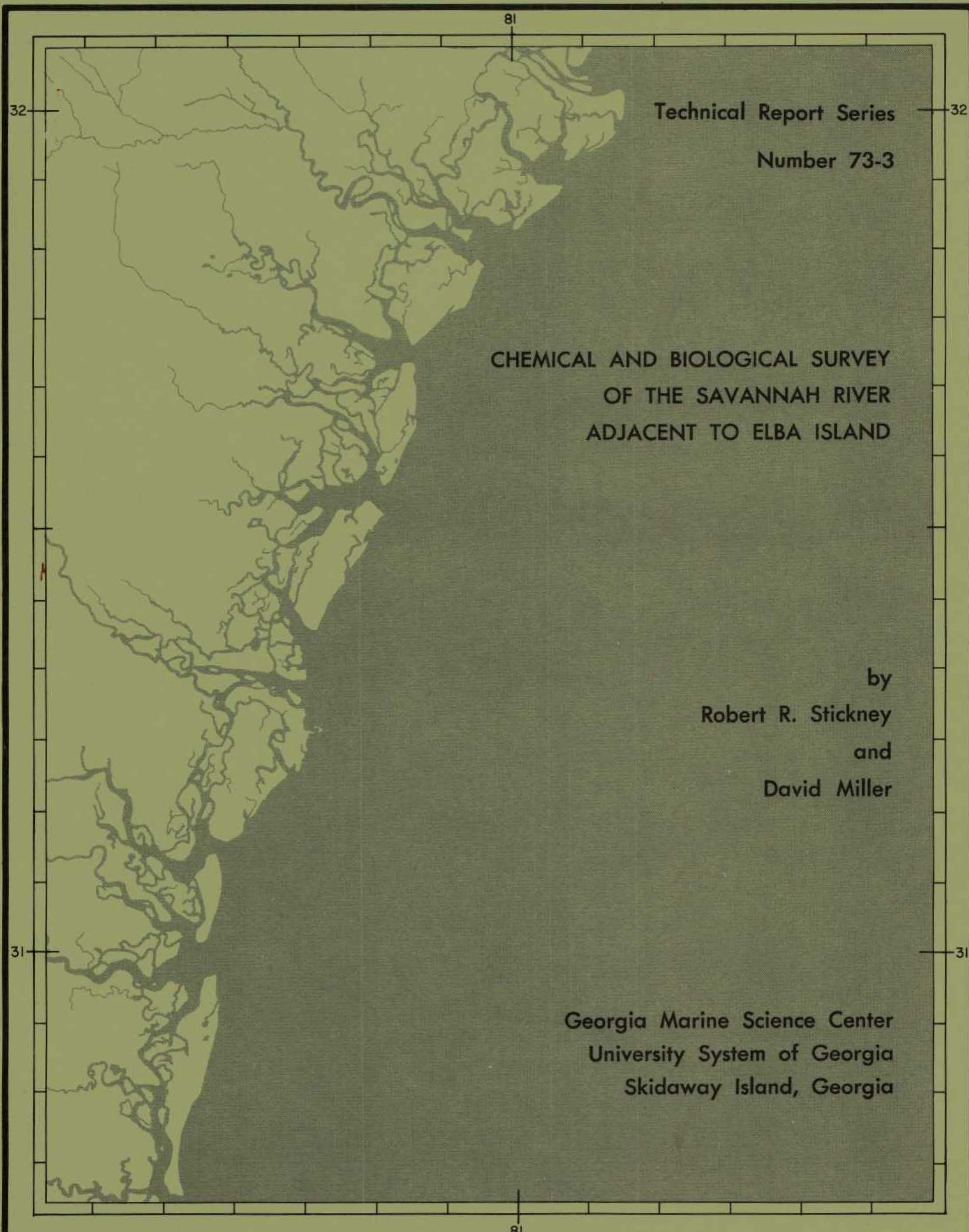

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CHEMICAL AND BIOLOGICAL SURVEY OF THE SAVANNAH RIVER ADJACENT TO ELBA ISLAND

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INTRODUCTION

The present study was supported by a grant from the Southern Natural Gas Company which plans to construct a regassification plant on Elba Island in the Savannah River (Figure 1) where liquified natural gas (LNG) will be off-loaded from ships, regassified and piped to distribution centers. The initial plan called for water from the Savannah River to be pumped into the plant where it would be used to carry away the thermal debt incurred in converting the LNG from the liquid to the gaseous state. This process water, when returned to the river, was expected to be cooled approximately $5^{o}F$ below ambient river temperature. No other changes in or additives to the process water were expected or comtemplated.

The present study was initiated to collect information on the basic water chemistry and faunal assemblages in the river adjacent to Elba Island prior to construction of the plant. The results of this study are intended to provide a data base for the water quality and biota in this section of the river under presently existing conditions of pollution from domestic, municipal and industrial sources against which any environmental effects of the regassification operation may be measured in the future.

The authors would like to express their appreciation to Messrs. Daniel Perlmutter, Douglas Mullis and Gary Taylor for field and laboratory assistance.

DESCRIPTION OF THE STUDY AREA

The Savannah River, separating Georgia and South Carolina, flows through a concentration of industrial and municipal areas during several of the last 25 miles of its course before entering the Atlantic Ocean. The City of Savannah is located approximately 10 miles above the river entrance. Located above, and adjacent to the city are several industrial plants involved in food, paper and chemical processing. The Port of Savannah receives numerous vessels daily. Access to the Port facilities is provided by a ship channel approximately 150 meters in width and 12 meters in depth. This channel, currently being increased to a depth of 15 meters, is dredged and otherwise maintained by the U.S. Army Corps of Engineers.

With the exception of one set of data obtained near the mouth of the Savannah River (Figure 1, station 5), the sampling stations were located near Elba Island. Station 1 was established in the South Channel of the Savannah River behind Elba Island. The water depth at this station varied between three and four meters depending upon the stage of the tide (the tidal range in the coastal region of Georgia is between two and three meters). The sediments, typical of Georgia estuarine areas, consisted of clay and mud rich in organic matter. On ebb tide some of the flow of the main channel Savannah River is diverted down the South Channel, through station 1.

Station 2 was located directly upstream from a large chemical plant, near Fort Jackson. Oil Company storage facilities were also located near this station. Water depth at station 2 and the following stations was 12 to 14 meters at low tide and up to 16 meters at high tide. Station 3 was established in the immediate vicinity of the proposed construction site on Elba Island. At present, there are no obvious sources of domestic or industrial effluents into the river downstream from station 3 until the immediate vicinity of the ocean. Station 4 was established just downstream of the eastern end of Elba Island. On one occasion a fifth station (station 5) was occupied for the purpose of obtaining data on the fish and macroinvertebrate populations. This station was established about 2 miles downstream from station 4.

During past years the Savannah River has been used for the disposal of various types of industrial, municipal and ship wastes. The city of Savannah is presently installing a sewage treatment plant and the major industries along the river have initiated various types of pollution control programs. The Savannah River was closed to commercial fishing along much of its lower reaches during 1971 due to excessive levels of mercury. Part of the river was reopened during 1972 but concern about the quality of fishes taken from the river is still expressed by local fishermen. Sport fishermen also complain about the "oily" taste of fishes caught in the Savannah River. The Savannah River is utilized by striped bass (*Morone saxatilis*) as a spawning area during the spring. Sportsmen, in addition to angling for striped bass, are also interested in the channel bass or red drum (*Sciaenops ocellata*) which attain large size in the Savannah River. Other species of sport and commercial interest are also present seasonally.

The coastal area of Georgia is characterized by vast expanses of marsh grass (predominantly *Spartina alterniflora* intertidally with *Juncus* sp. on higher ground). The Savannah River has been deeply channelized throughout the extent of the study area. Virtually all of the marsh has been eliminated along the river and has been covered with high spoil banks. Both sides of the river have been spoiled and maintenance dredging is required at frequent intervals to maintain the ship channel, thus adding to the dimensions of the spoil banks.

METHODS AND MATERIALS

Cruises were undertaken at monthly intervals beginning January, 1972 and terminating December, 1972. In April, July and October diurnal samples were obtained for water chemistry from each station at three hour intervals. Both routine monthly and diurnal water samples were obtained through utilization of either a Van Dorn or Kemmerer water sampling bottle. Samples were collected at the surface, bottom and at two meter intervals between.

Temperature was determined immediately after collection of each sample through use of a mercury-in-glass thermometer. Salinity was determined to the nearest part per thousand (ppt) by refractometry. The salinities obtained with the refractometer were checked and verified during one cruise with an induction salinometer.

Measurement of pH was done either in the field or in the laboratory using a Corning battery operated pH meter. Oxygen was determined by azide modification of the Winkler titration in most cases (APHA 1965); however, during the latter few months of the study an oxygen meter was used. Winkler titration of one or more replicate samples during each month when the oxygen meter was used verified the readings obtained from the meter.

Sampling of the parameters listed above carried out in this area by other agencies of federal and local government was not as intensive as that undertaken by us but provides additional information, especially upstream of our station (Georgia Water Quality Control Board 1972).

A ten minute otter trawl was made at each station during each month with a 6.1 meter wide at the mouth nylon otter trawl with 2.5 cm stretch mesh. The organisms captured were placed in 10% formalin solution and returned to the laboratory for examination. All animals were identified to species, counted and weighed. Individual lengths and weights were obtained in most cases; however, the data are presented on the basis of pooled data for the most part, since further reduction of these data did not appear to add to or modify the conclusions presented below.

RESULTS AND DISCUSSION

Temperature Regime (monthly)

Monthly temperature patterns for stations 1 through 4 are presented in Figure 2. Values for surface, midwater and bottom are given in addition to the mean for the water column. Values were obtained at two meter intervals, but are not presented due to the extremely narrow range in temperature with depth. Standard deviations are included in cases where the standard deviation exceeded ± 0.500. By comparing the points for any given month among the four stations it becomes apparent that there was little variation in temperature within or between stations. In addition, there was no evidence of thermal stratification within any station. In this respect, the Savannah River is similar to other rivers along the Georgia coast. None of the other estuarine waters in the area have shown thermal stratification. They are, for the most part, shallow and well mixed, thus, no stratification would be expected. Temperature readings in excess of $30^{o}C$ are common in Georgia estuaries during July and August. Several areas within a few miles of the Savannah River, Wilmington River and Ossabaw Sound exhibited 30°C temperatures during the summer, 1972. The maximum value obtained during the present study was 28°C which occurred during August at all stations. The lowest temperature obtained was 8°C at the two upstream stations (stations 1 and 2) during February, 1972. Stations 3 and 4 had temperatures of 10°C during February. Several stations in Ossabaw Sound and the Wilmington river, both within a few miles of the Savannah River, demonstrated the lowest winter temperatures, 10°C. There is some indication that the Savannah River does not get quite as warm as the surrounding area during the summer and that its winter temperatures are the same or possibly slightly less than surrounding areas. In general, the Savannah River temperature regime is not dramatically different from the surrounding estuarine areas.

Salinity Patterns (monthly)

Salinity patterns at two meter intervals monthly from stations 1 through 4 are presented in Figure 3. Station 1 is a shallow water station which showed a maximum depth of four meters. Because of the shoalness of this station, little salinity stratification was evident, although there was a slight tendency toward increasing salinity with depth during most months. This station is more typical of Georgia estuarine conditions where relatively shallow water is well mixed showing little or no salinity variability.

Stations 2 through 4, located in the middle of the Savannah River ship channel, showed a high degree of salinity stratification. The surface water was generally of low salinity at each of these stations with a tendency toward increasing surface values in the downstream direction. Salinity increased steadily with depth reaching levels in excess of 20 ppt at the bottom of the water column, which varied in depth from 10 to 16 meters depending upon the month and tidal stage.

Salinity data showed some aberrant patterns. During February, 1972, low salinities were recorded at all four stations, with station 3 being the only one among the four to approach the typical salinity configuration. The salinity patterns at station 2 were fairly consistant during all months with the exception of February. The normal pattern of increasing salinity with depth was disrupted during the November, 1972 sampling period at stations 3 and 4. The water column for this set of samples was apparently well mixed from surface to bottom. As will be shown later, this phenomenon also occurred during the diurnal sampling, and seemed to be associated with the passage of large ships. Samples taken within an hour or two following passage of a large vessel show a disruption of the normal salinity gradient.

pH Determinations (monthly)

The Savannah River receives acid wastes from chemical plant effluents which appear to affect the pH of the river. Monthly pH values, surface to bottom at two meter intervals in stations 1 through 4 are presented in Figure 4. Values obtained at station 2 were generally acid. Normal values for Georgia estuarine waters (based on data taken from the Skidaway River adjacent to the Skidaway Institute of Oceanogrphy) generally range between 7.5 and 7.9. As previously noted, a portion of the ebb flow of the Savannah River moves down the South Channel, thus allowing the low pH water access to station 1. In general, pH values obtained from the surface at stations 2 through 4 were slightly acid, although some neutral to slightly basic values were also obtained. A slight increase in pH with depth occurred at stations 2 through 4. During more than half of the sampling period all values obtained throughout the water column at station 2 were acid. This station is located in close proximity to a large chemical plant which emits acid effluents and the station would be expected to have been influenced by the discharge from the plant.

The pH values obtained from stations 3 and 4 approached or exceeded neutrality at some depths during most months. Exceptions occurred during February, March, April and July at both stations when the pH was acid throughout the water column. In each of these cases the tide was either falling or low, indicating the possibility that tidal influences were operating. (Table 1 indicates the tide stage for each month of sampling). During May, August and December the tide was also falling or low at the time of sampling and the trend was toward increasing pH with depth. The pH could not be determined at stations 3 and 4 during December due to failure of the pH meter in the field. It is not known whether acid discharge is constantly flowing into the river or is allowed to enter the river intermitently. A pollution abatement program initiated by the chemical company involved should effectively remove the acid effluent from the river in the future.

Dissolved Oxygen (monthly)

Dissolved oxygen demonstrated little variation with depth at all four sampling stations (Figure 5), although in many cases the surface values were slightly higher than those obtained at two meters. This could be associated with diffusion of atmospheric oxygen into the water. Seasonal patterns in dissolved oxygen levels were apparent. These patterns followed temperature to a great extent in that the high values of dissolved oxygen were recorded during the winter when the water was cold and low values were recorded during the summer when water temperature was high. Biologists consider dissolved oxygen levels below 5.0 mg/l detrimental to aquatic life. At station 1 the dissolved oxygen was consistantly below 5.0 mg/l during the period from April through September, corresponding with temperatures above 20 C for that station. The poorest water quality from the standpoint of dissolved oxygen levels was found at station 2 (Figure 5). Values fell from over 8.0 mg/l in February to less than 5.0 mg/l in March and continued at the lower levels through September. Values of less than 3.0 mg/l were observed in April, May and June at some depths, and fell below 2.0 at 4 meters and below during August. Dissolved oxygen values of less than 2.0 mg/l are potentially lethal to many species, especially if that level persists for any length of time.

Some increase in summer levels of dissolved oxygen occurred downstream. At station 3 the August dissolved oxygen level reached a low of 2.3 mg/l, while at station 4 the lowest value obtained during the same month was 3.0 mg/l. Most of the dissolved oxygen values obtained from station 3 during March through September were below 5.0 mg/l, while one or more values in excess of 5.0 mg/l were recorded at station 4 during every month except July.

It is likely that the heavy input of both domestic and municipal waste entering the Savannah River becomes diluted enough for some recovery of the river below station 2. Some data from a state governmental agency are available for locations both upstream and downstream of our stations (Georgia Water Quality Control

Board 1972). These data indicate that dissolved oxygen during 1970 and 1971 was very low from a point about 10 miles upstream (near station 3) to about 22 miles upstream from the ocean during the summer; an area encompassing the waterfront of the city of Savannah and the bulk of the industrial and port facilities associated with the Savannah River. From these data, it appears as though station 2 is at the lower extremity of the poorest water quality associated with the lower reaches of the Savannah River.

Temperature Regime (diurnal)

Diurnal temperature, salinity, pH and dissolved oxygen determinations were run on 21 April, 19 July and 23 October at three hour intervals. Problems in sampling equipment required termination of the 23 October sampling prior to collection of a complete 24 hour series. The effects of tidal amplitude on depth are clear in that the available sampling depth is reduced at low tide (cf. Figure 6).

Diurnal temperature data for each sampling period are presented for stations 1 through 4 in Figures 6 through 9, respectively. All data collected at two meter intervals from surface to bottom are presented in the figures. As was observed above in the discussion of the monthly samples, there was little variation with depth within a given station and also little variation between stations during the same month. In the present case, diurnal temperature variation was generally slight although a surprising increase in temperature was noted between the first two sets of samples at station 1 during April (Figure 6). This phenomenon was not repeated at any of the other stations during the same month or during any other month. Shallow waters are more susceptible to diurnal changes than are the deeper waters such as exist in stations 2 through 4. Diurnal temperature values were relatively constant within any one diurnal sampling period at stations 2 through 4 (Figures 7 through 9, respectively).

Salinity Patterns (diurnal)

Diurnal salinity data from stations 1 through 4 are presented in Figures 10 through 13, respectively. Only slight variations were observed diurnally at station 1 (Figure 10) and, as seen in the monthly data presented above (Figure 3), salinity increased only slightly with depth at station 1, irrespective of tidal stage.

The expected pattern of salinity variation with time at stations 2 through 4 (Figures 11 through 13) would be for salinity to increase with the rising tide at all depths, reaching a maximum at high tide and falling with the ebbing tide. While this general tendency did seem to occur at some depths and stations, there were many aberrant points in the data suggesting the presence of eddies or other disturbances in stratification. The normal stratification was disrupted in station 2 during the low tide period sampled in October when low salinities were recorded at all depths. A more typical salinity gradient existed at that station both three hours before and three hours after the aberrant condition. This disruption may have been associated with the passage of a ship just prior to the low tide sampling. The same phenomenon occurred during the same sampling period at station 3 (Figure 12). Station 4 did not seem to be affected in the same way (Figure 13). The normal routine of sampling was in increasing order by station and it is possible that sufficient time had elapsed between passage of a ship and the collection of the samples at station 4 to allow redistribution of the salinity gradient.

Another similar period of isohaline samples was found at station 4 on the first set of high tide samples, 21 April 1972. Records of passing ships were not kept as there seemed no point in doing so until the unusual salinity patterns emerged. The isohaline pattern was not recognized as being associated with shipping until the October diurnal sampling data when an observation of the data in the field showed the aberrant pattern. Verification of this point should be relatively simple and will be pursued in the future. The current patterns and possibility of turbulent mixing caused by passing ships are not completely understood in the Savannah River. Cooled water, such as that proposed for dumping in the river upon completion of the Southern Natural Gas Company liquid natural gas facility, will probably seek the level in the river where the same density exists. Mixing will occur when ships create turbulence and possibly at points of instability in the salinity stratification as were implied in some of our diurnal data.

pH Determinations (diurnal)

Diurnal pH values at station 1 showed patterns varying from acid to slightly alkaline independent of tidal stage during each of the three dates during which diurnal samples were taken (Figure 14). On 21 April acid values coincided with samples taken during the daytime, while alkaline determinations were obtained from night samples. This pattern did not hold up for the July and October samples, however. We have no data to show the quantity of acid wastes being added to the river on the dates in question or the schedule by which acids were being released from one or more industrial facilities on the river.

Diurnal patterns in pH for station 2 were similar to those previously described for station 1, except that at station 2 one period of predominantly alkaline conditions prevailed in the daytime (first period of rising tide, Figure 15). Once again it was not possible to coordinate pH values in the river with any specific industrial activities during the period in question.

Values for pH were consistently higher at stations 3 and 4 (Figure 16 and 17) than at stations 1 and 2 (Figure 14 and 15) throughout the diurnal studies. Station 3 and 4 as previously mentioned lie below all present point sources of industrial and municipal effluents except for those which may exist in the immediate vicinity of the Savannah River entrance. Some improvement in water quality was evident downstream from station 2, although normal pH levels for estuarine waters were only occasionally reached.

Monthly pH sampling demonstrated a general tendency toward increasing pH with depth during most months. The more intensive diurnal studies did not indicate that this pattern was constant over the tidal cycle. As salinity increases, the buffer capacity of the water also increases due to the presence of higher levels of carbonate and bicarbonate present in the higher salinity water. Since the buffering capacity of the water is disrupted to as great an extent with depth as at the surface, the acid is apparently mixing rather thoroughly through the water column.

Dissolved Oxygen (diurnal)

Diurnal dissolved oxygen values obtained from the diurnal sampling studies are presented for station 1 through 4 in Figures 18 through 21, respectively. Values of dissolved oxygen at the bottom of the water column at station 1 were generally above 5.0 mg/l during each of the three dates during which diurnal sampling was undertaken. Only in October did values consistently above 5.0 mg/l appear in the upper water levels. No extremely low values were obtained, although a few determinations only slightly in excess of 3.0 mg/l were obtained (Figure 18).

The diurnal variability in dissolved oxygen at station 2 showed some patterns which may have been related both with tide stage and time of day. Oxygen production by photosynthetic plants ceases during the darkness, thus the greatest respiration demand occurs at night when the supply of dissolved oxygen is not being replenished. The first low tide samples of 21 April 1972 were taken in the morning about 0800 and had strikingly low levels of dissolved oxygen (Figure 19). At low tide,water from upstream carrying waste effluents is not balanced by relatively unpolluted water from downstream. The two factors may have been the reason for the low oxygen levels seen at that time. On the next low tide stage of 21 April 1972 the oxygen was reduced from the previous falling tide samples but not to the extent of the early morning low tide levels. This pattern did not seem to hold up during the July and October diurnal sampling periods. During July the lowest levels of dissolved oxygen seemed to occur on high tide during the afternoon. (Each series of samples was initiated when low tide was occurring at about 0800.) Fluctuations during the other two diurnal sampling dates seemed to occur independent of daylight. On 23 October 1972 the highest levels of dissolved oxygen occurred during high tide as would be expected if the pollutional load was at its lowest level during the high tide period. The deviations from classical theory governing diurnal patterns in oxygen are obviously complicated beyond the factors outlined above.

In general, dissolved oxygen levels at stations 3 and 4 were consistently higher than those at stations 1 and 2. The idea that the pollution load seems to be reduced by the time the water reaches station 3 is supported by the fact that the lowest levels of dissolved oxygen occurred during low tide on all three sampling dates (Figure 20), consistent with the idea that incoming higher salinity water was carrying more oxygen than that carried by the more highly polluted water coming from upstream.

The higher levels of dissolved oxygen at stations 3 and 4 were generally consistent with the previously discussed better water quality at these stations when compared with stations 1 and 2. The lowest values of dissolved oxygen observed at station 4 also occurred during low tide; however, there appeared to be little effect related to time of day (Figure 21). The exception occurred when an aberrant 1.4 mg/l value was obtained at eight meters depth on falling tide during the April diurnal sampling period. Since the values above and below eight meters at that tide were in excess of 5.0 mg/l, it appears likely that the aberrant sample was due to an error in technique.

While there were definite trends toward increased values of dissolved oxygen at high tide at stations 3 and 4, the diurnal changes in dissolved oxygen within any station were not particularly dramatic. When low levels were obtained, as during the spring and summer, they tended to remain low throughout the day. A 2.0 mg/l diurnal change or less in dissolved oxygen was generally the case at most stations. This implies the lack of large algal blooms which might be expected to cause a large jump in oxygen level over a 24 hour period.

High turbidity and flowing water such as found in the Savannah River contribute to the low primary productivity, actual values for which are not presently available.

In summary of the chemical data, the values for temperature, salinity, pH and dissolved oxygen collected to date, give background information as to the water quality conditions to be expected over the period of a year in the vicinity of Elba Island. The diurnal studies indicate that samples taken during any tide and during any part of the day give values similar to those which might be expected during any other tide or part of the day. The exceptions appear to be that dissolved oxygen is slightly reduced during low tide periods at some stations. Indicators of pollution, such as pH and dissolved oxygen indicate that stations 1 and 2 are most severely affected, with generally improved water quality downstream of those stations. A strong salt wedge is established in the Savannah River throughout the year; however, there is no apparent temperature gradient.

Water quality conditions were not found to be as detrimental to the survival of marine organisms as might have been expected considering the amount of waste received by the Savannah River. pH levels were low for normal estuarine waters, but not to the extent where they would be lethal (usually below 5.0 for shrimp and many fishes). Dissolved oxygen, was low and often less than the generally recognized safe level 5.0 mg/l. During certain periods some organisms certainly must have been stressed to one degree or another.

Cool water, such as that proposed to be added to the river at the site of the Southern Natural Gas plant upon its completion has the potential for carrying more dissolved oxygen than that of the surrounding warmer water. While the winter and late fall dissolved oxygen levels are adequate, problems with oxygen could occur during the spring and summer in the Savannah River. If the water returned to the river after passage through the regassification plant is allowed to gain oxygen by turbulent exposure to the atmosphere, the oxygen conditions in the river may actually be improved. There should be no effect of addition of this cooled water on either salinity or pH.

Faunistic Studies

Lists of the species of vertebrate and invertebrate organisms captured during the 12 month trawl survey in the Savannah River are presented in Tables 2 and 3, respectively. Twenty-five species of fish and eight species of invertebrates were captured. Of these, 12 species of fish and five species of invertebrates were of either commercial or sport interest.

The fish population was dominated, both in number of species, and biomass, by fishes of the family sciaenidae. This family (the drum and croaker family) predominates all along the Georgia coast and is a dominant family to the north and south of the state of Georgia and into the Gulf of Mexico.

Many of the fishes and invertebrates captured are normal residents of Georgia estuarine waters. One, the white catfish, *Ictalurus catus*, is a freshwater species and cannot live in salinities above about 15 ppt (Kendall and Schwartz 1968). Freshwater fishes were a rarity, however, and the biota of the Savannah River was populated by several species which generally occur in high salinity water. For example: *Larimus fasciatus*, *Trichiurus lepturus*, *Spheoroides maculatus* and *Xiphopeneus kroyeri* were not captured in the estuarine waters adjacent to the Savannah River (Wilmington River), but have only been taken in the sounds and coastal waters of Georgia by workers at our laboratory. The presence of these organisms, and others, several miles upstream may be attributed to the presence of the strong salt wedge in the Savannah River. The depth of the channel, which creates conditions making the formation of the salinity gradient possible, has effectively displaced the mouth of river several miles upstream, at least insofar as bottom water is concerned. Since trawling provides for the capture of predominantly benthic organisms, those species which were restricted to the high salinity bottom water were captured. Pelagic animals are selected against by the otter trawl.

The total monthly biomass of organisms captured at each of the four stations is presented diagramatically in Figure 22 and the actual figures for each month are presented in Table 4 with means and standard deviations. The dramatic difference in total biomass captured between the summer (June, July and August) and the remaining nine months of the year is apparent in Figure 22, even though the vertical axis is a logarithmic function. A second depression in the general level of biomass occurred during February. These two periods of low biomass coincided with the coldest and warmest water temperatures of the year. In order to determine which if any, means were significantly different from the others, paired t tests were run comparing the means of the annual biomass between stations and comparing the means of the biomass collected at all stations between months. The results are presented in Table 5 and Figure 23. When the mean values of annual biomass between stations were compared (Table 5) we found no statistically significant differences even at the 0.10 level. Thus, even though the water quality conditions appear to be poorer at stations 1 and 2 than at stations 3 and 4, this is not reflected in the annual biomass figures insofar as organisms collected by trawling is concerned. The animals collected in the trawl in the Savannah River are in general, euryhaline and eurythermal forms well adapted to life in the Georgia estuaries, or forms found in the sounds or nearshore coastal waters. These animals are readily adaptable to harsh environmental conditions, so it is not surprising that they appeared able to adapt to conditions at the upstream stations which may have been somewhat less than optimum during portions of the year.

Figure 23 presents the t test results when the average biomass of samples collected at each of the four stations within each month were calculated and compared. Significant differences are noted below the values for t derived from standard statistical tables. Meaningful significant levels in the table should be considered as those at the 0.05 and 0.01 levels. For biological work, lower levels of significance are suspect. The mean biomass collected in February, which looked somewhat reduced from that obtained during all other months except June through August, was in fact, significantly lower than the mean biomass collected during all but the three summer months mentioned. The values obtained in June, July and August were not significantly different from each other, nor as stated above were they significantly different from the February mean biomass, but did differ at varying levels of significance from values obtained in most other months. The major exception was that the mean of the biomass from the four January samples was not significantly different from that of the other 11 months. This was largely due to the fact that the standard deviation for the

January samples was high. Examination of Table 4 will demonstrate that the standard deviation for January was higher than the mean, whereas during all other months the standard deviation was somewhat less than the mean value.

Thus, we found two significant pulses in the animal population. One depression in biomass occurred during February, and was probably associated with low temperature; the other occurred during the summer. Routine sampling in other estuarine areas along the Georgia coast has demonstrated that a winter depression in standing crop biomass, associated most dramatically with low temperature water, but beginning usually in the late fall or early winter and ending in March, is common throughout the area. On the other hand, high levels of biomass are generally common during the summer months, peaking in September when the shrimp population is moving through the estuaries. Therefore, the summer depression in biomass found in the Savannah River is somewhat unusual.

Examination of the species composition may give insight into some of the reasons for the peaks observed in biomass. A comparison of the percentage biomass contributed by vertebrates, monthly at each station is presented in Table 6. With very few exceptions, vertebrates dominated the biomass during each month at all stations. Only in September was the biomass of vertebrates at each of the four stations less than 50% of the total. In January through May vertebrates accounted for more than 70% of the biomass at each station. Beginning in June, while vertebrates were still generally dominant, there were one or more stations each month in which the percentage of vertebrate biomass fell below 70%.

Biomass contributed by vertebrates as opposed to invertebrates indicates that the pulses in biomass seen in Figure 22 and Table 4 may be largely accounted for by vertebrates. Invertebrates often dominate the biomass of trawl catches in Georgia, especially seasonally when blue crabs (Callinectes sapidus) and white shrimp (Penaeus setiferus) become abundant. Crabs did not contribute significantly to the trawl catches in the Savannah River during most months, and never were a dominant organism. Shrimp, while often present, and sometimes present in significant numbers were only dominant during a short period.

The percentages of total numbers contributed monthly at each station by invertebrates are presented in Table 7. In a general way Table 7 mirrors the data of Table 8 in that vertebrates dominated the quantity of individuals during the first half of the year. Once again, in September, there was a series of samples which showed a relatively lower percentage of vertebrates than did the previous samples, but the trend was reversed again in October. The November and December samples were definately dominated by invertebrates. During the last two months of the year numerous white shrimp (Penaeus setiferus) and sea bob shrimp (Xiphopeneus kroyeri) were captured, while relatively fewer fish were collected than in prior months.

Examination of the raw data pointed up the fact that the population of fishes was dominated by members of the family Sciaenidae, especially the croaker (Micropogon undulatus) and the star drum (Stellifer lanceolatus), while the invertebrates, when present in numbers, were dominated by Peneus setiferus. This can be seen in Table 8 which presents the total number of individual Micropogon undulatus, Stellifer lanceolatus and Penaeus setiferus captured at each station monthly during 1972.

The population of Micropogon undulatus reached a high level during March, April and May, and was thereafter a rather insignificant part of the total catch. The average weight of Micropogon undulatus during each month is presented in Figure 24. The few specimens captured during January and February were small (less than 10 g average). This small average weight continued when larger numbers of individuals came into the population during the March through May period. Beginning in August the average size of the few individuals caught increased monthly. This tends to indicate that the Savannah River was used as a nursery ground, and possibly a spawning ground for Micropogon undulatus and that after the spawing season the young fish left the river.

The pattern for Stellifer lanceolatus followed a trend similar to that of Micropogon undulatus for the first few months of 1972, except that a large number of individuals were present in January (Table 8), the average size of which was generally less than 5.0 g (Figure 25). Large numbers of Stellifer lancolatus were captured during the March through May period, although the average weight of these was somewhat higher than that of Micropogon undulatus for the same period. Relatively few Stellifer lanceolatus were present in the samples during the summer months, but large numbers began appearing in the fall, this time as smaller average weight individuals than those of the spring peak. The average weight increased from August through December, with animals of an older age class presumably moving in during November and December.

The pattern for Stellifer lanceolatus seems to indicate that they were eliminated by the cold water during February (this may also apply to Micropogon undulatus), but were numerous after the water temperature warmed. The spring population may have been spawned the previous fall and moved into the river with the warming water. This animal is usually found in the sounds, inhabiting water of salinities greater than 20 ppt. The Savannah River had the proper salinity regime for the species and apparently acted as a nursery area during the spring. The population apparently was eliminated during the summer, again, probably due to temperature. It is likely that they moved offshore until the water began cooling in September. The fall population was dominated by very small individuals which were probably spawned during 1972. As the water temperature began to cool this second peak was replaced by larger fish. The difference in average size between October and November indicates that at least two age classes were present whereas few large individuals were present during the months of September and October.

Penaeus setiferus made up an insignificant portion of the total number of organisms collected during most of the sampling period. Several individuals were captured during the spring, but the largest numbers were present beginning in September and running through December. Once again, the lowest numbers were recorded during the coldest and warmest months, February, June, July and August. The average weights of Penaeus setiferus collected at each station and month are present in Figure 26. The pattern is, in this case, rather random with no specific trends other than the fact that the few shrimp captured during the summer were juveniles. White shrimp spawn generally during May, but shrimp of all sizes are present in Georgia estuaries throughout the year in at least small numbers. Temperature seems to have been the limiting factor on the shrimp population as it was on the fishes discussed above.

During February, no particular species dominated the catch. All stations had very few organisms and usually had two or more species, except station 3 where no animals were captured during a 10 minute tow. The same trend was observed during the summer period, June through July. The population was generally made up of the same organisms which occurred prior to and after the summer, but the numbers and biomass were severely reduced during the period of warm temperature.

An additional trawl was made during October downstream from station 4 (Figure 1, station 5). The total weight of organisms in that sample was 3169.9g with 884 individuals collected in 13 species. The biomass was similar to that at the upstream stations, and was dominated by Stellifer lanceolatus, which followed the pattern exhibited upstream. No new species were found, nor was the population structure different in any significant way from that of the upstream stations.

Diversity was calculated using the Shannon-Weiner function, which has been used in Georgia by Dahlberg and Odum (1970) and is derived from information theory. This index appears to be one of the best for characterizing estuarine fish populations. Diversity indicates the relative "health" of the animal community, with increasing diversity being desirable. The results of the application of the selected diversity index to the population of animals in the Savannah River are presented in Table 9. In general, diversity was somewhat lower in most cases than is found in most Georgia estuarine situations. Values of less than

1.0000 are relatively uncommon in other areas except during the coldest winter months. However, in the Savannah River values of less than 1.0000 were the rule. The diversity index followed no particular pattern seasonally; all values being almost uniformly low regardless of whether they came from samples when biomass and numbers of organisms were high or low. During the winter months there was a trend toward higher diversity in a downstream direction; however, diversity was not higher at stations 3 and 4 during the summer months as would be expected if poor water quality were limiting the upstream fauna. From the diversity information presented, we would have to conclude that the Savannah River offers a unique situation in which large quantities of a few species can thrive. At no time does a highly diversified community become established.

The species composition of each station is presented in Tables 10 through 13.

In summary of the biological data, it is apparent that both biomass peaks exhibited in the data are due to fish pulses, the first (March through May) being due to the presence of large numbers of young Micropogon undulatus and Stellifer lanceolatus. The second pulse (September through January) is caused by an apparent new hatch of Stellifer lanceolatus and is augmented by Penaeus setiferus. Many other organisms are present, but the three discussed seem to dominate the population, insofar as those animals available to the trawl are concerned.

There are two periods during the year when the animal population is severely restricted; during the coldest part of the winter (February, in 1972) and during the summer (June through August). The reasons appear to be related to temperature and not to any pollution impingement. The water quality except for temperature may be sufficient for the survival of all of the species which are present during other times of the year in abundance. The addition of cool water from the Southern Natural Gas plant may offset some of the low biomass by decreasing ambient temperature. The effects of the effluent during the winter may be to increase the onset of evacuation of the fishes from the river when the temperature approaches 10 C and delay their return when the water begins to warm.

The Savannah River, apparently due wholly or in part to the fact that it has been channelized in excess of 15 meters depth, appears to displace the nursery ground for young Sciaenid fishes during large portions of the year. The numbers of small Micropogon undulatus and Stellifer lanceolatus which we captured in the river (often at a point over 10 miles upstream from the entrance) were not observed by us in any adjacent estuarine area, even if the salinity regime was similar.

In conclusion, the Savannah River is not a biological wasteland, as some would have us believe, but houses large quantities of Sciaenid and other fishes. Current studies aimed at investigating the feeding habits of these fishes as well as the quantity of benthic organisms present and their diversity are underway. Plans are also being formulated to examine the zooplankton and phytoplankton populations of the Savannah River to obtain information on the productivity present.

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Kendall, A.W., Jr. and F.J. Schwartz. 1968. Lethal temperature and salinity tolerances of the white catfish, Ictalurus catus, from the Patuxent River, Maryland. Ches. Sci. 9:103-108.

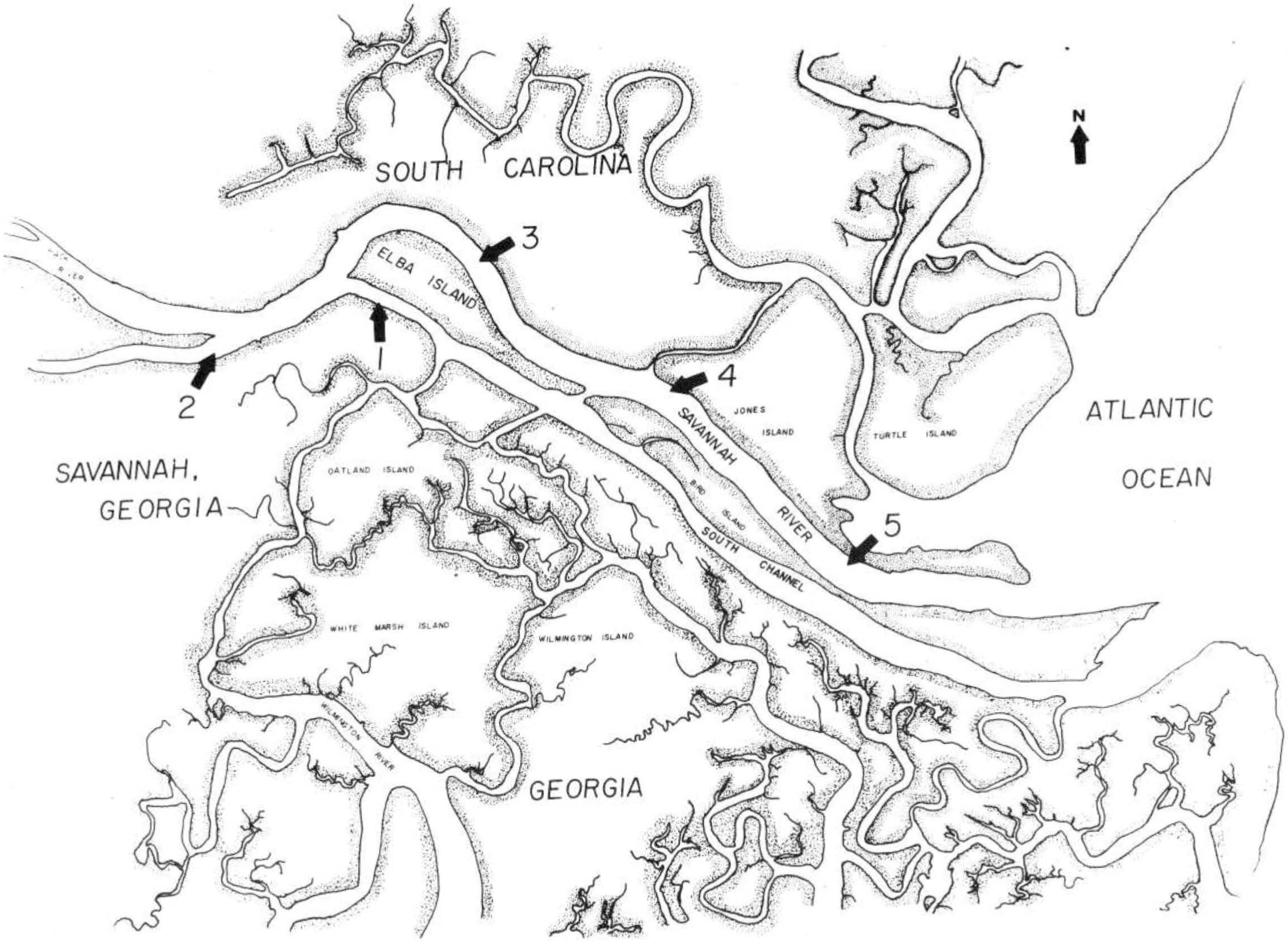

Figure 1. Location map for sampling stations occupied during the course of the study.

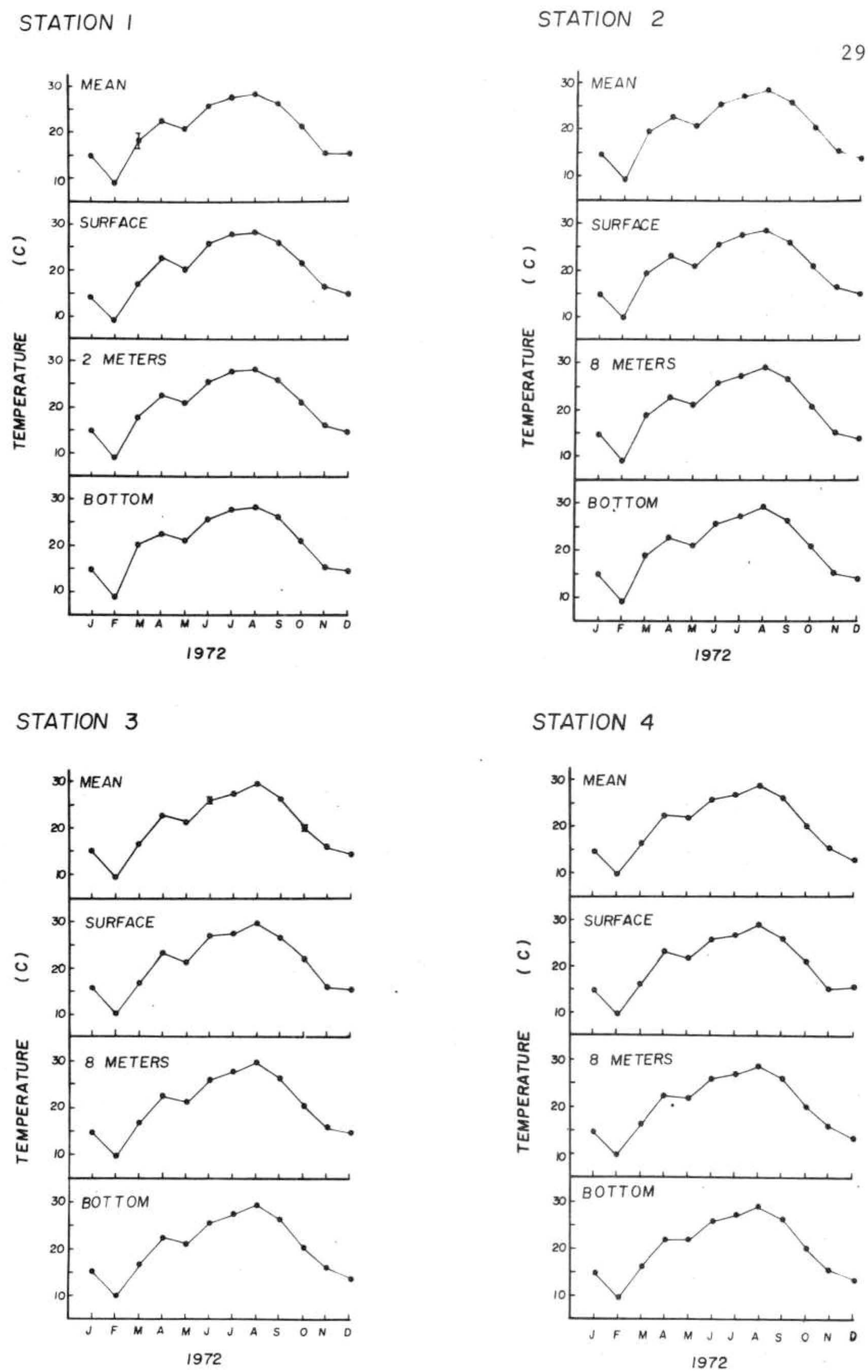

Figure 2. Monthly temperature determinations at stations 1 through 4 including values obtained from surface, midwater and bottom, and the mean value of the three. (Standard deviation of the mean is indicated where it exceeded ± 0.500).

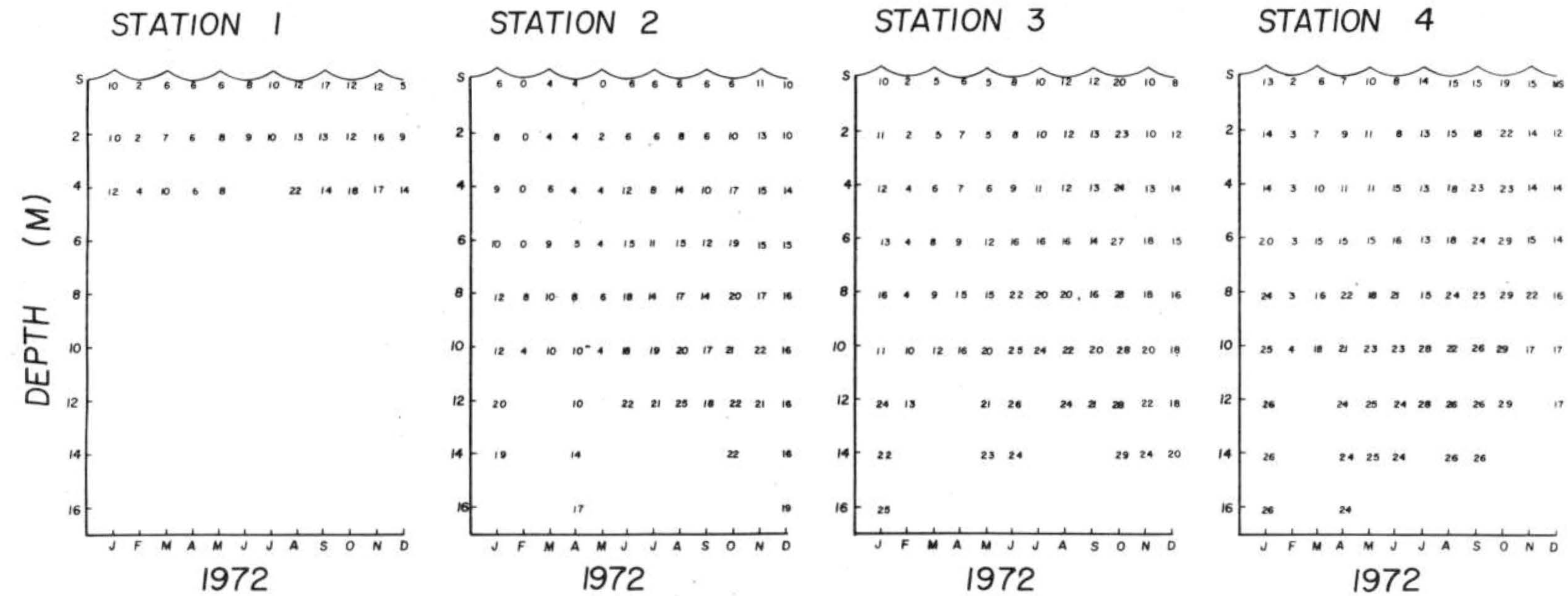

Figure 3. Monthly salinity determinations at two meter intervals, surface to bottom, from stations 1 through 4. (All values in parts per thousand.)

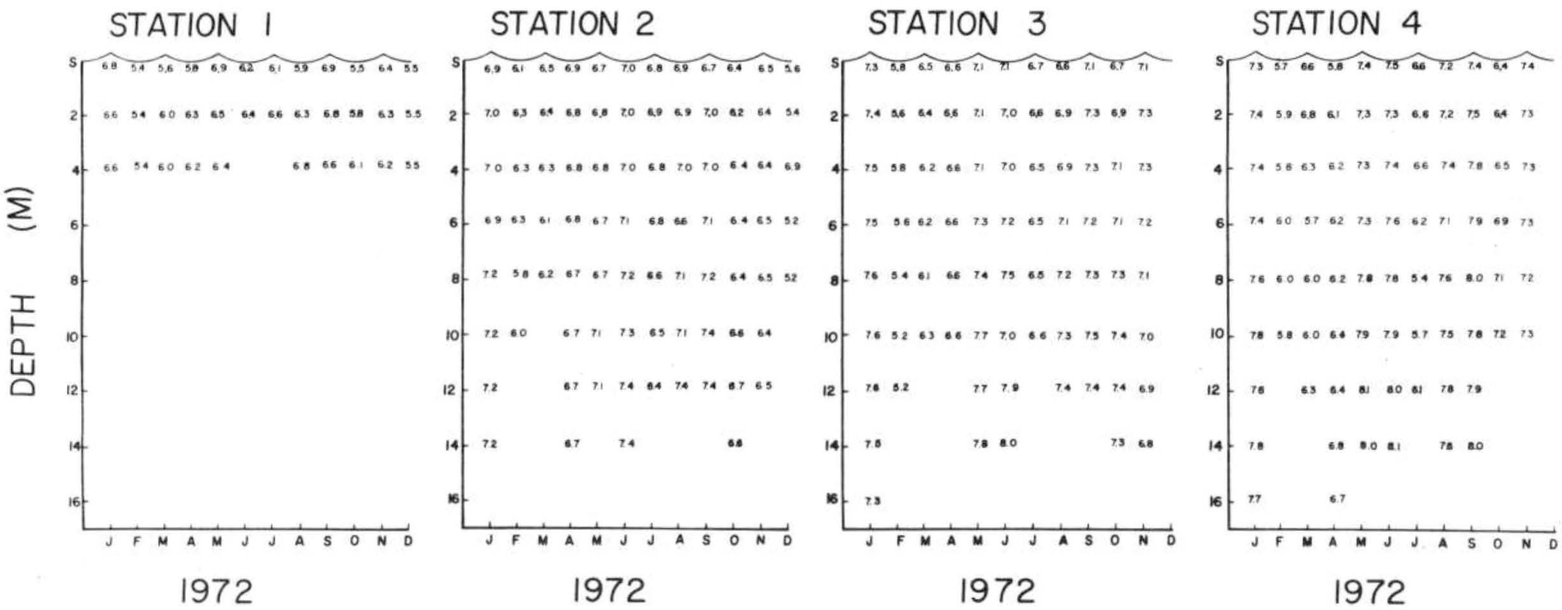

Figure 4. Monthly pH determinations at two meter intervals, surface to bottom, from stations 1 through 4.

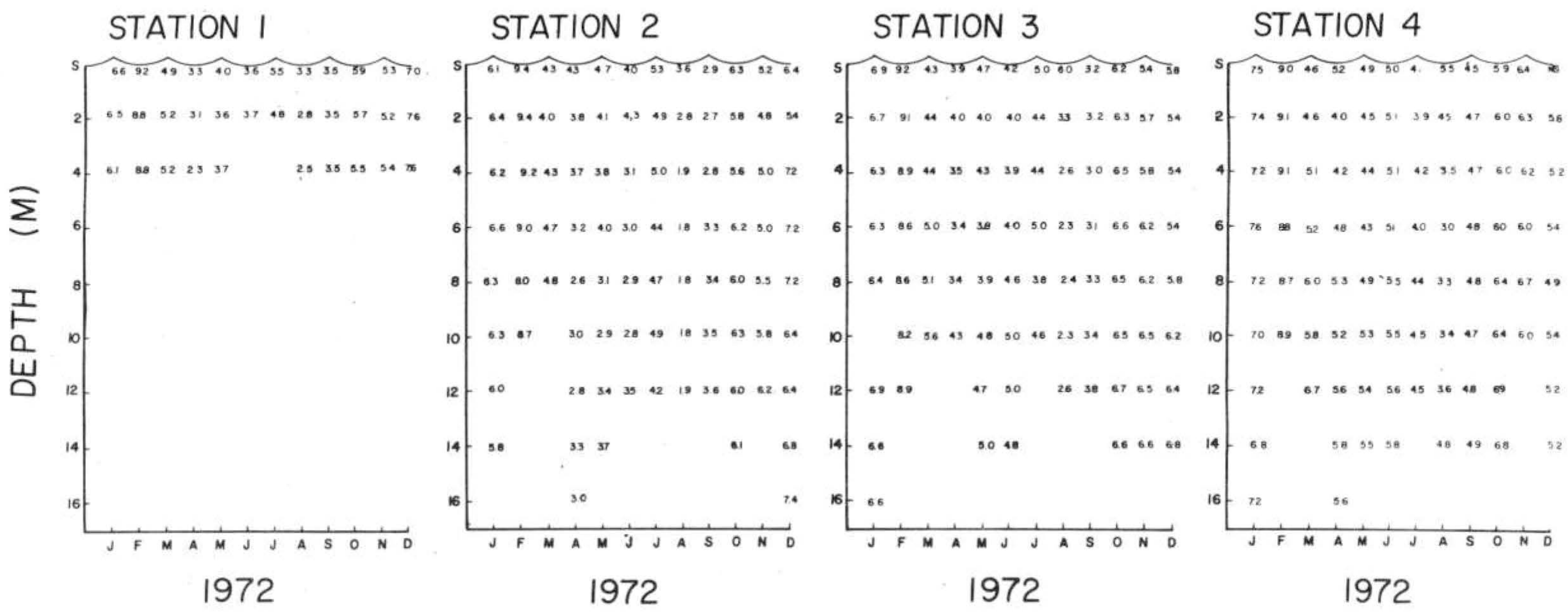

Figure 5. Monthly dissolved oxygen determinations at two meter intervals, surface to bottom, from stations 1 through 4. (All values in mg/l.)

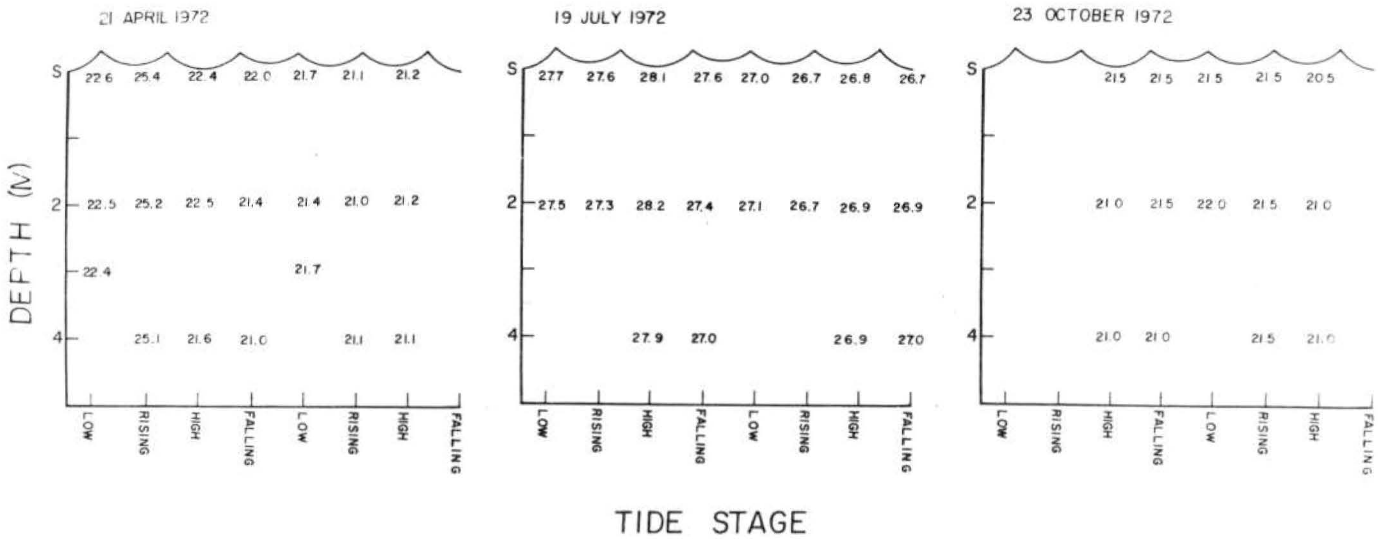

Figure 6. Diurnal temperature determinations from station 1 at two meter intervals, surface to bottom, on three dates during 1972. (All values in Celsius.)

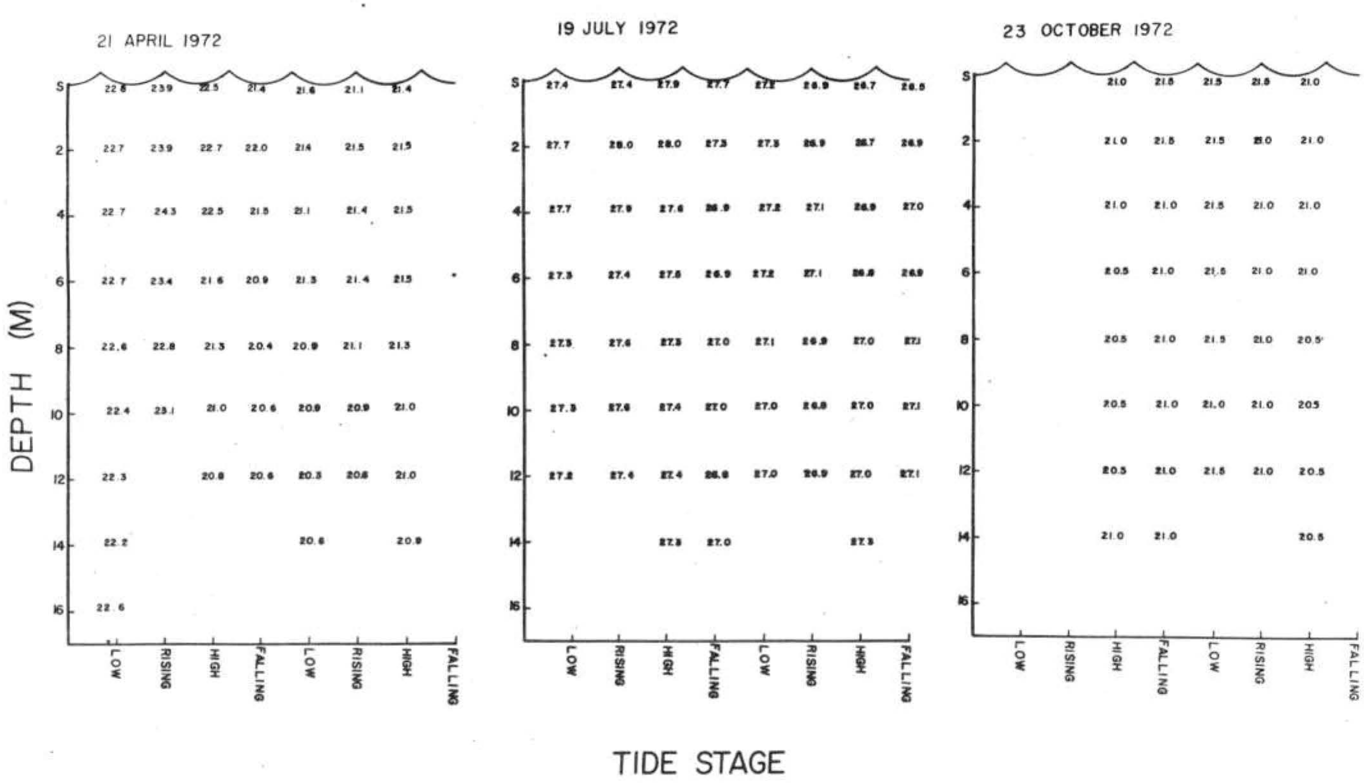

Figure 7. **Diurnal temperature determinations from station 2 at two meter intervals, surface to bottom, on three dates in 1972. (All values in Celsius.)**

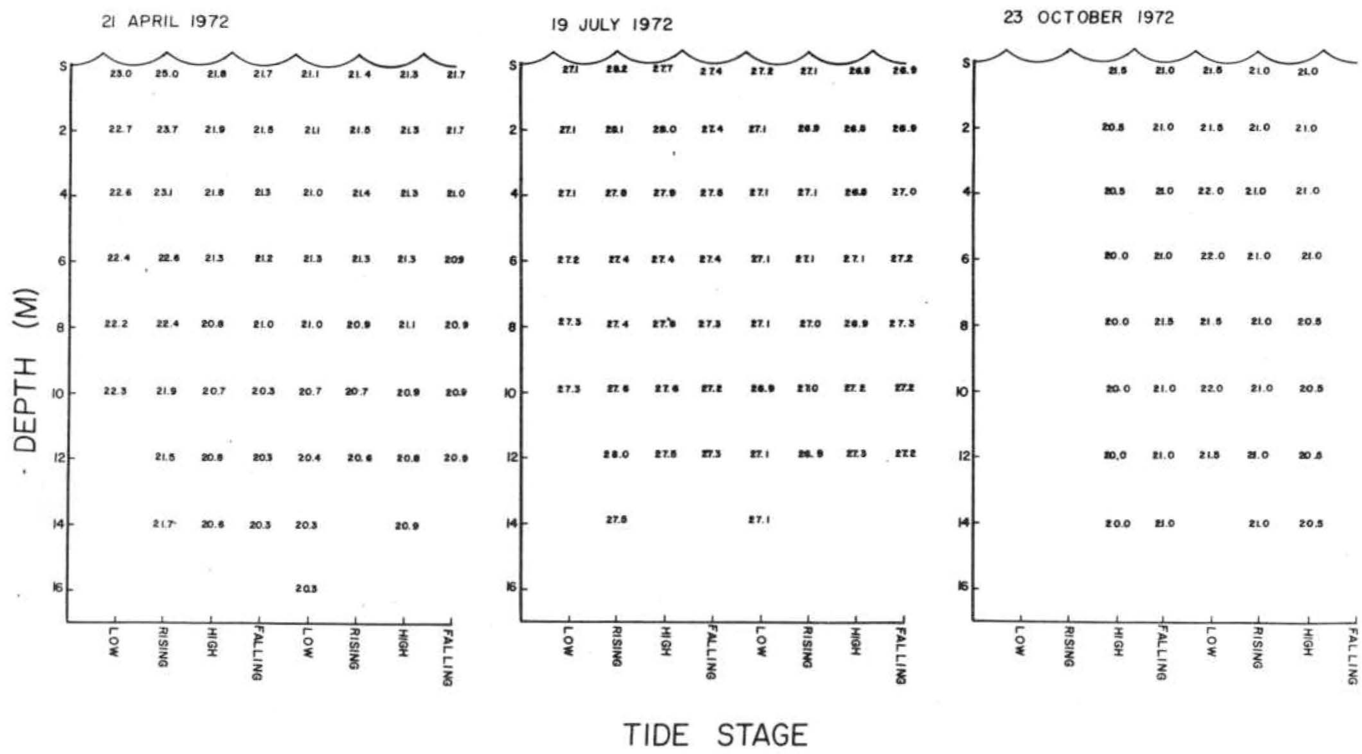

Figure 8. Diurnal temperature determinations from station 3 at two meter intervals, surface to bottom, on three dates during 1972. (All values in Celsius.)

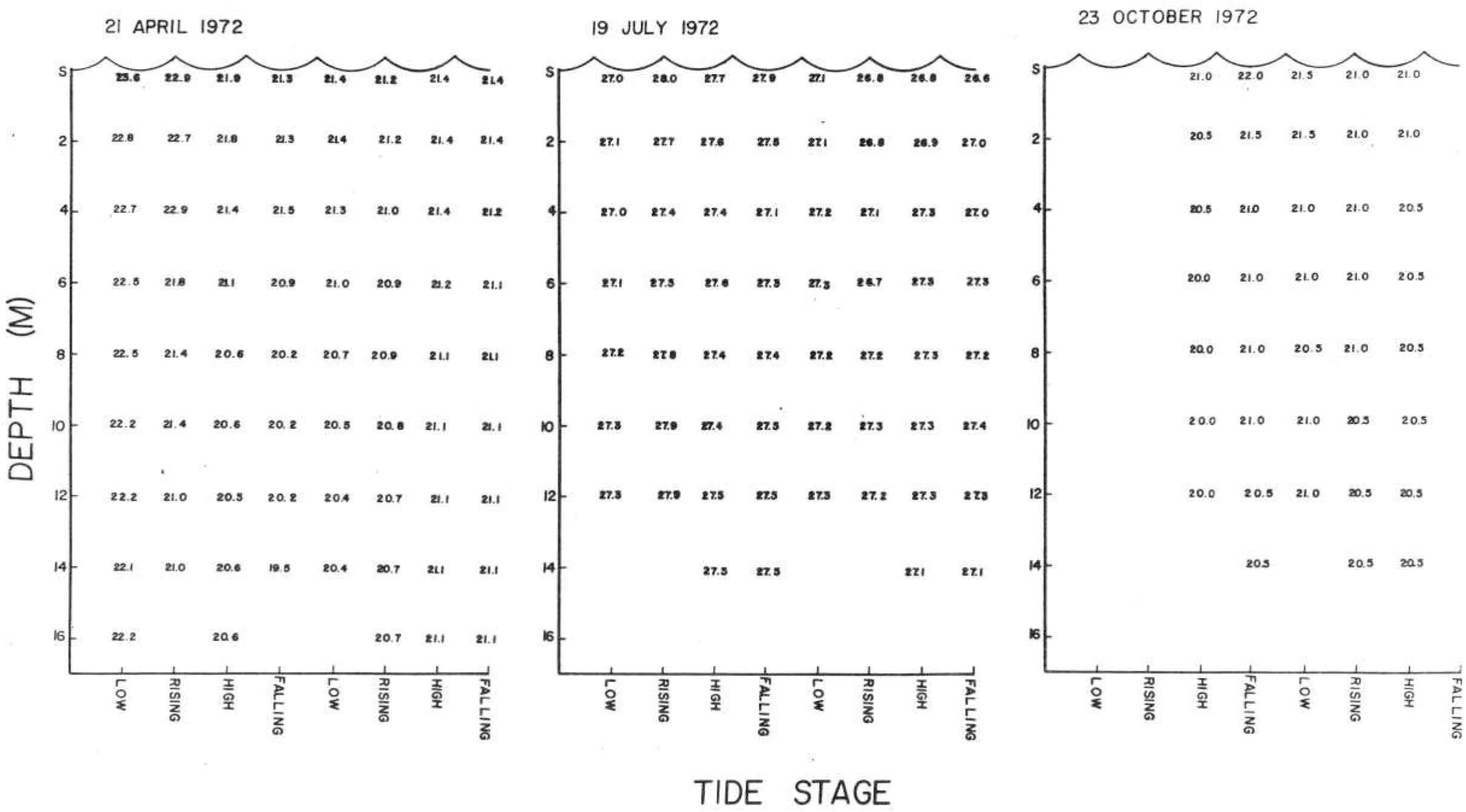

Figure 9. Diurnal temperature determinations from station 4 at two meter intervals, surface to bottom, on three dates during 1972. (All values in Celsius.)

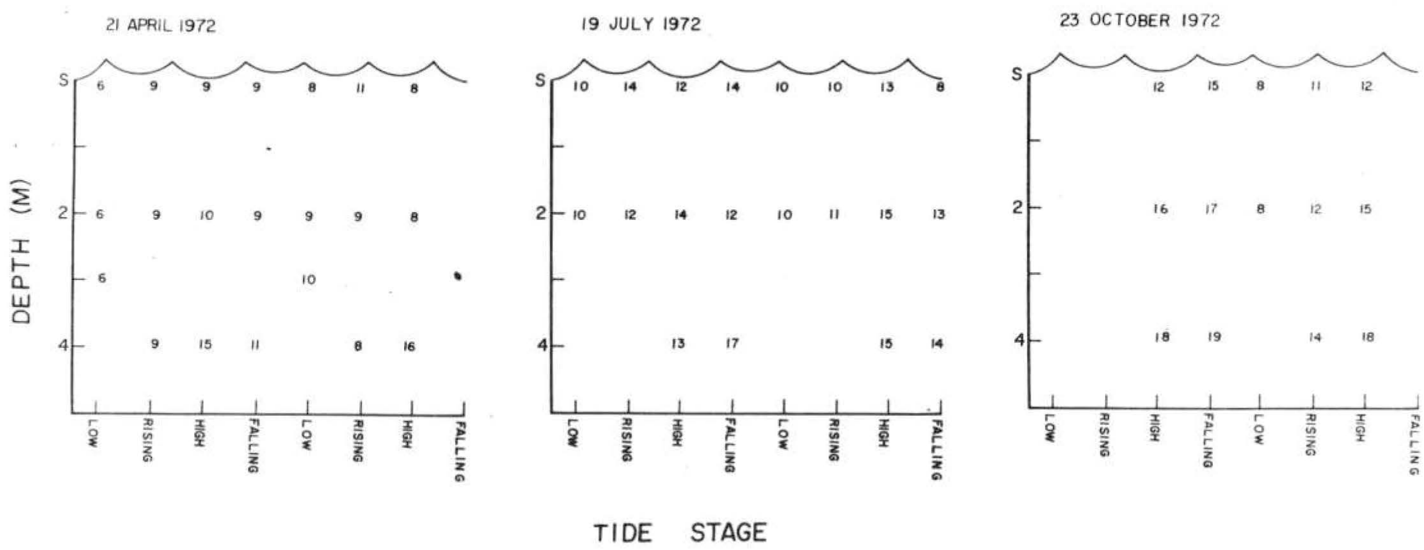

Figure 10. Diurnal salinity determinations from station 1 at two meter intervals, surface to bottom on three dates during 1972. (All values in parts per thousand.)

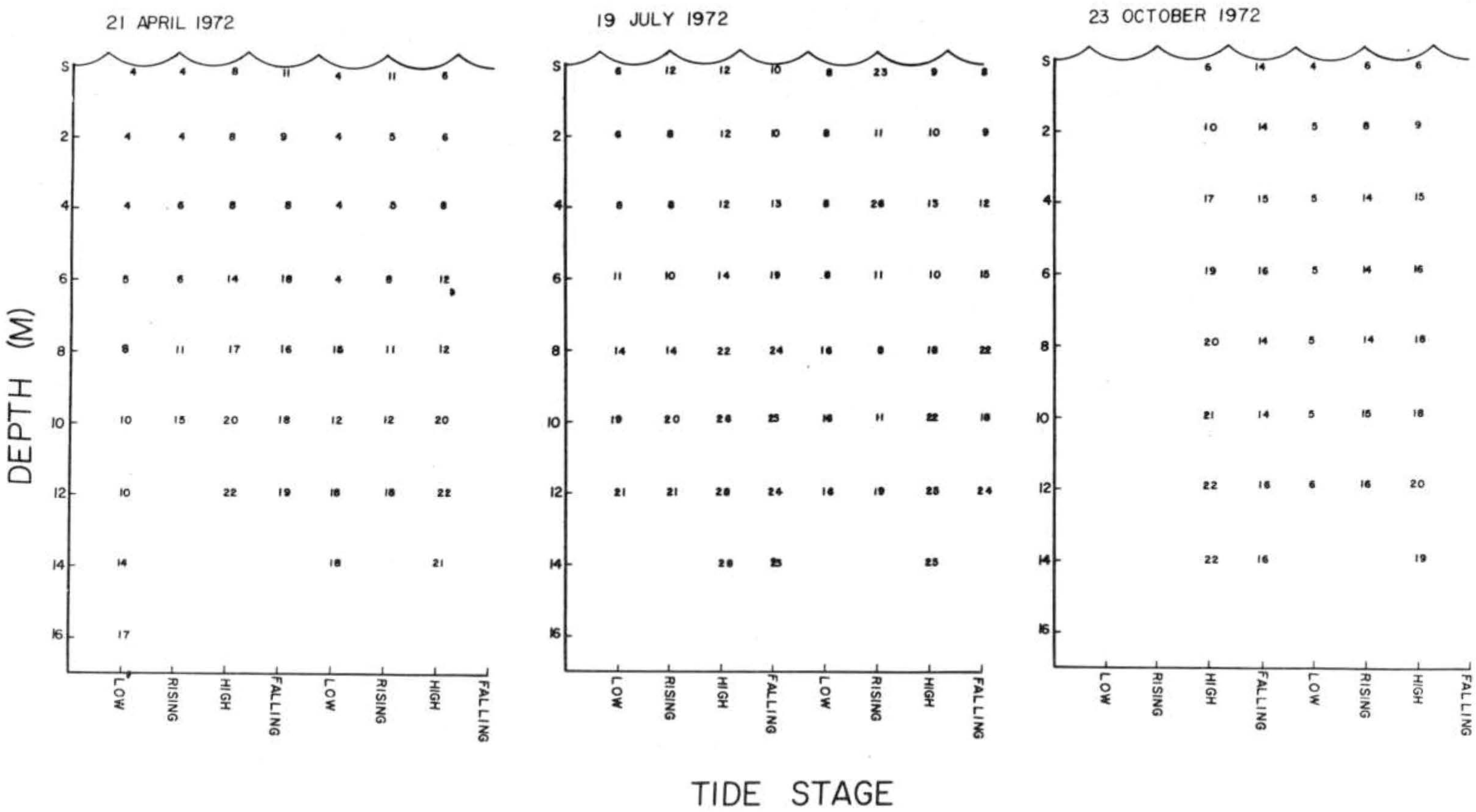

Figure 11. Diurnal salinity determinations from station 2 at two meter intervals, surface to bottom, on three dates during 1972. (All values in parts per thousand.)

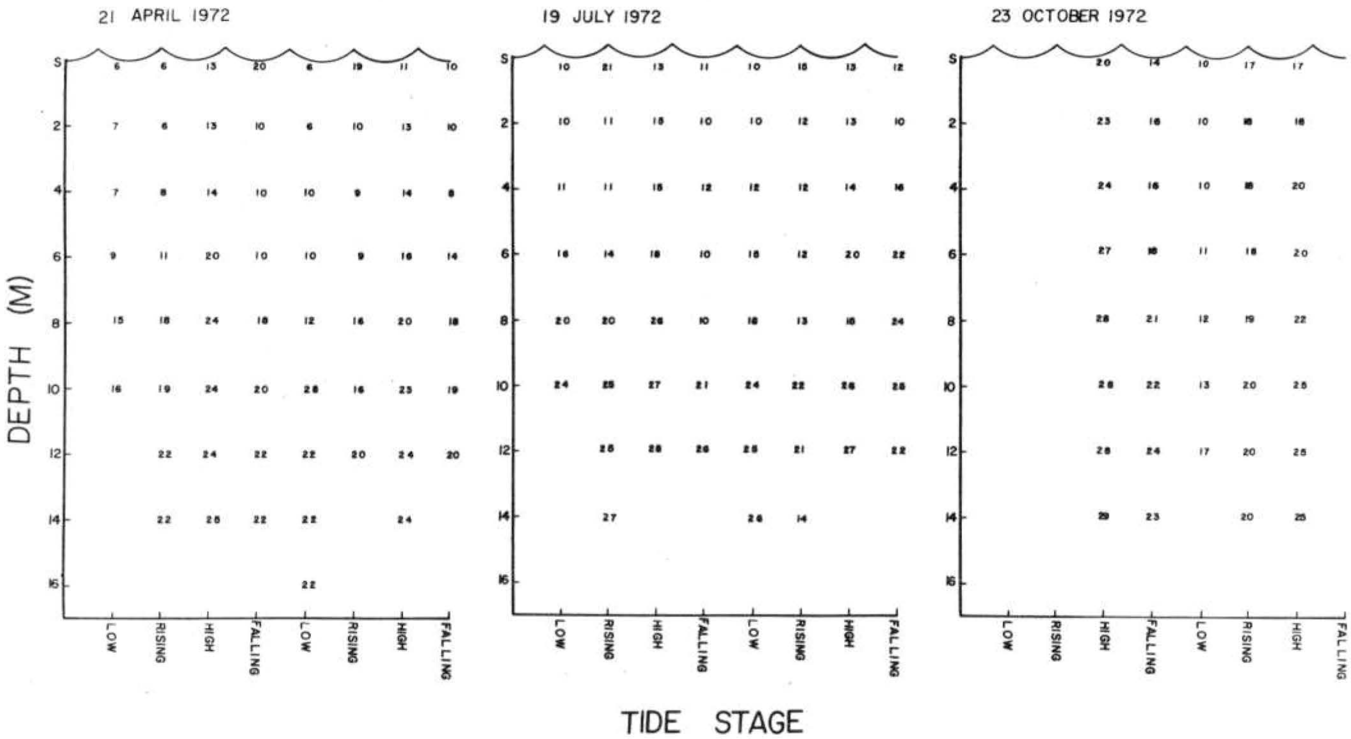

Figure 12. Diurnal salinity determinations from station 3 at two meter intervals, surface to bottom, on three dates during 1972. (All values in parts per thousand.)

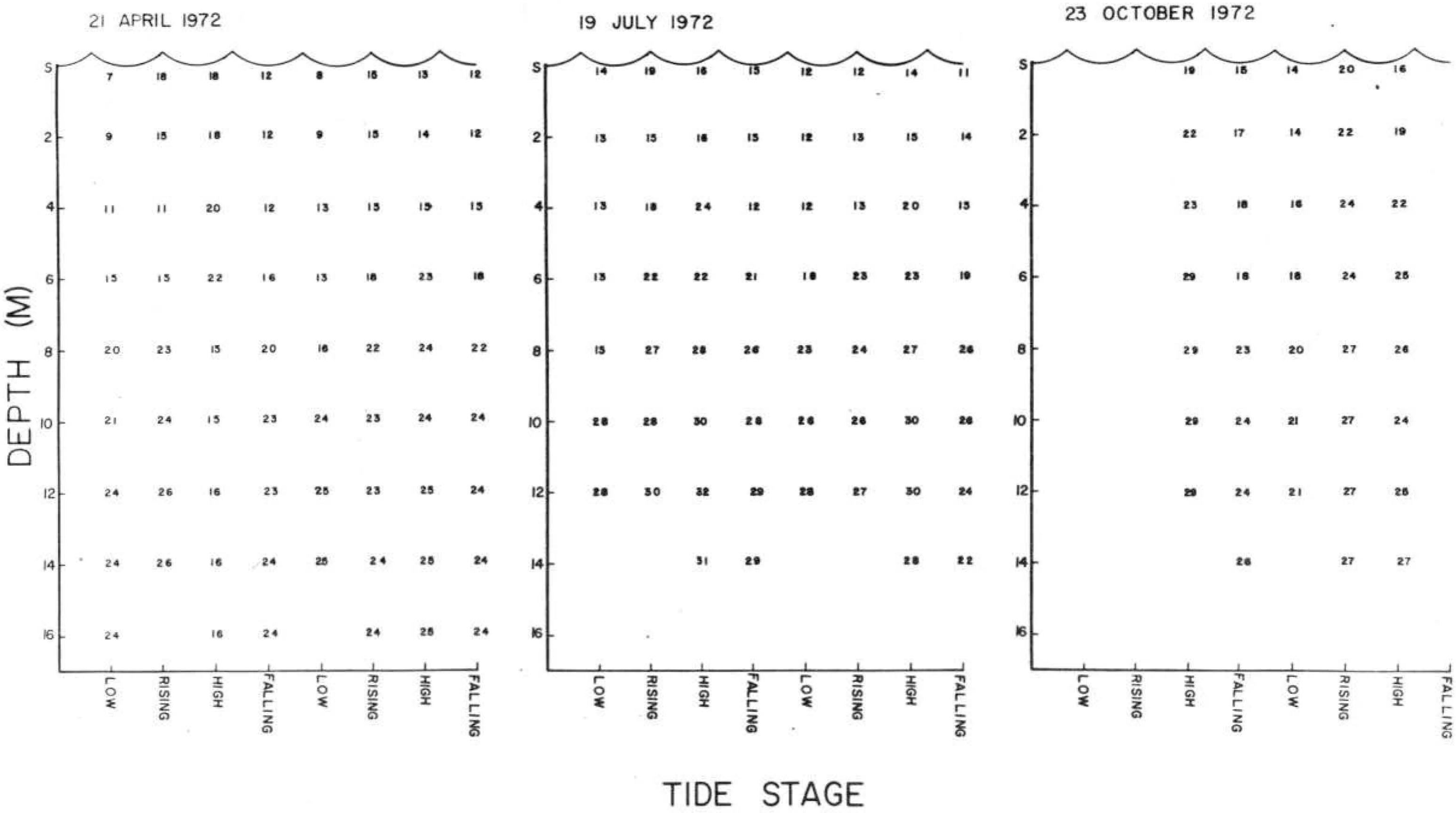

Figure 13. Diurnal salinity determinations from station 4 at two meter intervals, surface to bottom, on three dates during 1972. (All values in parts per thousand.)

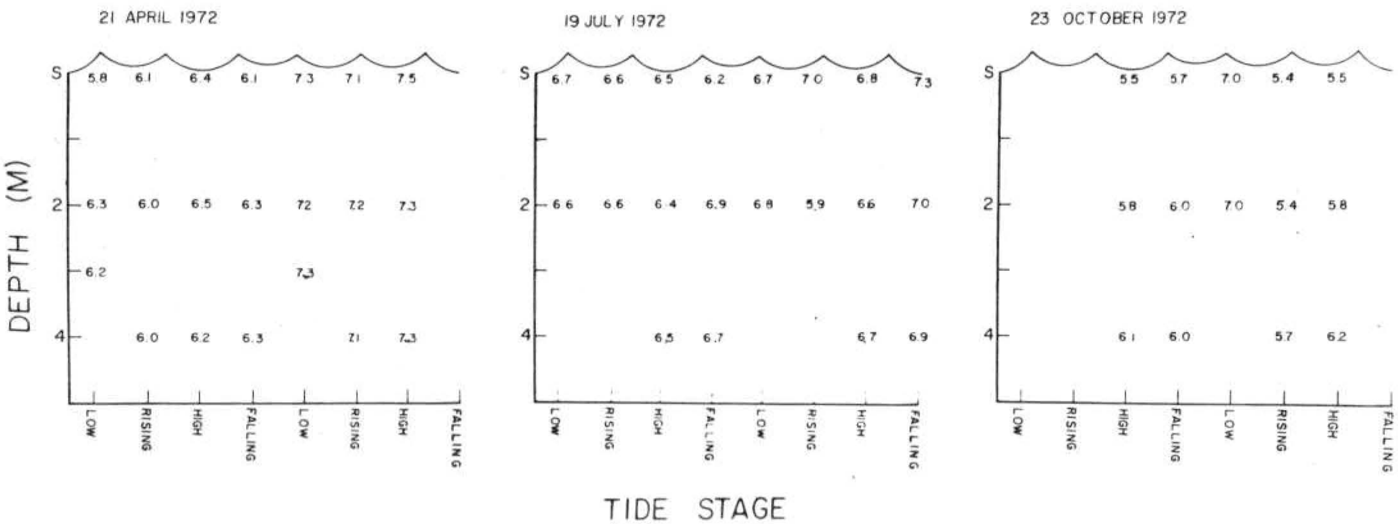

Figure 14. Diurnal pH determinations from station 1 at two meter intervals, surface to bottom, on three dates during 1972.

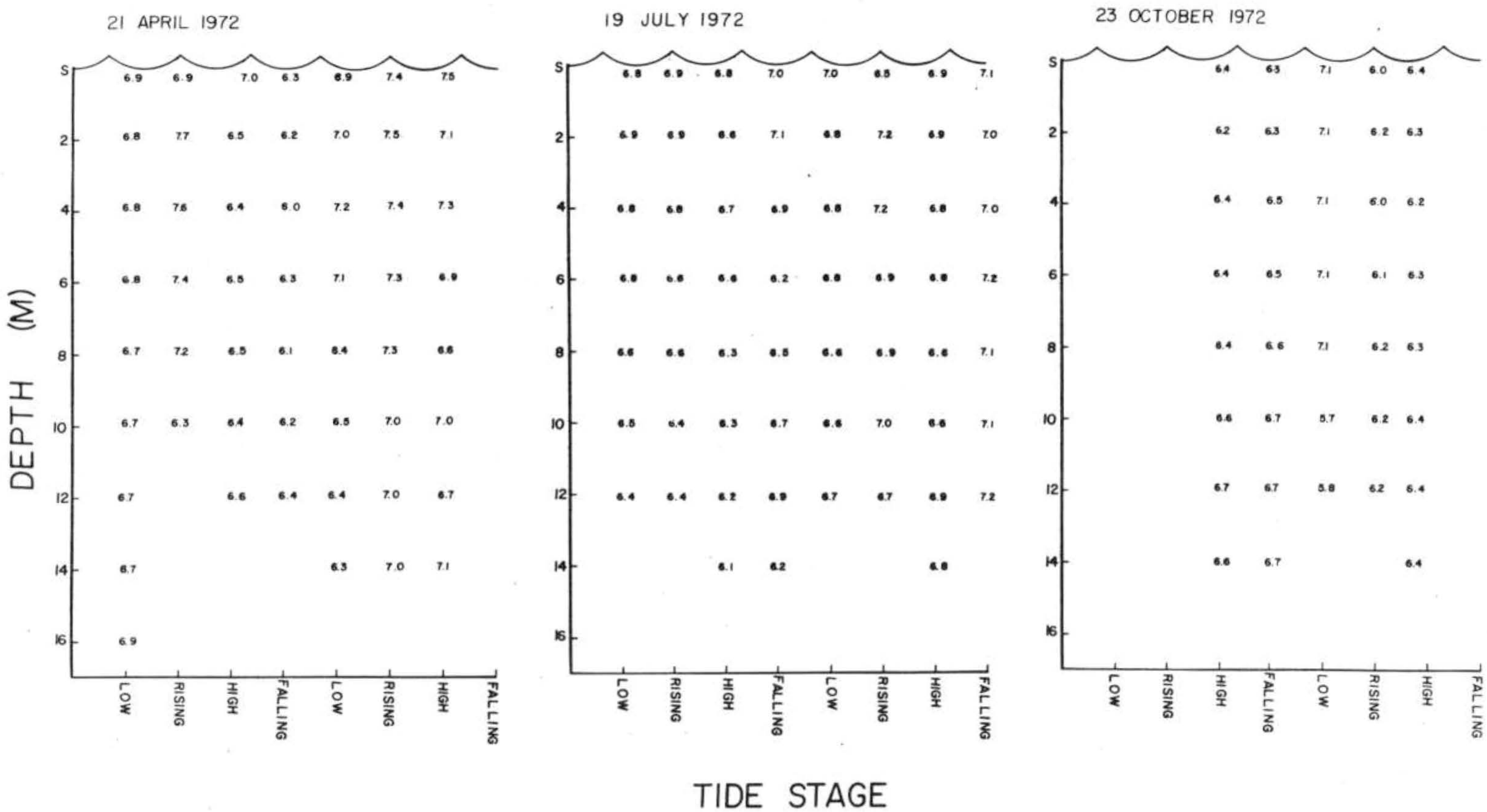

Figure 15. Diurnal pH determinations from station 2 at two meter intervals, surface to bottom, on three dates during 1972.

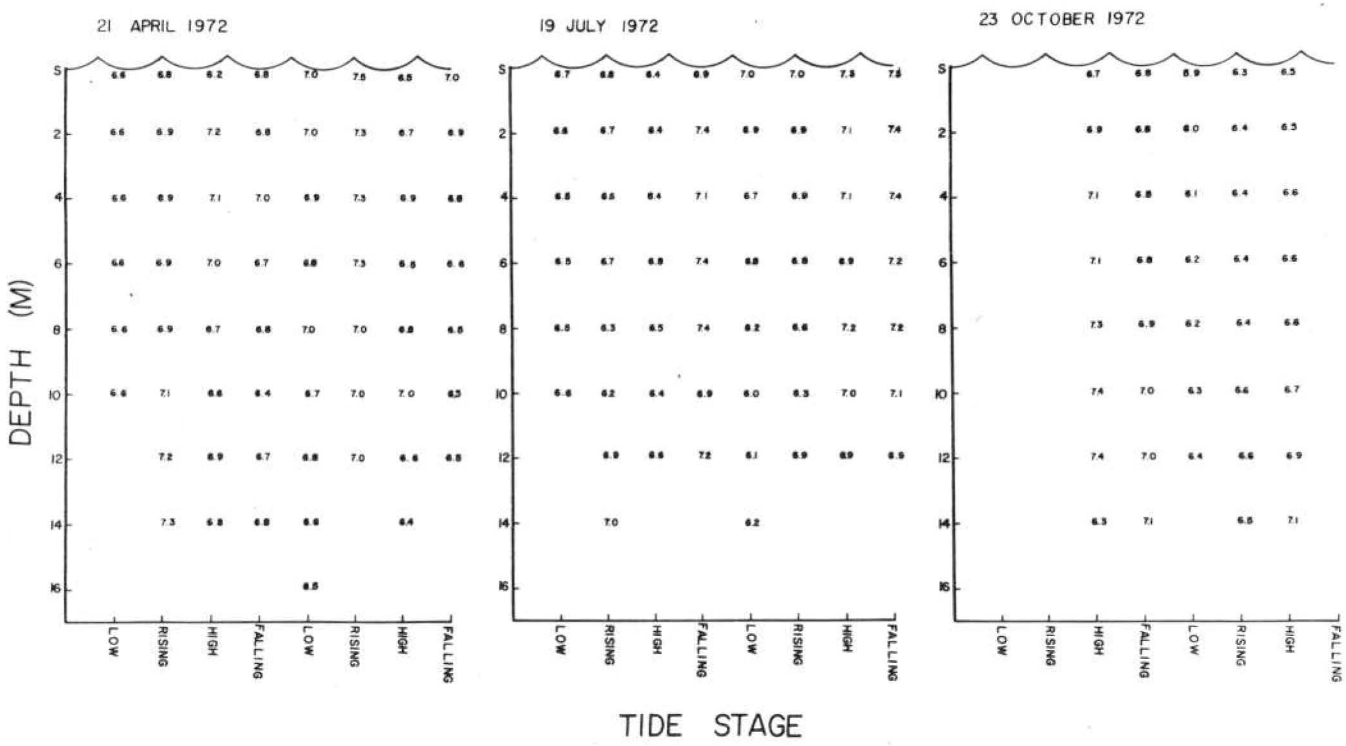

Figure 16. Diurnal pH determinations from station 3 at two meter intervals, surface to bottom, on three dates during 1972.

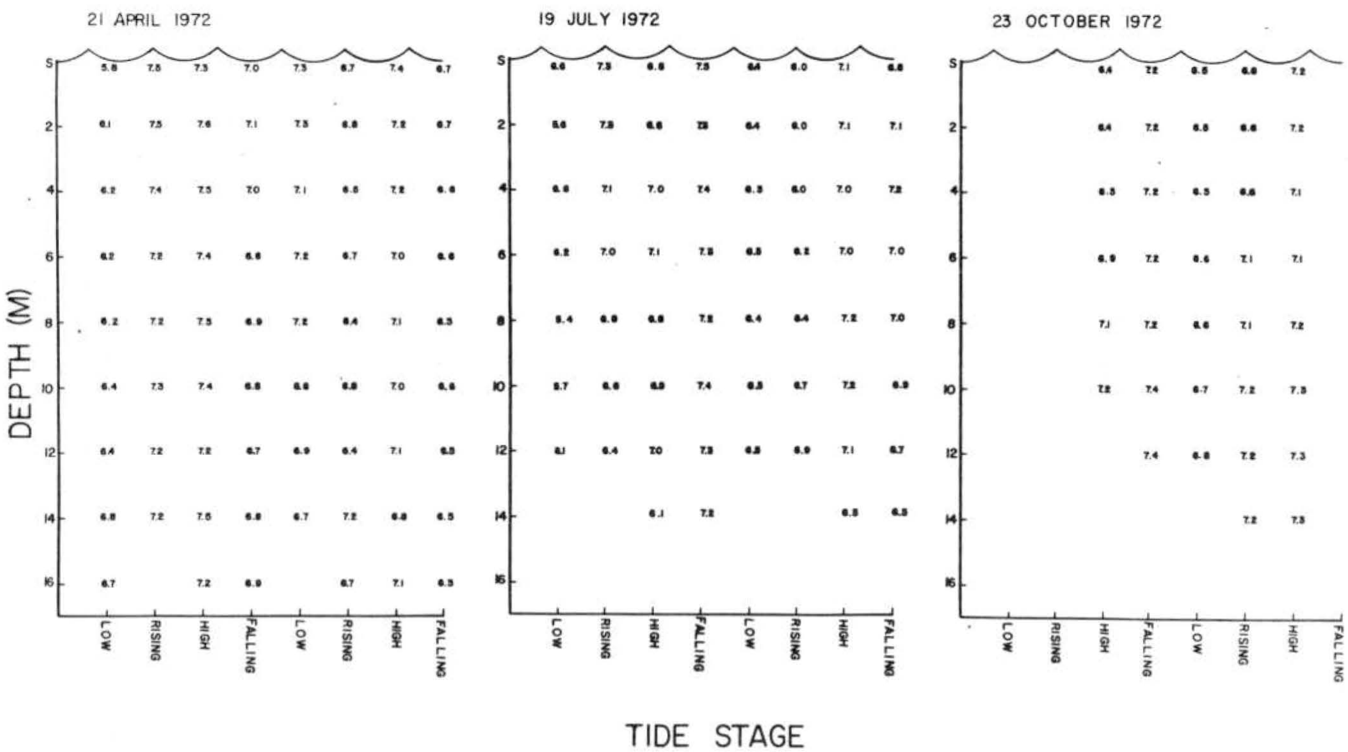

Figure 17. Diurnal pH determinations from station 4 at two meter intervals, surface to bottom, on three dates during 1972.

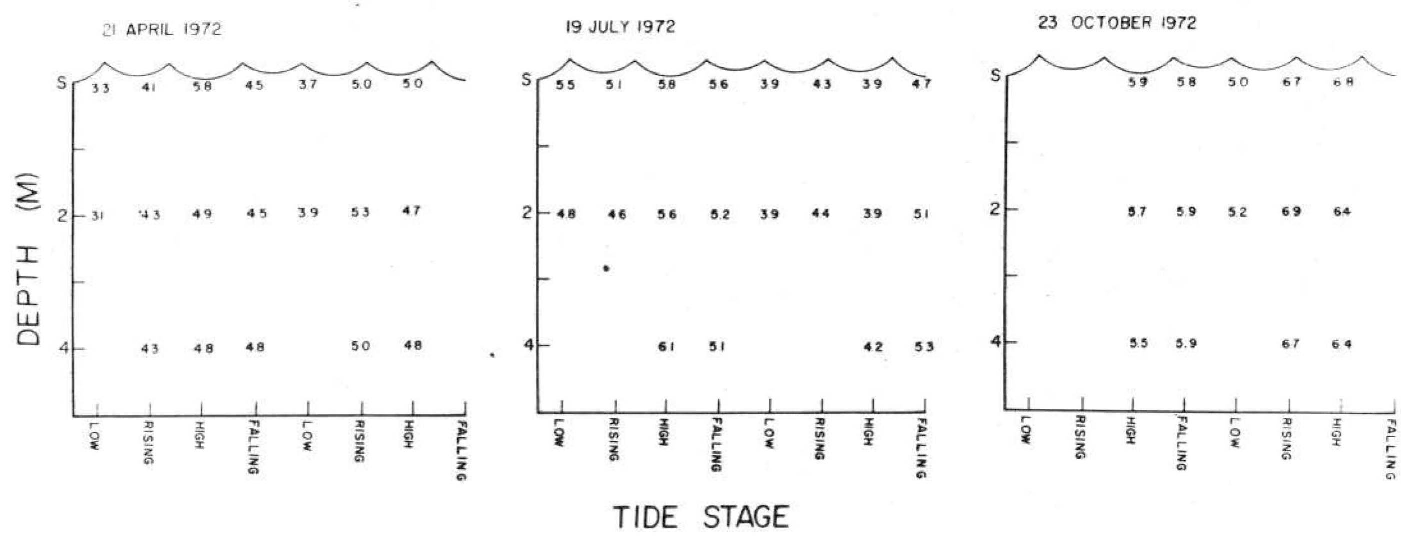

Figure 18. Diurnal dissolved oxygen determinations from station 1 at two meter intervals, surface to bottom, on three dates during 1972. (All values in mg/l.)

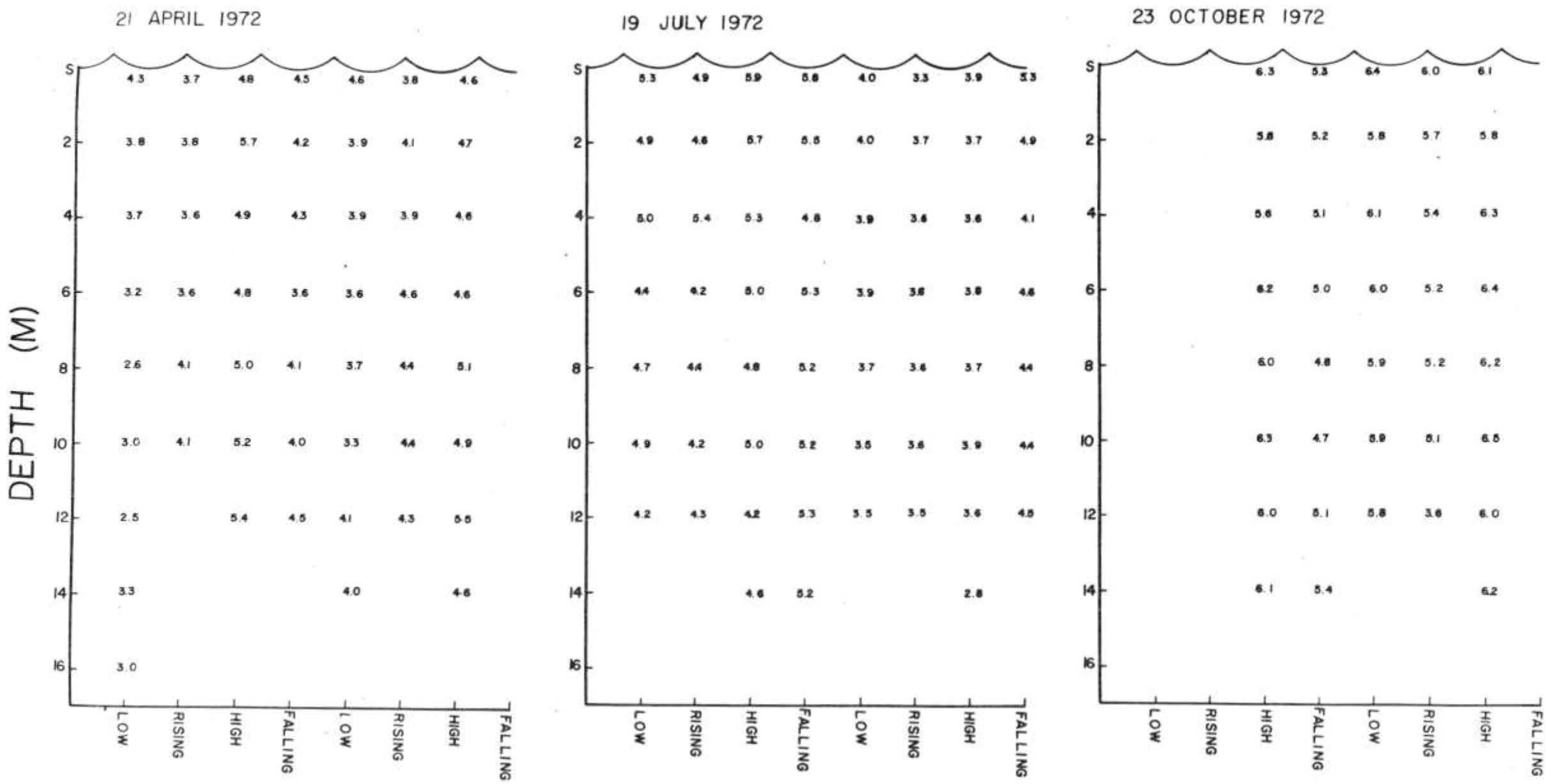

Figure 19. Diurnal dissolved oxygen determinations from station 2 at two meter intervals, surface to bottom, on three dates during 1972. (All values in mg/l.)

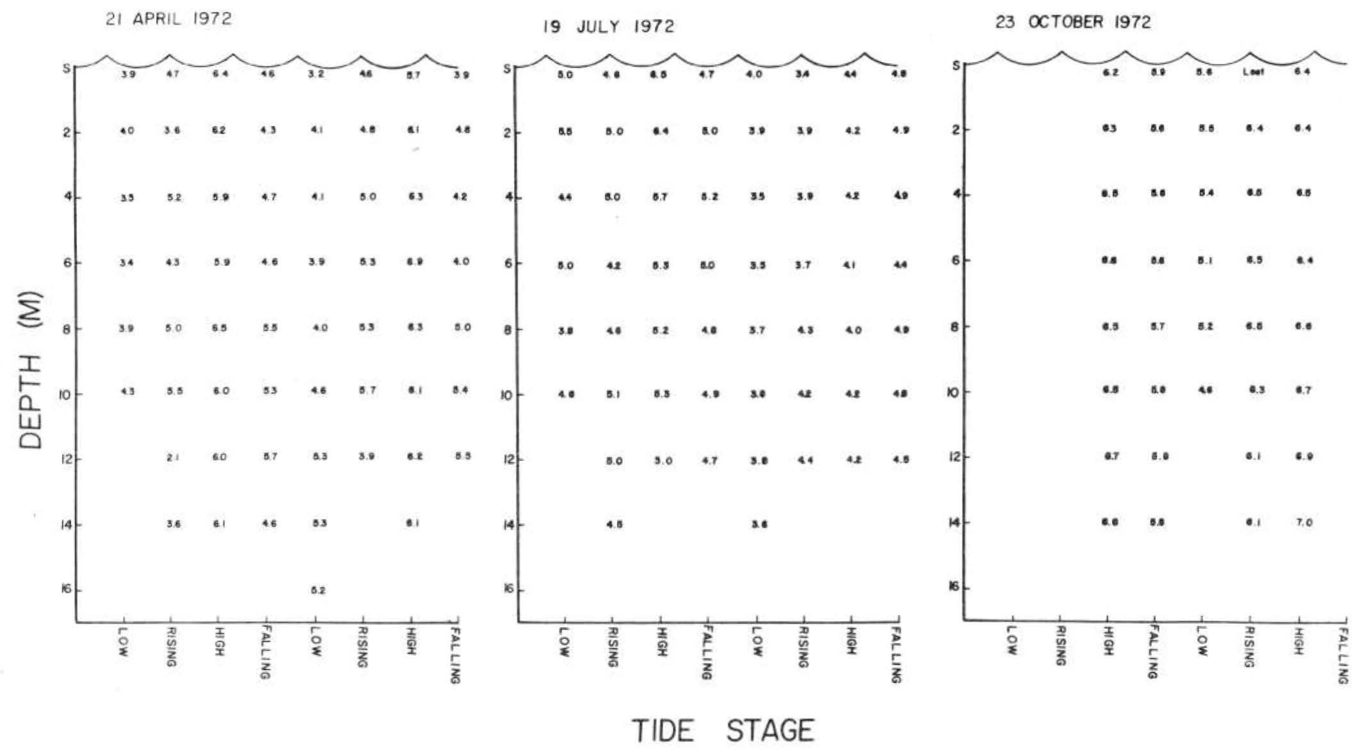

Figure 20. Diurnal dissolved oxygen determinations from station 3 at two meter intervals, surface to bottom, on three dates during 1972. (All values in mg/l.)

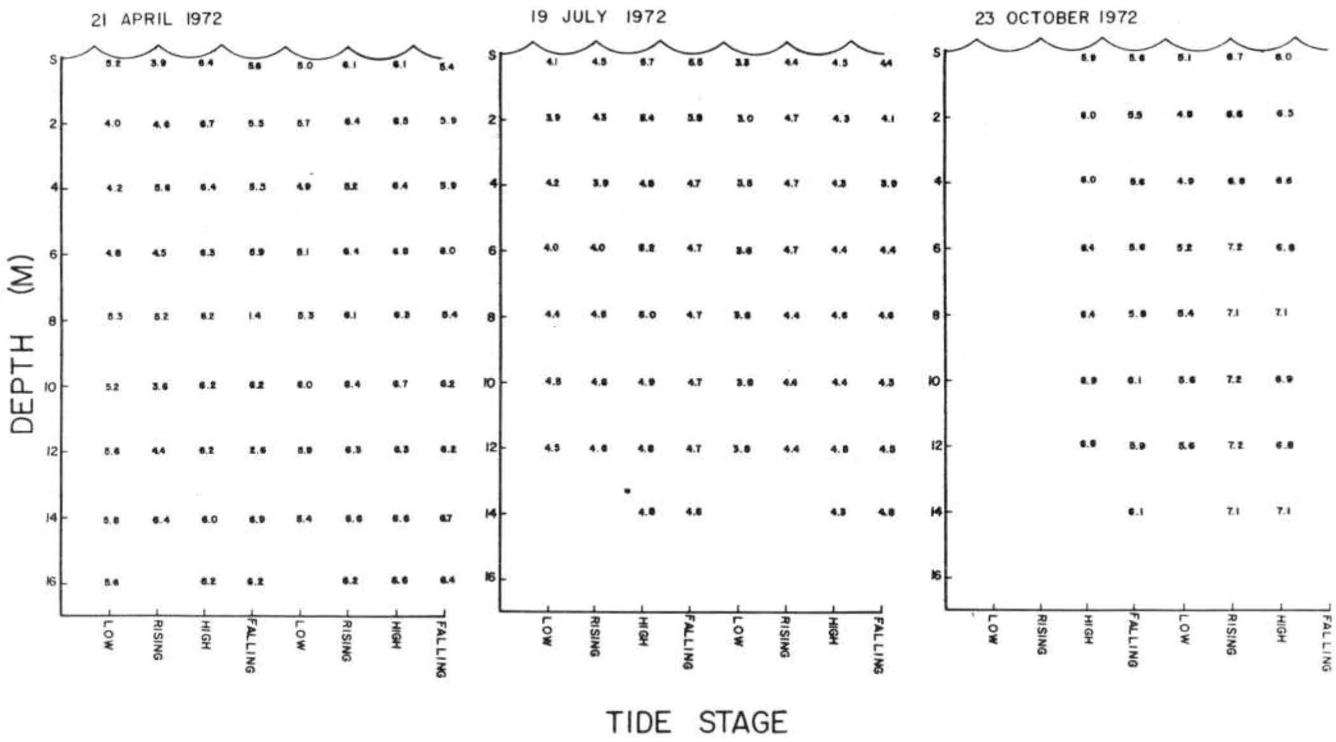

Figure 21. Diurnal dissolved oxygen determinations from station 4 at two meter intervals, surface to bottom, on three dates during 1972. (All values in mg/l.)

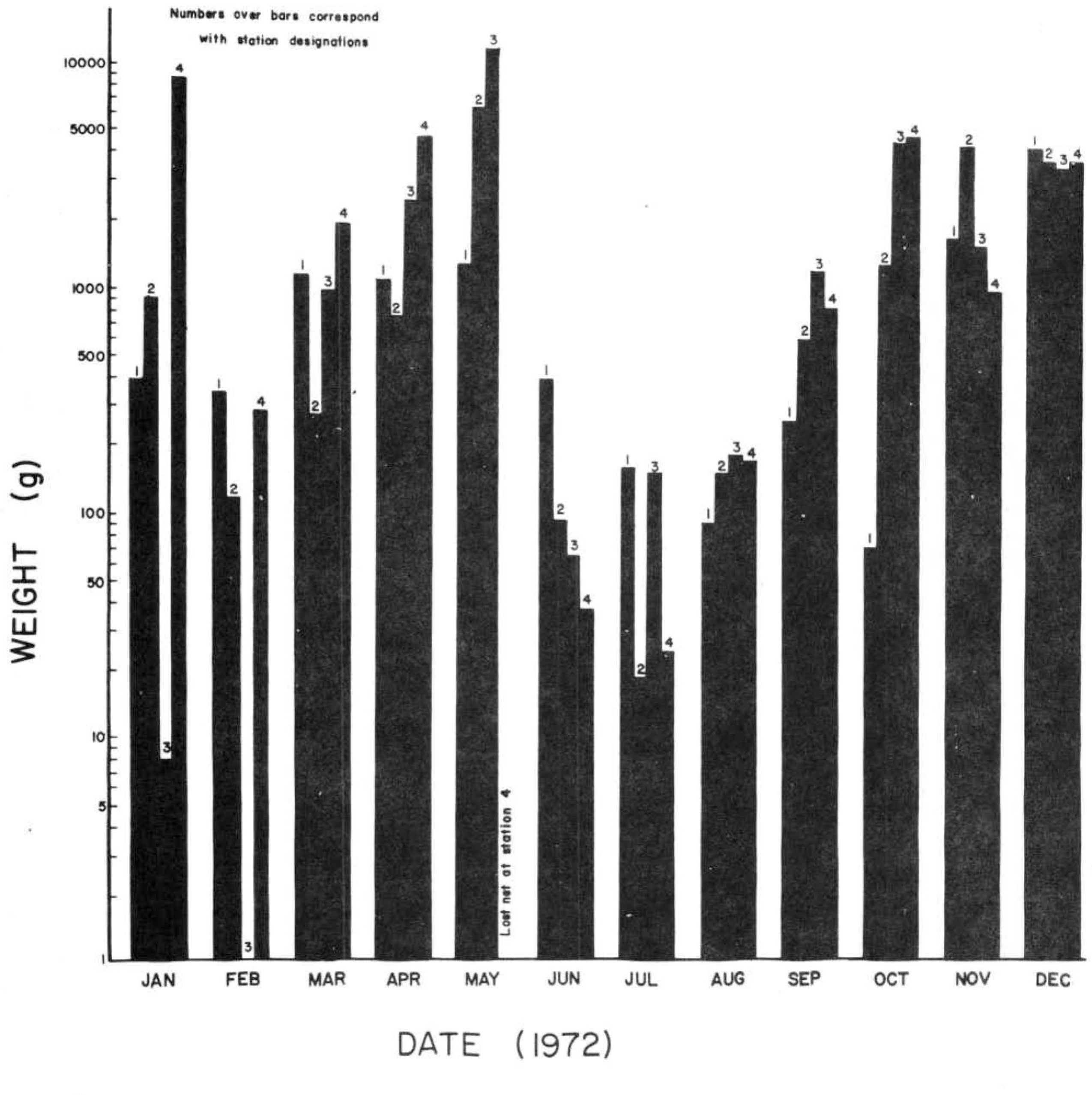

Figure 22. Total monthly biomass collected at each station during 1972.

Level of significance indicated below value for t

	JAN 2390.4	FEB 242.8	MAR 1054.4	APR 2181.5	MAY 6283.5	JUN 143.6	JUL 86.2	AUG 143.0	SEP 683.5	OCT 2571.0	NOV 2210.3
FEB 242.8	1.120										
MAR 1054.4	0.669	2.547 0.05									
APR 2181.5	0.097	2.277 0.05	0.184								
MAY 6283.5	1.147	2.470 0.05	2.092 0.05	2.038 0.05							
JUN 143.6	1.139	0.344	2.652 0.05	2.363 0.05	2.486 0.05						
JUL 86.2	1.169	1.119	2.883 0.05	2.533 0.05	2.510 0.05	0.641					
AUG 143.0	1.140	0.474	2.722 0.05	2.402 0.05	2.487 0.05	0.011	1.365				
SEP 683.5	0.852	2.470 0.05	0.906	0.970	2.251 0.05	2.633 0.05	3.084 0.05	2.830 0.05			
OCT 2571.0	0.080	2.111 0.05	1.288	1.177	1.323	2.144 0.05	2.200 0.05	2.149 0.05	1.629 0.10		
NOV 2210.3	0.079	2.876 0.05	1.499 0.10	1.305	1.558 0.10	2.929 0.05	3.025 0.05	2.946 0.05	2.076 0.05	0.260	
DEC 3645.5	0.635	20.143 0.01	7.052 0.01	5.580 0.01	1.066	20.136 0.01	22.467 0.01	22.582 0.01	11.787 0.01	0.943	1.966 0.05

Figure 23. Comparison of mean monthly biomass collected during 1972 by paired t test.

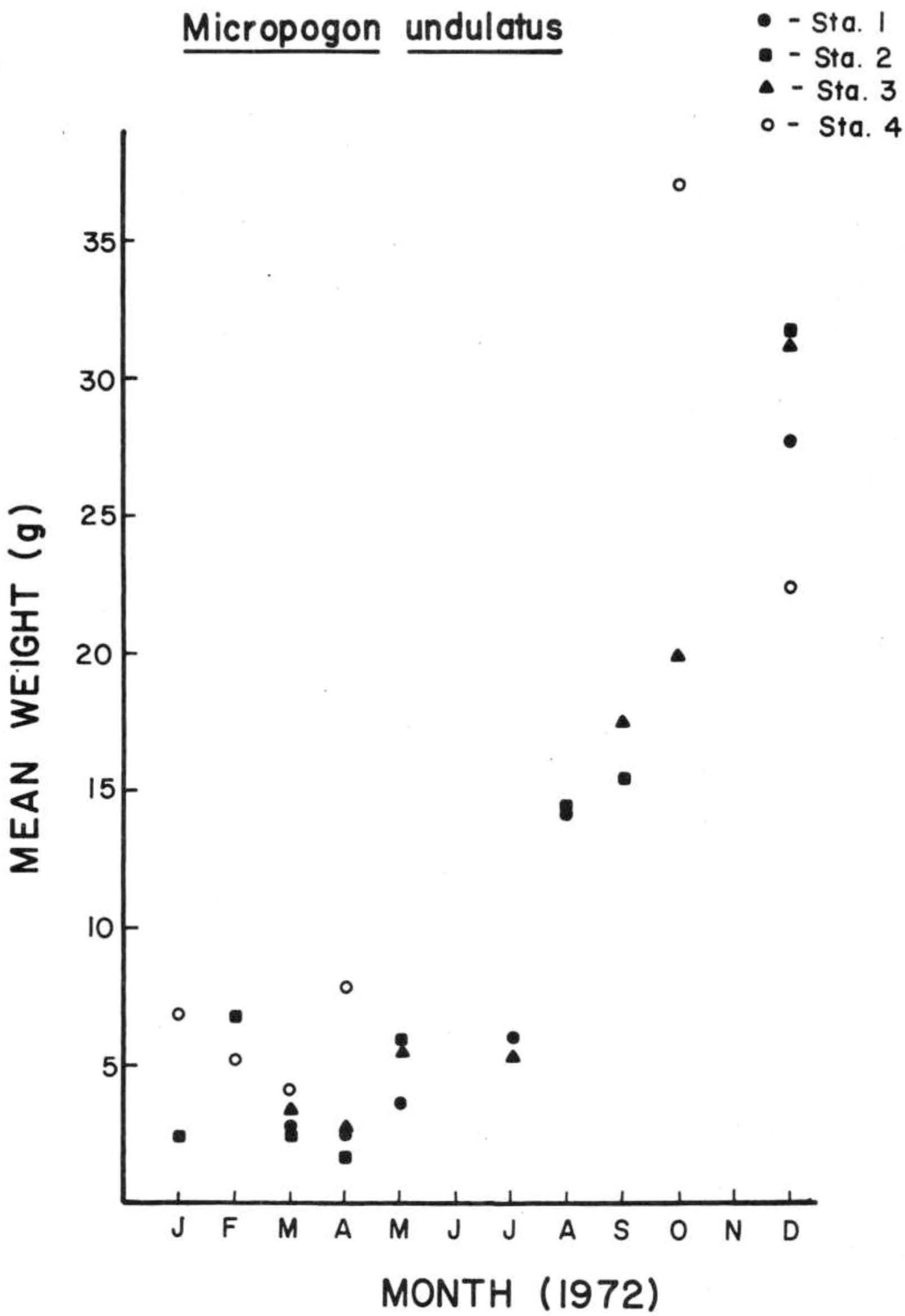

Figure 24. Average weight of Micropogon undulatus captured at each station monthly by otter trawling during 1972.

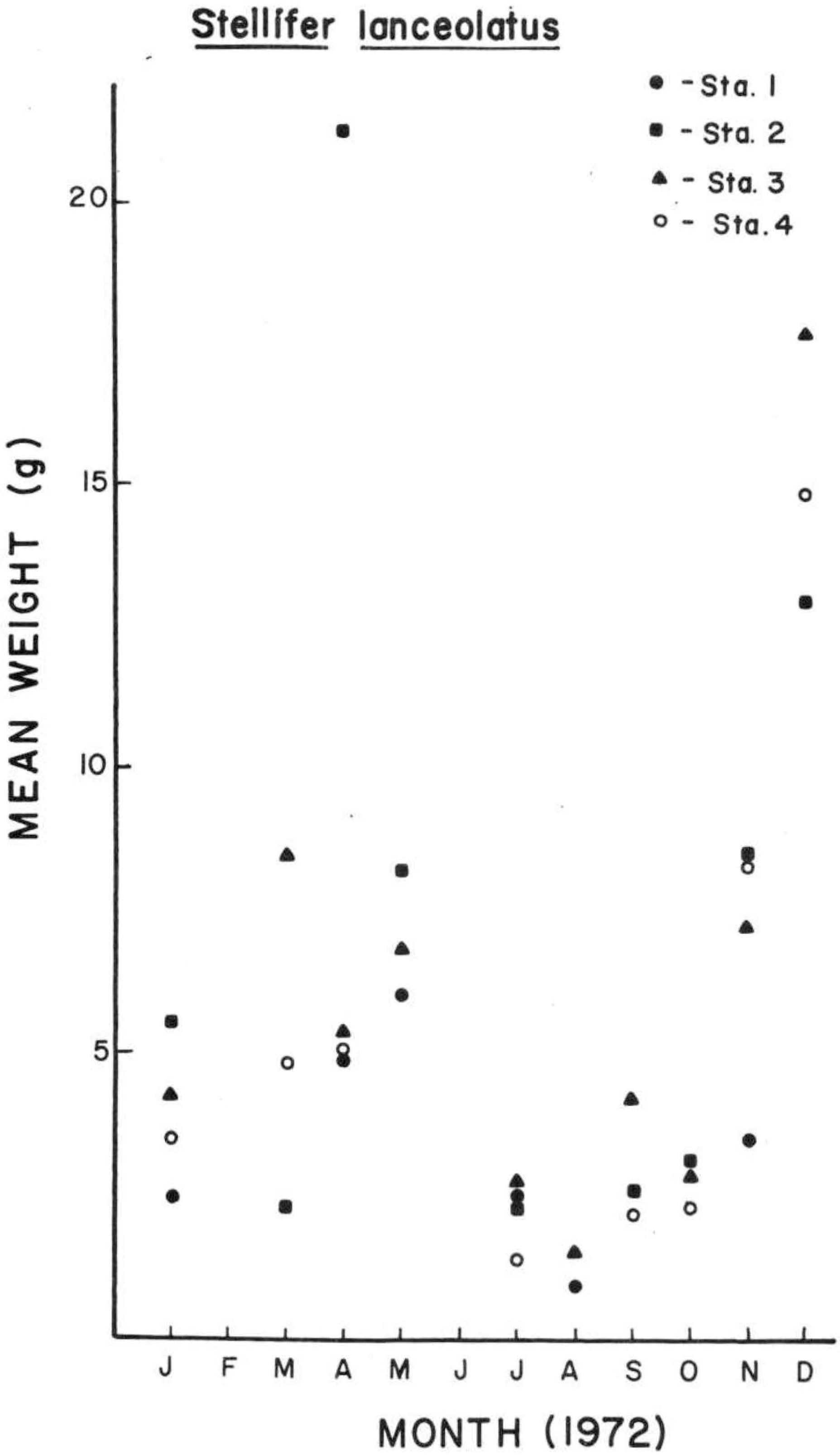

Figure 25. Average weight of Stellifer lanceolatus captured at each station monthly by otter trawling during 1972.

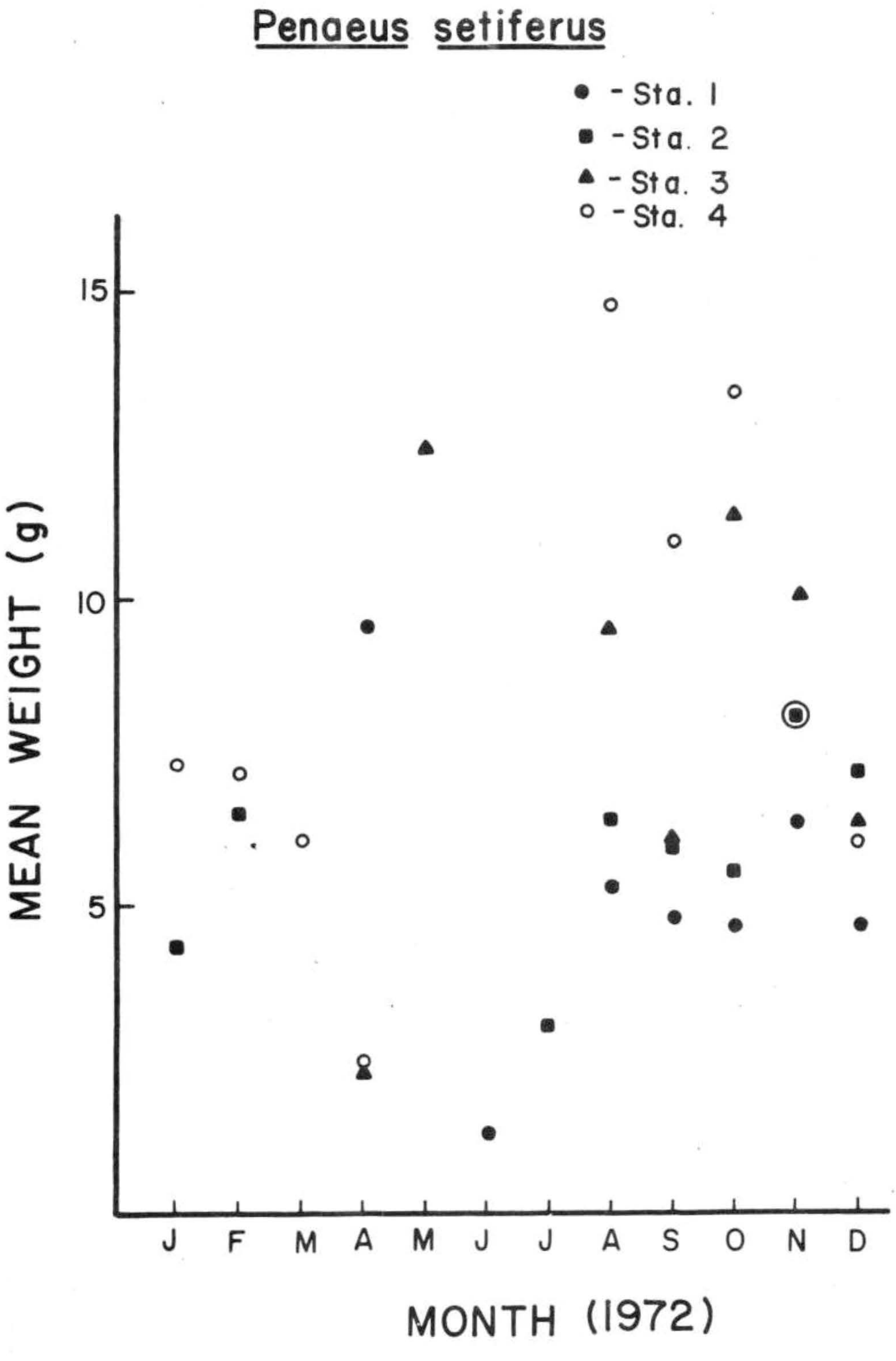

Figure 26. Average weight of Penaeus setiferus captured at each station monthly by otter trawling during 1972.

TABLE 1

Tide stage in the Savannah River during monthly sampling

Month (1972)	Tide Stage
January	Low to slightly rising
February	Falling
March	Falling
April	Falling
May	Falling
June	Low
July	Low
August	Low
September	Rising
October	High
November	High
December	Falling

TABLE 2

Scientific and common names of vertebrates captured in the Savannah River during 1972 by otter trawling

Family	Scientific Name[1]	Common Name
Clupeida	Brevoortia tyrannus[2]	Atlantic menhaden
	Opisthonema oglinum	Thread herring
Engraulidae	Anchoa hepsetus	Bay anchovy
	Anchoa mitchelli	Striped anchovy
Ictaluridae	Ictalurus catus[2]	White catfish
Ariidae	Arius felis	Sea catfish
	Bagre marinus[2]	Gaftopsail catfish
Batrachoididae	Opsanus tau	Oyster toadfish
Pomatomidae	Pomatomus saltatrix[2]	Bluefish
Carangidae	Chloroscombrus chrysurus	Atlantic bumper
	Vomer setapinnis	Atlantic moonfish
Sciaenidae	Bairdiella chrysura[2]	Silver perch
	Cynoscion regalis[2]	Weakfish
	Larimus fasciatus[2]	Banded croaker
	Leiostomus xanthurus[2]	Spot
	Micropogon undulatus[2]	Atlantic croaker
	Stellifer lanceolatus[2]	Star drum
Mugilidae	Mugil cephalus[2]	Striped mullet
Trichiuridae	Trichiurus lepturus	Atlantic cutlassfish
Stromateidae	Peprilus alepidotus	Harvestfish
Bothidae	Etropus crossotus	Fringed flounder
	Paralichthys lethostigma[2]	Southern flounder

TABLE 2 (continued)

Scientific and common names of vertebrates captured in the Savannah River during 1972 by otter trawling

Family	Scientific Name[1]	Common Name
Soleidae	Trinectes maculatus	Hogchoker
Cynoglossidae	Symphurus plagiusa	Blackcheek tonguefish
Tetraodontidae	Sphoeroides maculatus	Northern puffer

[1] Fishes placed in phylogenetic order according to American Fisheries Society (1970).

[2] Commercially valuable or sought by sport fishermen.

TABLE 3

Scientific and common names of invertebrates captured in the Savannah River during 1972 by otter trawling

Family	Scientific Name	Common Name
Penaeidae	Penaeus aztecus[1]	Brown shrimp
	Penaeus duorarum[1]	Pink shrimp
	Penaeus setiferus[1]	White shrimp
	Xiphopeneus kroyeri[1]	Seabob
Portunidae	Callinectes sapidus[1]	Blue crab
	Portunus gibbesii	Crab
Squillidae	Squilla empusa	Mantid shrimp
Loliginidae	Loliguncula brevis	Squid

[1] Commercially valuable species

TABLE 4

Total monthly biomass (g) of organisms collected at each station with mean, standard deviation

Month	Station Number 1	2	3	4	Monthly Total	Monthly Mean	Monthly Standard Deviation
January	380.0	897.5	7.4	8276.6	9561.5	2390.4	3941.1
February	337.3	113.9	0.0	277.1	728.3	182.1	153.8
March	1109.2	264.1	954.0	1890.1	4217.4	1054.4	667.3
April	1064.1	735.7	2354.9	4571.1	4611.8	1153.0	838.8
May	1252.2	6130.2	11468.2	Lost Net	18850.6	6283.5	5109.7
June	384.8	90.9	62.6	36.1	574.4	143.6	162.3
July	156.7	17.8	147.0	23.1	344.6	86.2	76.0
August	88.8	146.4	175.6	167.1	577.9	144.5	39.1
September	249.3	572.9	1182.1	809.7	2814.0	703.5	393.1
October	68.0	1258.5	4352.4	4604.9	10283.8	2571.0	2258.2
November	2247.4	4187.7	1513.7	950.9	8899.7	2224.9	1412.1
December	4090.9	3523.3	3388.2	3579.6	14582.0	3645.5	307.6
Total for station	11428.7	17938.9	25605.6	21072.3	-	-	-
Monthly mean	952.4	1494.9	2133.8	1915.7	-	-	-
Standard deviation	1180.8	2001.9	3268.4	2600.0	-	-	-

TABLE 5

Comparison of average monthly biomass of organisms collected at each trawl station during 1972. The comparisons were made utilizing the paired t test

Comparison Between Stations	Mean Annual Biomass	t [1]	degrees of freedom
1	1030.8	0.81	22
2	1325.3		
1	1030.8	1.18	22
3	2320.6		
1	1030.8	1.16	21
4	2289.1		
2	1325.3	0.58	22
3	2320.6		
2	1325.3	0.44	21
4	2289.1		
3	2320.6	0.18	21
4	2289.1		

1 None of the values obtained is significant at the 0.10 level or below.

TABLE 6

Percentage of total biomass contributed monthly at each station by vertebrates collected by otter trawling during 1972.

Month	Station Number 1	2	3	4
January	100.0	94.0	100.0	86.8
February	100.0	71.3	No specimens	94.8
March	100.0	100.0	99.2	97.6
April	70.7	100.0	81.7	76.0
May	97.6	96.0	98.8	Lost net
June	63.9	100.0	100.0	100.0
July	33.0	83.1	96.2	100.0
August	82.1	73.8	63.6	81.4
September	5.7	45.3	22.5	48.5
October	51.6	79.6	68.4	80.0
November	17.3	52.4	38.1	63.1
December	87.4	58.1	65.5	72.7

TABLE 7

Percentage of total number of organisms contributed monthly at each station by vertebrates collected by otter trawling during 1972.

	Station Number			
Month	1	2	3	4
January	100.0	98.6	100.0	90.8
February	100.0	70.6	No Specimens	90.4
March	100.0	93.5	99.3	97.7
April	80.3	100.0	96.4	95.9
May	97.7	98.5	99.2	Lost net
June	96.1	100.0	100.0	100.0
July	90.0	85.7	95.6	100.0
August	57.1	75.0	87.5	66.7
September	5.9	48.6	21.4	86.4
October	61.1	81.6	86.4	87.3
November	34.3	9.4	22.2	47.1
December	26.8	25.7	22.9	35.5

TABLE 8

Total numbers of Micropogon undulatus, Stellifer Lanceolatus and Penaeus setiferus captured monthly by otter trawling during 1972.

Month	Micropogon undulatus	Stellifer lanceolatus	Penaeus setiferus
January	4	186	26
February	7	0	2
March	174	310	12
April	598	644	50
May	487	1443	7
June	0	0	1
July	10	52	1
August	3	59	15
September	8	160	269
October	9	2347	45
November	0	239	294
December	38	134	212

TABLE 9

Diversity of organisms captured at each station monthly during January through October, 1972, according to the diversity index $H = -\sum pi \ln pi$ where pi = the proportion of the total contributed by species i.

Station	JAN	FEB	MAR	APR	MAY	JUNE
1	0.6931	0.6931	.9743	1.2331	1.0168	0.5648
2	0.2941	0.6057	1.1039	0.2186	0.6053	0.3767
3	0.6931	NS	.9152	0.8492	0.3314	0.5690
4	1.0092	1.5257	0.5509	NS	Lost Net	1.0985

NS - No specimens in sample

TABLE 9
(continued)

Diversity of organisms captured at each station monthly during January through October, 1972, according to the diversity index $H = -\Sigma\, pi \ln pi$ where pi = the proportion of the total contributed by species i.

Species	JULY	AUG	SEPT	OCT	NOV	DEC
1	0.9974	1.2773	0.3895	0.9579	.5990	1.2815
2	0.7967	1.4119	1.5447	0.6085	0.9631	1.0180
3	1.0720	0.7154	0.9740	0.6633	1.0654	1.2230
4	0.0000	1.2864	0.7816	0.6148	1.6224	1.6966

TABLE 10

Species composition of fishes and macroinvertebrates as indicated by the number of individuals of each species captured monthly at station 1 by otter trawling during 1972

Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VERTEBRATES												
Clupeidae												
Brevoortia tyrannus	--	1	--	1	--	--	--	1	--	--	--	--
Opisthonema oglinum	--	--	--	--	--	--	--	2	--	--	--	--
Engraulidae												
Anchoa mitchelli	--	--	--	24	--	--	--	--	1	9	--	--
Ariidae												
Arius felis	--	1	4	2	--	--	--	--	1	--	--	6
Sciaenidae												
Bairdiella chrysura	--	--	--	--	--	59	--	--	--	2	1	15
Cynoscion regalis	--	--	--	--	--	--	1	--	--	--	--	--
Leiostomus xanthurus	--	--	1	--	90	--	1	--	--	--	2	--
Micropogon undulatus	--	--	3	107	140	--	6	1	--	--	--	1
Stellifer lanceolatus	1	--	--	5	3	--	1	--	--	--	14	3
Mugilidae												
Mugil cephalus	1	--	--	--	--	--	--	--	--	--	--	--
Bothidae												
Paralichthys lethostigma	--	--	--	--	--	--	--	--	--	--	--	1
Soleidae												
Trinectes maculatus	--	--	--	4	17	14	--	--	1	--	2	1
Cynoglossidae												
Symphurus plagiusa	--	--	--	--	--	--	--	--	--	--	4	1
INVERTEBRATES												
Penaeidae												
Penaeus duorarum	--	--	--	--	--	1	--	--	--	--	--	--
Penaeus setiferus	--	--	--	32	--	1	--	3	47	7	204	80
Xiphopeneus kroyeri	--	--	--	--	--	--	--	--	--	--	1	8
Portunidae												
Callinectes sapidus	--	--	--	3	6	1	1	--	1	--	8	2
Total number captured each month	2	2	8	178	256	76	10	7	51	18	236	118
Total yearly catch: 762												

TABLE 11

Species composition of fishes and macroinvertebrates as indicated by the number of individuals of each species captured monthly at station 2 by otter trawling during 1972

Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VERTEBRATES												
Clupeidae												
Brevoortia tyrannus	--	--	2	3	48	14	--	--	--	--	--	1
Engraulidae												
Anchoa mitchelli	--	--	--	2	1	--	--	--	11	--	--	--
Ictaluridae												
Ictalurus catus	--	--	--	--	--	--	--	--	--	--	1	--
Ariidae												
Arius felis	--	--	--	--	--	--	--	--	2	--	--	--
Bagre marinus	--	--	--	--	--	--	--	--	--	1	--	--
Pomatomidae												
Pomatomus saltatrix	--	--	--	--	--	2	--	--	--	--	--	--
Carangidae												
Vomer setapinnis	--	--	--	--	--	--	--	--	1	--	--	--
Sciaenidae												
Bairdiella chrysura	3	--	--	--	2	--	--	--	1	1	1	--
Cynoscion regalis	--	--	--	--	--	--	5	8	2	--	--	--
Leiostomus xanthurus	--	--	--	--	1	--	--	--	--	--	--	--
Micropogon undulatus	3	12	21	206	276	--	--	2	8	--	--	21
Stellifer lanceolatus	141	--	1	4	3	--	1	7	22	302	169	90
Scombridae												
Scomberomorus maculatus	--	--	--	--	--	--	--	--	2	--	--	--
Stromateidae												
Peprilus alepidotus	--	--	--	--	--	--	--	1	--	--	--	--
Soleidae												
Trinectes maculatus	1	--	4	--	1	--	--	--	1	2	1	9
Cynoglossidae												
Symphurus plagiusa	--	--	1	--	--	--	--	--	--	--	1	--
INVERTEBRATES												
Penaeidae												
Penaeus setiferus	2	5	--	--	--	--	1	6	53	7	39	38
Xiphopeneus kroyeri	--	--	--	--	--	--	--	--	1	62	290	312
Portunidae												
Callinectes sapidus	--	--	2	--	3	--	--	--	--	--	3	--
Total number captured each month	149	17	31	215	335	16	7	24	104	375	505	471

Total yearly catch: 2249

TABLE 12

Species composition of fishes and macroinvertebrates as indicated by the number of individuals of each species captured at station 3 by otter trawling during 1972

Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VERTEBRATES												
Clupeidae												
Brevoortia tyrannus	--	--	2	3	10	1	--	--	--	3	--	--
Engraulidae												
Anchoa hepsetus	--	--	--	--	--	--	--	--	--	1	--	--
Anchoa mitchelli	1	--	--	--	5	--	3	--	2	1	--	--
Ariidae												
Arius felis	--	--	--	--	--	--	--	--	7	3	--	1
Bagre marinus	--	--	--	--	--	--	--	--	--	3	--	--
Pomatomidae												
Pomatomus saltatrix	--	--	--	--	--	1	--	--	--	--	--	--
Carangidae												
Vomer setapinnis	--	--	--	--	--	--	--	--	2	--	--	--
Sciaenidae												
Bairdiella chrysura	--	--	2	--	--	4	--	--	2	4	4	13
Cynoscion regalis	--	--	--	--	--	--	3	4	6	8	2	--
Leiostomus xanthurus	--	--	2	--	--	--	1	--	--	--	--	2
Menticirrhus americanus	--	--	--	--	--	--	--	--	1	--	--	--
Micropogon undulatus	--	--	145	104	71	--	4	--	1	--	--	7
Stellifer lanceolatus	1	--	8	83	1437	--	32	52	20	907	38	16
Trichiuridae												
Trichiurus lepturus	--	--	--	--	3	--	--	--	--	--	--	--
Stromateidae												
Peprilus alepidotus	--	--	--	--	1	--	--	--	--	6	--	--
Bothidae												
Paralichthys lethostigma	--	--	--	--	--	--	--	--	--	--	--	1
Soleidae												
Trinectes maculatus	--	--	--	--	--	--	--	--	--	1	1	3
Cynoglossidae												
Symphurus plagiusa	--	--	--	--	--	--	--	--	--	2	4	36
INVERTEBRATES												
Penaeidae												
Penaeus setiferus	--	--	--	4	7	--	--	5	145	11	23	38
Xiphopeneus kroyeri	--	--	--	--	--	--	--	2	6	128	147	227
Portunidae												
Callinectes sapidus	--	--	--	2	4	--	1	--	--	1	--	1
Squillidae												
Squilla empusa	--	--	1	1	1	--	--	--	--	--	2	--
Loliginidae												
Loliguncula brevis	--	--	--	--	1	--	1	1	--	8	--	--
Total number captured each month	2	0	160	197	1540	6	45	64	192	1087	221	345

Total yearly catch: 3859

TABLE 13

Species composition of fishes and macroinvertebrates as indicated by the number of individuals of each species captured at station 4 by otter trawling during 1972

Classification	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
VERTEBRATES												
Clupeidae												
Brevoortia tyrannus	--	--	2	--	--	--	--	--	2	--	--	--
Engraulidae												
Anchoa hepsetus	--	--	--	--	--	--	--	--	1	--	--	--
Anchoa mitchelli	--	--	11	--	--	1	--	5	9	6	--	--
Ariidae												
Arius felis	--	--	--	--	--	--	--	--	1	--	--	--
Batrachoididae												
Opsanus tau	2	--	--	2	--	--	--	--	--	--	--	2
Pomatomidae												
Pomatomus saltatrix	--	--	--	--	--	1	--	--	--	--	--	--
Carangidae												
Chloroscombrus chrysurus	--	--	--	--	--	1	--	--	--	--	--	--
Sciaenidae												
Bairdiella chrysura	--	1	6	--	--	--	--	--	--	--	8	11
Cynoscion regalis	--	--	--	1	--	--	--	--	1	14	--	--
Larimus fasciatus	--	--	--	--	--	--	--	--	--	--	--	2
Leiostomus xanthurus	--	1	--	--	--	--	--	--	--	--	--	1
Menticirrhus americanus	--	--	--	--	--	--	--	--	--	3	--	--
Micropogon undulatus	1	7	14	160	--	--	--	--	--	9	--	9
Stellifer lanceolatus	39	--	302	413	--	--	18	--	118	1138	18	25
Trichiuridae												
Trichiurus lepturus	--	--	--	--	--	--	--	1	--	--	--	--
Bothidae												
Etropus crossotus	--	--	--	--	--	--	--	--	--	--	1	--
Soleidae												
Trinectes maculatus	42	7	--	1	--	--	--	--	--	6	--	14
Cynoglossidae												
Symphurus plagiusa	273	3	1	3	--	--	--	--	--	1	14	34
Tetraodontidae												
Sphoeroides maculatus	--	--	--	--	--	--	--	--	--	1	--	--
INVERTEBRATES												
Penaeidae												
Penaeus aztecus	--	--	--	--	--	--	--	1	--	--	--	--
Penaeus setiferus	24	2	7	14	--	--	--	1	15	20	28	56
Xiphopeneus kroyeri	--	--	--	--	--	--	--	1	--	149	17	119
Portunidae												
Callinectes sapidus	12	--	1	10	--	--	--	--	1	2	1	3
Portunus gibbesii	--	--	--	--	--	--	--	--	--	1	--	--
Squillidae												
Squilla empusa	--	--	--	1	--	--	--	--	--	--	--	--
Total number captured each month	393	21	344	605	0	3	18	9	148	1350	87	276

Total yearly catch: 3254