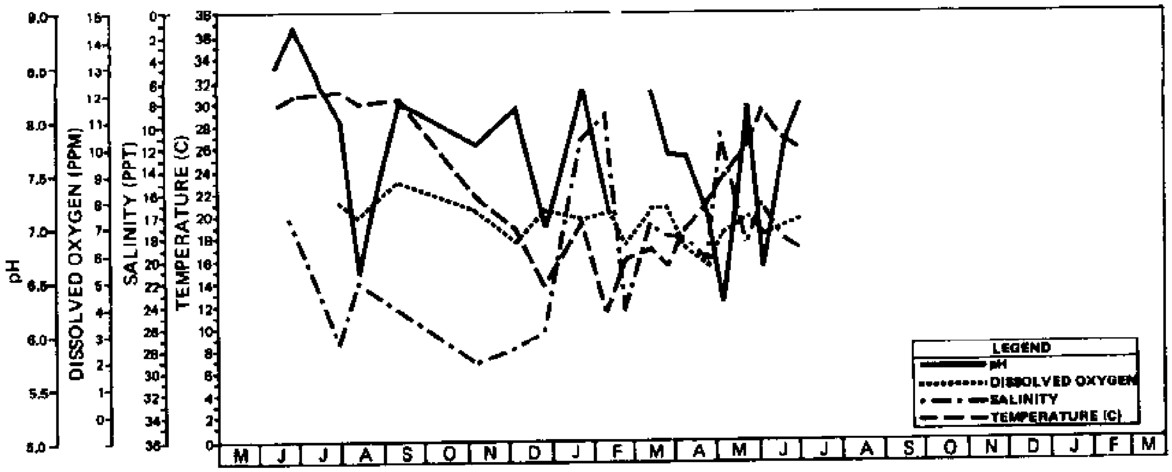

Figure 18. Station 107 Physical-Chemical Trends.

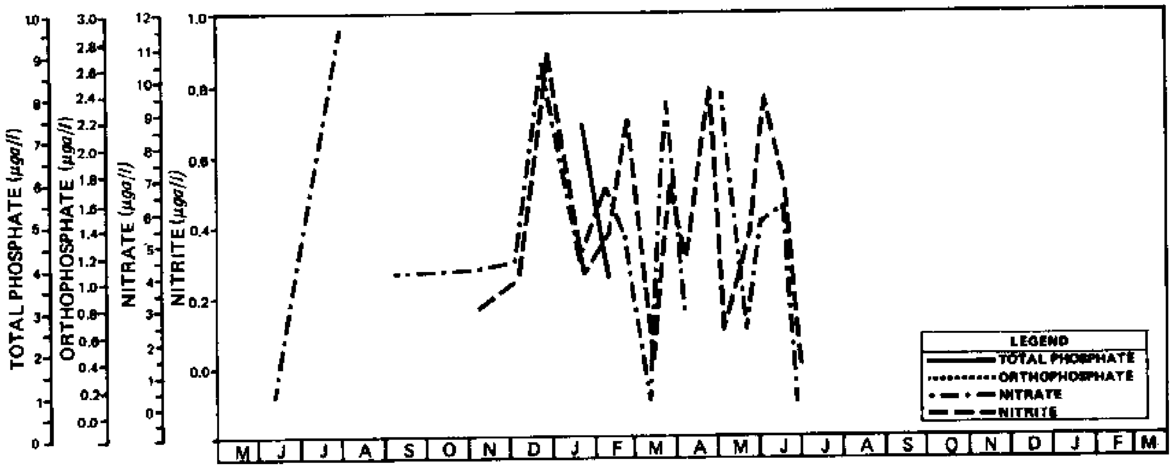

Figure 19. Station 107 Nutrient Trends.

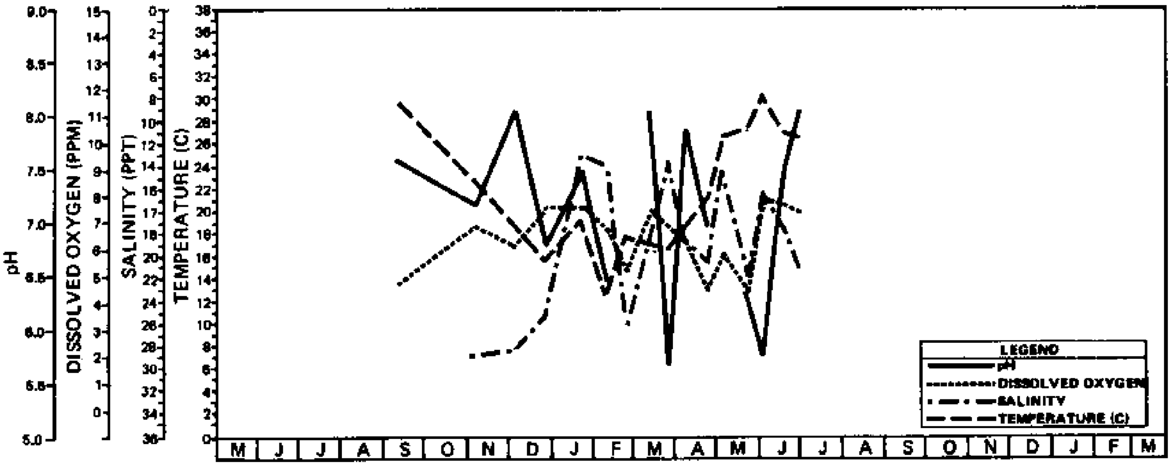

Figure 20. Station 108 Physical-Chemical Trends

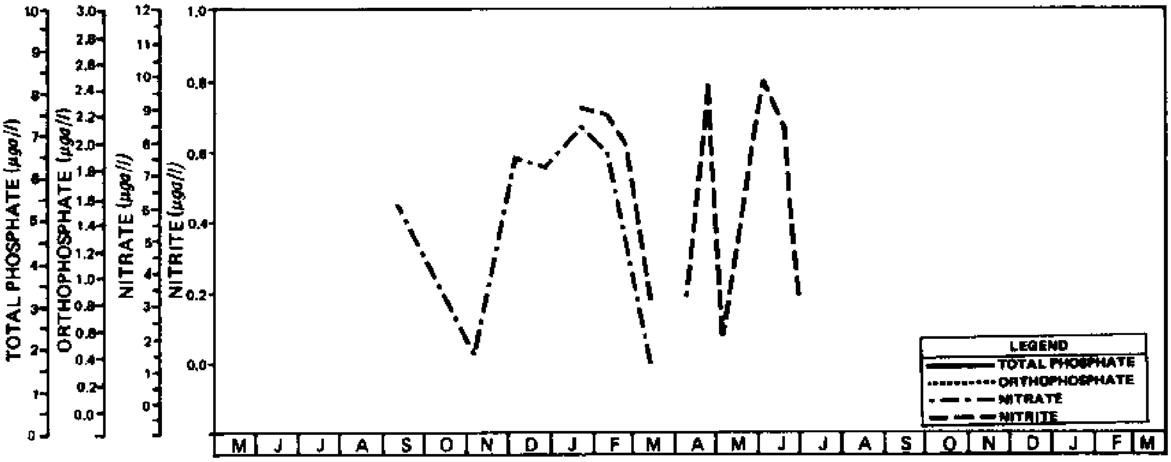

Figure 21. Station 108 Nutrient Trends.

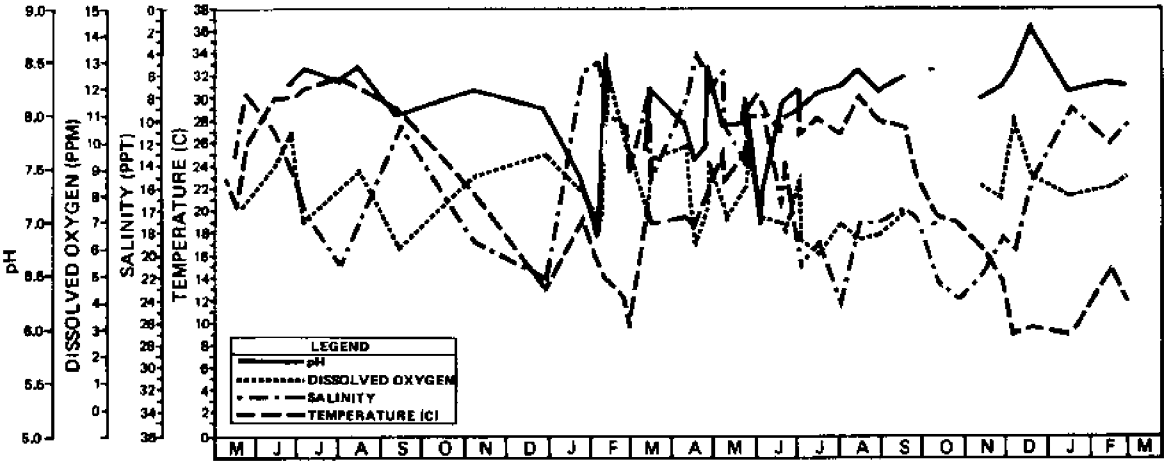

Figure 22. Station 27 Physical-Chemical Trends.

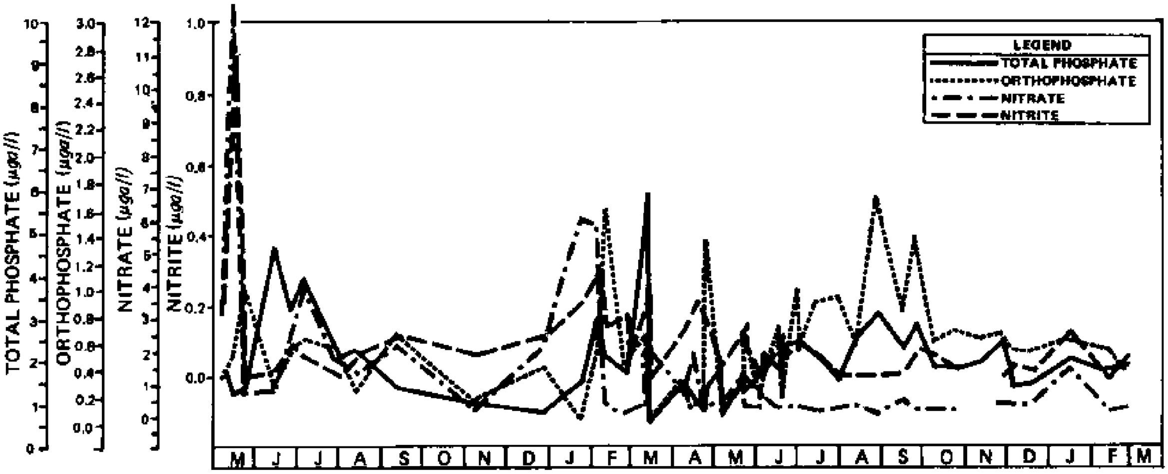

Figure 23. Station 27 Nutrient Trends.

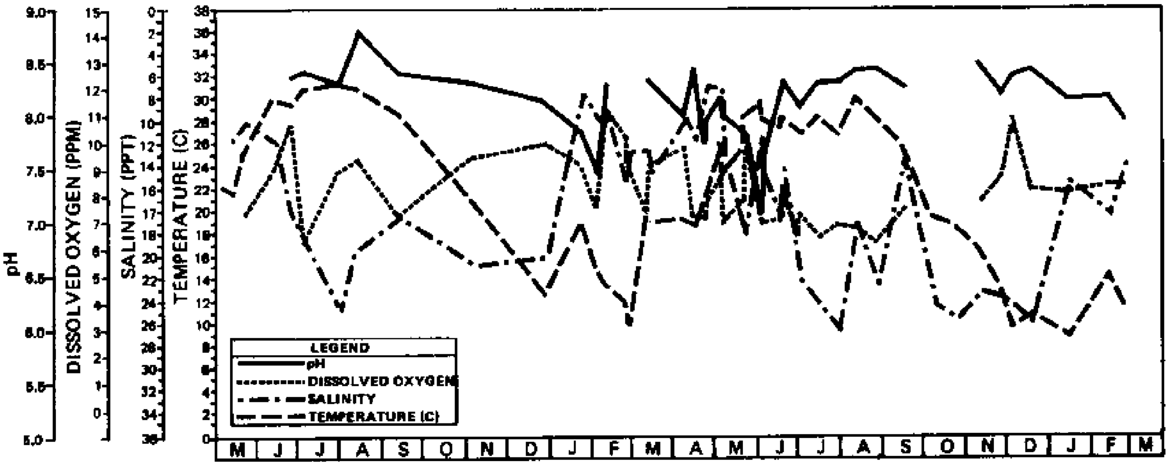

Figure 24. Station 41 Physical-Chemical Trends.

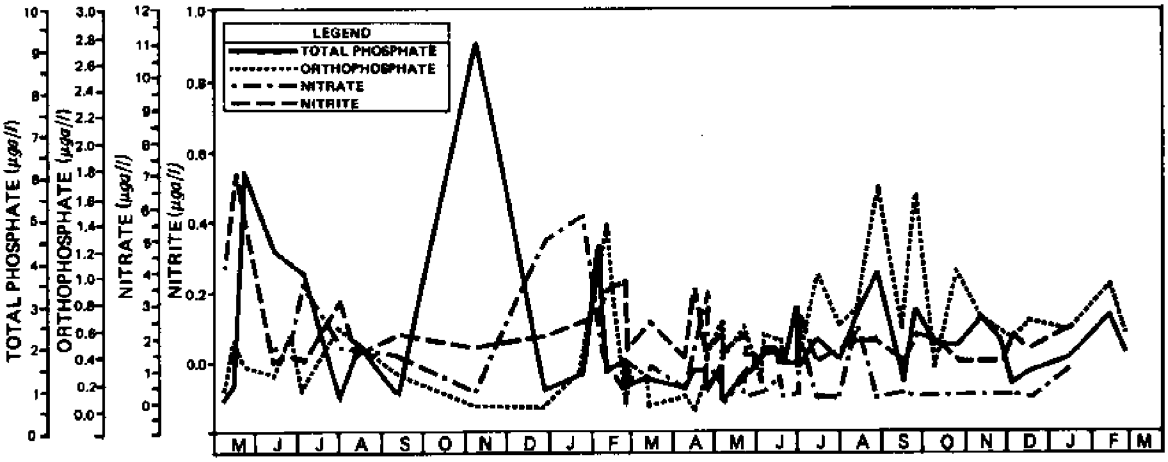

Figure 25. Station 41 Nutrient Trends.

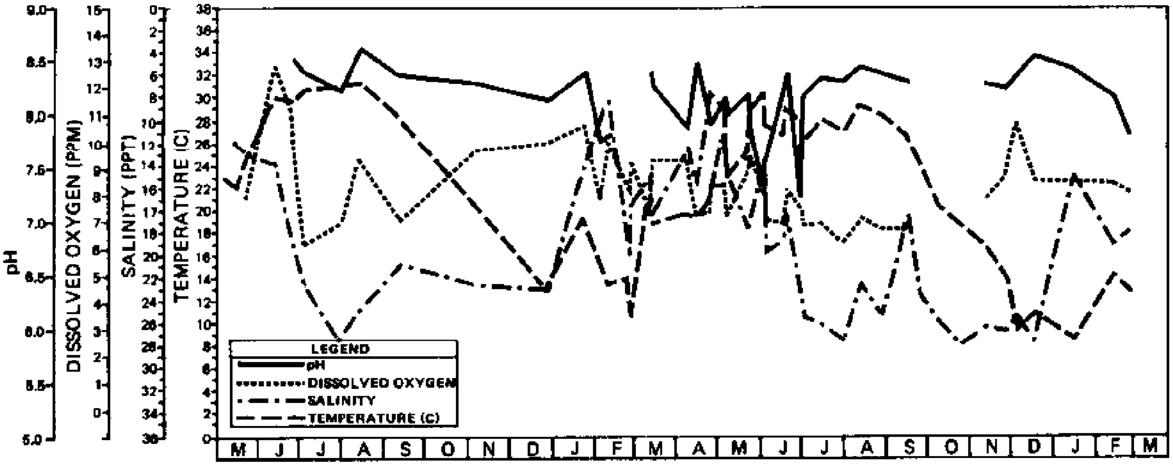

Figure 26. Station 45 Physical-Chemical Trends.

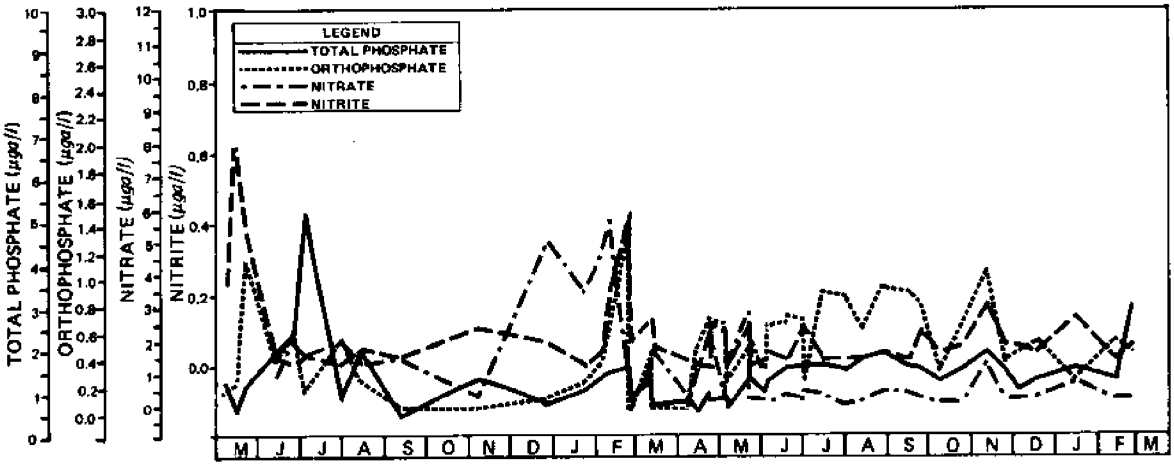

Figure 27. Station 45 Nutrient Trends.

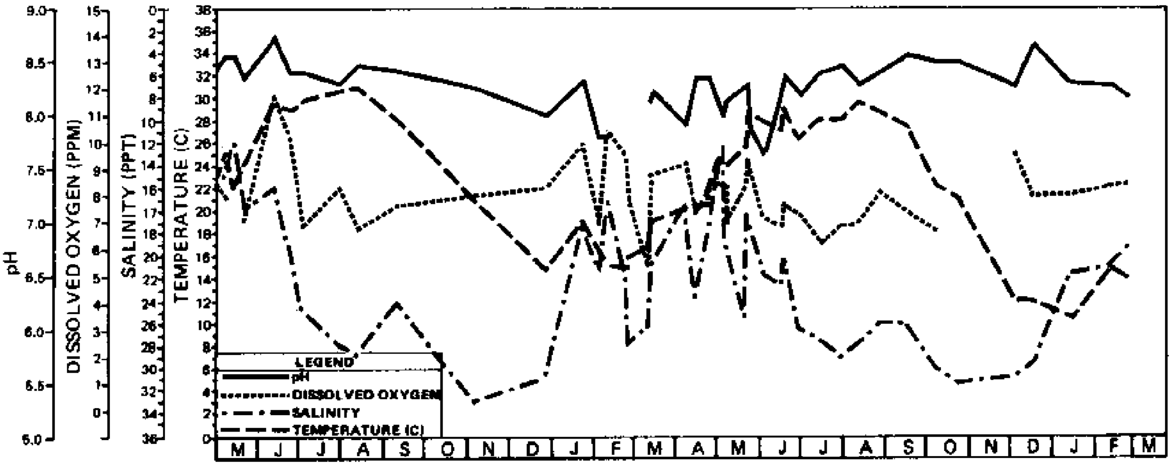

Figure 28. Station 55 Physical-Chemical Trends.

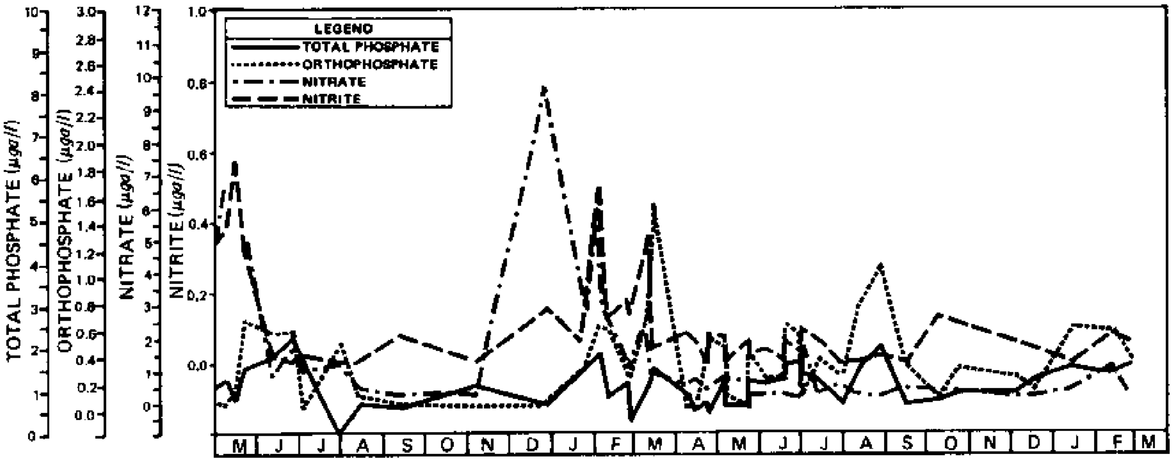

Figure 29. Station 55 Nutrient Trends.

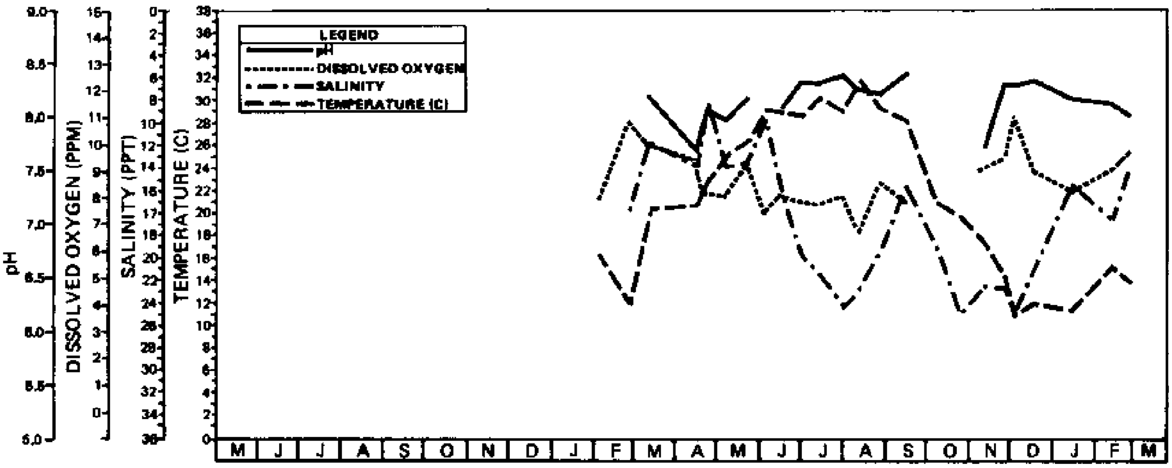

Figure 30. Station 165 Physical-Chemical Trends.

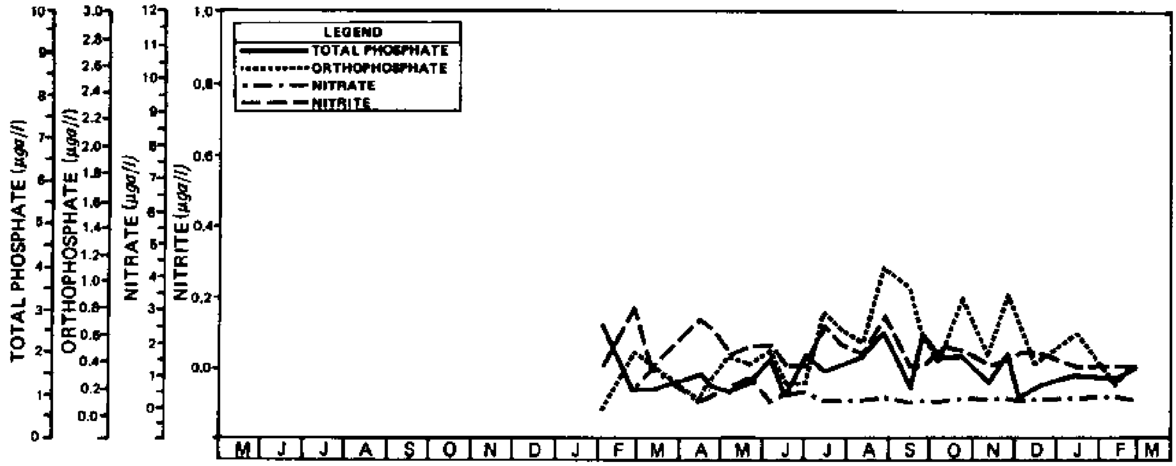

Figure 31. Station 165 Nutrient Trends.

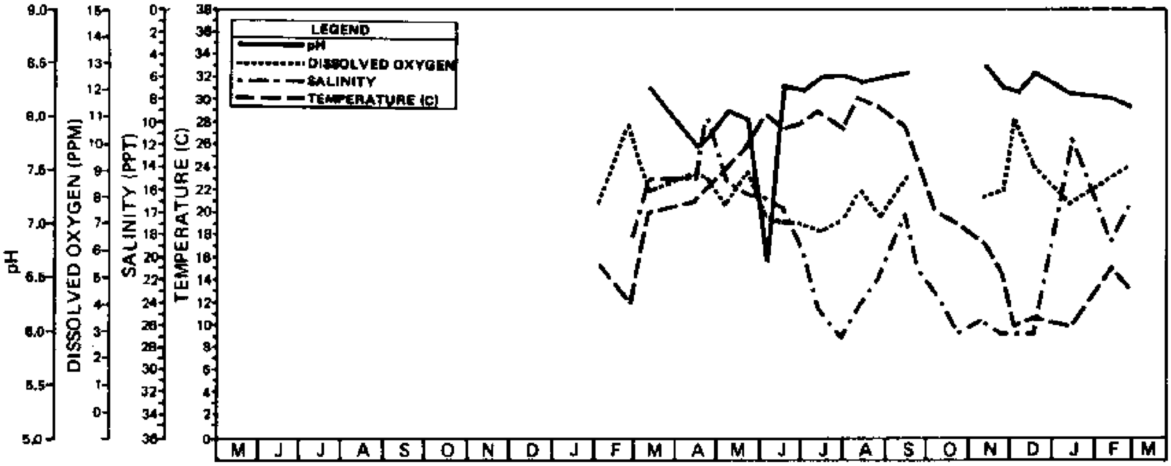

Figure 32. Station 131 Physical-Chemical Trends.

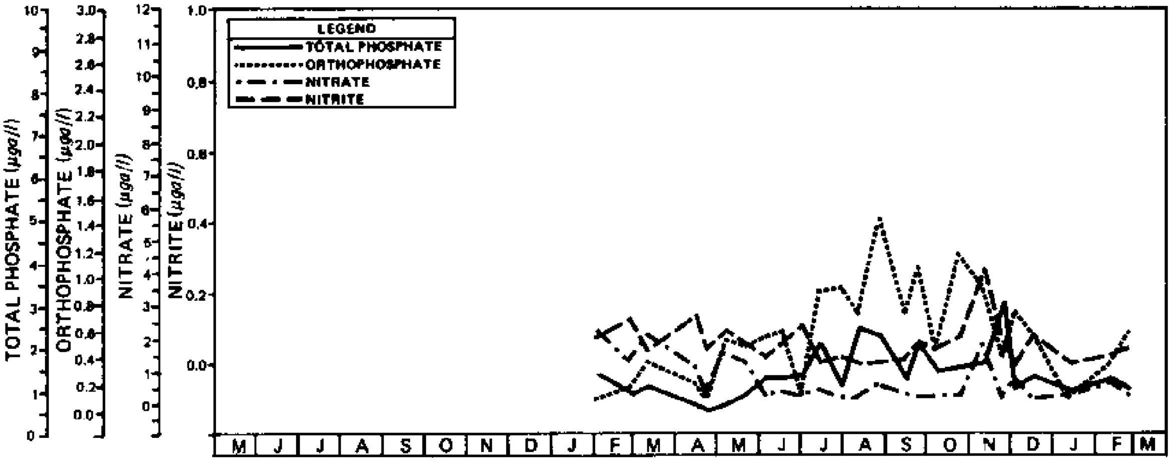

Figure 33. Station 131 Nutrient Trends.

Figure 50. Distribution of Average Levels of Orthophosphate (μga/l).

Figure 51. Distribution of Maximum Levels of Orthophosphate (μga/l).

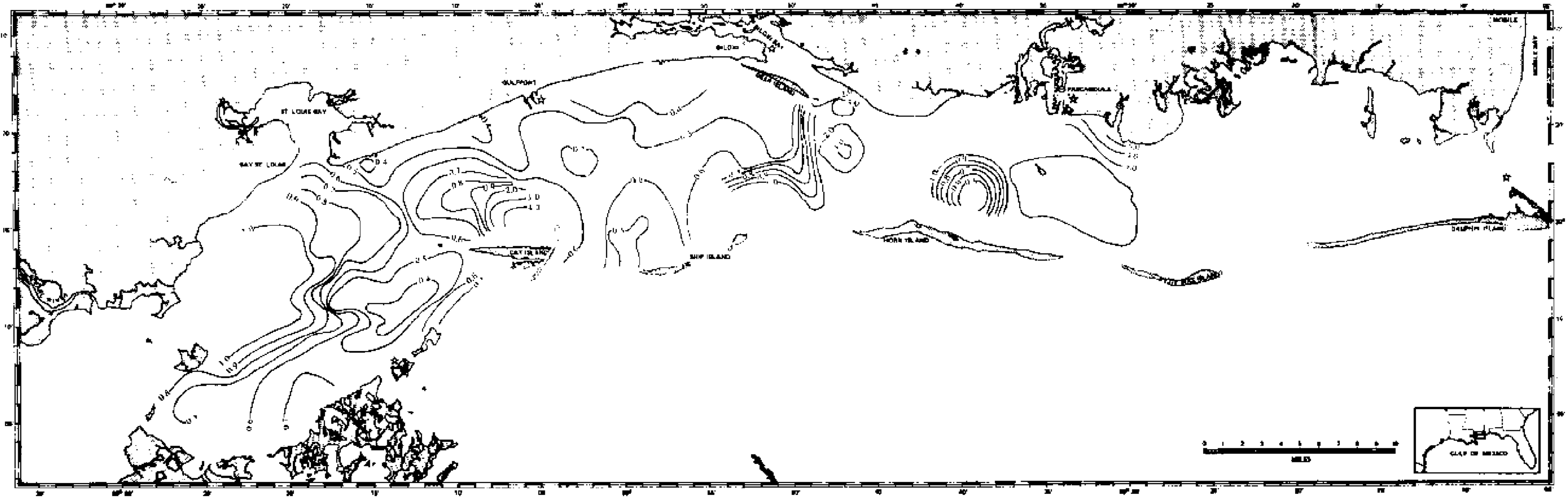

Figure 48. Distribution of Average Levels of Nitrate (μga/l).

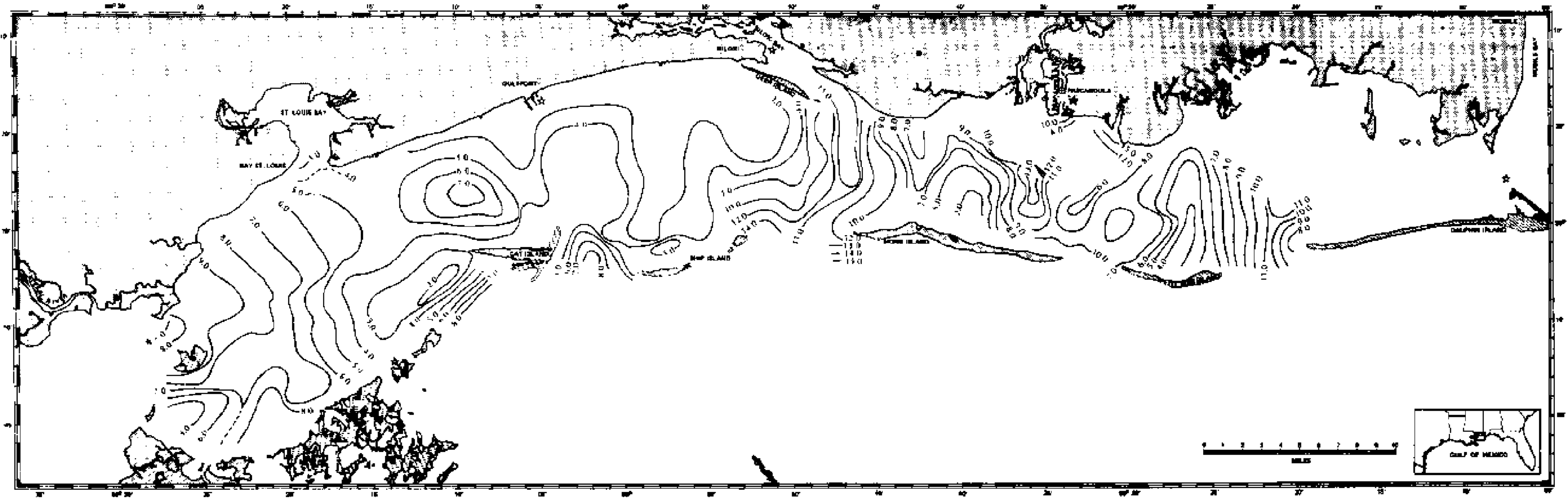

Figure 49. Distribution of Maximum Levels of Nitrate (μga/l).

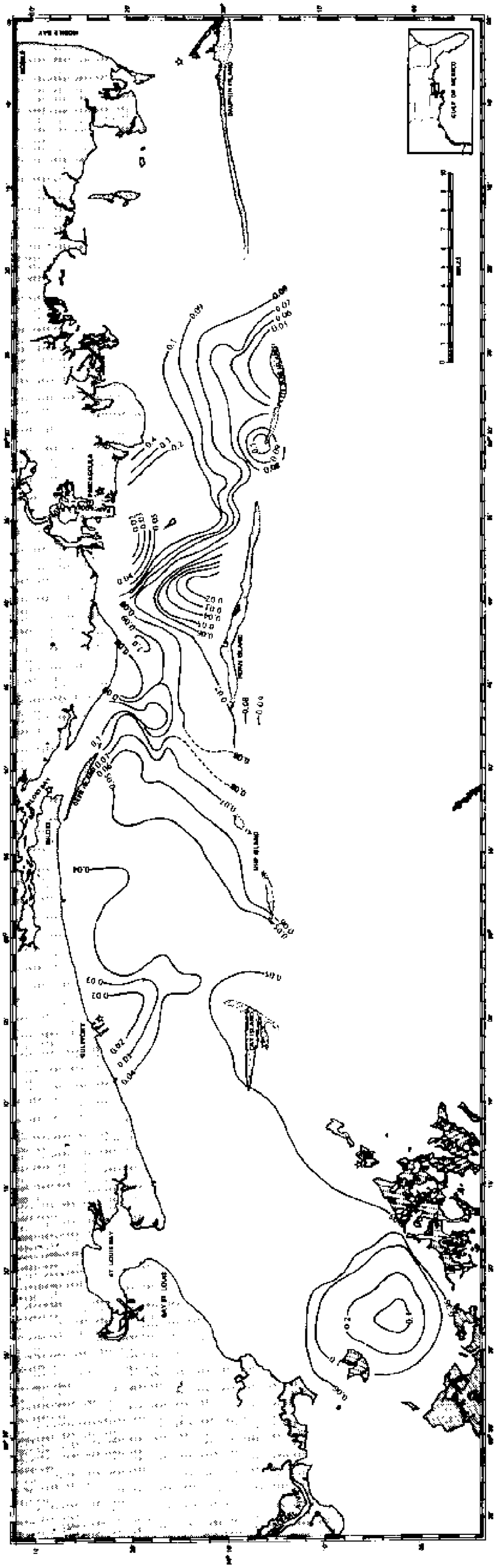

Figure 46. Distribution of Average Levels of Nitrite (μga/l).

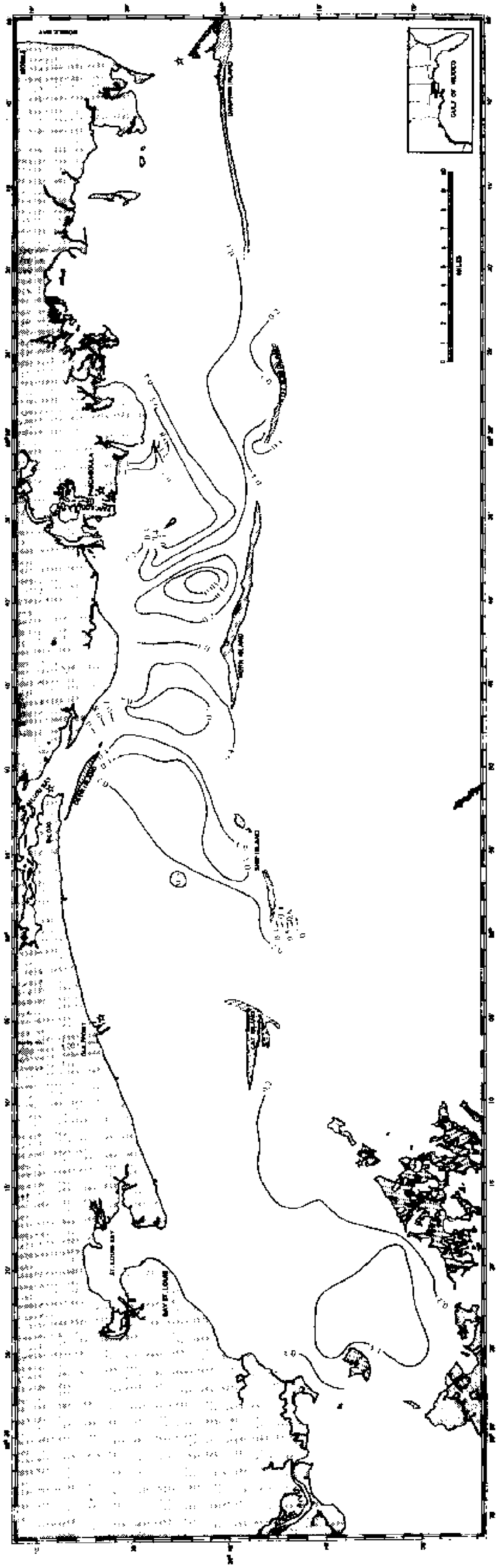

Figure 47. Distribution of Maximum Levels of Nitrite (μga/l).

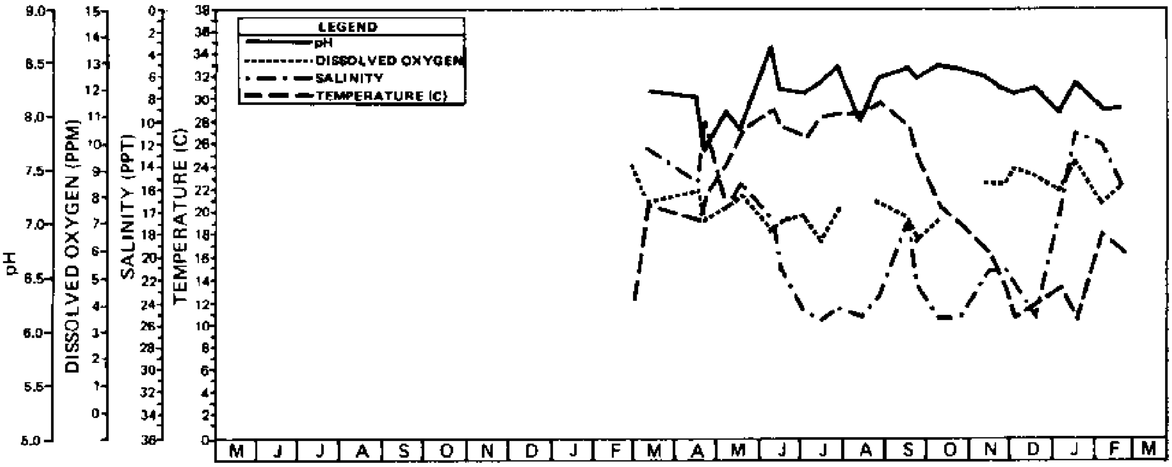

Figure 44. Station 175 Physical-Chemical Trends.

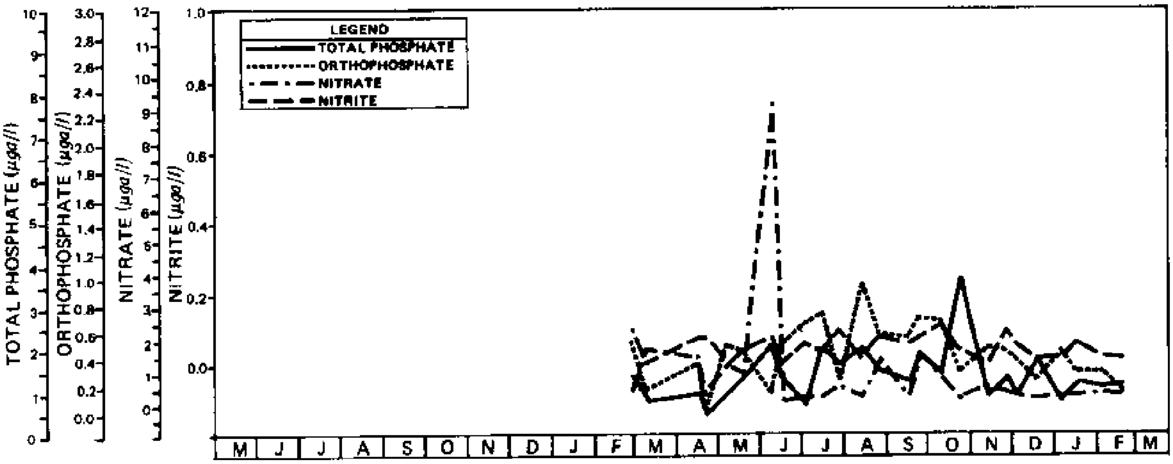

Figure 45. Station 175 Nutrient Trends.

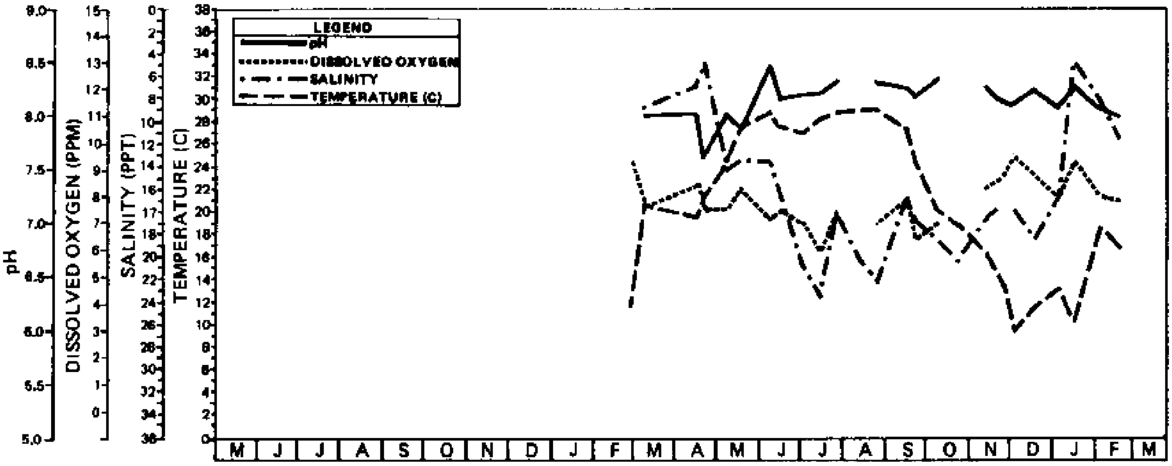

Figure 42. Station 171 Physical-Chemical Trends.

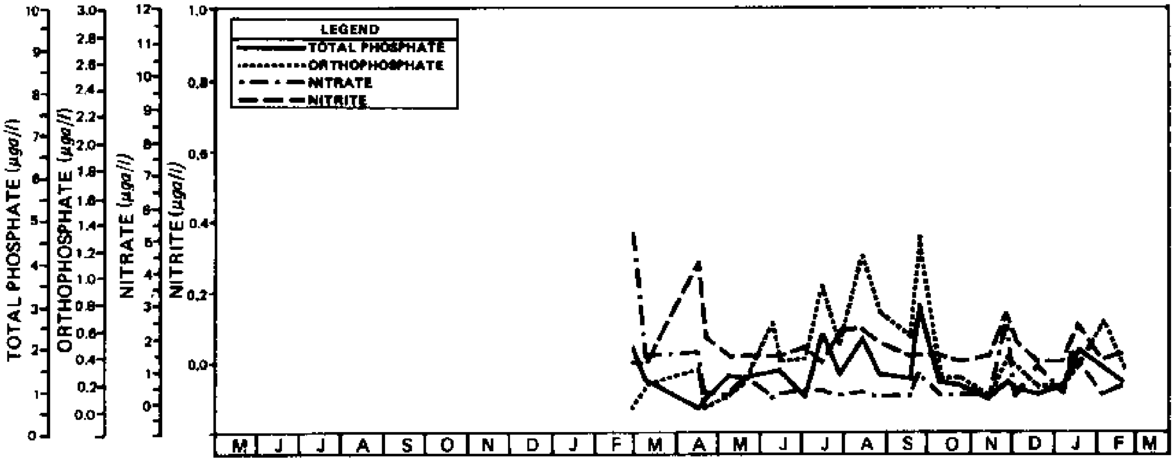

Figure 43. Station 171 Nutrient Trends.

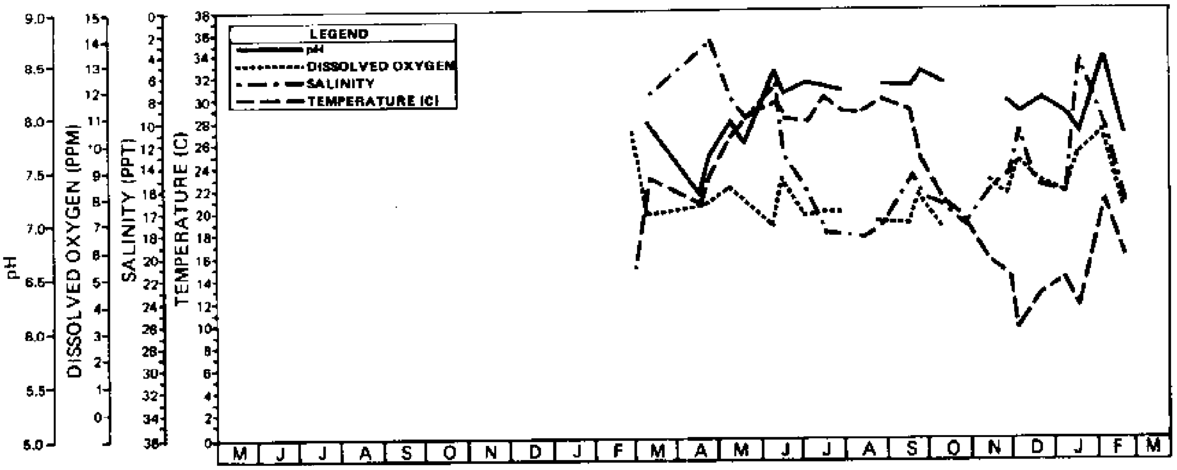

Figure 40. Station 211 Physical-Chemical Trends.

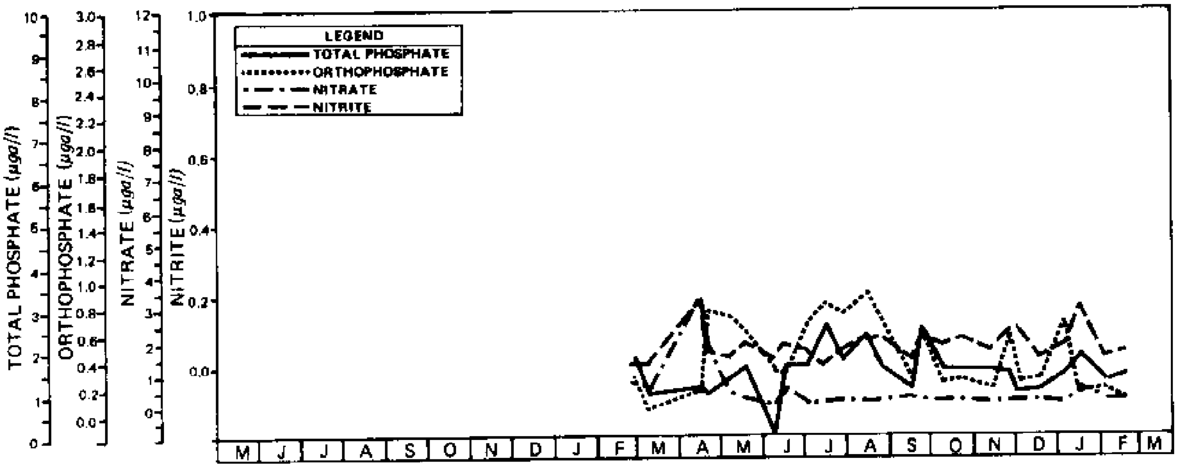

Figure 41. Station 211 Nutrient Trends.

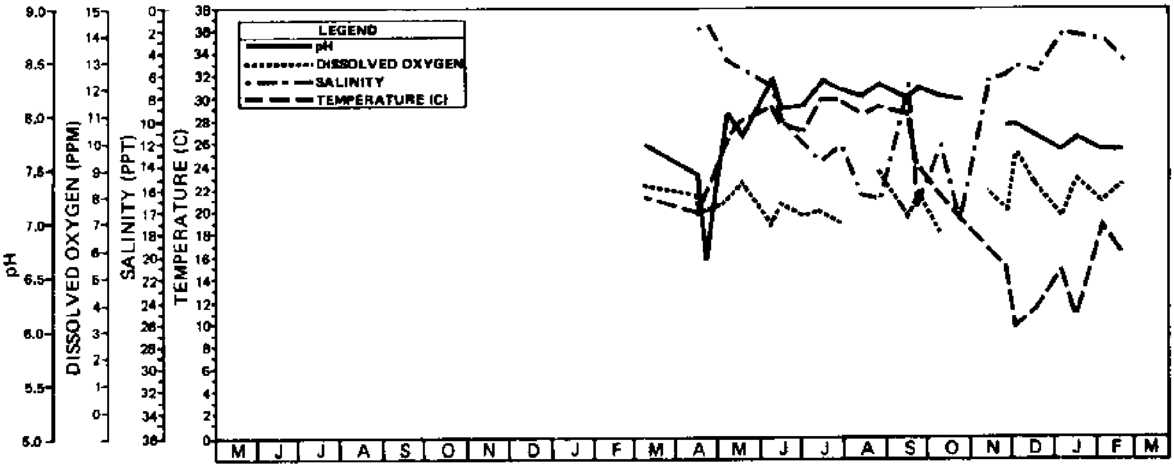

Figure 38. Station 195 Physical-Chemical Trends.

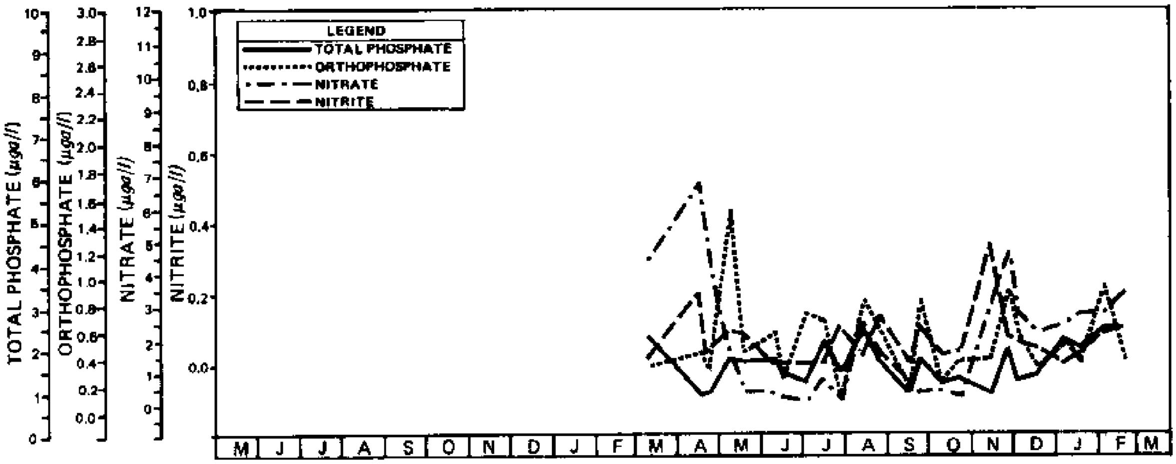

Figure 39. Station 195 Nutrient Trends.

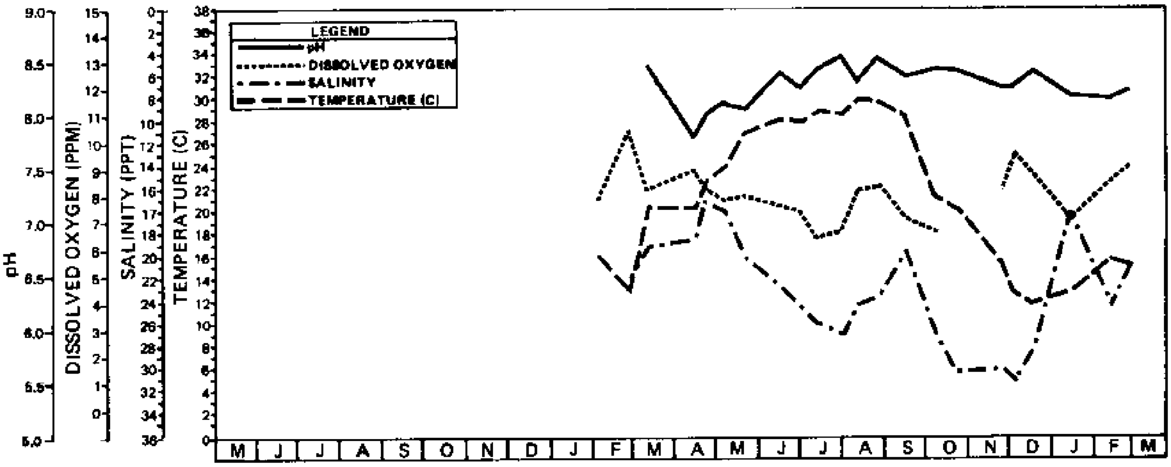

Figure 34. Station 141 Physical-Chemical Trends.

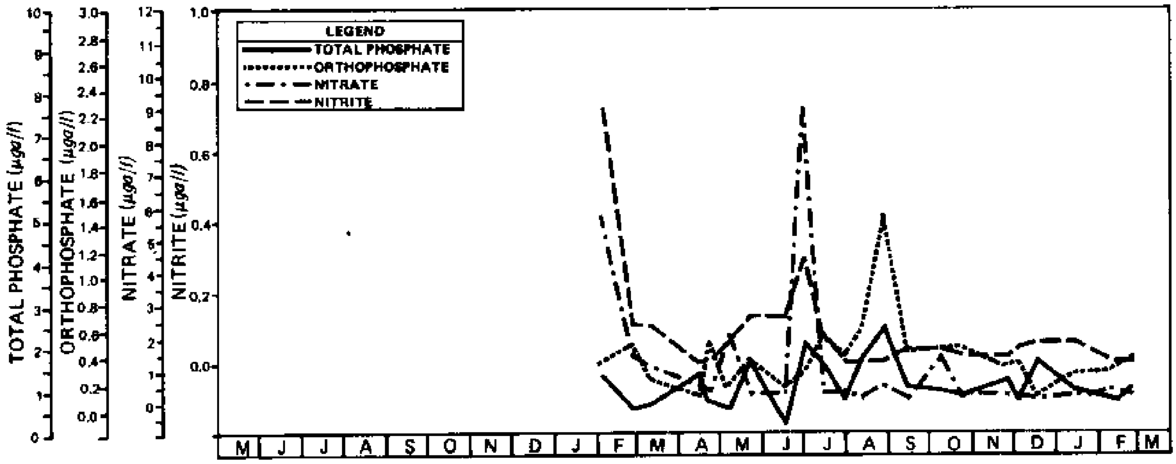

Figure 35. Station 141 Nutrient Trends.

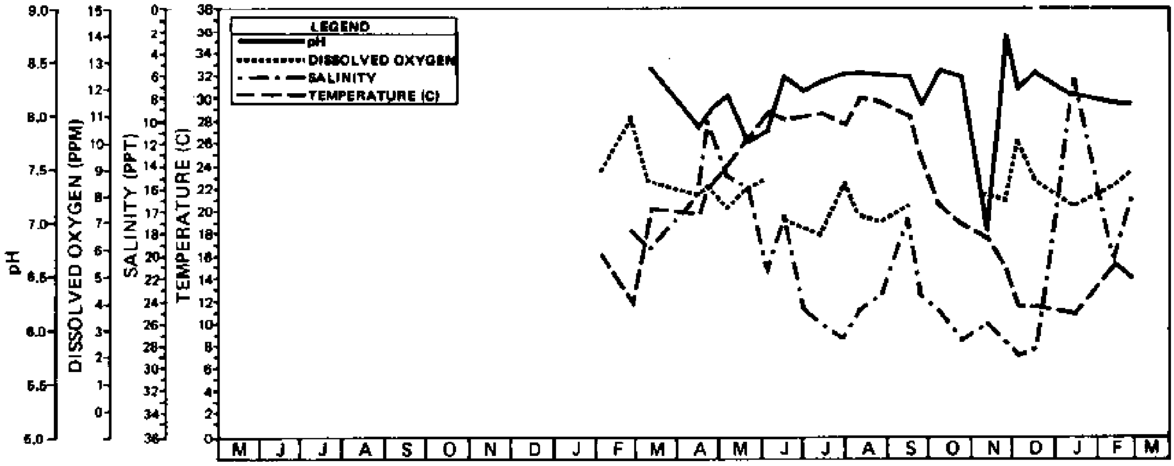

Figure 36. Station 137 Physical-Chemical Trends.

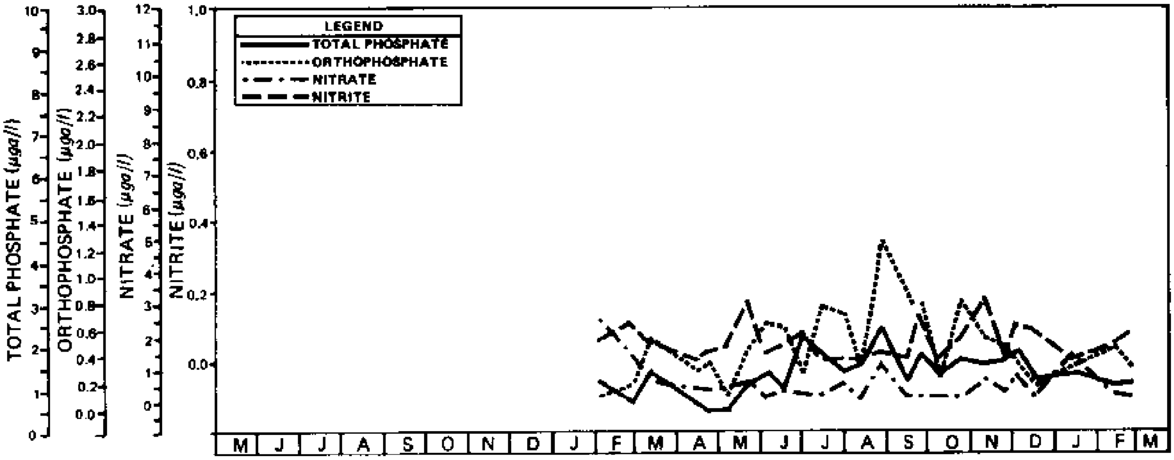

Figure 37. Station 137 Nutrient Trends.

Figure 52. Distribution of Minimum Levels of Total Phosphate (μga/l).

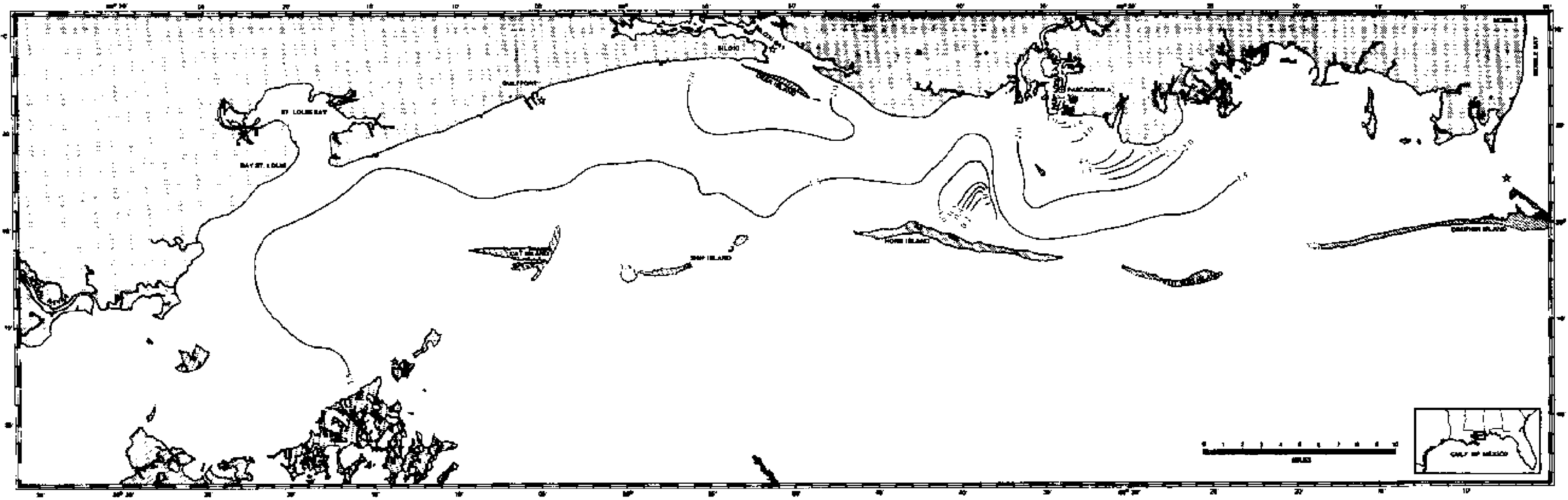

Figure 53. Distribution of Average Levels of Total Phosphate (μga/l).

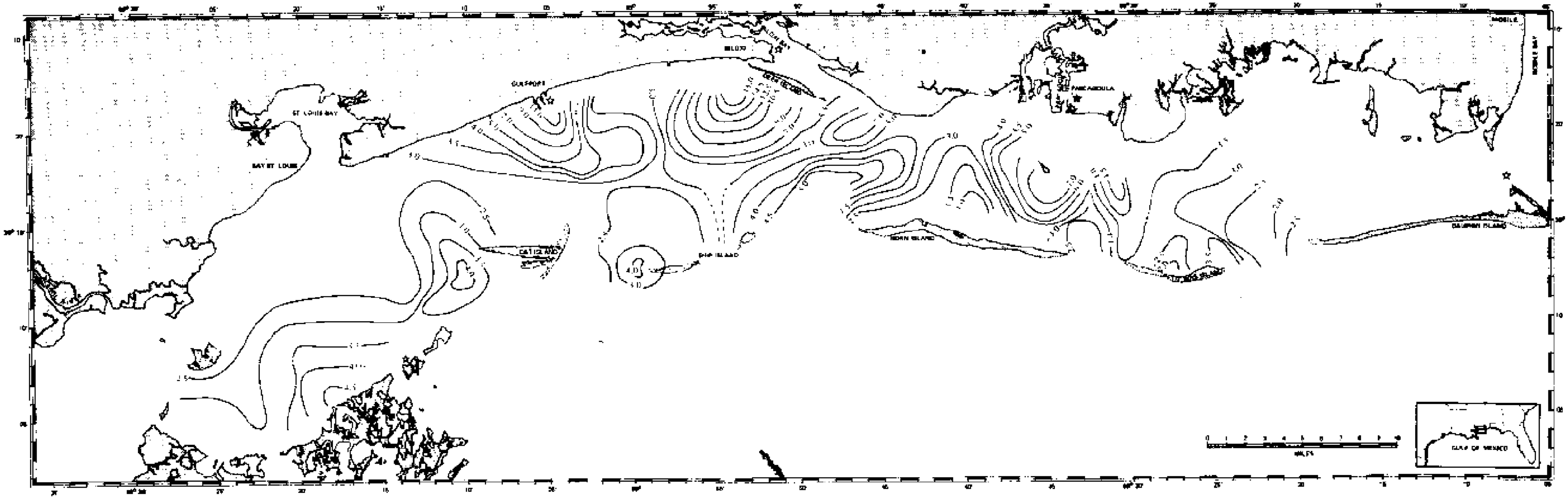

Figure 54. Distribution of Maximum Levels of Total Phosphate (μga/l).

DISCUSSION AND SUMMARY

Referring to nutrient data previously collected in Pascagoula River (Christmas and Eleuterius 1973), the author found that nutrient levels above the Escatawpa River-Pascagoula River confluence were consistently much lower than those in the lower Pascagoula River. The high levels and variability of phosphorus and nitrogen in the lower Pascagoula River reflect the local introduction of effluents.

The apparent inverse relationship between levels of nitrate and phosphorus appears to be limited to the lower Pascagoula River and probably reflects changes in activities in the drainage basin. The levels of all nutrients generally declined seaward to the island passes. Seaward of the island passes, nitrate was found to attain levels exceeding those of Sound waters. Since a paucity of information exists on the chemistry of the near continental shelf waters, the author can offer no explanation.

The waters within and in the vicinity of the Bayou Casotte canal show consistently high levels of phosphorus and nitrate with observed maximum values: total phosphate, 91.380 μga/ℓ; orthophosphate, 67.900 μga/ℓ; nitrate, 57.207 μga/ℓ; nitrite, 3.129 μga/ℓ. As shown, the major portion of the phosphorus is inorganic. An industrial park contiguous to the canal contains several chemical plants that manufacture fertilizer.

A station in outer Biloxi Bay, another source of nutrients, showed the following maximum levels: total phosphate, 19.800 μga/ℓ (bottom water); orthophosphate, 2.030 μga/ℓ (bottom water); nitrate, 12.328 μga/ℓ; nitrite, 0.900 μga/ℓ.

The trends in nutrient levels were less erratic in the area between Ship Island Pass and the area east of Gulfport. The hydrography of this area is predominately influenced by Gulf waters since there is no notable introduction of fresh water in the vicinity.

Station 195, located four miles seaward of Pearl River and in the path of its outflowing waters, expressed relatively low levels of nutrients as indicated by their maximums: total phosphate, 2.490 μga/ℓ; orthophosphate, 1.470 μga/ℓ; nitrate, 6.626 μga/ℓ; nitrite, 0.330 μga/ℓ.

The inorganic phosphate levels decreased westward through the Sound with the average values west of Biloxi not exceeding 0.5 μga/ℓ.

In a general manner, the levels of nutrients declined and became less erratic westward through Mississippi Sound. In addition, with one exception, there existed a seaward decline in the nutrient levels; the exception being that stations seaward of the barrier islands attained higher levels of nitrate than most stations within the Sound.

The primary sources of nutrients in the Sound are Pascagoula River, Bayou Casotte, Biloxi Bay and Pearl River. Pearl River's contribution, indicated here by a single station removed four miles from the mouth, appears to be low. A more direct investigation of the lower Pearl River and the contiguous Lake Borgne waters is needed to clarify its influence on the chemistry of west Mississippi Sound. In order to properly monitor and manage the estuarine waters of Mississippi Sound, a comprehensive study of the Sound's chemistry is necessary. The emphasis in such a study should be with those parameters that are known to have a sizable effect on the biota.

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APPENDIX

Table IV. Statistics on the Levels of Total Phosphate (µga/l) (Continued)

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
109	S	21	4.4700	0.540	32.230	31.690	7.1745
109	B	19	3.8720	1.080	17.230	16.150	4.2240
123	S	12	1.7540	0.730	3.770	3.040	0.8934
125	S	25	2.2350	0.780	7.880	7.100	1.4187
127	S	25	1.6990	0.890	3.560	2.670	0.6677
129	S	25	1.5440	0.770	2.860	2.090	0.5095
131	S	25	1.4460	0.600	3.080	2.480	0.5897
133	S	25	1.3230	0.600	2.730	2.130	0.4577
135	S	25	1.3150	0.570	2.180	1.610	0.3676
137	S	25	1.3490	0.510	2.390	1.879	0.4782
137	B	25	2.4300	0.730	6.840	6.110	1.6351
139	S	25	1.5000	0.530	4.670	4.140	0.8518
139	B	24	1.7070	0.470	3.420	2.950	0.6910
141	S	22	1.1620	0.270	2.450	2.180	0.5362
141	B	22	2.8220	0.910	12.590	11.680	2.4964
143	S	25	1.2360	0.670	2.020	1.350	0.3812
145	S	25	1.4680	0.910	5.930	5.020	1.0109
147	S	25	1.3630	0.420	3.320	2.900	0.5921
149	S	25	1.3350	0.660	2.090	1.430	0.3885
149	B	25	5.6070	0.930	30.150	29.220	6.7076
151	S	25	1.5490	0.270	4.190	3.919	0.8050
151	B	25	8.2650	0.530	38.660	38.130	10.7277
153	S	25	1.5410	0.650	3.000	2.350	0.6460
155	S	25	1.3570	0.650	2.000	1.350	0.3607
157	S	50	1.3360	0.070	2.630	2.560	0.4701
159	S	50	1.5170	0.550	2.430	1.880	0.4732
161	S	50	1.6370	0.410	3.880	3.470	0.6479
163	S	25	1.9850	0.370	11.000	10.630	1.9730
163	B	25	5.9370	1.250	25.880	24.630	6.5969
165	S	25	1.6070	1.000	2.600	1.600	0.4625
167	S	25	1.6090	0.650	2.720	2.070	0.4825
169	S	24	2.3890	0.880	17.320	16.440	3.2261
169	B	25	0.0000	0.000	0.000	0.000	0.0000
171	S	25	1.3340	0.550	2.930	2.380	0.5351
173	S	25	1.3340	0.680	4.230	3.549	0.6949
175	S	25	1.3810	0.510	3.600	3.090	0.6302
177	S	25	1.2880	0.820	2.150	1.330	0.3447
179	S	25	1.2740	0.550	2.310	1.760	0.4301
181	S	25	1.4030	0.640	3.150	2.510	0.5880
183	S	25	1.5530	0.750	3.690	2.940	0.7474
185	S	25	1.5670	0.750	4.690	3.939	0.8233
187	S	25	1.5710	0.820	3.080	2.260	0.5987
189	S	25	1.4400	0.570	2.850	2.280	0.5081
191	S	24	1.5840	0.920	3.440	2.520	0.5667
193	S	24	1.3940	0.640	2.310	1.670	0.4297
195	S	24	1.6720	0.950	2.490	1.540	0.5096
197	S	25	1.6610	0.950	2.920	1.970	0.5190
199	S	25	1.5080	0.890	2.620	1.730	0.4425
201	S	25	1.5750	0.900	2.530	1.630	0.4337
203	S	25	1.3300	0.600	2.710	2.110	0.4960
205	S	25	1.5460	0.510	2.550	2.040	0.5455
207	S	25	1.4530	0.920	2.500	1.580	0.4140
209	S	25	1.4380	0.830	2.460	1.630	0.4038
211	S	25	1.5140	0.050	2.590	2.540	0.5196

Table I. Statistics on the Levels of Nitrite-Nitrogen (μga/l).

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
27	B	47	0.0960	0.000	0.900	0.900	0.1399
27	B	40	0.0540	0.000	0.364	0.364	0.0951
39	S	22	0.1420	0.000	0.717	0.717	0.1910
39	B	15	0.0130	0.000	0.202	0.202	0.0521
41	S	46	0.0820	0.000	0.525	0.525	0.1061
41	B	40	0.0550	0.000	0.550	0.550	0.1038
43	S	22	0.1170	0.000	0.550	0.550	0.1565
43	B	15	0.0030	0.000	0.055	0.055	0.0142
45	S	47	0.0810	0.000	0.600	0.600	0.1174
45	B	40	0.0670	0.000	0.513	0.513	0.1020
47	S	32	0.0740	0.000	0.375	0.375	0.1016
49	S	34	0.0880	0.000	0.375	0.375	0.0911
51	S	44	0.0650	0.000	0.410	0.410	0.0954
53	S	48	0.0680	0.000	0.425	0.425	0.0948
53	B	40	0.0930	0.000	0.619	0.619	0.1604
55	S	44	0.0950	0.000	0.575	0.575	0.1315
55	B	36	0.2940	0.000	4.216	4.216	0.7338
57	S	19	0.0710	0.000	0.282	0.282	0.0767
59	S	20	0.0510	0.000	0.256	0.256	0.0687
61	S	19	0.0610	0.000	0.256	0.256	0.0746
63	S	19	0.0560	0.000	0.333	0.333	0.0773
65	S	19	0.0750	0.000	0.403	0.403	0.1035
67	S	18	0.0750	0.000	0.431	0.431	0.1081
67	B	16	0.5120	0.020	3.115	3.095	0.7208
69	S	20	0.1120	0.000	0.558	0.558	0.1656
69	B	17	0.5440	0.000	2.942	2.942	0.6672
71	S	21	0.0640	0.000	0.231	0.231	0.0747
71	B	18	0.5470	0.020	3.289	3.269	0.7370
72	S	16	0.0460	0.000	0.222	0.222	0.0590
72	B	15	0.0040	0.000	0.071	0.071	0.0183
73	S	18	0.0410	0.000	0.154	0.154	0.0489
75	S	18	0.0820	0.000	0.250	0.250	0.0817
77	S	18	0.0760	0.000	0.288	0.288	0.0867
79	S	18	0.0650	0.000	0.291	0.291	0.0819
80	S	11	0.1030	0.000	0.430	0.430	0.1178
81	S	22	0.0910	0.000	0.252	0.252	0.0781
81	B	18	0.2040	0.000	0.914	0.914	0.2271
83	S	22	0.1100	0.000	0.414	0.414	0.1144
83	B	19	0.4820	0.000	2.206	2.206	0.4790
85	S	22	0.1540	0.000	0.752	0.752	0.1637
85	B	19	0.5620	0.000	2.748	2.748	0.6367
87	S	22	0.1340	0.000	0.673	0.673	0.1506
87	B	19	0.3990	0.000	1.243	1.243	0.3482
89	S	20	0.1330	0.000	0.404	0.404	0.1428
89	B	19	0.6730	0.000	4.272	4.272	0.9693
91	S	19	0.1430	0.000	0.614	0.614	0.1701
93	S	18	0.0510	0.000	0.168	0.168	0.0558
95	S	19	0.1020	0.000	0.462	0.462	0.1256
97	S	18	0.0070	0.000	0.187	0.187	0.0670
99	S	18	0.0650	0.000	0.161	0.161	0.0575
101	S	19	0.1010	0.000	0.308	0.308	0.1089
103	S	18	0.0780	0.000	0.280	0.280	0.0794
105	S	18	0.0800	0.000	0.336	0.336	0.1132
107	S	20	0.4900	0.000	1.853	1.853	0.4607
107	B	17	0.5300	0.041	2.449	2.408	0.5628
108	S	17	0.8350	0.074	3.129	3.055	0.7410
108	B	16	0.4870	0.000	1.682	1.682	0.4160

Table I. Statistics on the Levels of Nitrite-Nitrogen (μga/l). (Continued)

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
109	S	21	0.0206	0.000	1.545	1.545	0.3343
109	B	19	0.5520	0.000	1.827	1.827	0.4959
123	S	12	0.1060	0.000	0.336	0.336	0.1368
125	S	25	0.0510	0.000	0.214	0.214	0.0499
127	S	25	0.0630	0.000	0.250	0.250	0.0691
129	S	25	0.0470	0.000	0.226	0.226	0.0545
131	S	25	0.0550	0.000	0.259	0.259	0.0574
133	S	25	0.0630	0.000	0.434	0.434	0.0900
135	S	25	0.0620	0.000	0.189	0.189	0.0539
137	S	25	0.0480	0.000	0.167	0.167	0.0498
137	B	25	0.2370	0.000	1.208	1.208	0.3223
139	S	25	0.0470	0.000	0.226	0.226	0.0574
139	B	23	0.3510	0.035	1.416	1.381	0.4031
141	S	22	0.0830	0.000	0.710	0.710	0.1550
141	B	22	0.3920	0.000	1.310	1.310	0.3990
143	S	25	0.0540	0.000	0.167	0.167	0.0463
145	S	25	0.0390	0.000	0.132	0.132	0.0418
147	S	25	0.0450	0.000	0.224	0.224	0.0526
149	S	25	0.0510	0.000	0.206	0.206	0.0520
149	B	25	0.1990	0.000	0.933	0.933	0.2387
151	S	25	0.0330	0.000	0.131	0.131	0.0359
151	B	25	0.1290	0.000	0.561	0.561	0.1511
153	S	25	0.0580	0.000	0.248	0.248	0.0570
155	S	25	0.0540	0.000	0.255	0.255	0.0652
157	S	50	0.0610	0.000	0.283	0.283	0.0661
159	S	50	0.0580	0.000	0.230	0.230	0.0498
161	S	50	0.0480	0.000	0.283	0.283	0.0591
163	S	25	0.0044	0.000	0.275	0.275	0.0636
163	B	25	0.1970	0.000	2.734	2.734	0.5435
165	S	25	0.0430	0.000	0.161	0.161	0.0502
167	S	25	0.0350	0.000	0.111	0.111	0.0354
169	S	24	0.0450	0.000	0.151	0.151	0.0431
171	S	25	0.0430	0.000	0.283	0.283	0.0621
173	S	25	0.0420	0.000	0.159	0.159	0.0401
175	S	25	0.0470	0.000	0.108	0.108	0.0332
177	S	25	0.0430	0.000	0.124	0.124	0.0352
179	S	25	0.0600	0.000	0.195	0.195	0.0508
181	S	25	0.0460	0.000	0.159	0.159	0.0464
183	S	25	0.0450	0.000	0.159	0.159	0.0390
185	S	25	0.0530	0.000	0.177	0.177	0.0454
187	S	24	0.0430	0.000	0.212	0.212	0.0493
189	S	25	0.3680	0.000	8.000	8.000	1.5905
191	S	24	0.0490	0.000	0.168	0.168	0.0488
193	S	24	0.0540	0.000	0.248	0.248	0.0583
195	S	24	0.0610	0.000	0.330	0.330	0.0750
197	S	25	0.0560	0.000	0.212	0.212	0.0561
199	S	25	0.0550	0.000	0.301	0.301	0.0626
201	S	24	0.0460	0.000	0.212	0.212	0.0493
203	S	25	0.0560	0.000	0.170	0.170	0.0493
205	S	25	0.0490	0.000	0.230	0.230	0.0514
207	S	25	0.0610	0.000	0.195	0.195	0.0505
209	S	25	0.0490	0.000	0.177	0.177	0.0512
211	S	25	0.0520	0.000	0.177	0.177	0.0441

Table II. Statistics on the Levels of Nitrate-Nitrogen (μga/l).

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
27	S	47	0.1770	0.022	12.328	12.306	2.1435
27	B	40	0.7780	0.000	6.746	6.746	1.4176
39	S	22	3.5420	0.107	23.145	23.038	5.3504
39	B	15	0.2720	0.000	2.980	2.980	0.8009
41	S	46	1.6750	0.059	17.148	17.089	3.1339
41	B	40	0.4870	0.000	3.547	3.547	0.8385
43	S	22	3.4190	0.052	21.710	21.658	5.4923
43	B	15	0.2570	0.000	2.464	2.464	0.7091
45	S	47	1.6390	0.027	14.482	14.455	2.8683
45	B	40	0.8750	0.000	9.117	9.117	1.6902
47	S	32	1.9110	0.077	15.270	15.193	3.9291
49	S	34	1.6660	0.064	12.560	12.496	3.0745
51	S	44	1.2300	0.018	15.030	15.012	2.6020
53	S	48	1.3550	0.072	10.807	10.735	2.2131
53	B	40	0.8460	0.000	7.246	7.246	1.6025
55	S	44	1.5430	0.072	15.129	15.057	2.8582
55	B	36	1.6770	0.000	7.184	7.184	2.3278
57	S	19	1.2760	0.054	7.654	7.600	1.9009
59	S	20	1.7770	0.047	12.444	12.397	3.0821
61	S	19	1.7420	0.000	11.170	11.170	2.7552
63	S	19	1.4530	0.134	9.601	9.467	2.2689
65	S	19	1.7360	0.030	10.276	10.246	2.6813
67	S	18	1.4760	0.048	5.319	5.271	1.5441
67	B	16	3.4740	0.288	8.221	7.933	2.7005
69	S	20	1.7830	0.136	8.414	8.278	2.2533
69	B	17	3.7180	0.165	8.450	8.285	2.8212
71	S	21	2.3110	0.113	13.022	12.909	3.3336
71	B	18	3.9710	0.528	8.881	8.353	2.5042
72	S	16	1.2500	0.171	3.276	3.105	1.0334
72	B	15	0.1730	0.000	2.596	2.596	0.6702
73	S	18	1.3900	0.054	6.138	6.084	1.6933
75	S	18	1.6850	0.115	11.147	11.032	2.6342
77	S	18	1.6130	0.059	7.067	7.008	1.9413
79	S	18	1.0680	0.026	3.642	3.616	1.2299
80	S	11	1.3270	0.087	5.134	5.047	1.5446
81	S	22	2.0460	0.174	7.965	7.691	2.0559
81	B	18	2.9980	0.071	8.113	8.042	2.7624
83	S	22	1.5600	0.090	6.744	6.654	1.6787
83	B	19	3.7290	0.393	7.773	7.380	2.4557
85	S	22	2.1150	0.255	6.150	5.895	1.8112
85	B	19	4.0960	0.129	10.116	9.987	3.0113
87	S	22	2.7360	0.097	7.406	7.309	2.0805
87	B	19	4.3730	0.012	10.776	10.764	3.1574
89	S	20	3.5760	0.152	11.095	10.943	2.6041
89	B	19	3.8580	0.000	10.730	10.730	3.2610
91	S	19	2.4140	0.155	13.942	13.787	3.1979
93	S	18	1.5250	0.137	4.960	4.823	1.5327
95	S	19	1.8760	0.161	10.392	10.231	2.6063
97	S	18	1.9680	0.083	7.459	7.376	2.2161
99	S	18	1.3540	0.144	8.337	8.193	1.9386
101	S	19	1.7430	0.063	6.608	6.545	2.0783
103	S	18	1.2160	0.063	5.855	5.792	1.5914
105	S	18	1.8150	0.053	11.607	11.554	2.7558
107	S	20	6.1110	0.112	20.109	19.997	5.0313
107	B	17	4.5040	0.304	11.364	11.060	3.3924
108	S	17	14.8030	0.985	57.207	56.222	18.6173
108	B	16	4.4240	0.020	10.782	10.762	3.1936

Table II. Statistics on the Levels of Nitrate-Nitrogen (μga/l). (Continued)

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
109	S	21	4.2860	0.285	8.099	7.814	2.4114
109	B	19	3.8690	0.044	10.190	10.146	3.0971
123	S	12	1.4550	0.140	5.327	5.187	1.6443
125	S	25	0.4970	0.047	3.127	3.080	0.6989
127	S	25	0.4480	0.059	2.578	2.519	0.6224
129	S	25	0.6740	0.030	4.262	4.232	1.0261
131	S	25	0.5650	0.045	2.066	2.021	0.6366
133	S	25	0.4860	0.059	4.267	4.208	0.8613
135	S	25	0.6900	0.024	5.423	5.399	1.2320
137	S	25	0.4720	0.059	2.398	2.339	0.5441
137	B	25	1.2870	0.104	6.546	6.442	1.6898
139	S	25	0.4110	0.081	2.530	2.449	0.5050
139	B	23	1.6900	0.171	6.594	6.423	1.7082
141	S	22	1.0930	0.058	8.884	8.826	2.1270
141	B	22	1.6150	0.043	9.137	9.094	2.0632
143	S	25	0.6740	0.004	8.963	8.959	1.7998
145	S	24	0.5740	0.045	4.400	4.355	0.9877
147	S	25	0.5370	0.056	5.133	5.077	1.0357
149	S	25	0.6300	0.023	5.569	5.546	1.1493
149	B	25	1.6900	0.134	9.985	9.851	2.4010
151	S	25	0.7500	0.059	5.920	5.861	1.2219
151	B	25	1.9520	0.076	17.991	17.915	3.9743
153	S	25	0.5210	0.054	3.062	3.008	0.6953
155	S	25	5.6800	0.020	4.618	4.598	0.9708
157	S	50	0.6160	0.034	4.011	3.977	0.9920
159	S	49	0.8900	0.051	7.819	7.768	1.5773
161	S	50	0.3690	0.034	2.695	2.661	0.4965
163	S	25	0.5670	0.045	2.930	2.885	0.7727
163	B	25	0.8850	0.043	4.694	4.651	1.1157
165	S	25	0.3180	0.023	2.266	2.243	0.4658
167	S	25	0.3090	0.068	1.589	1.521	0.3687
169	S	24	0.4310	0.034	2.185	2.151	0.5198
171	S	25	0.6830	0.086	5.090	5.004	1.0660
173	S	25	0.4130	0.000	1.610	1.610	0.4516
175	S	25	0.8420	0.025	9.039	9.014	1.7718
177	S	25	0.4180	0.086	2.780	2.694	0.6292
179	S	25	0.4340	0.029	3.633	3.604	0.7721
181	S	25	0.3600	0.031	2.290	2.259	0.5486
183	S	25	0.6390	0.029	7.250	7.221	1.5379
185	S	25	0.7820	0.028	7.520	7.492	1.5892
187	S	25	0.6370	0.029	9.070	9.041	1.8210
189	S	25	0.5540	0.000	6.280	6.280	1.3285
191	S	24	0.7140	0.034	3.618	3.584	1.0929
193	S	24	0.8850	0.034	9.829	9.795	2.0126
195	S	24	1.9190	0.067	6.626	6.559	1.7791
197	S	25	1.8600	0.047	10.180	10.133	2.6340
199	S	25	1.3320	0.109	8.660	8.551	2.4191
201	S	24	1.0760	0.059	8.281	8.222	2.0972
203	S	25	0.8370	0.049	5.470	5.421	1.3807
205	S	25	0.8930	0.047	5.573	5.526	1.4515
207	S	25	0.5410	0.001	2.480	2.479	0.8152
209	S	25	0.5900	0.047	3.656	3.609	0.9383
211	S	25	0.3690	0.029	3.238	3.209	0.6885

Table III. Statistics on the Levels of Inorganic Phosphate (μga/l).

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
27	S	48	0.5390	0.000	1.640	1.640	0.3730
27	B	40	0.5980	0.000	2.030	2.030	0.6389
39	S	22	0.3810	0.000	1.000	1.000	0.2749
39	B	15	0.0310	0.000	0.470	0.470	0.1213
41	S	47	0.4920	0.000	1.640	1.640	0.3813
41	B	40	0.5670	0.000	2.860	2.860	0.6813
43	S	22	0.3590	0.000	0.880	0.880	0.3079
43	B	15	0.0350	0.000	0.530	0.530	0.1368
45	S	47	0.4630	0.000	1.380	1.380	0.3138
45	B	40	0.3600	0.000	1.270	1.270	0.3726
47	S	32	0.4290	0.000	2.300	2.300	0.4012
49	S	34	0.4170	0.080	1.160	1.080	0.2346
51	S	44	0.3720	0.000	1.020	1.020	0.1955
53	S	48	0.3660	0.000	1.030	1.030	0.2549
53	B	40	0.3120	0.000	1.730	1.730	0.3816
55	S	44	0.3380	0.000	1.500	1.500	0.3132
55	B	36	0.2590	0.000	1.060	1.060	0.3142
57	S	19	0.3930	0.000	1.200	1.200	0.3068
57	B	14	0.0000	0.000	0.000	0.000	0.0000
59	S	20	0.4590	0.000	1.580	1.580	0.4127
61	S	19	0.5250	0.000	1.390	1.390	0.4255
63	S	19	0.4650	0.000	1.190	1.197	0.3497
65	S	19	0.3930	0.000	1.080	1.080	0.3180
67	S	18	0.3110	0.000	0.770	0.770	0.2462
67	B	16	0.4530	0.000	1.550	1.550	0.3830
69	S	20	0.4060	0.000	1.350	1.350	0.3295
69	B	17	0.4570	0.000	1.820	1.820	0.4514
71	S	21	0.5270	0.000	1.580	1.580	0.3579
71	B	18	0.5070	0.000	1.350	1.350	0.3639
72	S	16	0.5290	0.000	2.300	2.300	0.5556
72	B	15	0.0800	0.000	1.200	1.200	0.3098
73	S	18	0.3740	0.000	1.250	1.250	0.3436
75	S	18	0.4170	0.000	1.650	1.650	0.4357
77	S	18	0.3560	0.000	1.000	1.000	0.3249
79	S	18	0.5810	0.000	2.450	2.450	0.5831
80	S	11	0.4850	0.000	1.190	1.190	0.3508
81	S	22	0.6010	0.000	1.980	1.980	0.5157
81	B	18	0.9960	0.000	4.500	4.500	1.3518
83	S	22	0.7160	0.000	2.860	2.860	0.6806
83	B	19	1.3330	0.000	11.200	1.120	2.5756
85	S	22	1.6590	0.000	12.300	12.300	2.5996
85	B	19	1.2230	0.000	8.910	8.910	1.9786
87	S	22	1.1130	0.000	3.950	3.954	1.0473
87	B	19	0.7830	0.000	2.730	2.730	0.6896
89	S	21	1.0770	0.000	4.830	4.830	1.2415
89	B	19	1.0690	0.140	4.910	4.770	1.0909
91	S	19	0.7710	0.000	5.500	5.500	1.1948
93	S	18	0.4390	0.070	0.950	0.880	0.2576
95	S	19	0.4570	0.000	1.360	1.360	0.3904
97	S	18	0.4710	0.000	1.130	1.130	0.3539
99	S	18	0.3290	0.000	0.910	0.910	0.2654
101	S	19	0.4510	0.000	1.600	1.600	0.3950
103	S	18	0.3920	0.000	0.900	0.900	0.3176
105	S	18	0.4090	0.000	1.020	1.020	0.3211
107	S	20	18.8670	0.140	65.600	65.460	18.1905
107	B	17	5.6550	0.280	18.400	18.120	5.5922

Table III. Statistics on the Levels of Inorganic Phosphate (μga/l). (Continued)

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
108	S	17	39.7570	4.570	67.900	63.330	18.9263
108	B	16	8.4210	0.680	18.800	18.120	5.8520
109	S	21	1.9670	0.000	26.500	26.500	5.6807
109	B	19	2.6590	0.230	19.500	15.270	4.8462
123	S	12	0.6520	0.000	2.000	2.000	0.6992
125	S	25	0.7510	0.070	2.930	2.860	0.6237
127	S	25	0.6200	0.000	2.100	2.100	0.4874
129	S	25	0.5400	0.060	1.800	1.740	0.4325
131	S	25	0.5560	0.070	1.430	1.360	0.3572
133	S	25	0.5120	0.160	1.360	1.200	0.2891
135	S	25	0.4510	0.070	1.160	1.090	0.2505
137	S	25	0.4410	0.070	1.230	1.160	0.2807
137	B	25	0.6460	0.000	1.650	1.650	0.4540
139	S	25	0.4970	0.140	1.360	1.220	0.2906
139	B	24	0.6490	0.000	2.000	2.000	0.5420
141	S	22	0.3690	0.070	1.430	1.360	0.2742
141	B	22	0.6650	0.000	1.740	1.740	0.5090
143	S	25	0.4450	0.000	1.360	1.360	0.3173
145	S	25	0.4110	0.060	1.430	1.370	0.2825
147	S	25	0.4010	0.000	0.910	0.910	0.2691
149	S	25	0.4510	0.070	1.290	1.220	0.2870
149	B	25	0.6470	0.000	1.350	1.350	0.4436
151	S	25	0.4370	0.130	1.500	1.370	0.3108
151	B	25	2.7400	0.000	48.200	48.200	9.4942
153	S	25	0.4750	0.130	1.090	0.960	0.2497
155	S	25	0.4150	0.080	1.000	0.920	0.2209
157	S	50	0.4030	0.000	0.930	0.930	0.2339
159	S	50	0.4330	0.000	1.200	1.200	0.2878
161	S	50	0.4580	0.000	1.090	1.090	0.2975
163	S	25	0.5280	0.000	1.660	1.660	0.4026
163	B	25	1.2560	0.000	11.400	11.400	2.3652
165	S	25	0.4730	0.000	1.070	1.070	0.2640
167	S	25	0.4950	0.000	1.180	1.180	0.3406
169	S	24	0.5460	0.000	1.430	1.430	0.3469
171	S	25	0.3870	0.000	1.270	1.270	0.3333
173	S	25	0.4090	0.000	1.200	1.200	0.2878
175	S	25	0.4130	0.000	0.930	0.930	0.2137
177	S	25	0.3410	0.000	1.070	1.070	0.2503
179	S	25	0.3710	0.000	0.800	0.800	0.2520
181	S	25	0.4060	0.000	1.000	1.000	0.3004
183	S	25	0.3540	0.000	0.910	0.910	0.2461
185	S	24	0.3700	0.000	1.200	1.200	0.2717
187	S	25	0.3630	0.000	0.870	0.870	0.1929
189	S	25	0.3600	0.000	0.930	0.930	0.2290
191	S	24	0.3990	0.070	0.870	0.800	0.2324
193	S	24	0.3780	0.000	0.860	0.860	0.2236
195	S	24	0.5100	0.080	1.470	1.390	0.3079
197	S	25	0.4110	0.080	0.730	0.650	0.1899
199	S	25	0.3660	0.000	0.910	0.910	0.2329
201	S	25	0.3890	0.000	0.840	0.840	0.2231
203	S	25	0.3850	0.000	0.910	0.910	0.2226
205	S	25	0.4090	0.000	1.070	1.070	0.2745
207	S	25	0.3380	0.000	0.930	0.930	0.2310
209	S	25	0.3530	0.000	1.000	1.000	0.2550
211	S	25	0.3940	0.000	0.870	0.870	0.2638

Table IV. Statistics on the Levels of Total Phosphate (μga/l).

STATION	DEPTH	NUMBER OBSERVATIONS	MEAN	MINIMUM	MAXIMUM	RANGE	STANDARD DEVIATION
27	S	48	2.0050	0.570	5.860	5.290	0.9645
27	B	40	2.8790	0.000	19.800	19.800	3.8184
39	S	22	1.9380	0.700	4.130	3.430	0.9336
39	B	15	0.2590	0.000	2.090	2.090	0.6865
41	S	47	2.1350	0.760	9.130	8.370	1.5236
41	B	40	3.3660	0.000	12.000	12.000	3.4864
43	S	22	1.5840	0.620	3.480	2.860	0.8077
43	B	15	0.1520	0.000	1.620	1.620	0.4410
45	S	47	1.4840	0.480	5.250	4.770	0.7440
45	B	40	1.4200	0.000	11.180	11.180	1.8649
47	S	32	1.4530	0.510	4.590	4.080	0.7741
49	S	34	1.2140	0.460	3.120	2.660	0.5740
51	S	44	1.2340	0.050	8.450	8.400	1.1957
53	S	48	1.1840	0.050	1.940	1.890	0.4348
53	B	40	0.9060	0.000	3.210	3.210	0.8388
55	S	44	1.1400	0.050	2.250	2.200	0.4819
55	B	36	0.9520	0.000	5.070	5.070	0.9898
57	S	19	1.4200	0.450	2.570	2.120	0.6449
59	S	20	1.4350	0.480	3.980	3.500	0.7818
61	S	19	1.6990	0.420	4.530	4.110	1.0922
63	S	19	1.3670	0.480	2.660	2.180	0.6164
65	S	19	1.2620	0.450	2.130	1.680	0.5312
67	S	18	1.0900	0.280	2.230	1.950	0.5540
67	B	16	1.3450	0.710	2.100	1.390	0.4275
69	S	20	1.2510	0.280	3.730	3.450	0.7731
69	B	17	1.1950	0.610	2.100	1.490	0.4355
71	S	21	1.4550	0.530	3.800	3.270	0.7891
71	B	18	1.6430	0.640	3.740	3.100	0.7964
72	S	16	1.0410	0.350	1.850	1.500	0.4374
72	B	15	0.0860	0.000	1.300	1.300	0.3356
73	S	18	1.2820	0.420	4.160	3.740	0.8758
75	S	18	1.1570	0.420	2.050	1.629	0.5273
77	S	18	1.2420	0.550	2.930	2.380	0.6137
79	S	18	1.4370	0.570	2.880	2.310	0.6548
80	S	11	1.2890	0.530	2.340	1.810	0.5758
81	S	22	1.5690	0.650	3.270	2.620	0.7286
81	B	18	3.0350	0.890	11.110	10.220	2.8044
83	S	22	2.0930	0.660	5.250	4.590	1.2462
83	B	19	2.8350	0.560	10.220	9.660	2.3475
85	S	22	4.3080	0.940	18.560	17.620	4.3002
85	B	19	4.7540	1.320	16.610	15.290	4.0275
87	S	22	3.8750	0.850	18.490	17.640	3.9736
87	B	19	8.7190	1.150	29.520	28.370	9.6811
89	S	21	2.9160	0.790	8.620	7.830	2.2269
89	B	19	4.9350	0.970	20.930	19.960	5.7442
91	S	19	2.1230	0.570	8.060	7.490	1.7637
93	S	18	1.7480	0.690	4.150	3.460	0.8473
95	S	19	1.8060	0.540	5.630	5.090	1.1448
97	S	18	2.0010	0.890	5.060	4.170	1.0226
99	S	18	1.5040	0.820	2.900	2.080	0.5600
101	S	19	1.7990	0.810	3.320	2.510	0.7616
103	S	18	1.5970	0.810	3.770	2.960	0.7098
105	S	18	1.2080	0.490	1.960	1.470	0.3787
107	S	20	25.2850	1.330	70.090	68.760	21.0467
107	B	16	15.0510	2.540	63.370	60.830	15.0297
108	S	17	51.3230	6.920	91.380	84.460	29.6851
108	B	16	20.4060	3.190	56.270	53.080	16.1869