United States
Environmental Protection
Agency

Environmental Research
Laboratory
Gulf Breeze FL 32561

August 1980

Research and Development

EPA

Water Quality Studies in Santa Rosa Sound, Pensacola, Florida

WATER QUALITY STUDIES IN SANTA ROSA SOUND, PENSACOLA, FLORIDA

by

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Grant #R-803566

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ABSTRACT

Water samples were collected from six stations in Santa Rosa Sound and Little Sabine Bay, Florida, every two weeks between October, 1977, and June, 1979. The samples, taken at the surface, mid-depth, and bottom of each station, were analyzed for temperature, salinity, pH, transparency, inorganic carbon, 5-day biochemical oxygen demand, dissolved oxygen, orthophosphate, poly-phosphate, ammonia, nitrate, and non-volatile grease and oil; bacteria were enumerated; phytoplankton were identified and enumerated; and the water column primary productivity was measured.

Although there were seasonal changes, there were few intra or inter station differences on each sampling day. However, Little Sabine Bay exhibited lower water transparency, higher BOD, higher rates of primary production, higher concentrations of non-volatile grease and oil, and larger numbers of bacteria and phytoplankton than Santa Rosa Sound.

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ACKNOWLEDGMENTS

This research was supported by grant number R-805366 from the Environmental Protection Agency. Supplementary funds were also from the Santa Rosa Island Authority. The authors gratefully acknowledge the cooperation and encouragement provided by the Project Officer, Dr. Gerald Walsh. Appreciation is also extended to Mr. Douglas Flythe for computer programming assistance, and to all the undergraduate and graduate students who assisted throughout the duration of the project.

INTRODUCTION

The various aspects of eutrophication in natural waters have been under extensive study during recent years (Shapiro and Ribeiro, 1965; McCarty and Harris, 1967; Putnam, 1967; Reimold and Daiber, 1967; Thomann and Marks, 1967; Ballinger, 1968; Welch, 1968, 1969; Bellamy et.al., 1969; Edmondson, 1969; Hutchinson, 1969; Porges, 1969; Pritchard, 1969; also reviews by Patrick, 1968; and Sinha, 1970). Of particular interest have been the roles of nutrients in growth of algal populations and consequent acceleration of natural eutrophication due to input of nutrients in natural waters. Recently, more and more such nutrification occurrences have been traced to activities of man (see reviews by Gerloff, 1969; Provasoli, 1969; Hannah, Simmons and Moshiri, 1973; Moshiri, Aumen and Crumpton, 1980).

In spite of progress in the field of algal nutrition (see Martin, 1968; Lackey, 1967; Bernhard and Zattera, 1969; also reviews by Provasoli, 1958; Lewis and Guillard, 1963; Fogg, 1965), reliable techniques still need to be developed for the quantitative estimation of nutrient supplies to aquatic plants. The first step in the development and application of such techniques involves determination of the concentration of certain nutrients in the system and the relative availability of these substances for algal growth. Because of their availability in sewerage effluents and natural runoffs, carbon dioxide, nitrogen, and phosphorus have been shown to be three of the most important components because of their stimulating effect on algal growth. Inflow of such nutrients results in increased production of algae and changes in their community species composition. This may result in blooms of undesirable species, usually blue-greens and armoured dinoflagellates. Algal components of such systems are usually unpalatable to herbivores, yielding accumulation of algal masses which can result in the death of fish and shellfish (Ryther, 1954; Ragotzkie and Pomeroy, 1957). Therefore, information on nutrient sources and availability are of paramount importance in predicting occurrences and periodicities of algal blooms, as well as in the control of nuisance growths of algal populations. In addition, since pollution wastes are usually a major source of nutrient input in natural waters, results of assay work aid in the development of techniques for the alleviation of pollution problems. (Sylvester and Anderson, 1960, 1964; Gerloff, 1969; Hannah, Simmons and Moshiri, 1973).

In the past four years, reports of fish and shellfish kills, as well as other signs of serious water quality degradation, have caused much concern and speculation in northwestern Florida's extensive estuaries. Santa Rosa Sound, in Escambia and Santa Rosa Counties, Florida, has shown signs of degradation. This body of water extends westward from Choctawhatchee Bay to Pensacola Bay and opens to the Gulf of Mexico at Fort Pickens. Due to its long narrow make-up, variable depth, remote connection with the Gulf and the presence of obstructions (bridges, etc.), Santa Rosa Sound may not be expected to possess sufficient circulation and flushing to aid in dissipation of pollutants and waste waters entering it directly or indirectly from a number of industrial and municipal sources (see pp. 15-75 in The Proceedings of Conference on Pollution of the Interstate Waters of the Escambia River Basin, Vol. 1, 1970). This phenomenon may contribute to factors which have caused short-term poor water quality, and will cause eventual eutrophication of this body of water. Therefore, an all-out effort must be mounted to prevent further degradation of this valuable estuary and steps toward its recovery implemented if algal blooms and fish kills of great proportions, similar to those which have occurred, are to be avoided.

The present investigation was directed at monitoring water quality parameters in Santa Rosa Sound and was designed to give detailed information concerning its present water quality status. Although a number of studies have been conducted on Escambia and East Bays, little information was previously available on the water quality of Santa Rosa Sound.

METHODS

All sample collection was accompanied by measurement of physical-chemical parameters at each of six collection sites including Little Sabine Bay and Quietwater Beach (station Q) (Figure 1). Such parameters included salinity, temperature, dissolved oxygen, pH, BOD, inorganic carbon, and light penetration. All measurements and water column samples were taken bi-weekly from the six stations indicated in Figure 1 at the depths of 0.5m and 2.0m beneath the surface, and 0.5m above the bottom. In this report, surface and bottom samples are referred to as S and B, respectively, and are preceeded by the station number. Water column samples for analyses were obtained with a Van Dorn sampler, placed on ice and returned to the laboratory for analyses as outlined in Figure 2. At the time of sampling, meteorological and tide conditions were recorded. All analyses were conducted in laboratory facilities at the University of West Florida in Pensacola, Florida.

Salinity, temperature, and dissolved oxygen were measured in situ using a YSI portable dissolved oxygen meter and salinometer. A Sargent-Welch field pH meter was utilized for pH determinations. Light penetration was measured with a Secchi disk. Inorganic carbon analyses were conducted in the laboratory on a Beckman total carbon analyzer. Water samples for algal analyses were preserved with 5% buffered glutaraldehyde and cell numbers and types were determined to genus or, when possible, species, using a Wild M-40 inverted microscope and the settling chamber technique.

Bacterial biomass is an important indicator of the condition of an aquatic system (Rheinheimer, 1971; Kuznetsov, 1972; Sorokin and Kadota, 1972). Therefore, sterile sampling techniques and laboratory procedures described by Rodina (1972) were used to investigate this indicator in the Sound and Little Sabine Bay. By observing the difference in bacterial biomass that may exist at the various stations under different nutrient and organic loadings, it was possible to relate this parameter to water quality status in the study area.

Water samples were also analyzed for the concentration of ammonia, employing nesslerization and spectrophotometric analysis according to the method of Solorzano (1969); and for nitrate using the technique described by Kahn and Brezenski (1967). For phosphate determinations, the analysis relied primarily on methods described by Strickland and Parsons (1968). Orthophosphate concentrations were determined by reactions with an acidified molybdate solution to form a phosphomolybdate heteropoly acid, the concentrations of whose reduced form (phosphomolybdenum blue) were determined spectrophotometrically. Polyphosphate concentrations were analyzed by methods described in the EPA Manual of Methods for Chemical Analysis of Water and Wastes (1976). Grease and oil concentrations in the water column of stations 3, 4, 6, and Q, and in bilgewater samples from boats moored at the marina near station 4 (Figure 1), were determined according to the methods presented in Standard Methods for the Examination of Water and Wastewater (1975). Soxhlet extractions (Standard Methods, 1975) were also performed to determine grease and oil concentrations in the sediments of stations 3, 4, Q, and 6.

The productivity of algal cells was determined in conjunction with the above mentioned tasks. The complex of productivity studies was conducted once every two weeks using the C-14 technique as modified by Goldman and Armstrong (1969), and Goldman, Moshiri, and de Amezaga (1972). Determinations were made from water samples taken from surface, mid-water, and bottom at the six stations (Figure 1) and incubated in BOD bottles suspended at the depths from which the samples were taken. At the end of a 4-hour incubation period, they were preserved with 5% buffered glutaraldehyde and returned to the laboratory for filtration through 0.45μ membrane filters. Activities of the samples were then determined using a Beckman LS-133 liquid scintillation counter.

Two consecutive diel studies were conducted at each of the six stations once each season during the first year, and twice during the second year at stations 2 and 4 to determine diel trends in phytoplankton and water column nutrients. These studies also included the measurement of water quality parameters already described. Primary productivity measurements were made twice during each of these seasonal studies.

RESULTS AND DISCUSSION

Due to the voluminous data collected, only representative examples of results are given as figures in the text. As sampling began in October 1977, the first hatch mark on the horizontal axis of the figures represents October. Stations 1, 2, 5, and 6 in the Sound, and stations 3 and 4 in Little Sabine Bay, were similar with respect to major trends in the various parameters. Mid-depth samples did not differ significantly from surface water samples. For this reason, surface and bottom data from stations 2 and 4 are presented as examples in this report when pertinent.

In August of 1979, a study was conducted at the request of the Sabine Island Laboratory to monitor water quality indices during an outbreak of *Gonyaulax monilata* in Santa Rosa Sound. The data from this study is presented in Appendix I and is discussed in the supplement at the end of this report. The two diel studies conducted during the second year of the project yielded data which varied little from those collected during the regular sampling regimen, and are included in Appendix II.

Physical-Chemical Factors

Water column temperature in Santa Rosa Sound followed temporal patterns ranging from a low of 6°C to a high of 32°C. Temperature values from station 2S are given in Figure 3a and are representative of all sample sites. Consistent pH values were demonstrated year-round at all collection sites regardless of depth, and are exemplified by data shown in Figure 3B.

Salinities in the Sound and in Little Sabine Bay varied widely both temporally and spatially. Figures 4a and 4b give salinity values at station 2, the deepest of all stations. There, surface salinity varied temporally, with lowest values occurring during spring, when rainfall is usually greatest. Also notable is the fact that bottom waters, particularly at the deeper sampling locations (stations 2 and 6), showed consistently higher salinities with less influence from meteorological phenomena and more influence from tidal conditions (compare Figures 4a and 4b with Table 1).

Secchi disk readings indicated generally lower water transparency during summer at all locations, as shown by data from station 2 (Figure 5a). Of special note is the apparent lower water transparency over most of the year in the more shallow and morphometrically restricted Little Sabine Bay when compared to the Sound waters (Figure 5b).

Dissolved oxygen (D.O.) followed temporal patterns with higher and lower concentrations associated with cooler and warmer months respectively (Figure 6a). Bottom water from the deeper sites (stations 2 and 6) periodically had extremely low D.O. concentrations, especially during summer. This is of particular importance with respect to station 2 (Figure 6b) near the Environmental Protection Agency's (EPA) Gulf Breeze Environmental Research Laboratory on Sabine Island. Water for bioassay studies at the laboratory is drawn from this region in the Sound, and could cause serious problems in culture work, especially during coincident periods of high biochemical oxygen demand. This may have been the case in several instances when culture problems were encountered and will be discussed later in this report. Dissolved oxygen concentrations in Little Sabine Bay did not differ significantly from those in the Sound and also exhibited periods of depletion in bottom water during warm weather (Figures 7a and 7b).

Values for biochemical oxygen demand (B.O.D.) were sporadic at all sample locations, with the highest in surface waters of Sound stations (Figures 8a and 8b) and in surface and bottom waters in Little Sabine Bay (Figures 9a and 9b). If B.O.D. values and D.O. concentrations for summer are compared (Figures 6b and 8b), it is apparent that on several occasions high B.O.D. values occurred simultaneously with low D.O. concentrations. Although it is realized that intake water to the Sabine Island wet lab does not come from bottom depths at station 2, the presence of these conditions are significant because of the proximity of station 2 to the EPA facilities. The phenomenon described above may account for problems experienced with regard to animal mortalities at EPA's Sabine Island laboratory facilities. This is especially the case if the culture water is permitted to stand without aeration. Precautionary measures should be taken during the summer months to eliminate or reduce the possibility of D.O. depletion in intake waters drawn to the wet lab facilities.

Concentrations of non-volatile greases and oils in the water column were below detectable limits at the four stations sampled over most of the one-year period (stations 3, 4, Q, and 6) (Figure 1 and Table 2). Detectable concentrations of these substances occurred at all stations during July and were most likely related to increased recreational boat activity in Little Sabine Bay and the Sound. Bilgewater samples from pleasure craft moored at the marina in Little Sabine Bay had concentrations of non-volatile greases and oils as high as 1.5 mg/l, making this a probable source of contamination within the Bay and associated waterways during high boat use periods. Grease and oil concentrations lower than those associated with summer months were observed in November and may be attributed to low tide coinciding with the 9:00 AM sampling time (Table 1).

Soxhlet extractions of sediments obtained during spring and summer of 1979 from stations 3, 4, Q, and 6 (Figure 1) yielded detectable concentrations of non-volatile greases and oils on only one occasion from station Q (Figure 1). Either these substances do not accumulate in the sediment in large amounts, or the spatial distribution of such accumulations is patchy.

Water column nutrients within Santa Rosa Sound and Little Sabine Bay showed no definite temporal trends. Differences existed, however, between surface and bottom water samples in certain instances. Concentrations of nitrate-nitrogen (Figures 10 and 11) ranged from undetectable amounts to peaks which were observed periodically at all stations. This is graphically illustrated by data from station 4 in Little Sabine Bay (Figure 11a). Ammonia-nitrogen concentrations in the water column also showed no clear trends with time, but were higher in bottom water samples than in surface water over most of the study period (Figures 12 and 13). This probably reflects higher levels of organic decomposition at the sediment-water interface.

Orthophosphate concentrations were consistent at all stations as represented by data from station 2 (Figures 14a and 14b). No clear spatial differences can be detected when vertical or horizontal inter- or intra-station comparisons are made. The phenomenon of low but consistent orthophosphate concentrations in the water column may be related to sediment-water phosphate exchange mechanisms whose presence has been suggested in other local estuarine waters (Moshiri and Crumpton, 1978). Poly-phosphate concentrations were comparable to those of orthophosphate (Figures 15a and 15b), and exhibited no apparent differences temporally or spatially.

Biological Factors

Bacterial cells were present consistently throughout the duration of the study, with larger biomass in surface waters during warm months (Figures 16a and 16b). It is notable that bottom waters of stations 2 and 6 (the deepest stations) did not exhibit significant increases in bacterial biomass during the summer months. The greater biomass of bacteria in surface samples during warm weather corresponds well with the higher biochemical oxygen demand during the same period (Figures 8a, 9a, and 16a, 17a). This phenomenon is correlated with D.O. and B.O.D. patterns described and must be considered in conjunction with precautionary measures stated in relationship to water drawn for experimental purposes at EPA's Sabine Island laboratories. Figures 17a and 17b suggest a larger bacterial biomass in Little Sabine Bay than in the Sound.

There were seasonal trends in autotrophic uptake of C-14. Warm months and surface waters showed the highest values for carbon fixation as compared with cool months and deep waters (Figures 18a and 18b). Little Sabine Bay had higher rates of primary production in surface and bottom waters when compared to the Sound, particularly at station 3- the shallowest and most restricted sampling site in the Bay (Figures 19a and 19b). Due to the narrow entrance from the Sound to Little Sabine Bay, circulation within this small system would be expected to be minimal. This phenomenon may be the factor that contributes to the higher primary productivity of these Bay stations over those of the Sound waters. Comparison of physical-chemical aspects of Bay and Sound waters presented earlier in this report also confirm this hypothesis.

Phytoplankton

Phytoplankton genera were grouped into five categories for the purpose of detecting trends. These are as follows:

1. Microflagellates (flagellated genera, but not those belonging to the Dinophyceae)
2. Two Nitzschia species (Bacillariophyceae) less than 1.0μ in diameter. This group was established because of their high numbers and because of their relatively high surface area-to-volume ratios.
3. Diatoms (Bacillariophyceae) (other than those in group 2).
4. Dinoflagellates (Dinophyceae).
5. Blue-green algae (Cyanophyceae).

Diatoms were in greater diversity than the other groups. Forty-seven genera were identified (Table 3) and a classical bimodal pattern of seasonal abundance was observed, with population peaks in spring and fall. Spring peak numbers were comparable at stations 2 and 4, but fall peaks were greater at station 4, possibly reflecting residual effects of summer biotic activities and corresponding well with higher carbon fixation rates at this Little Sabine station (Figures 18a-19b).

The most dominant spring genus was Cyclotella (valve 4-9μ). This genus was found in almost all samples observed. Cyclotella species appeared to be most heavily concentrated in the bottom samples. A fall peak comparable in population numbers to those of spring was noted at station 4. Ceratulina was the dominant genus of the fall plankton at this station. Station 2 also had fall population maxima but numbers were significantly less than those of station 4. The dominant genera of the station 2 fall peak were Leptocylindrus and the spring dominant, Cyclotella.

Microflagellates were the most important group in terms of standing crop, with densities as high as 43,000 cells/ml. Seventeen identifiable genera and five unknown genera were encountered, with Rhodomonas, Cryptomonas, and Calycomonas in highest numbers. High densities of an unidentified chrysophyte were observed in the spring of both years.

A microflagellate group with cells too small for routine identification (3X2μ) had the greatest overall abundance, with greater numbers at station 4 than station 2. The general trend for the microflagellate group was one of population maxima in spring, declining through the summer, and reaching lowest numbers in fall (Table 3). A sharp increase in numbers comparable to the summer maximum also occured in winter. This increase may be the result of coincidental decreases in the number of diatoms during this period.

Numbers in the Nitzschia species group were more comparable to the microflagellate group than to other diatoms. This group was composed of two species, N. paradoxa and N. lineola. Each of these species was 1.0μ or less in diameter and 7-10μ in length. Because these organisms were found in relatively high numbers most of the year, they may have been of prime importance to the productivity of the waters monitored during this study. The general trend for the Nitzschia group was similar to that of the microflagellates. High numbers occured during spring, summer, and winter, and low numbers were found in the fall. Again, the low autumn numbers of these species could be attributed to the fall bloom of larger diatoms out-competing the Nitzschia species. As with the microflagellate and other diatom groups, the Nitzschia group was more abundant at station 4 than at other stations, possibly reflected by the greater carbon fixation activity at this site.

Thirteen genera of dinoflagellates were identified (Table 3). The genus which occurred most frequently and had the highest densities was Prorocentrum. A spring population peak of this genus occurred at station 4. Three other population peaks were also observed in the fall, two at station 2 and one at station 4. A time lag of approximately two weeks was noted between each of the population maxima. The first bloom of Prorocentrum was noted at station 2, followed by one at station 4, which in turn was followed by another at station 2.

Another bloom of dinoflagellates was observed during the summer months of 1978. This bloom occured at station 4. The dominant genus was Gymnodinium, which occured in numbers between 138-211 cells/ml. This organism appeared to be primarily a surface inhabitant. Numbers observed from bottom samples ranged from 0-9 cells/ml. No such blooms were observed from samples taken at station 2 during this period.

Blue-green algae tended to be most numerous during the summer months. Three genera of blue-green algae were identified: Spirulina, Coccochloris, and Agmenellum. Those unidentified were grouped into either filamentous or coccoid categories. Blue-green numbers were significantly higher at station 4 than at station 2. Up to 40,000 cells/ml were observed at this station. Maxima at station 2 did not exceed 7,000 cells/ml.

In general, phytoplankton numbers tended to be the greatest during the spring and fall months. Numbers for all groups except the blue-greens were highest in the spring. Microflagellates were least numerous in the fall. However, this reduction in microflagellate cell numbers was coincidental with increases in numbers of diatoms and dinoflagellates. Blooms of blue-greens occurred primarily during the summer months when population numbers of the other groups were on the decline.

Of all stations studied, the two stations located in Little Sabine Bay (stations 3 and 4) had the greatest numbers of all groups at any point in time (Table 3). These also showed the highest carbon fixation activity (Figures 18a-19a). The species diversity (as determined by numbers of species) at all of the stations was, however, approximately the same. Eighty genera were identified from Little Sabine Bay and Santa Rosa Sound.

CONCLUSIONS

It is evident from the results of this investigation that Santa Rosa Sound exhibits no serious degradation of water quality when compared to other local estuarine systems which have experienced at least some human influence. A study of Escambia Bay (see Effects of Pollution on Water Quality, Escambia River and Bay, Florida, 1970), especially in the regions north of the L&N railroad trestle, demonstrates higher nutrient concentrations than encountered in the present study. This region of Escambia Bay has been well documented as to the extent and effect of discharges from domestic and industrial sources. The concentrations of nutrients in Santa Rosa Sound are more comparable to those documented for Catfish Basin, a bayou located on the eastern side of Blackwater Bay, Santa Rosa County, Florida (Adams, 1970). This bayou has been used by the principal investigator and others (Adams, 1970) as an example of a relatively undisturbed estuarine system.

Although the general water quality of Santa Rosa Sound seems to be comparable to more pristine systems, problems may be encountered during warm months with respect to the use of its waters in bioassay studies and other experiments conducted at the Environmental Research Laboratory at Gulf Breeze. Precautions should be taken during these periods to avoid occurrences similar to those involving animal mortalities at the Laboratory during the summers of 1978 and 1979.

Little Sabine Bay, in comparison to Santa Rosa Sound, shows signs of nutrification as evidenced by higher nutrient concentrations, lower water transparency, increased primary productivity and algal numbers, and other signs of water quality degradation to which reference has been made previously in this report. Measures should be taken in the future to prevent any further input of pollutants into the Bay, as circulation and flushing capacities appear to be minimal.

SUPPLEMENT

A monitoring program of selected water quality parameters in Santa Rosa Sound was conducted at the request of the Environmental Research Laboratory during an outbreak of Gonyaulax monilata in August of 1979. A review of the literature indicated that red tide occurrences and resulting mortalities of fish in the Gulf of Mexico had been documented extensively (Gunter, 1942; Gunter, et. al., 1948; Connell and Cross, 1950; Howell, 1953; Finucane, 1960; Gates and Wilson, 1960; Finucane, et. al., 1964; Williams and Ingle, 1972; Moshiri, Crumpton, and Blaylock, 1978). To date, the primary cause for such kills had been attributed directly to the toxin released by certain dinoflagellates. Of these, the one most frequently studied and cited has been Gymnodinium breve, followed by Gonyaulax monilata (Howell, 1953; Starr, 1958; Gates and Wilson, 1960; Marvin and Proctor, 1965; Ray and Aldrich, 1966).

Our studies in Pensacola Bay and Santa Rosa Sound during the past 10 years have included observations of a number of dinoflagellate blooms with accompanying fish kills at certain instances (Moshiri, Crumpton, and Blaylock, 1978). Of these, the one of particular interest and severity was the extensive outbreak of Gonyaulax monilata in Santa Rosa Sound, and the resulting fish kills during August, 1979. Our data collected during the occurrence of this event suggest additional factors, which, along with the "direct toxin theory", must be considered at least as co-causative agents in such cases of red tide fish mortalities.

METHODS

Water samples were collected from five locations (the G stations of Figure 1) at 11:00 AM and 11:00 PM daily on alternate days between August 15 and 27, 1979. The station G4 sample was obtained each time from the unfiltered Sound water trough within the wet lab facilities of the Environmental Research Laboratory. It is this water which is used for bioassay studies and culturing of experimental organisms.

Measurements were taken of temperature, dissolved oxygen, 5-day biochemical oxygen demand (BOD), salinity, pH, nitrate nitrogen, orthophosphate, organic carbon, bacterioplankton, and phytoplankton. Field parameters such as dissolved oxygen and salinity were measured using appropriate meters. Samples for water chemistry were collected in acid-rinsed polyethylene bottles and transported to the laboratory on ice. Bacterioplankton and phytoplankton samples were fixed in the field with 5% neutralized glutaraldehyde for examination using the settling chamber technique. For bacteria, both numbers and biomass estimations were made. Other methodology details have been described elsewhere (Moshiri, et. al., 1974; Moshiri, Crumpton, and Blaylock, 1978; Moshiri, Crumpton, and Aumen, 1979).

RESULTS AND DISCUSSION

The highest counts of *G. monilata* were obtained from a single sampling east of station G5 (Figure 1). During this one event, chains of cells representing densities as high as 1800 cells/ml were observed. These very high numbers were accompanied by elevated dissolved oxygen concentrations of 16.0 mg/l and by bacterial numbers and biomass exceeding the highest observed at the regular sampling stations.

Regular sampling at the designated five stations yielded *G. monilata* counts ranging from 5 cells/ml during the lowest concentrations to over 500 cells/ml during peaks. Highest and lowest numbers were reported from locations G2 and G5 respectively (Figure 1). Close similarities were observed between these patterns and those of bacterial cell numbers and biomass from corresponding collection locations (Figure 20). High *G. monilata* and bacterial cell concentrations were also accompanied by extremely high and fluctuating BOD values and expected high dissolved oxygen concentrations, even during evening hours (Figure 21). Low concentrations for dissolved organics (3.0 - 14.0 mg/l) in the presence of large bacterial numbers and biomass were also indicative of the rapid utilization of this energy source by bacterioplankton. There seemed to be no apparent relationships between inorganic phosphorus, nitrate nitrogen, and other parameters measured. Although isolated fish kills occurred in Santa Rosa Sound throughout the duration of our study, none were observed at any of the established sampling locations. Most references that discuss fish mortalities during red tide outbreaks cite a single cause, namely the direct toxicity of the metabolites released by the dinoflagellates involved (Gates and Wilson, 1960; Aldrich, Ray, and Wilson, 1967; Sievers, 1969). Our studies, however, showed biochemical oxygen demands far in excess of the 3.0 - 5.0 mg/l we have found in the same waters even during periods of accidental inputs of large volumes of domestic wastewater (Figure 21). Interestingly, these high BOD values were also accompanied by relatively high dissolved oxygen concentrations of 7.0 - 12.0 mg/l (Figure 21). Connell and Cross (1950) also cite very high BOD values under similar circumstances but report accompanying anoxic conditions. High BOD values were also observed at station G4 within the wet lab facilities. If this water is allowed to stand for any time period, oxygen depletion could rapidly occur resulting in mortalities of laboratory organisms. Problems of this nature have been experienced at this facility and point to the need for precautionary measures to prevent further occurrences of this nature.

Our data suggest that the high cell concentrations of *G. monilata* and correspondingly increased photosynthetic activity were the causes of high oxygen production and concentration even in the presence of high biochemical oxygen demands (Figure 21). Since no fish kills were observed or reported from our sampling locations even during the peaks of *Gonyaulax* densities, it seems logical to conclude that a single factor, such as direct metabolite toxicity, may not be responsible for massive fish mortalities normally observed during red tide occurrences. We suggest that, for such kills to occur, a combination of factors must take place simultaneously. These include a decline in dinoflagellate cell numbers following an outbreak, followed by the expected reduction in photosynthetic activity, increased bacterial numbers and involvement, and consequential increases in BOD promoted by the presence of an abundance of particulate and dissolved organic substrates.

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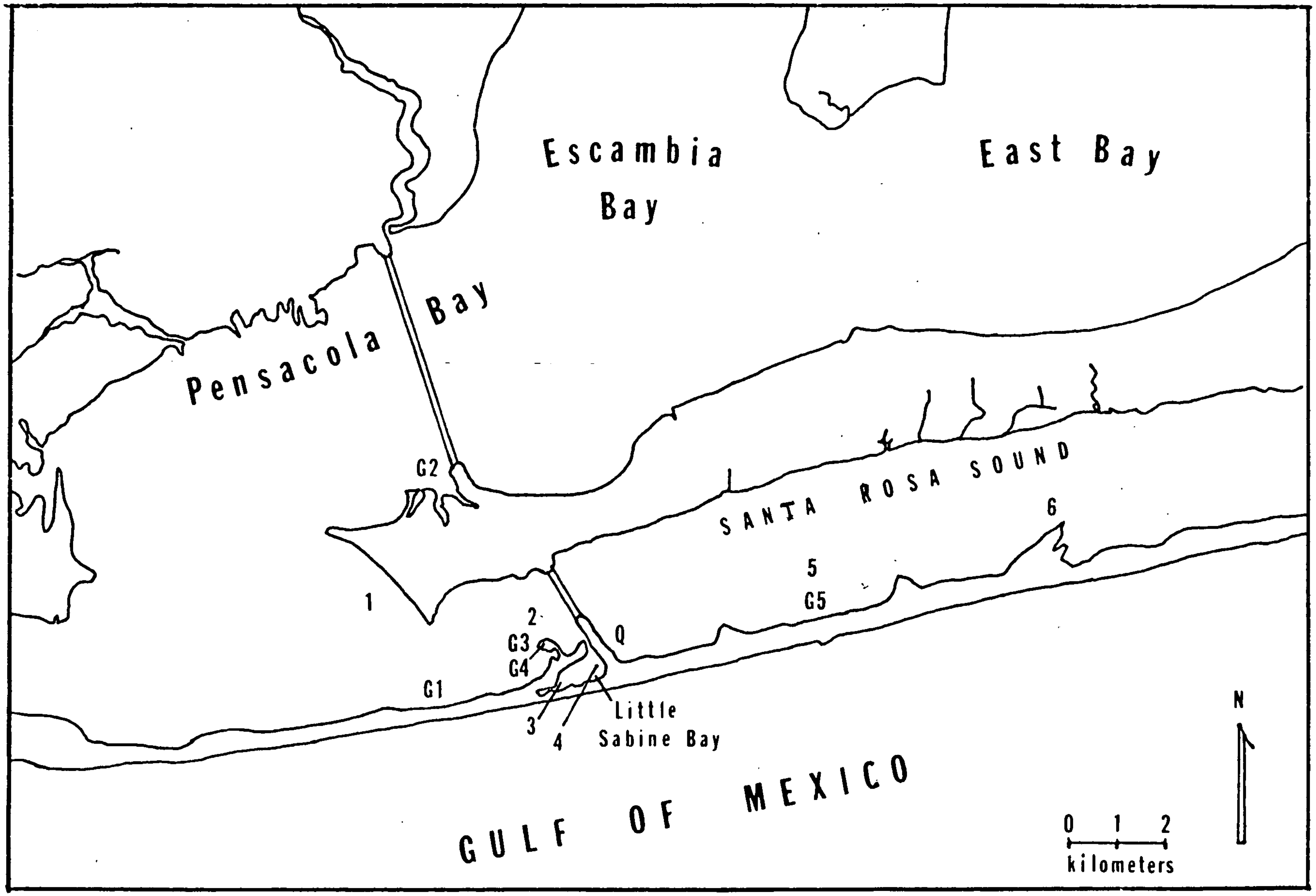


Figure 1. Map of Santa Rosa Sound and vicinity showing sampling sites.

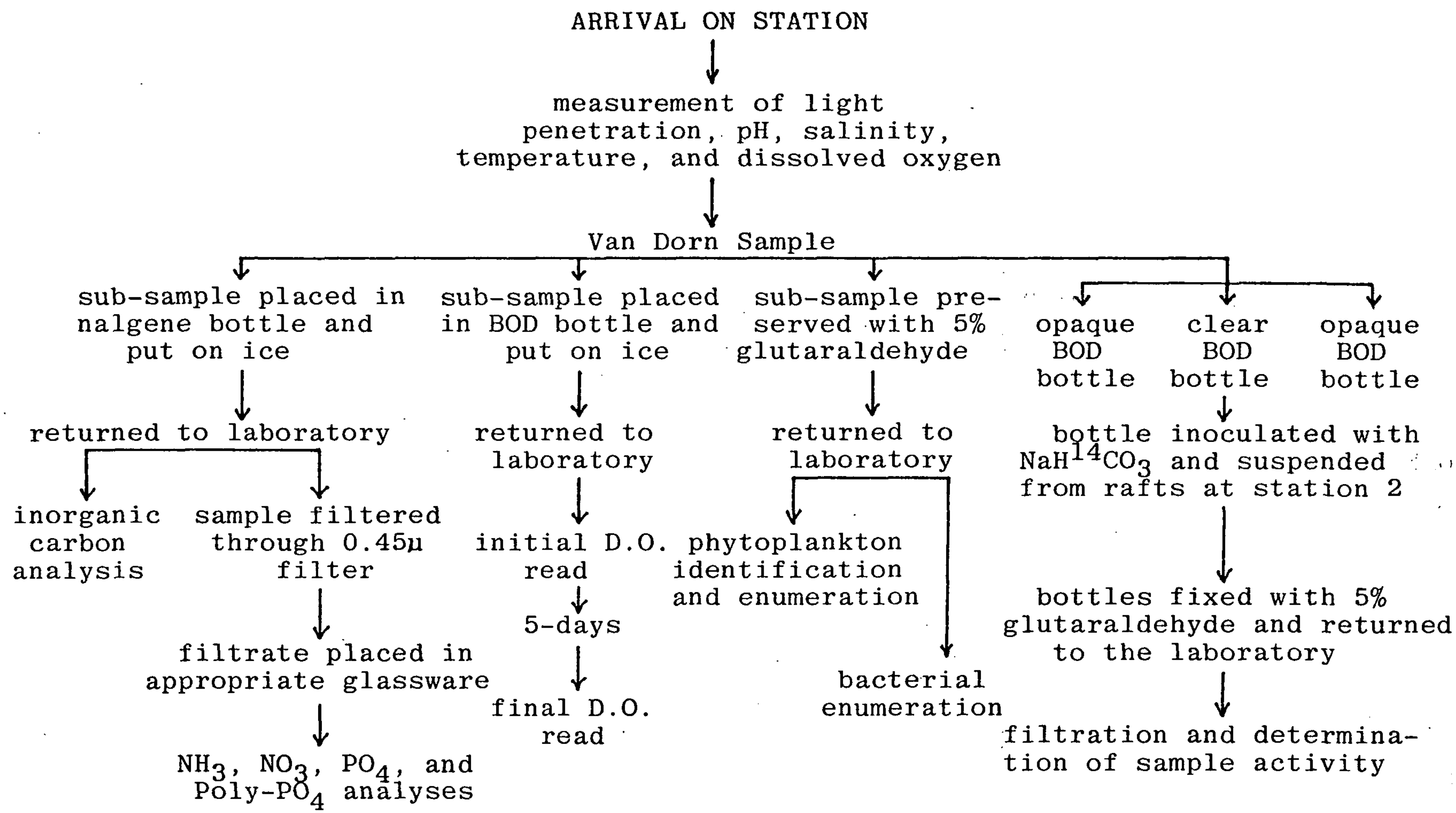
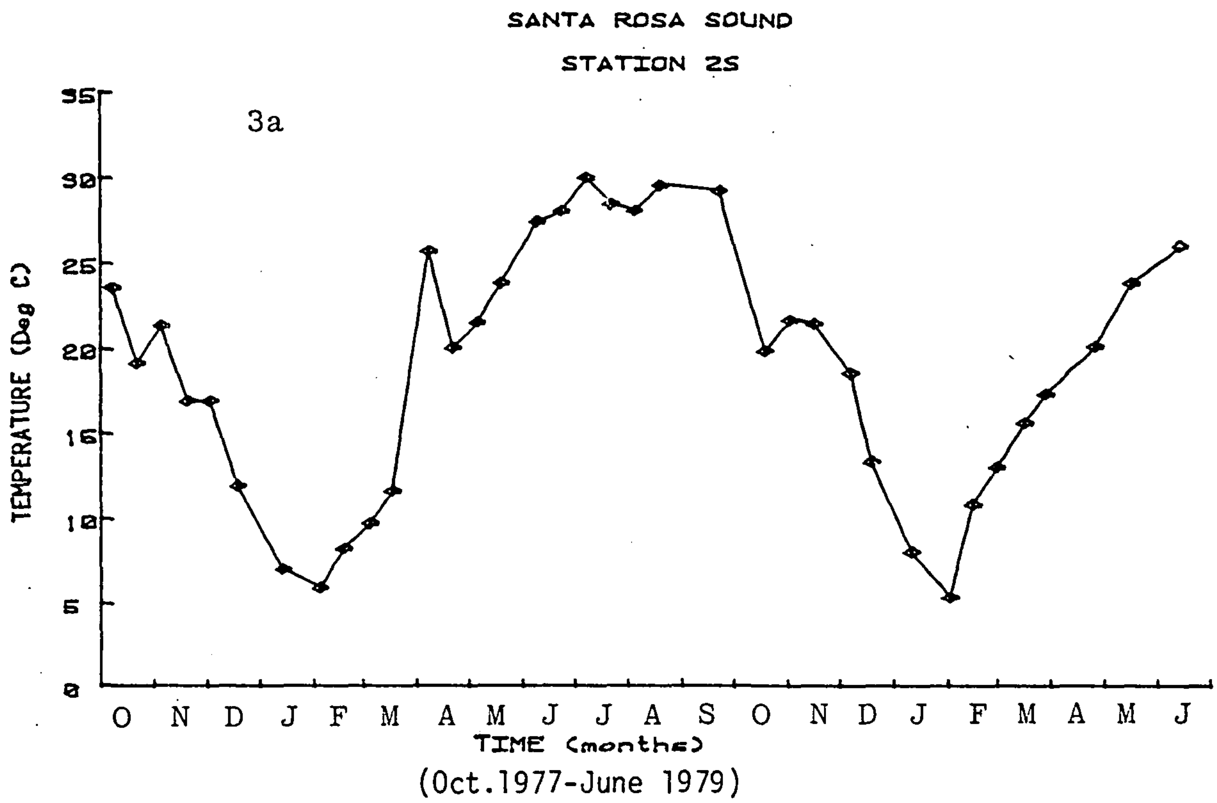
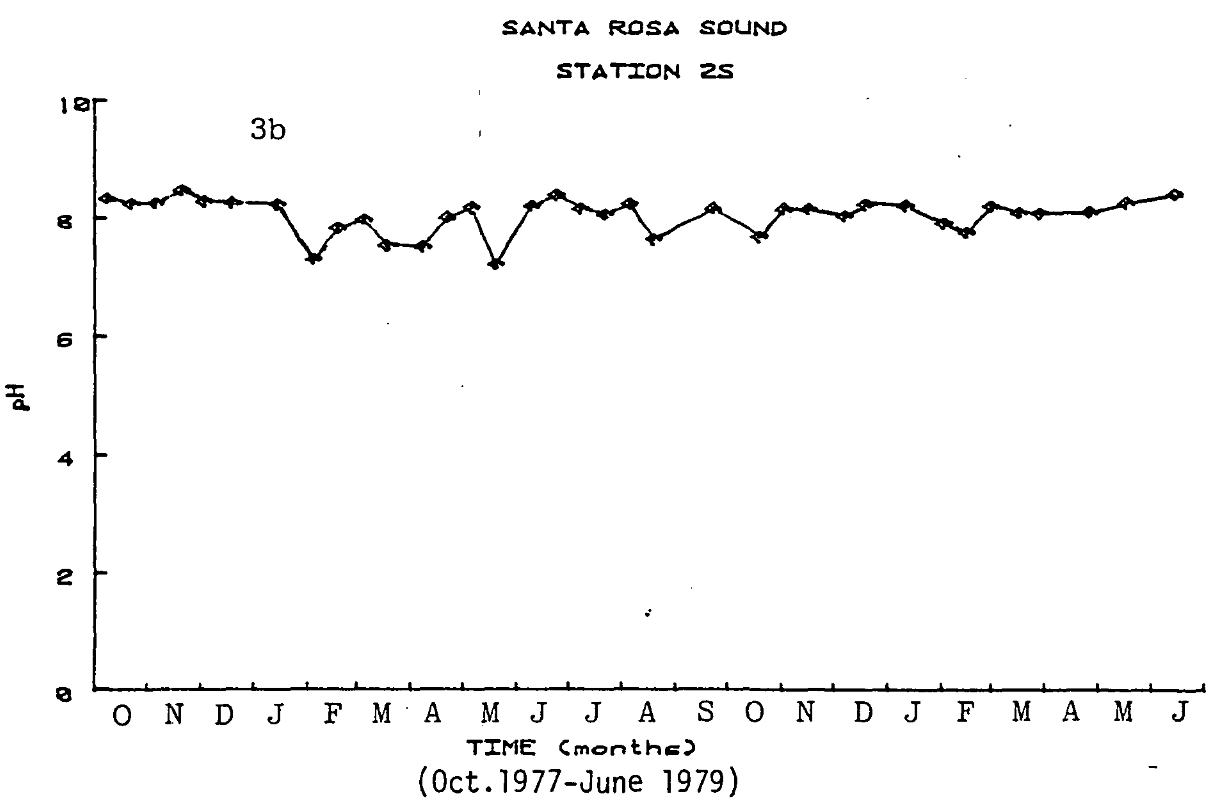
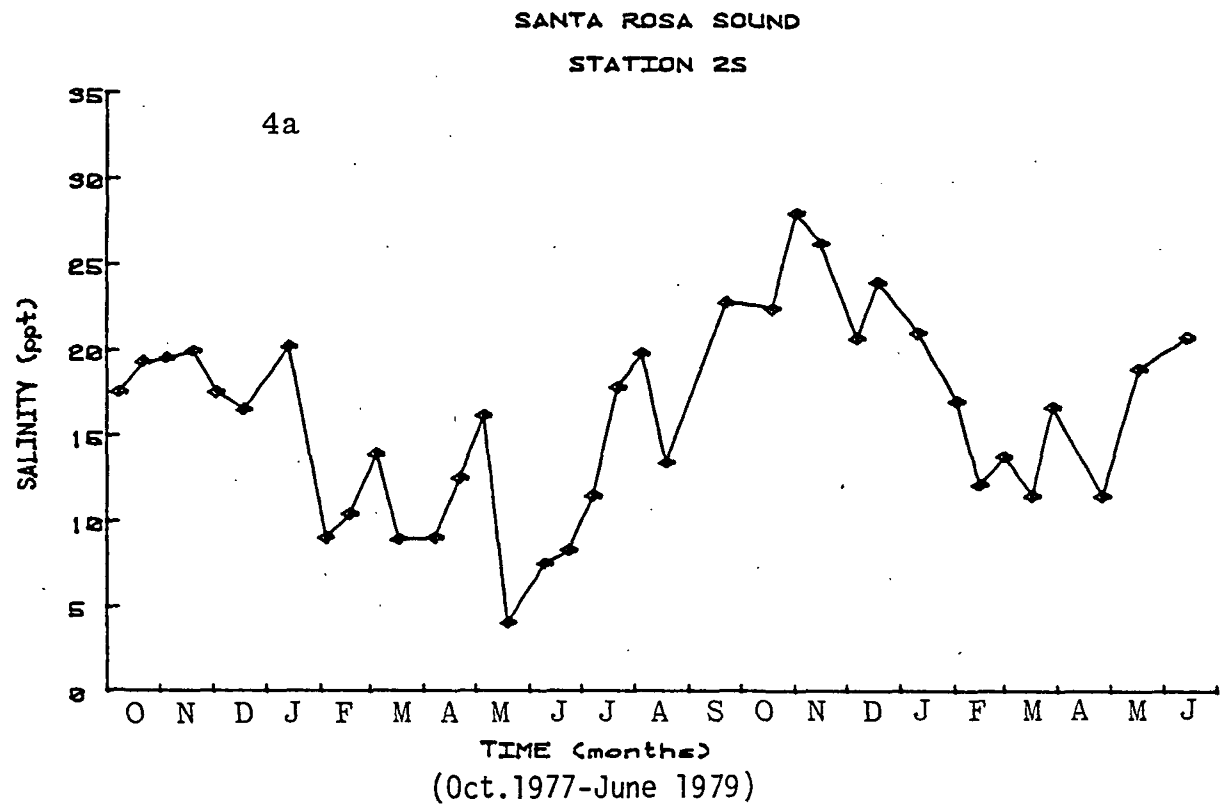


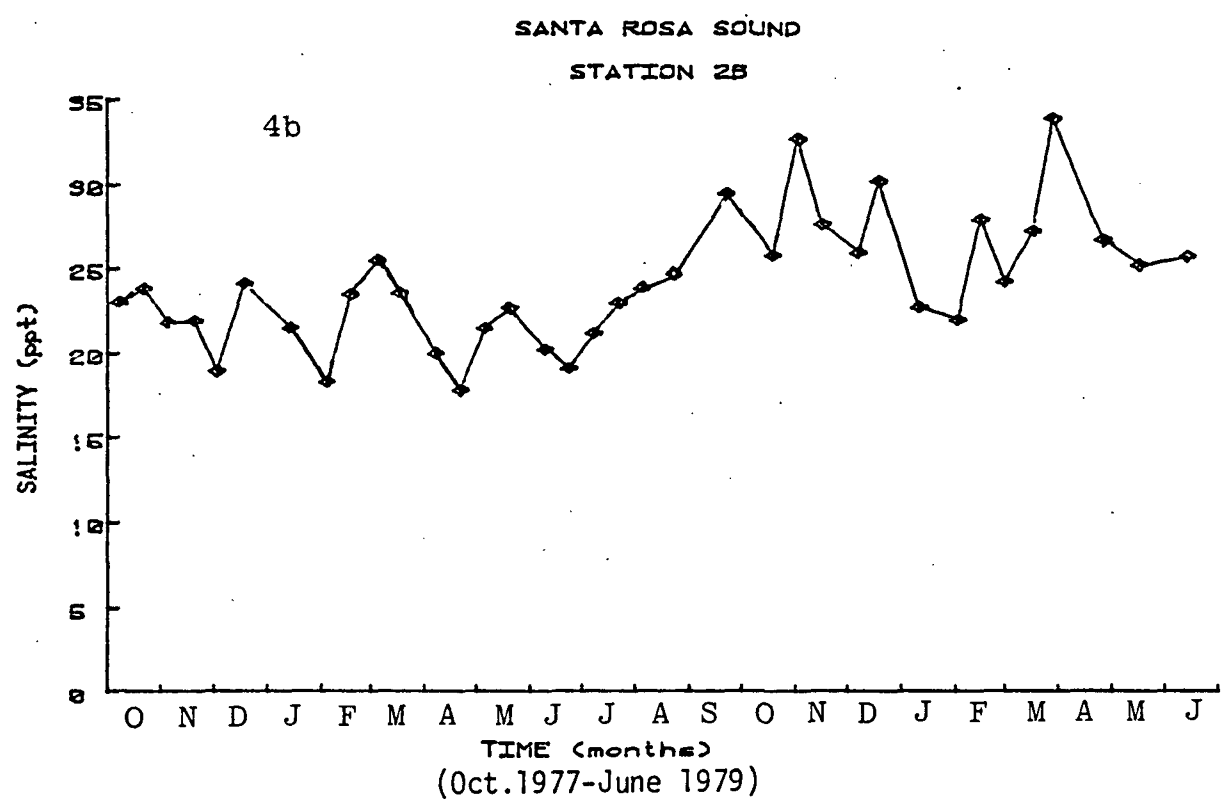
Figure 2. Flow chart depicting the regular sampling regimen conducted at each station for each depth.



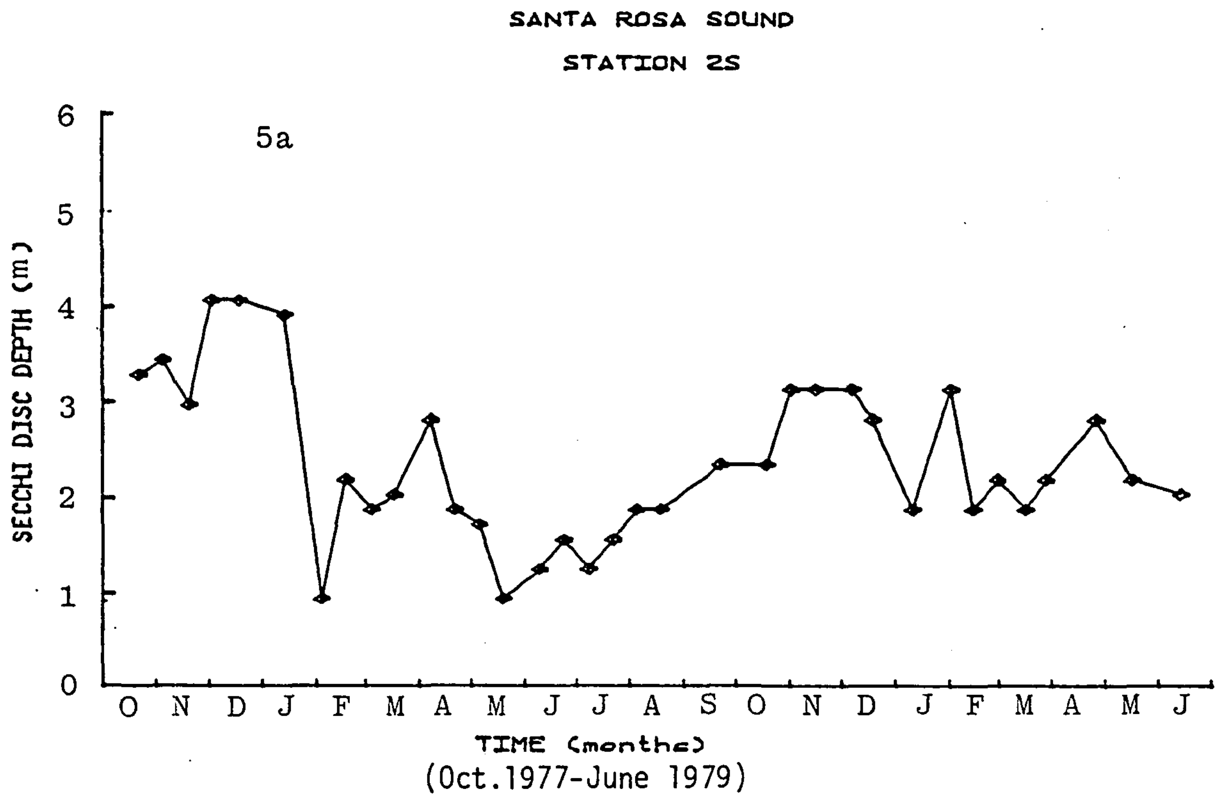


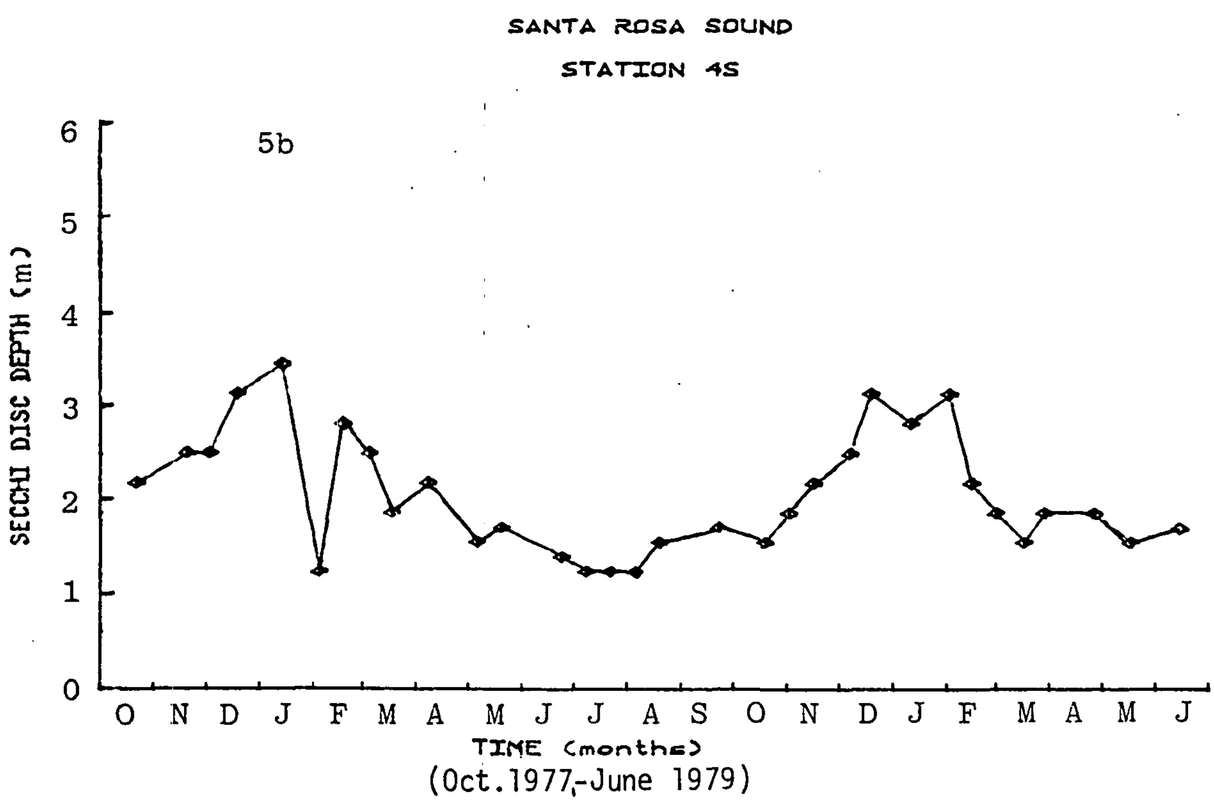
Figures 3a and 3b. Temperature and pH values at station 2S in Santa Rosa Sound.



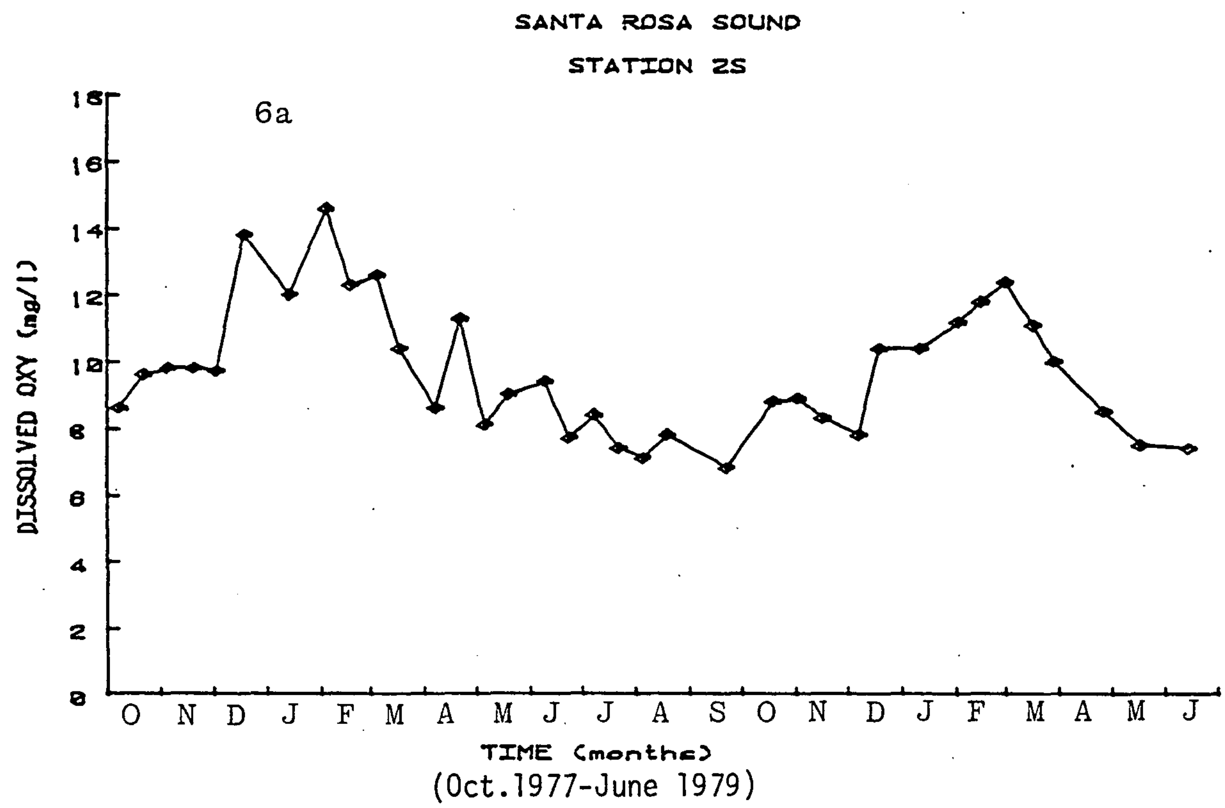


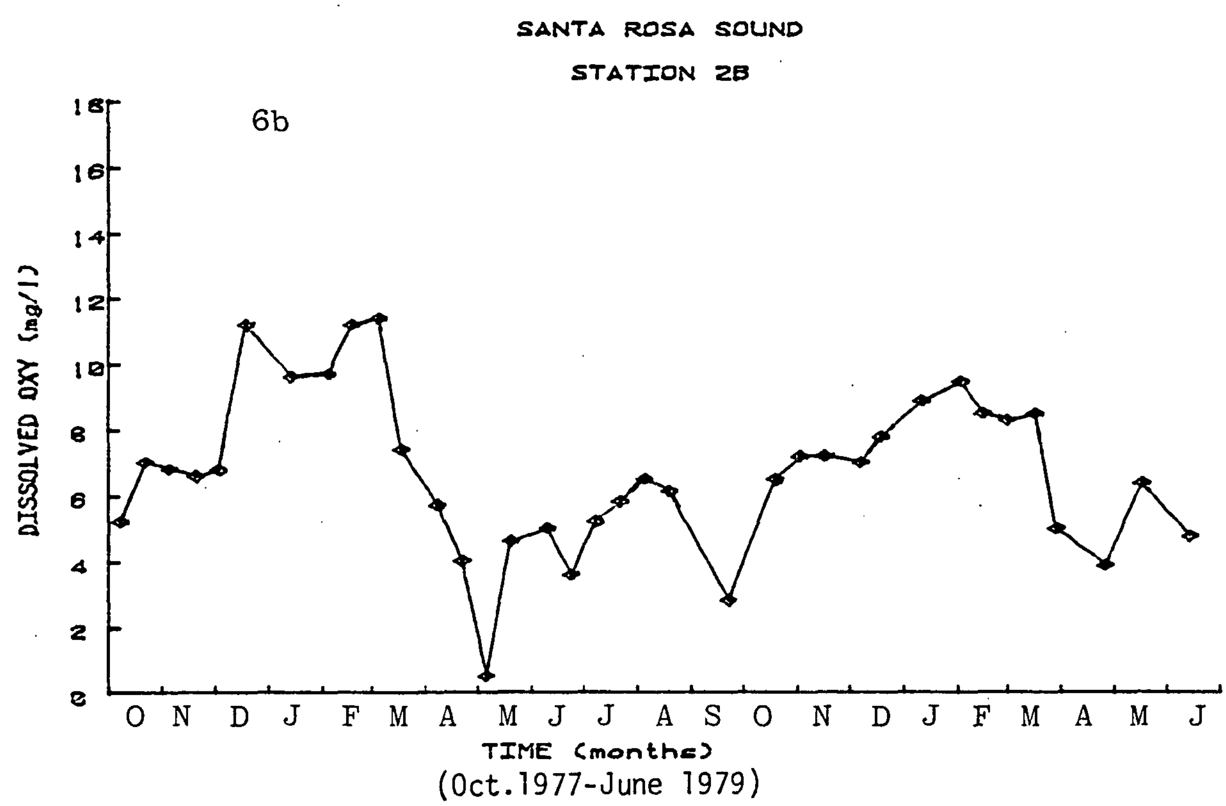
Figures 4a and 4b. Salinities at stations 2S and 2B in Santa Rosa Sound.



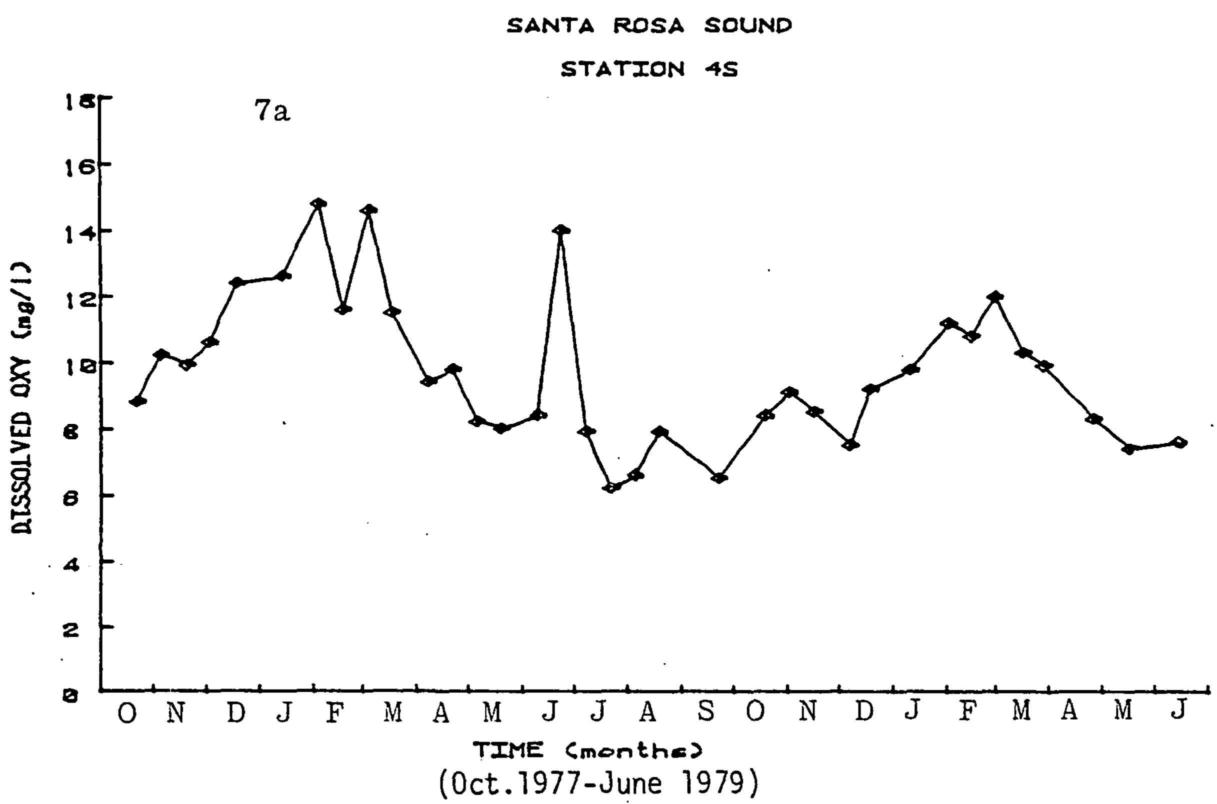


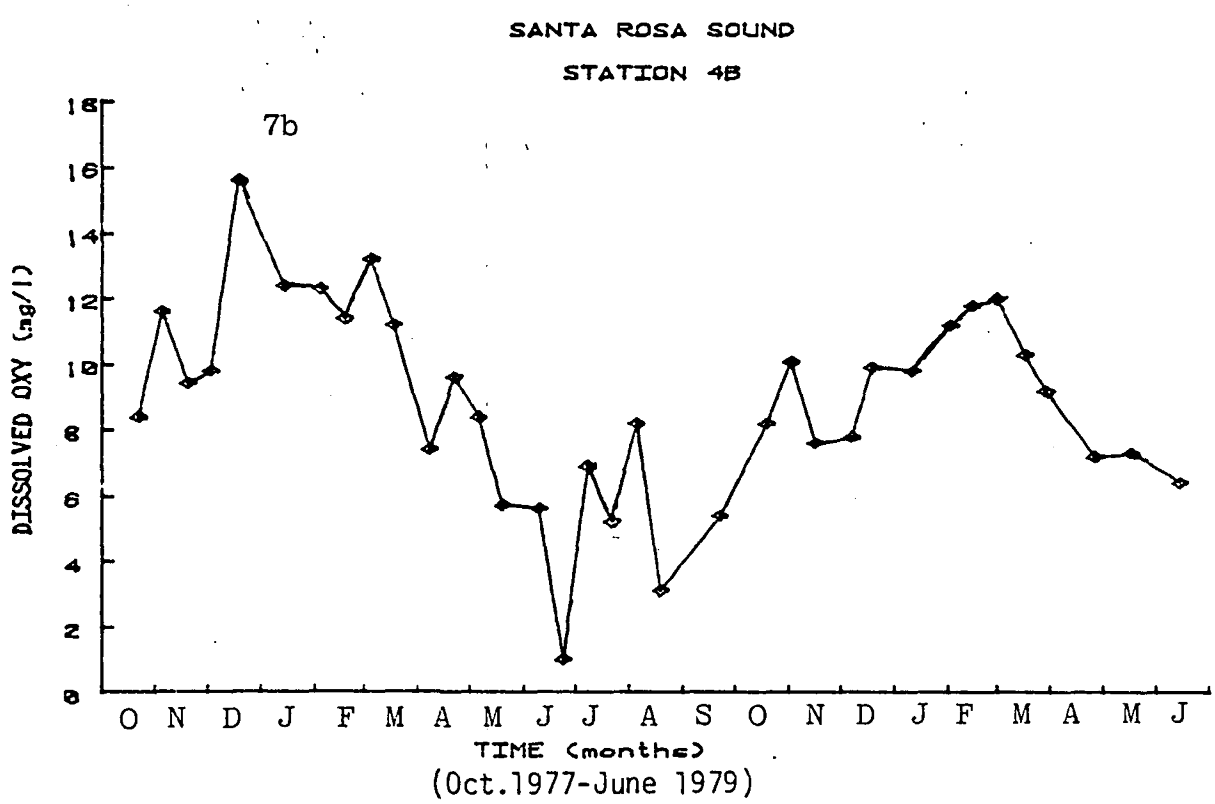
Figures 5a and 5b. Secchi disk readings at stations 2S and 4S in Santa Rosa Sound.



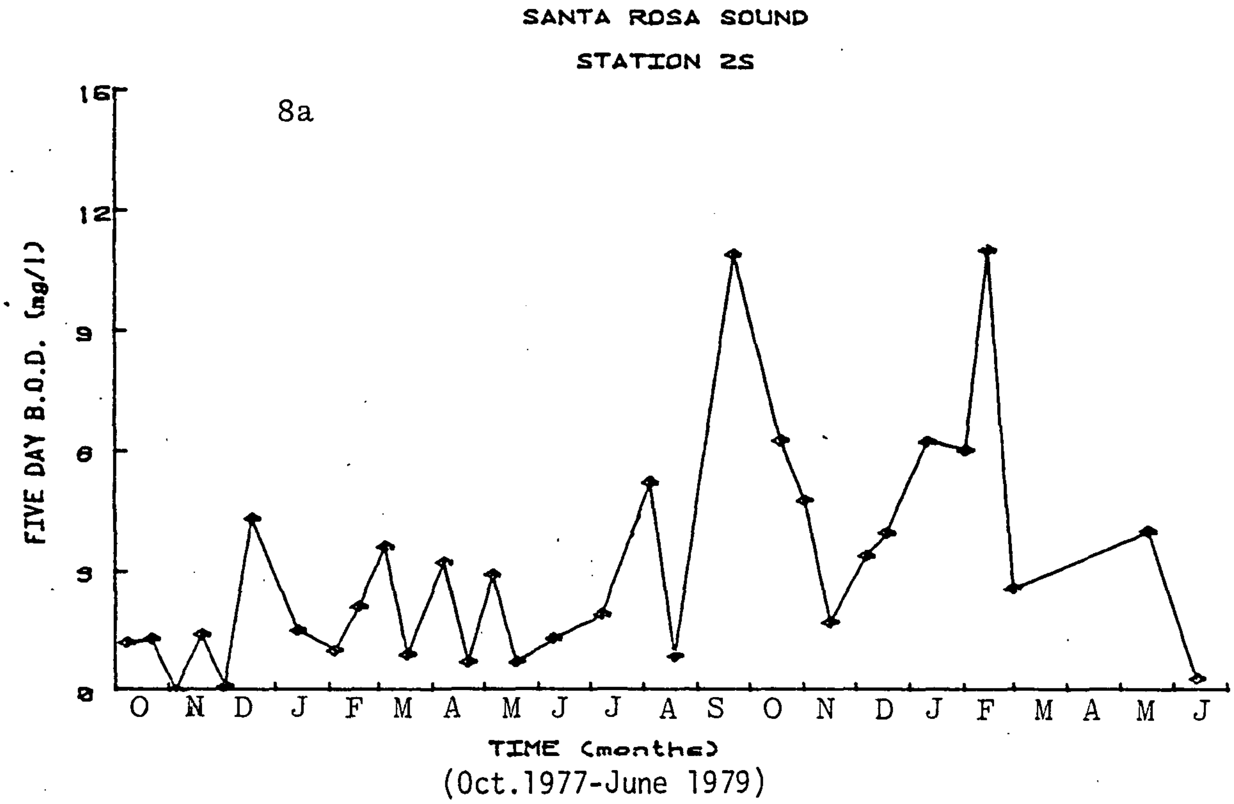


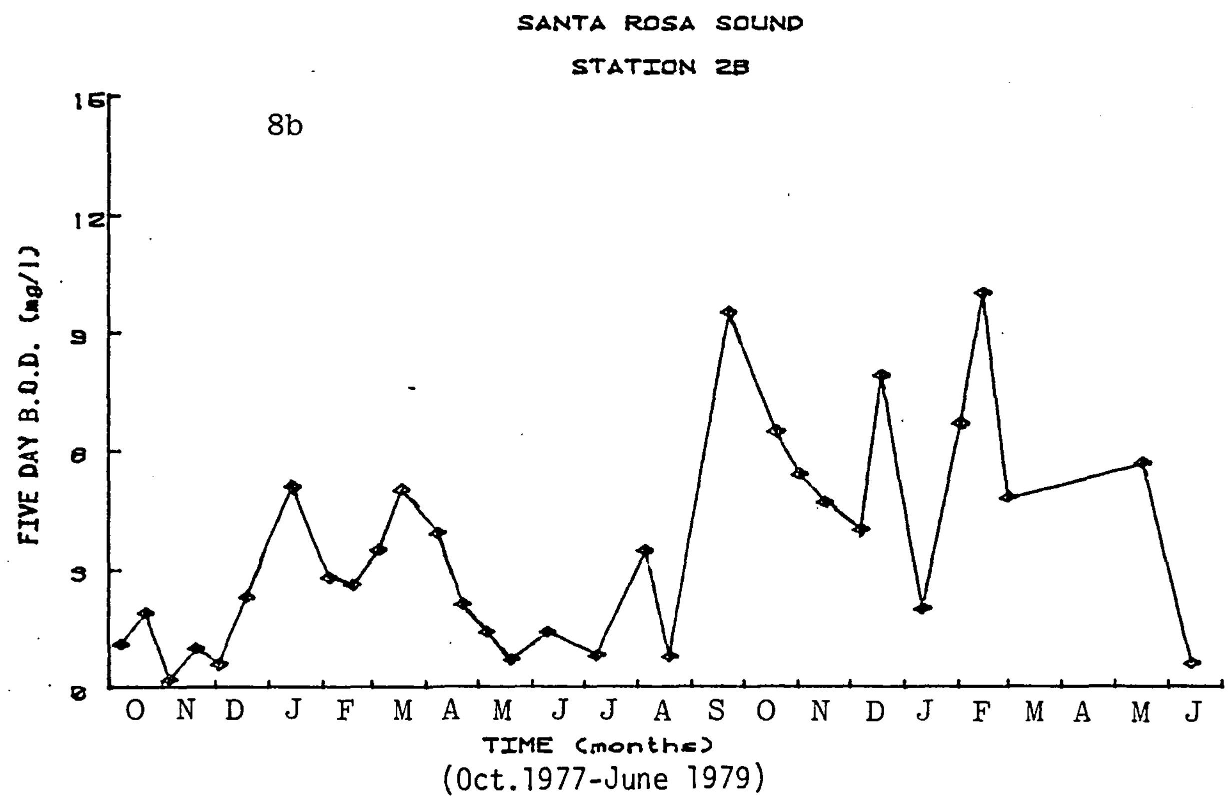
Figures 6a and 6b. Dissolved oxygen concentrations at stations 2S and 2B in Santa Rosa Sound.



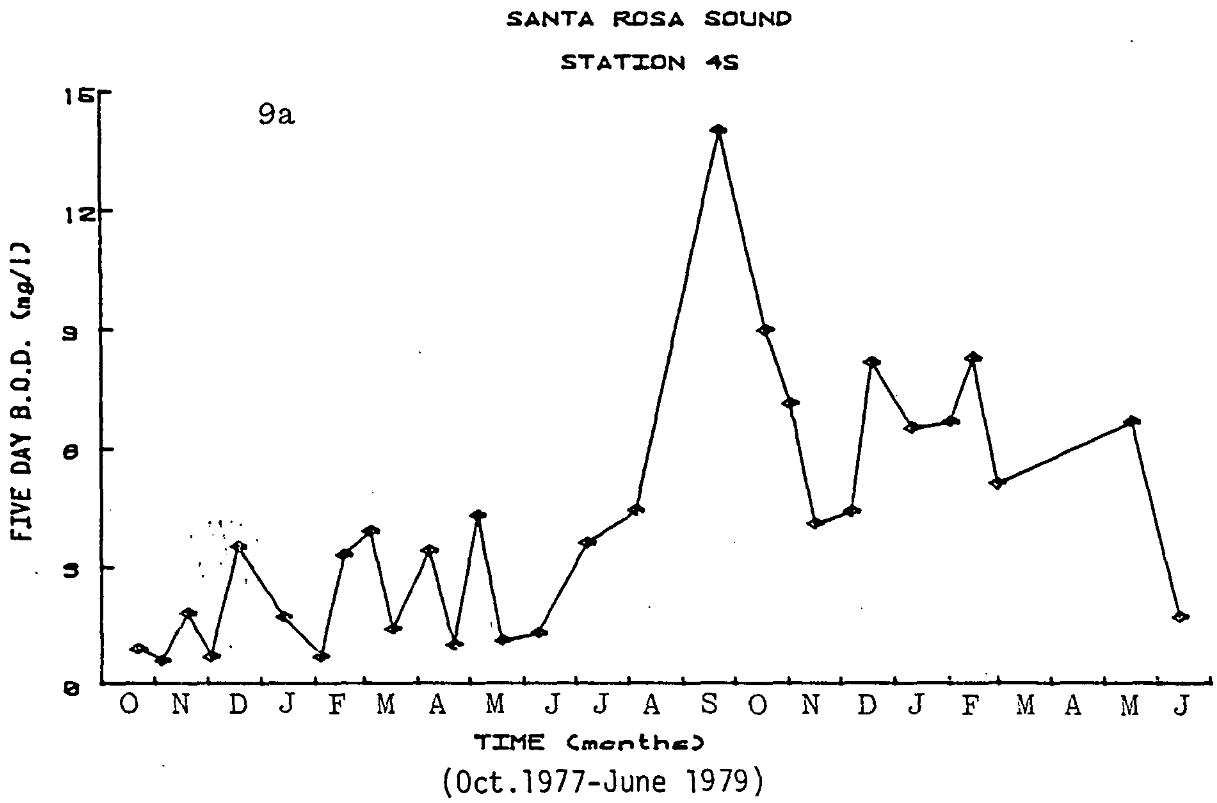


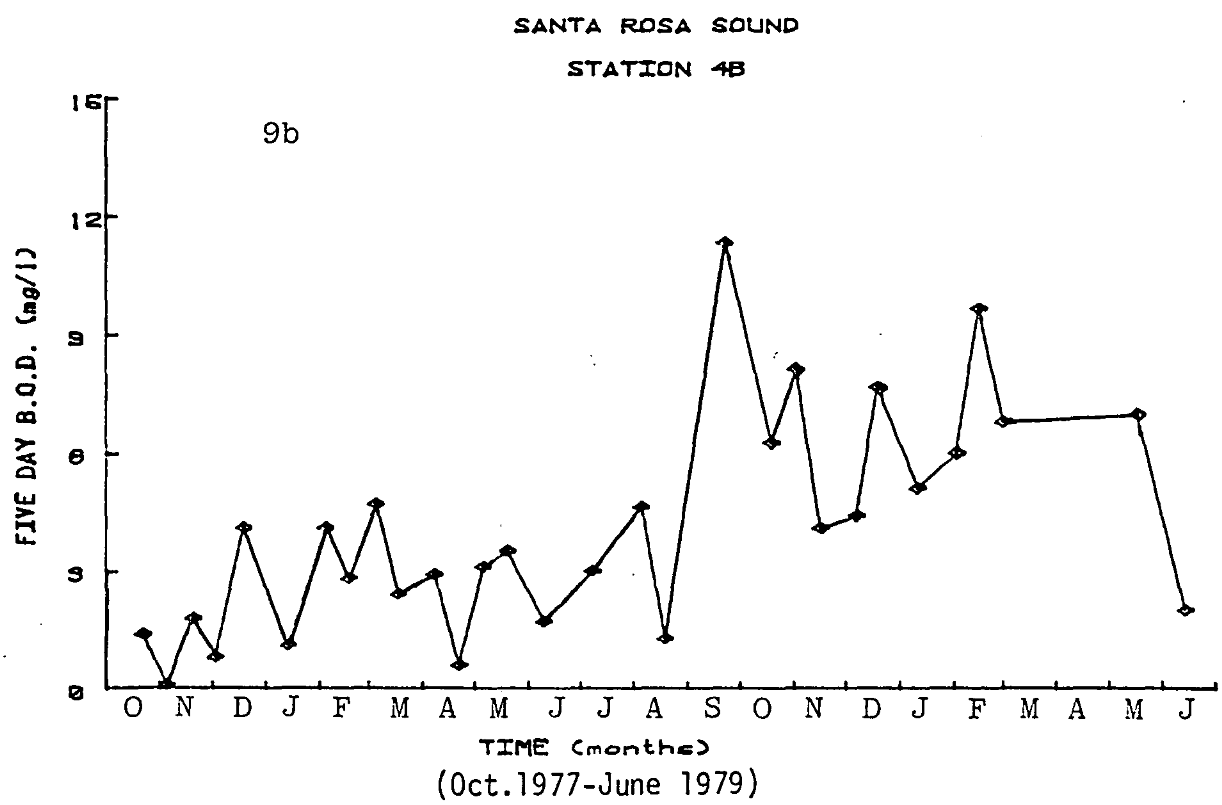
Figures 7a and 7b. Dissolved oxygen concentrations at stations 4S and 4B in Santa Rosa Sound.



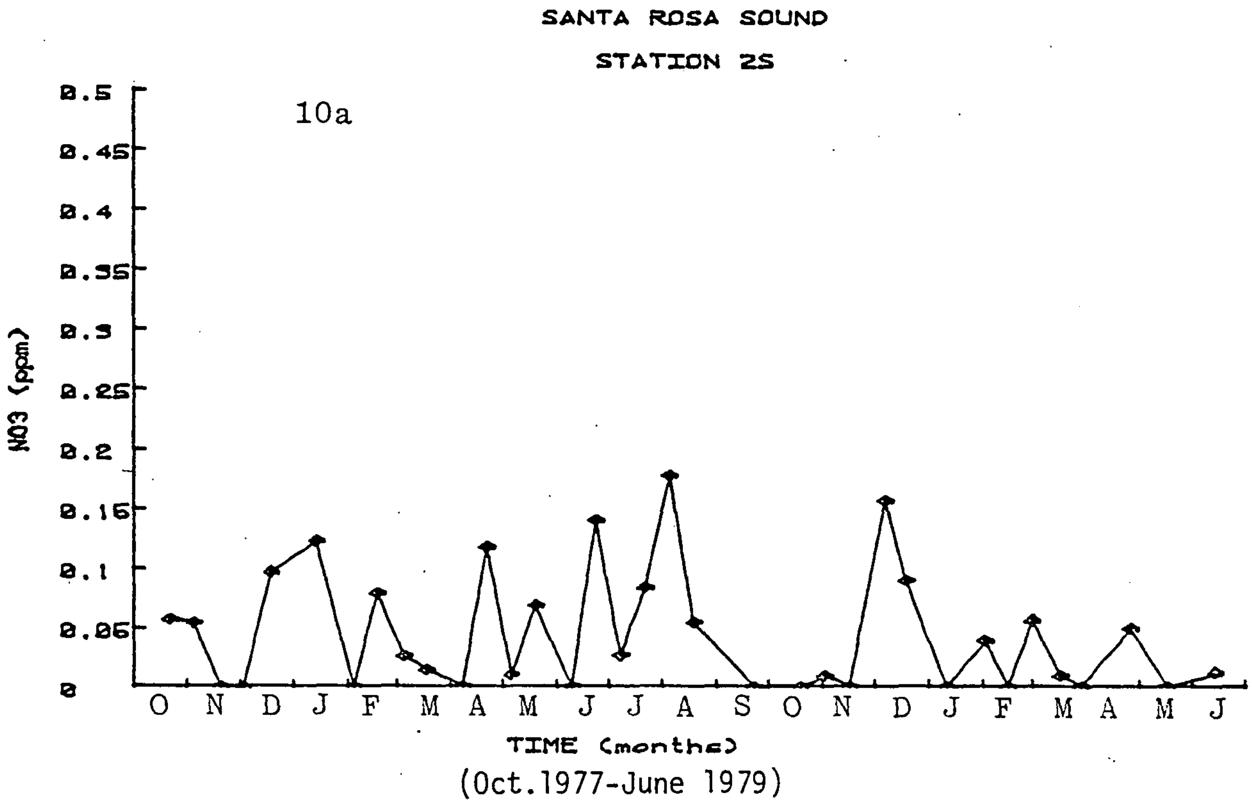


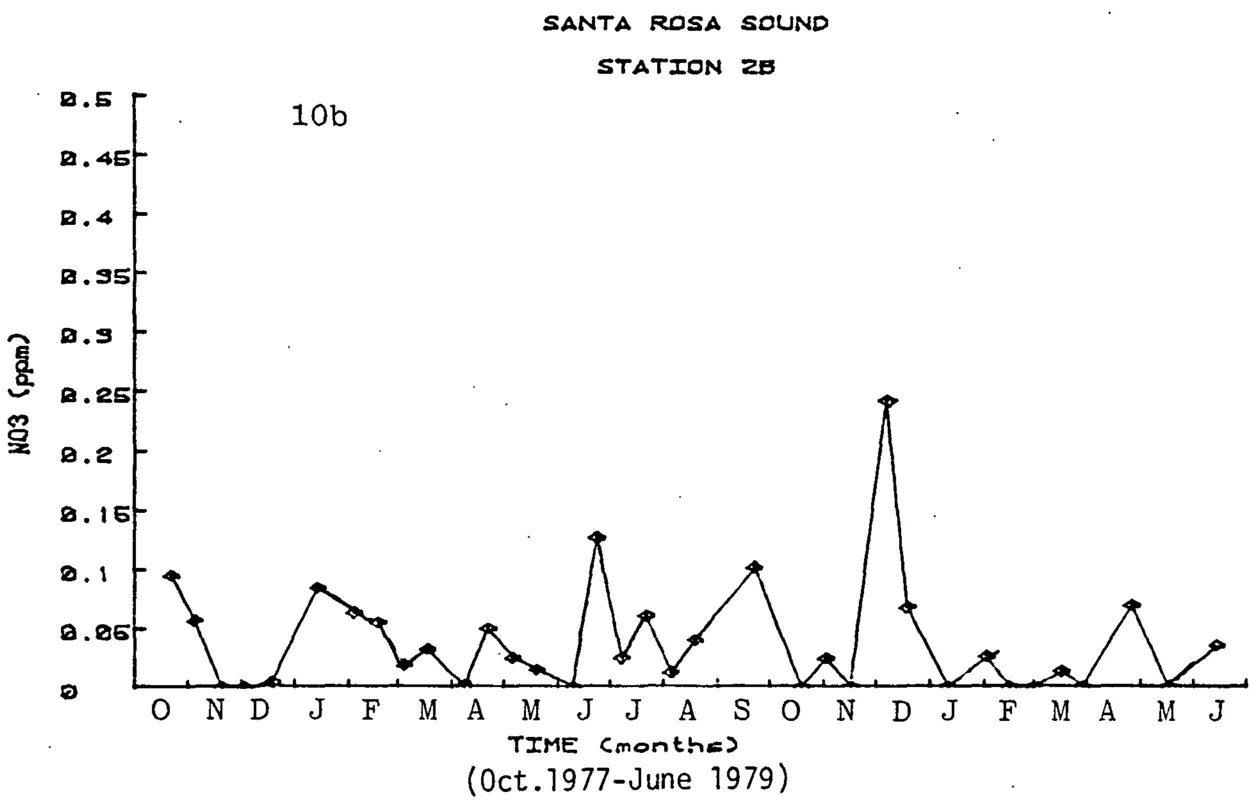
Figures 8a and 8b. Biochemical oxygen demand at stations 2S and 2B in Santa Rosa Sound.



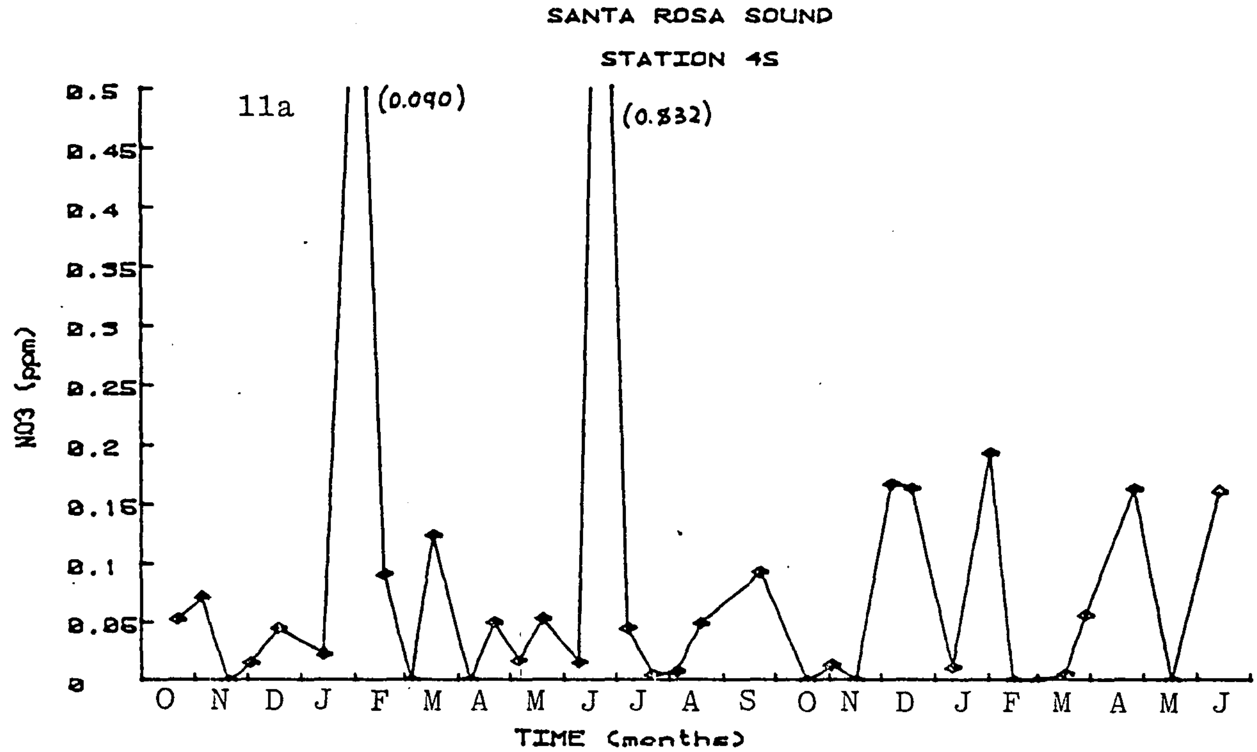


Figures 9a and 9b. Biochemical oxygen demand at stations 4S and 4B in Santa Rosa Sound.

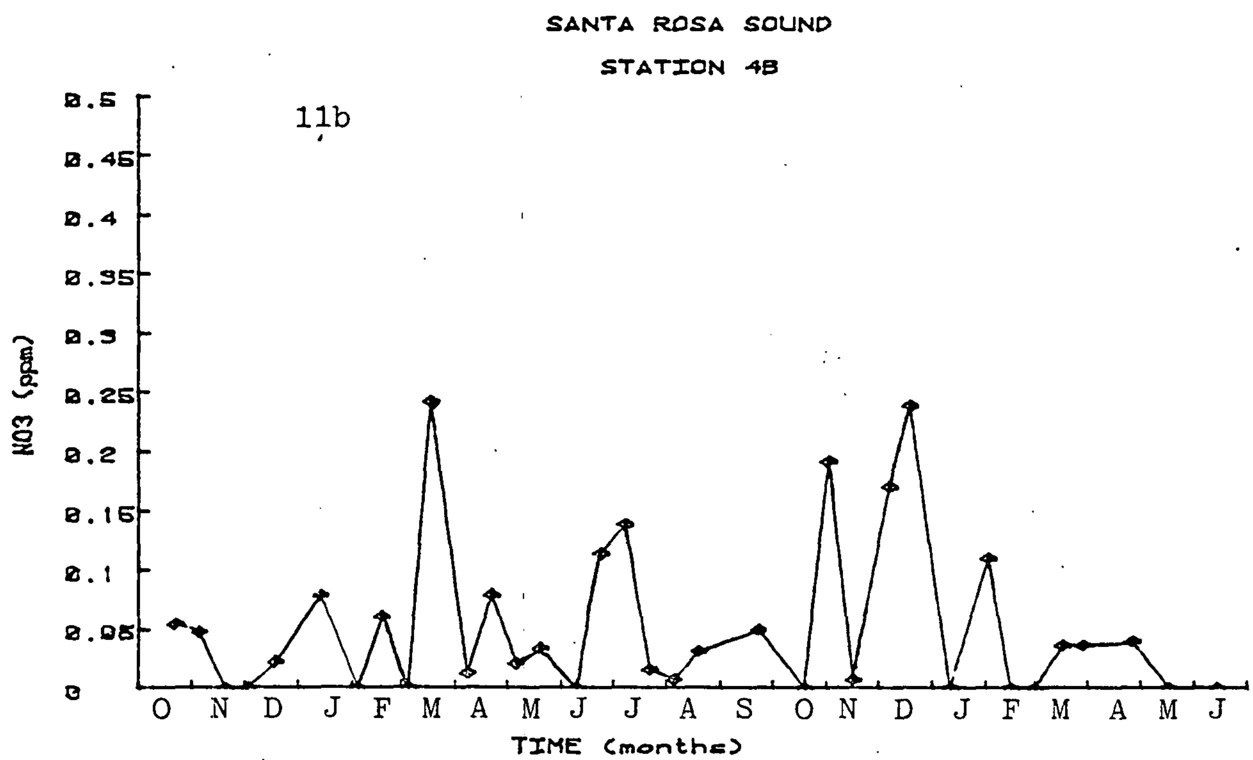




Figures 10a and 10b. NO_3-N concentrations at stations 2S and 2B in Santa Rosa Sound.

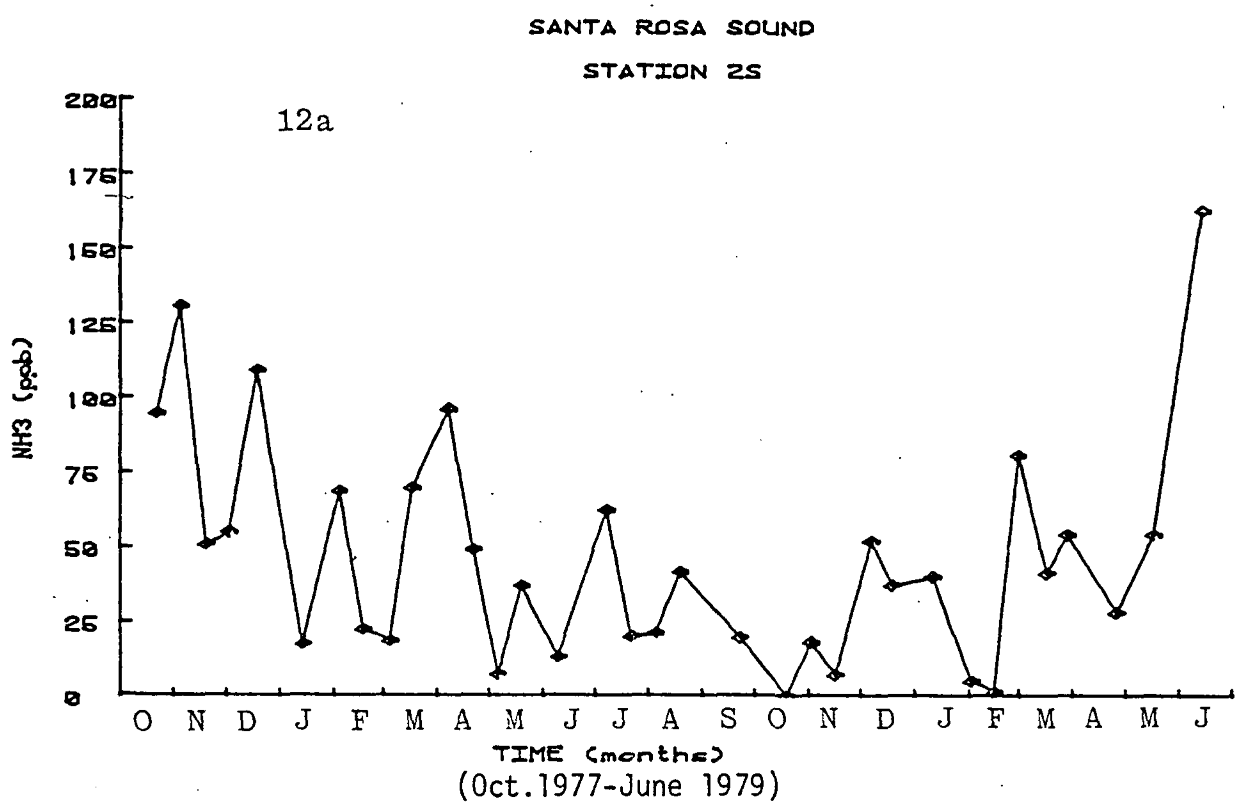


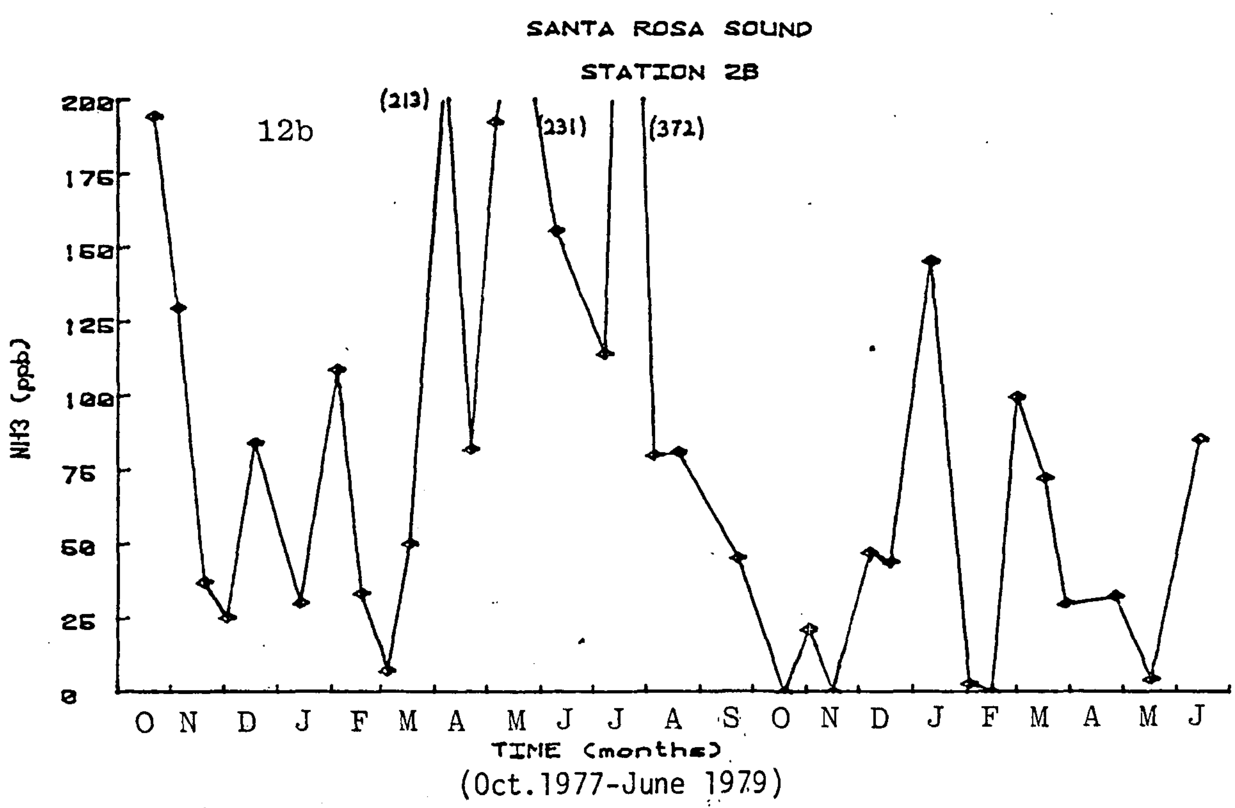
(Oct.1977-June 1979)



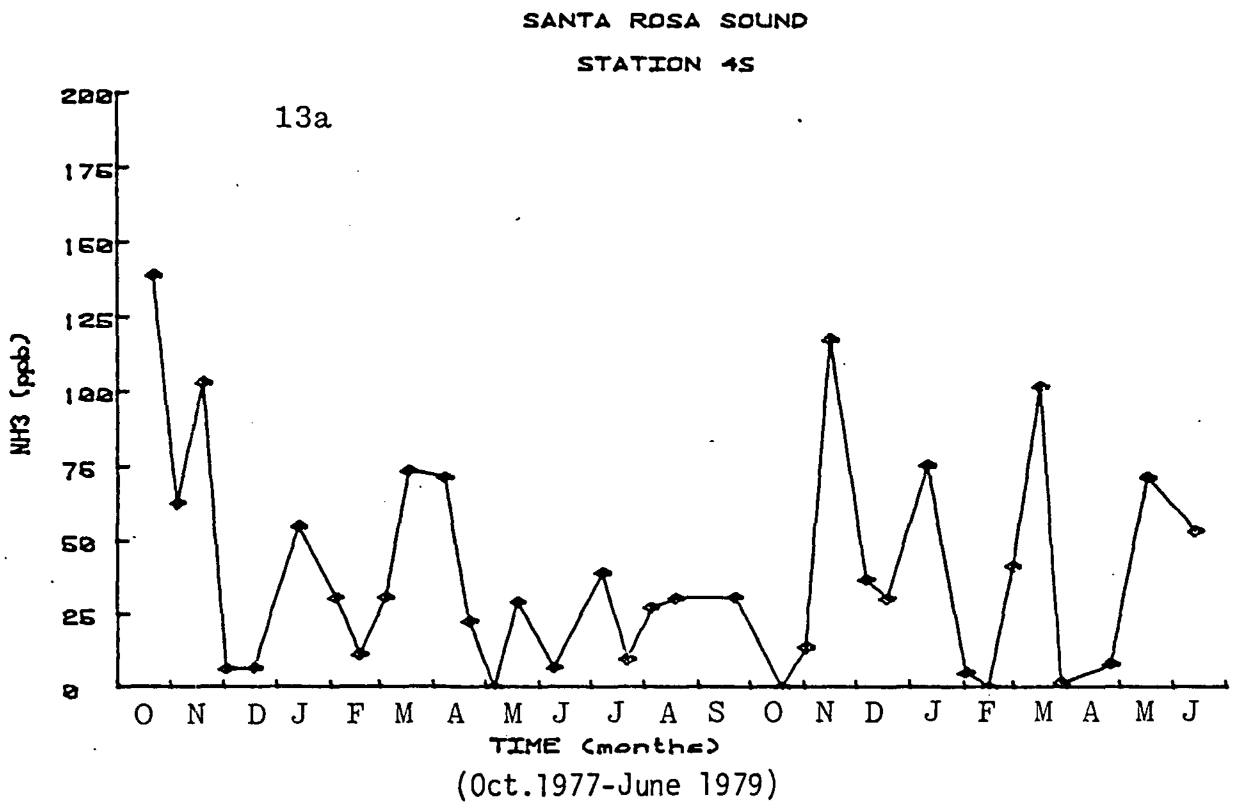
(Oct.1977-June 1979)

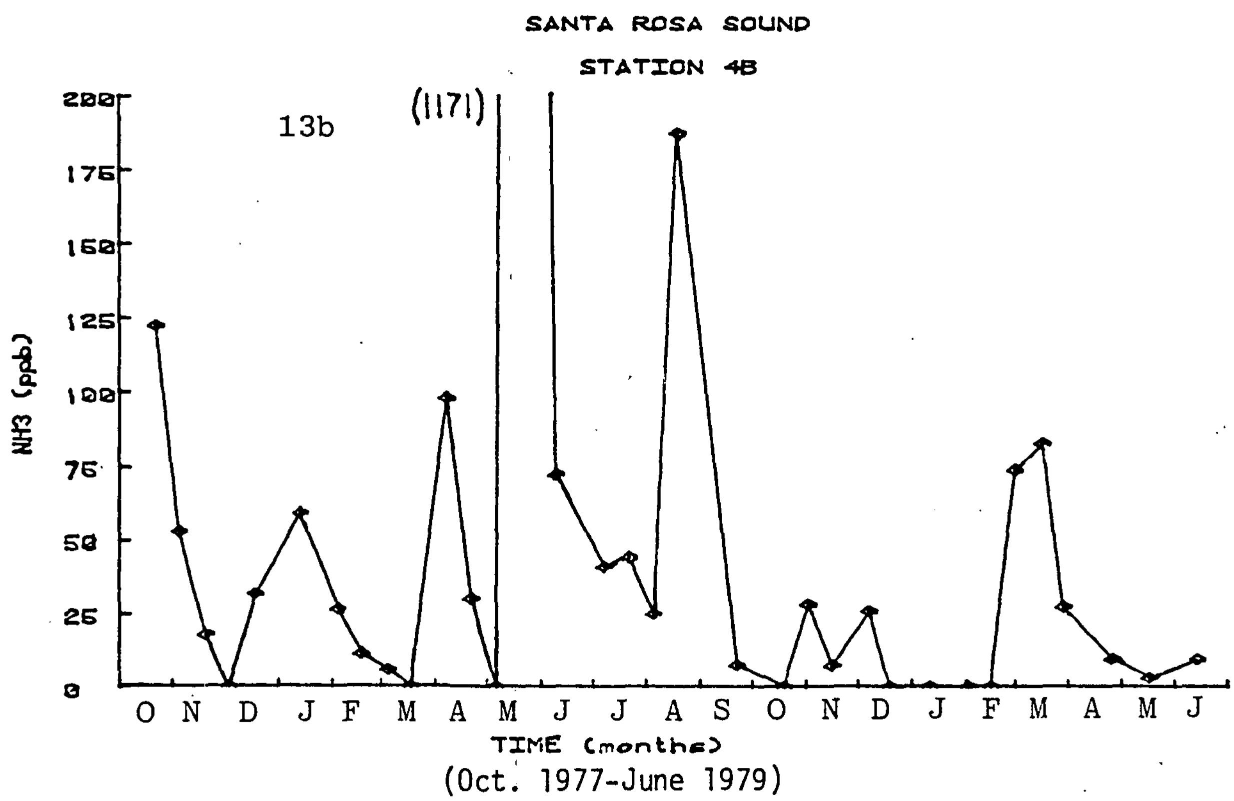
Figures 11a and 11b. NO_3-N concentrations at stations 4S and 4B in Santa Rosa Sound.



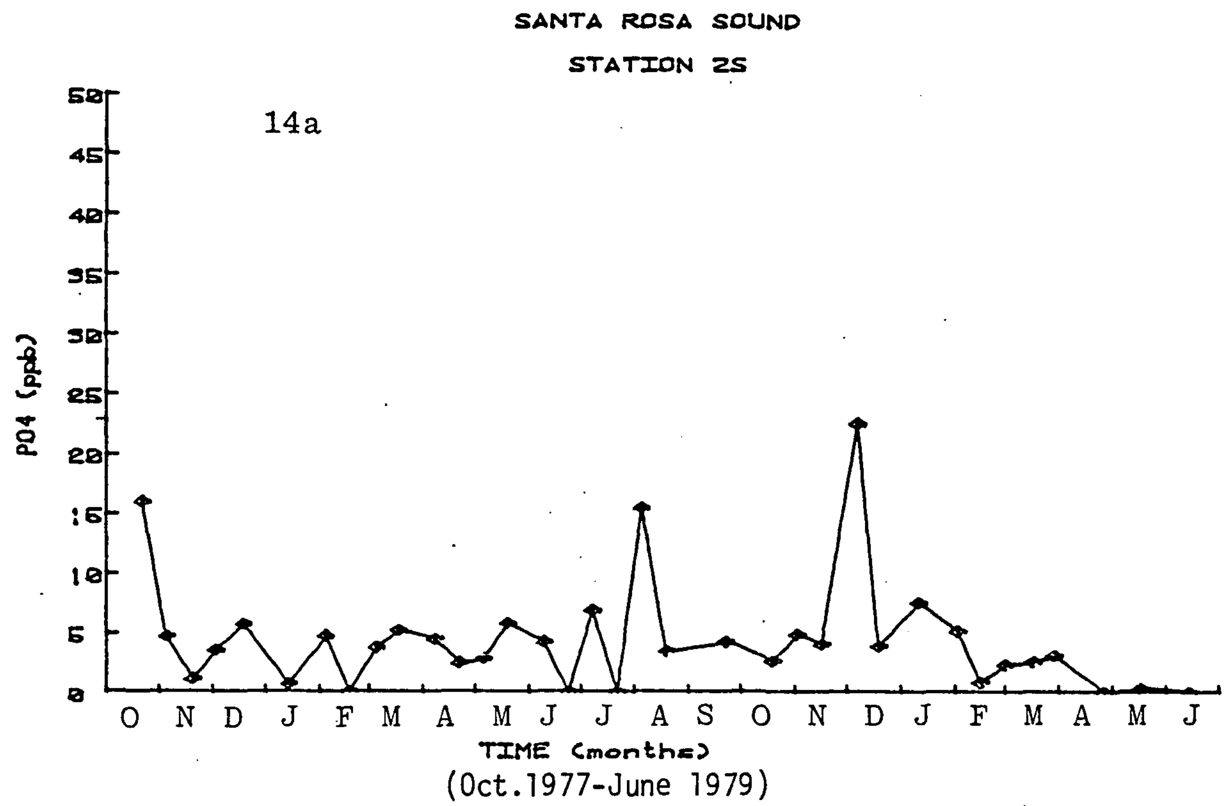


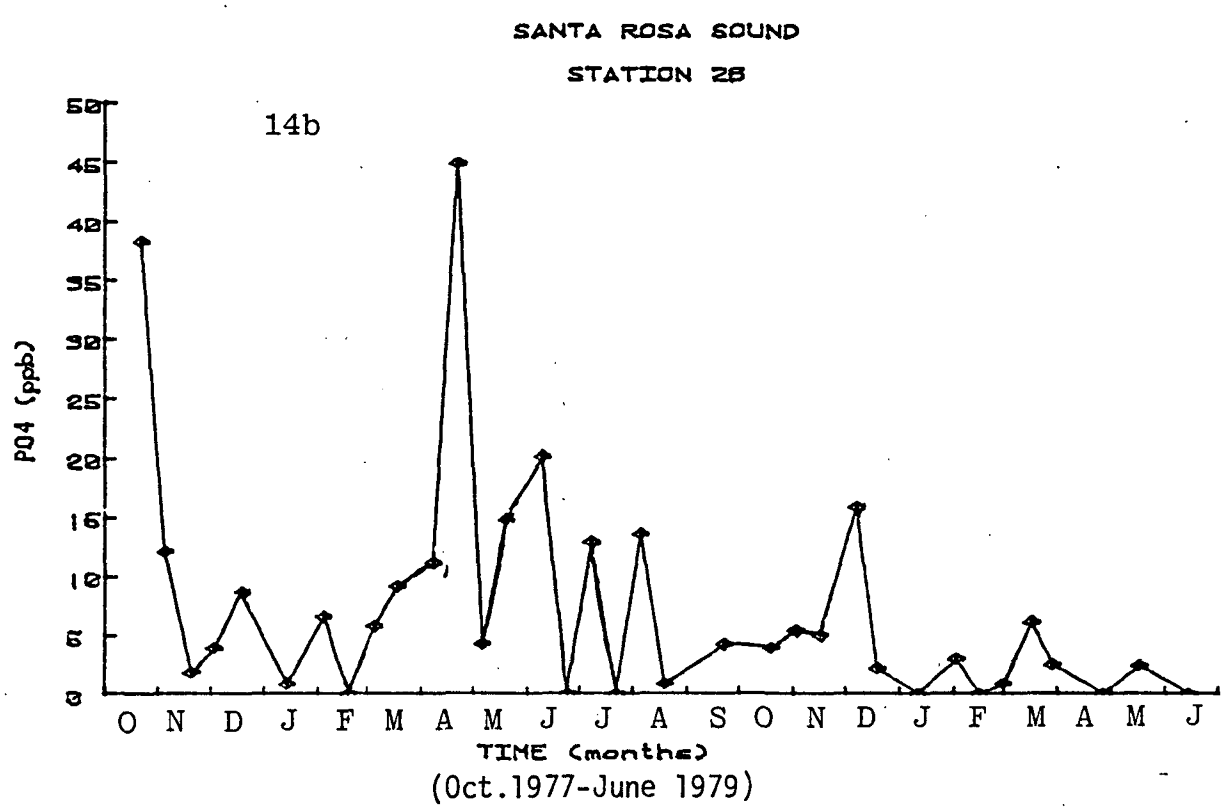
Figures 12a and 12b. NH_3-N concentrations at stations 2S and 2B in Santa Rosa Sound.



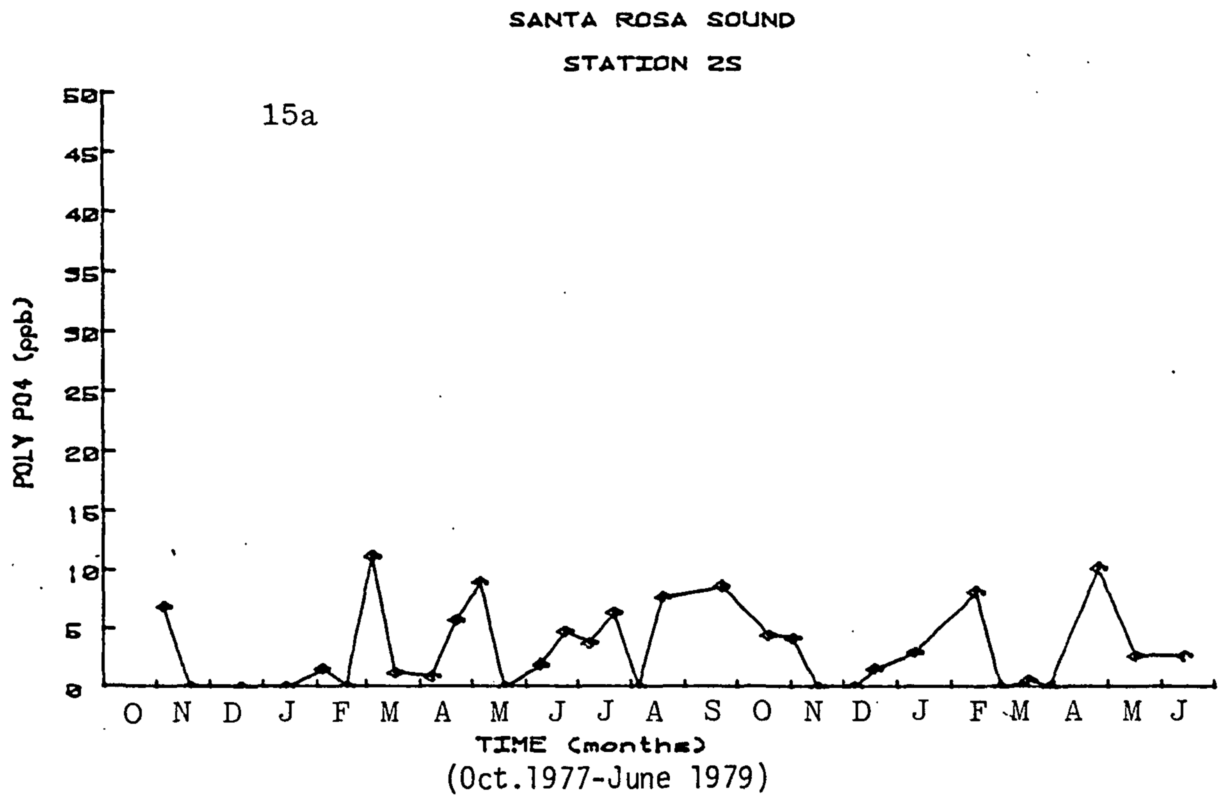


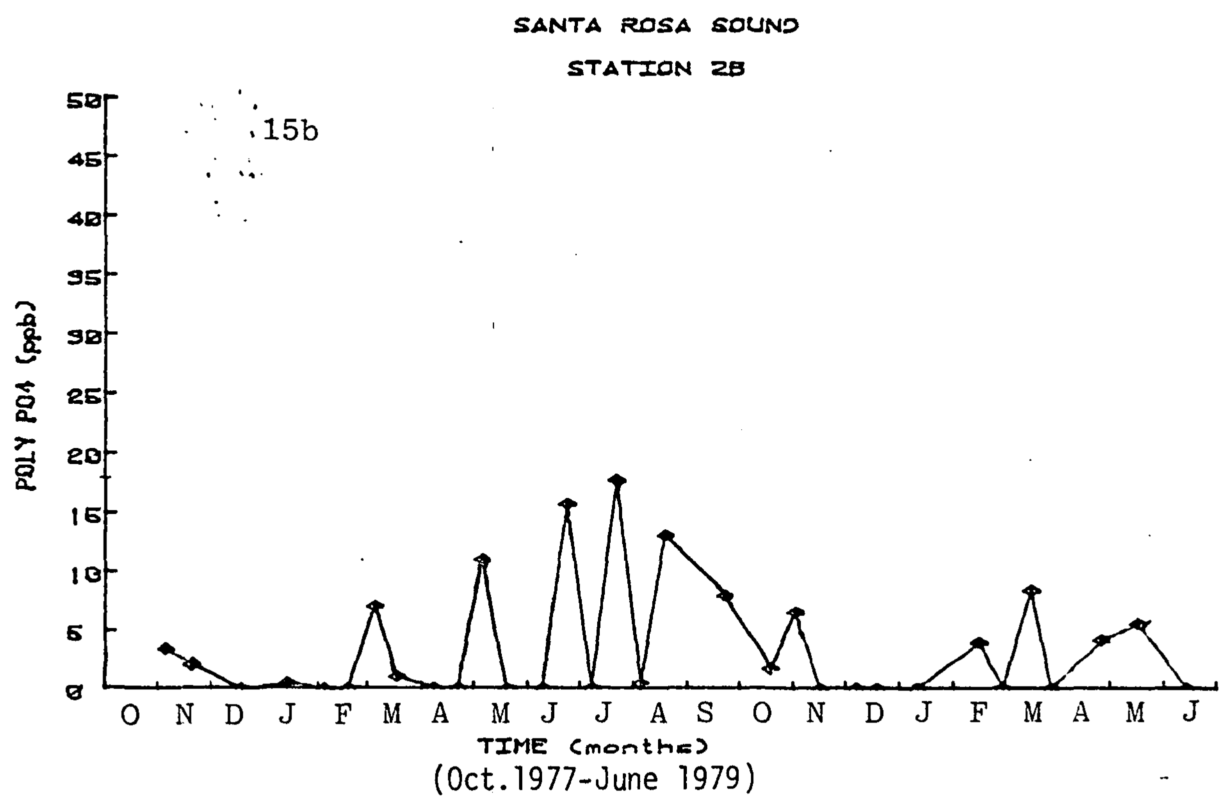
Figures 13a and 13b. NH_3-N concentrations at stations 4S and 4B in Santa Rosa Sound.



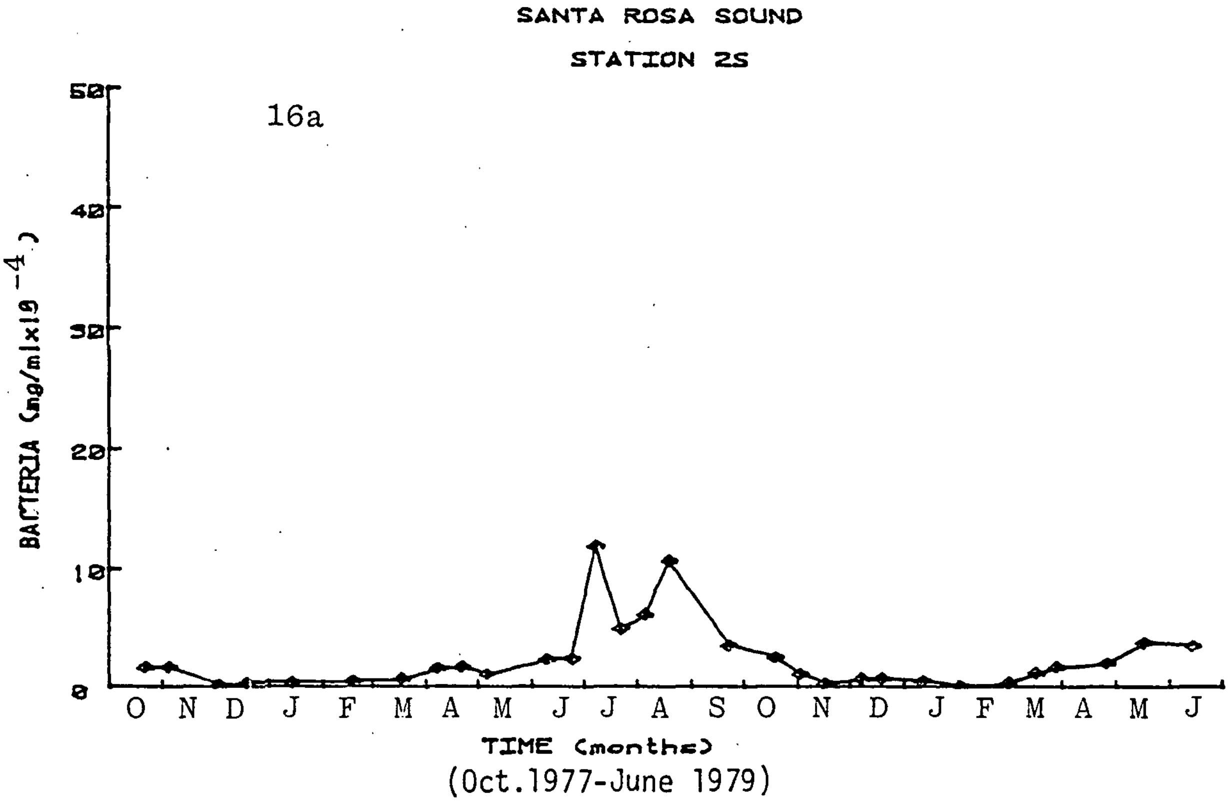


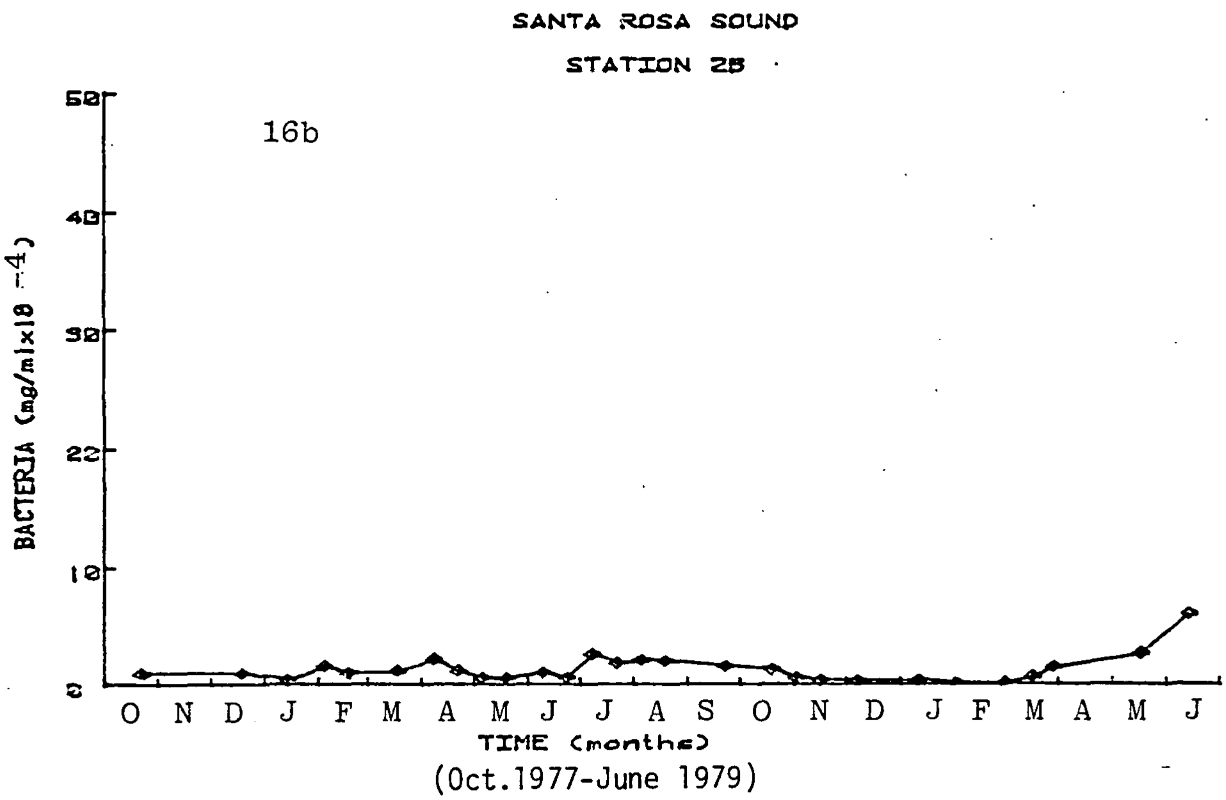
Figures 14a and 14b. PO_4-P concentrations at stations 2S and 2B in Santa Rosa Sound.



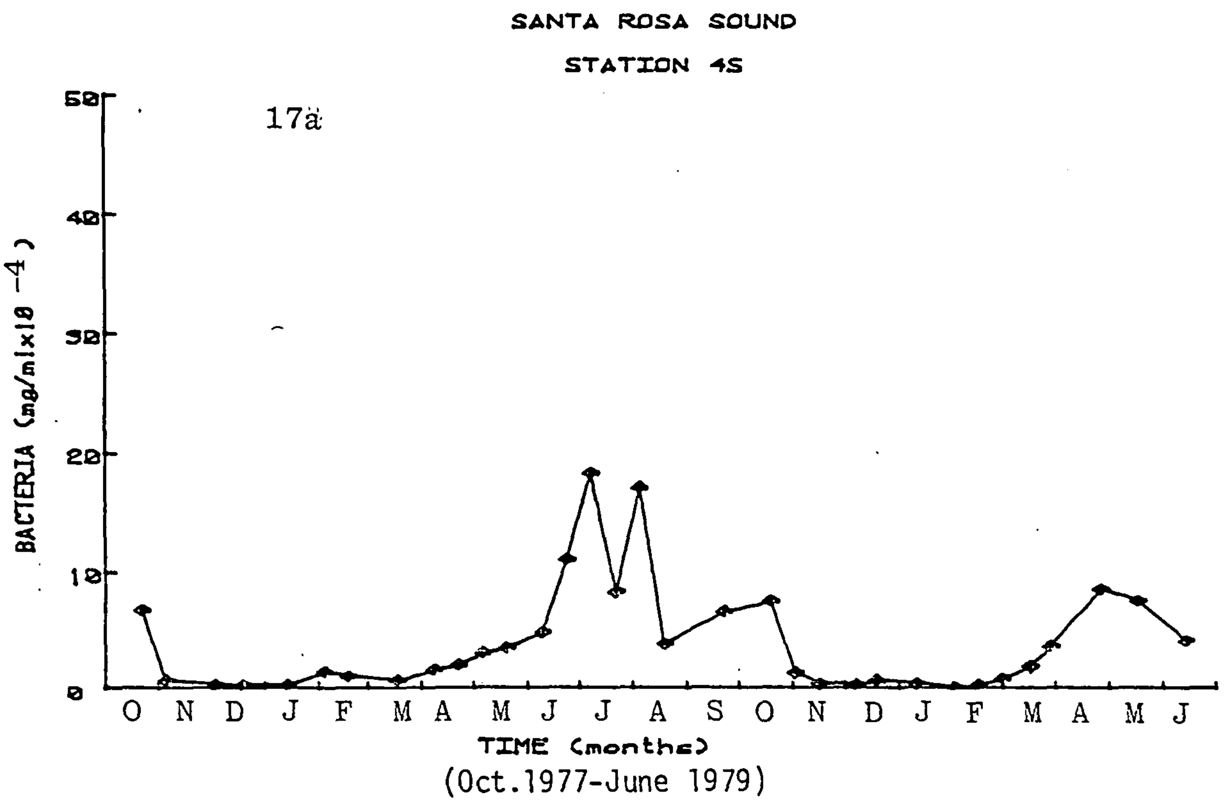


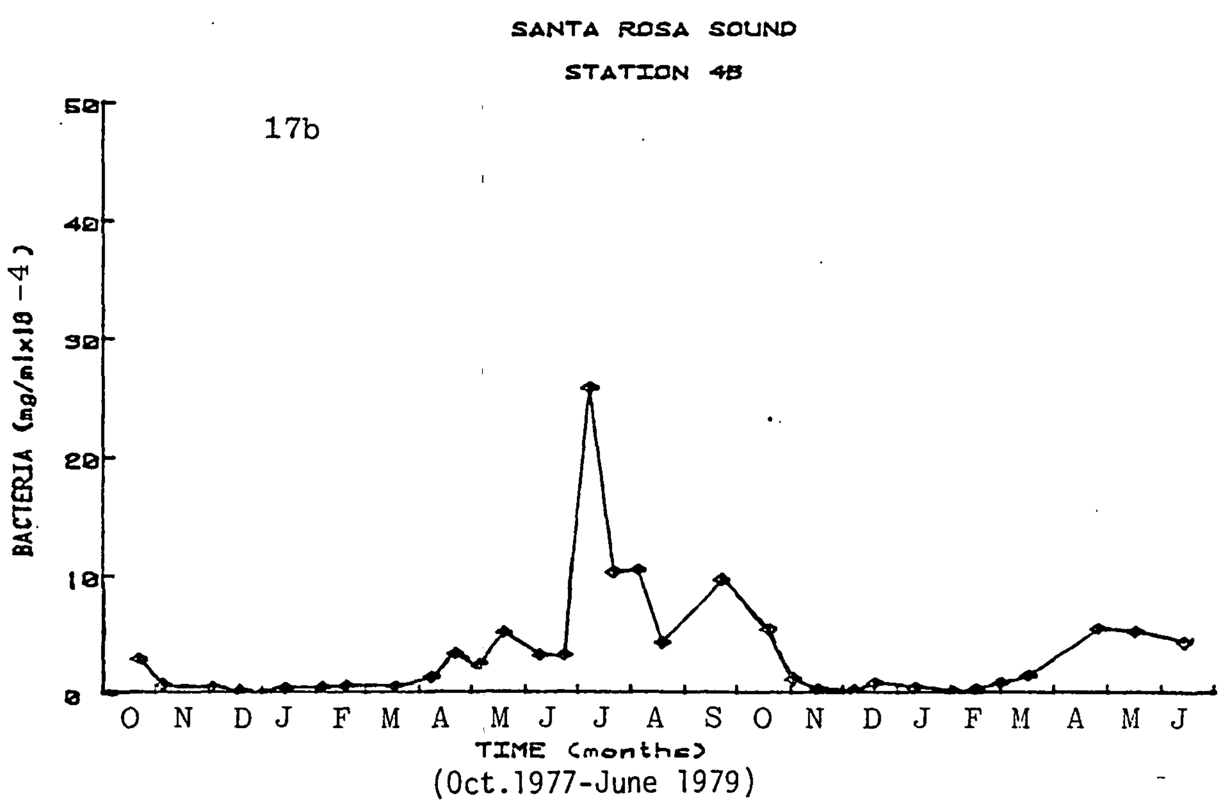
Figures 15a and 15b. Poly-PO_4 concentrations at stations 2S and 2B in Santa Rosa Sound.



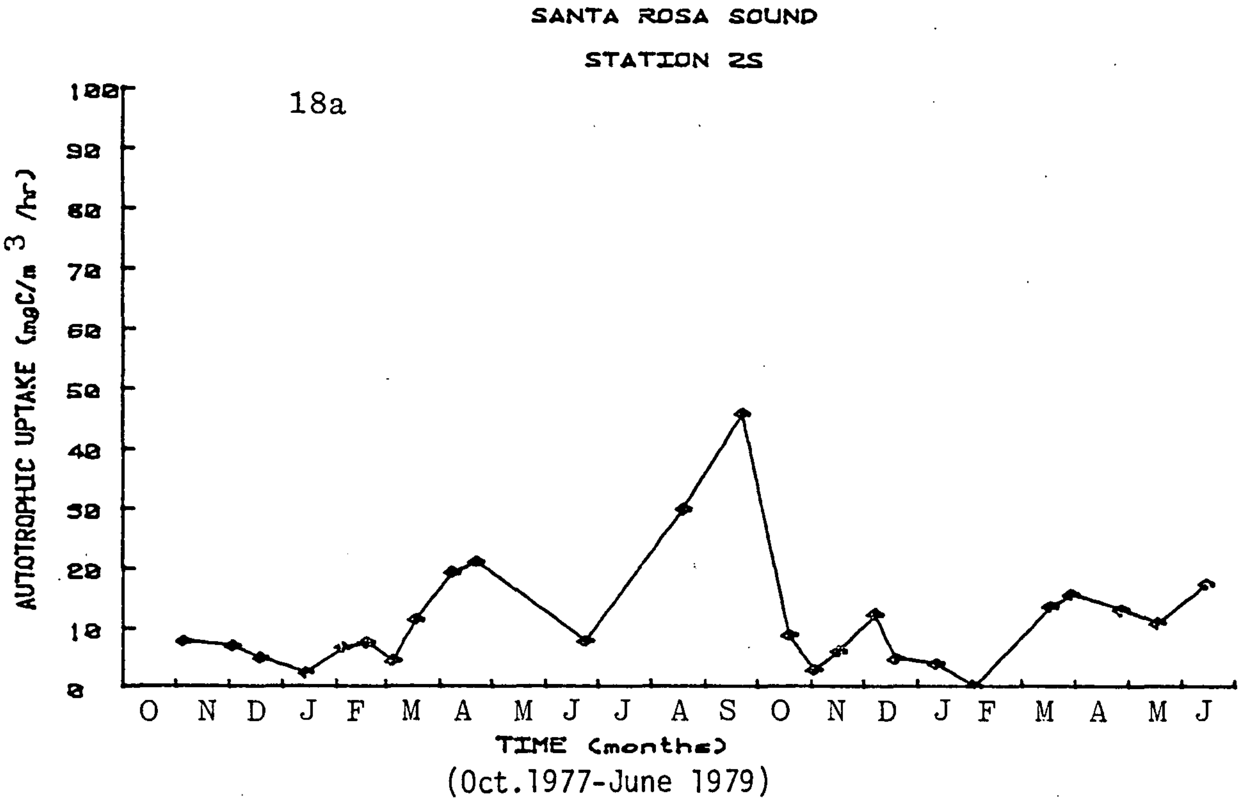


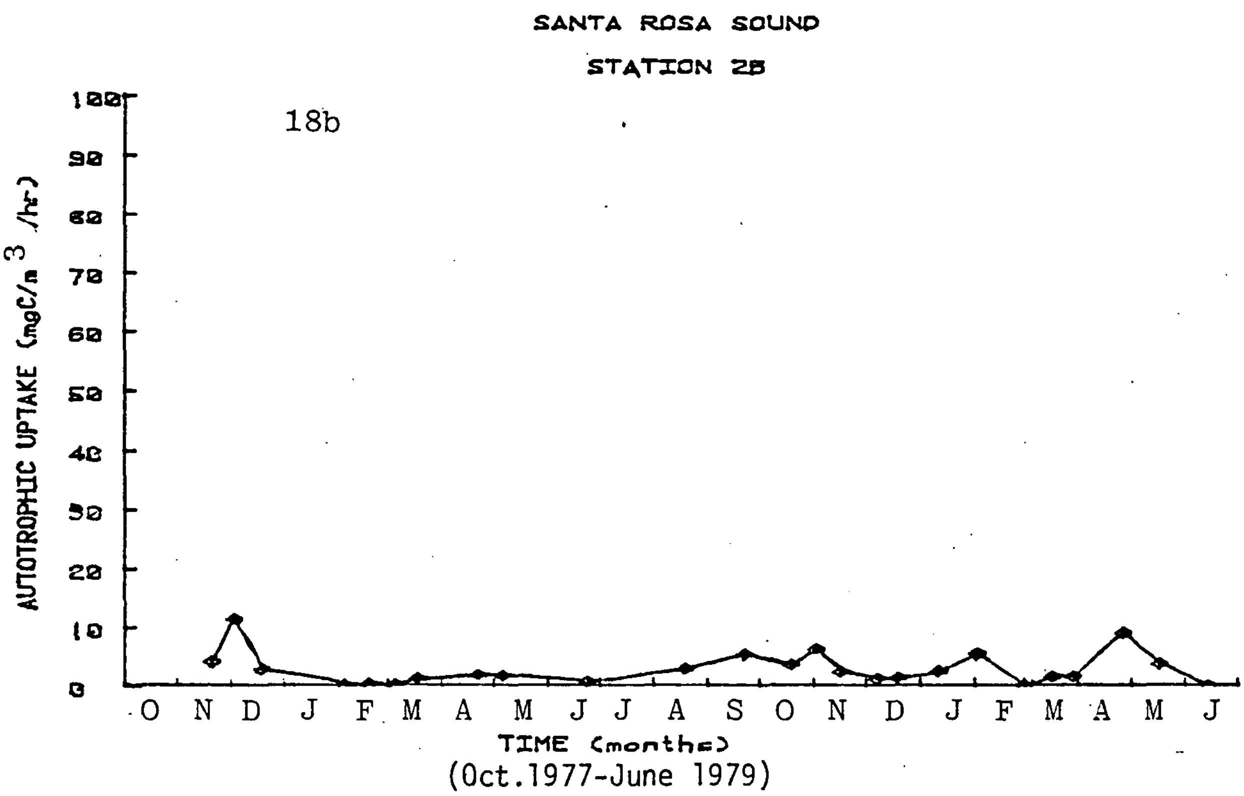
Figures 16a and 16b. Bacterial biomass at stations 2S and 2B in Santa Rosa Sound.



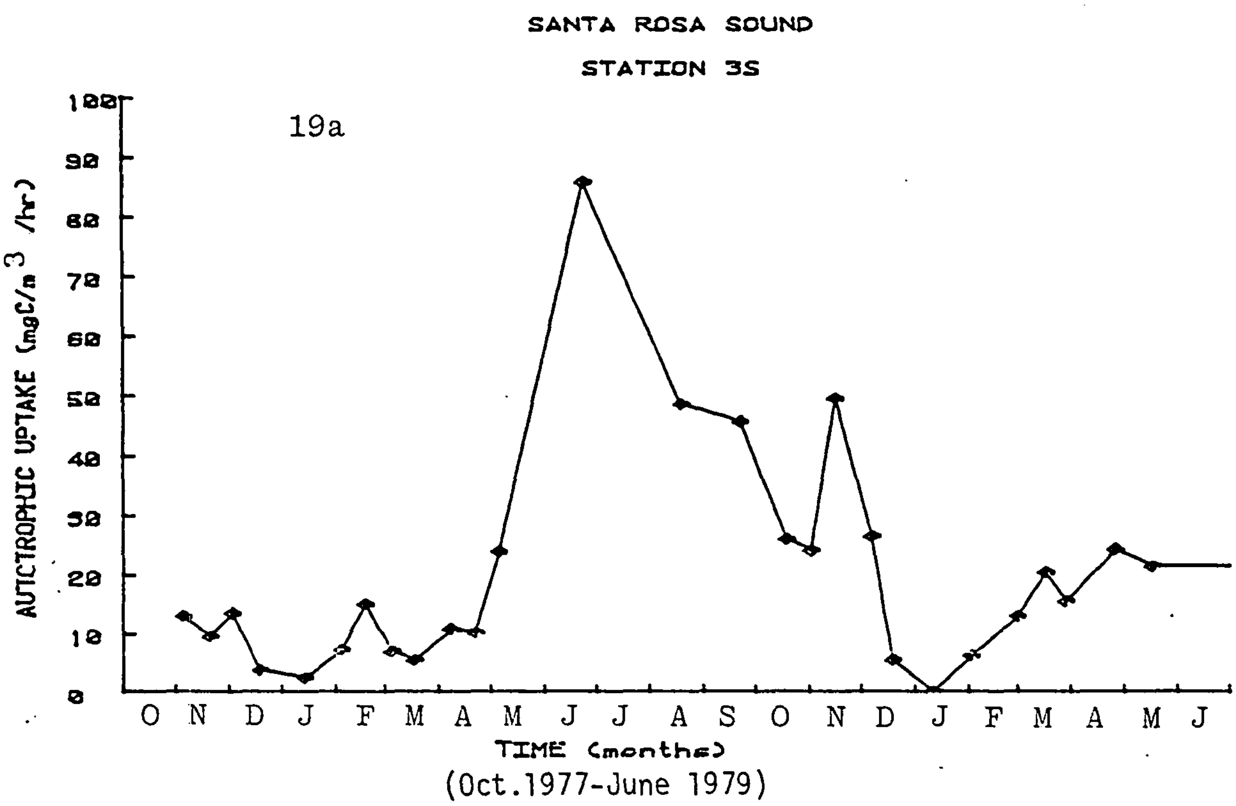


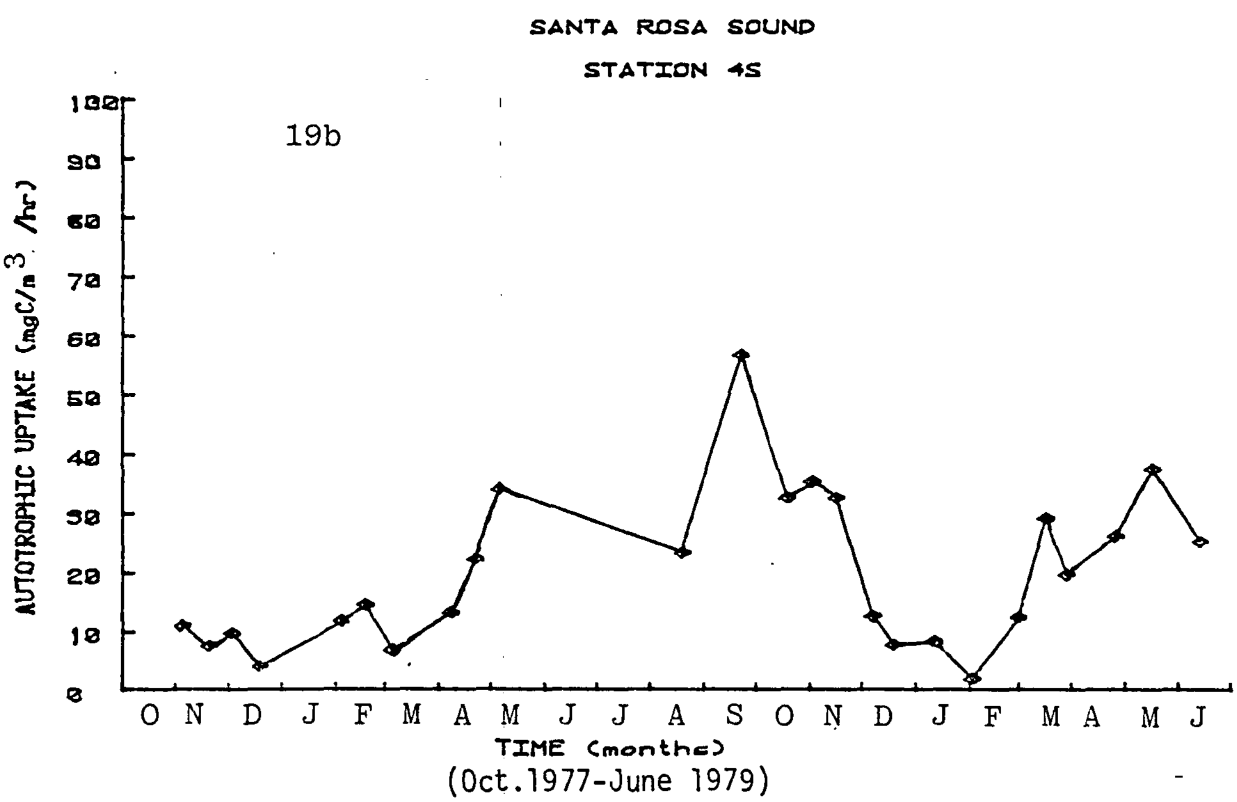
Figures 17a and 17b. Bacterial biomass at stations 4S and 4B in Santa Rosa Sound.





Figures 18a and 18b. Autotrophic uptake at stations 2S and 2B in Santa Rosa Sound.





Figures 19a and 19b. Autotrophic uptake at stations 3S and 4S in Santa Rosa Sound.

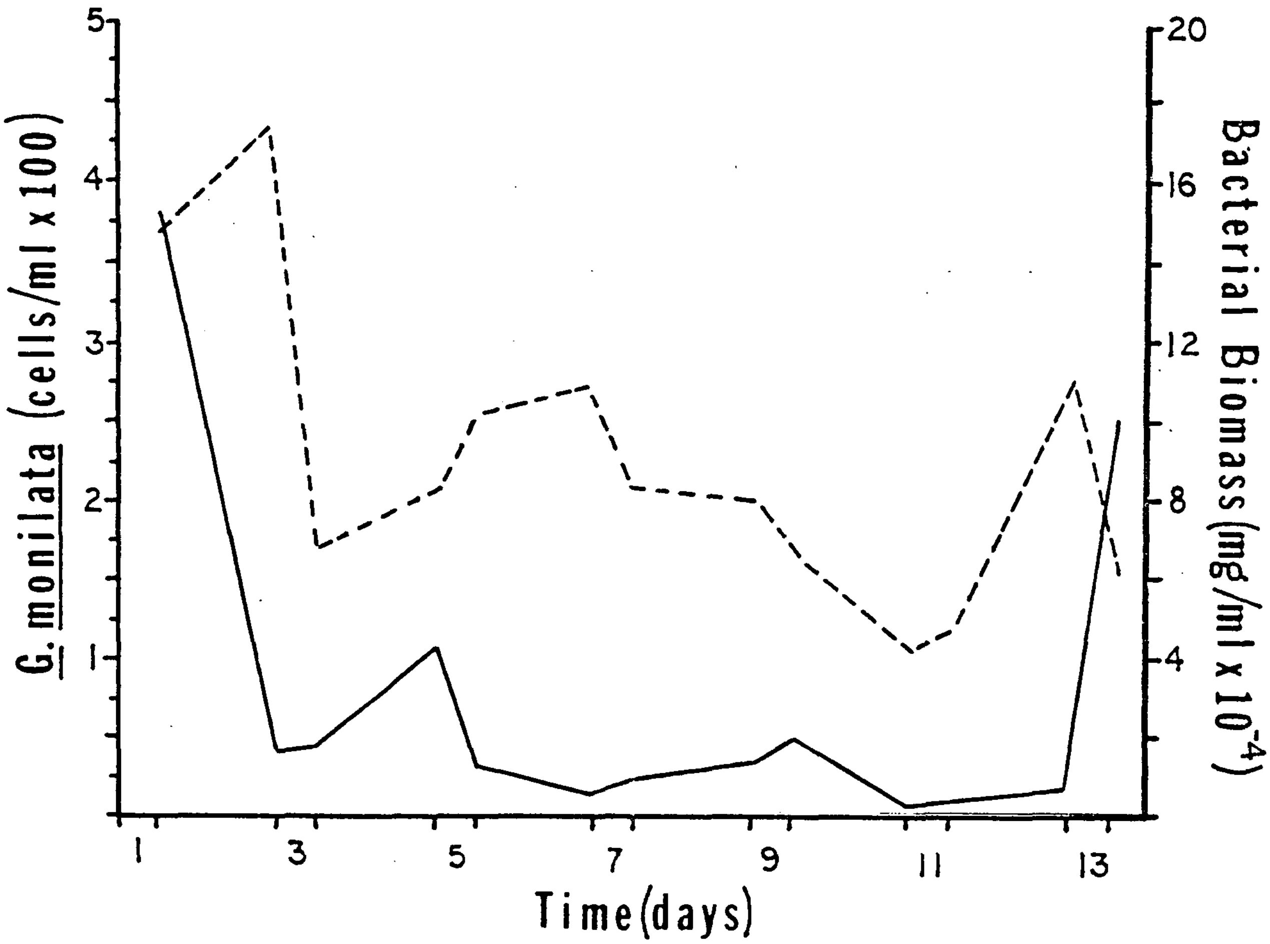


Figure 20. Numbers of Gonyaulax monilata (solid line) and bacterial biomass (dashed line) at station G1 in Santa Rosa Sound.

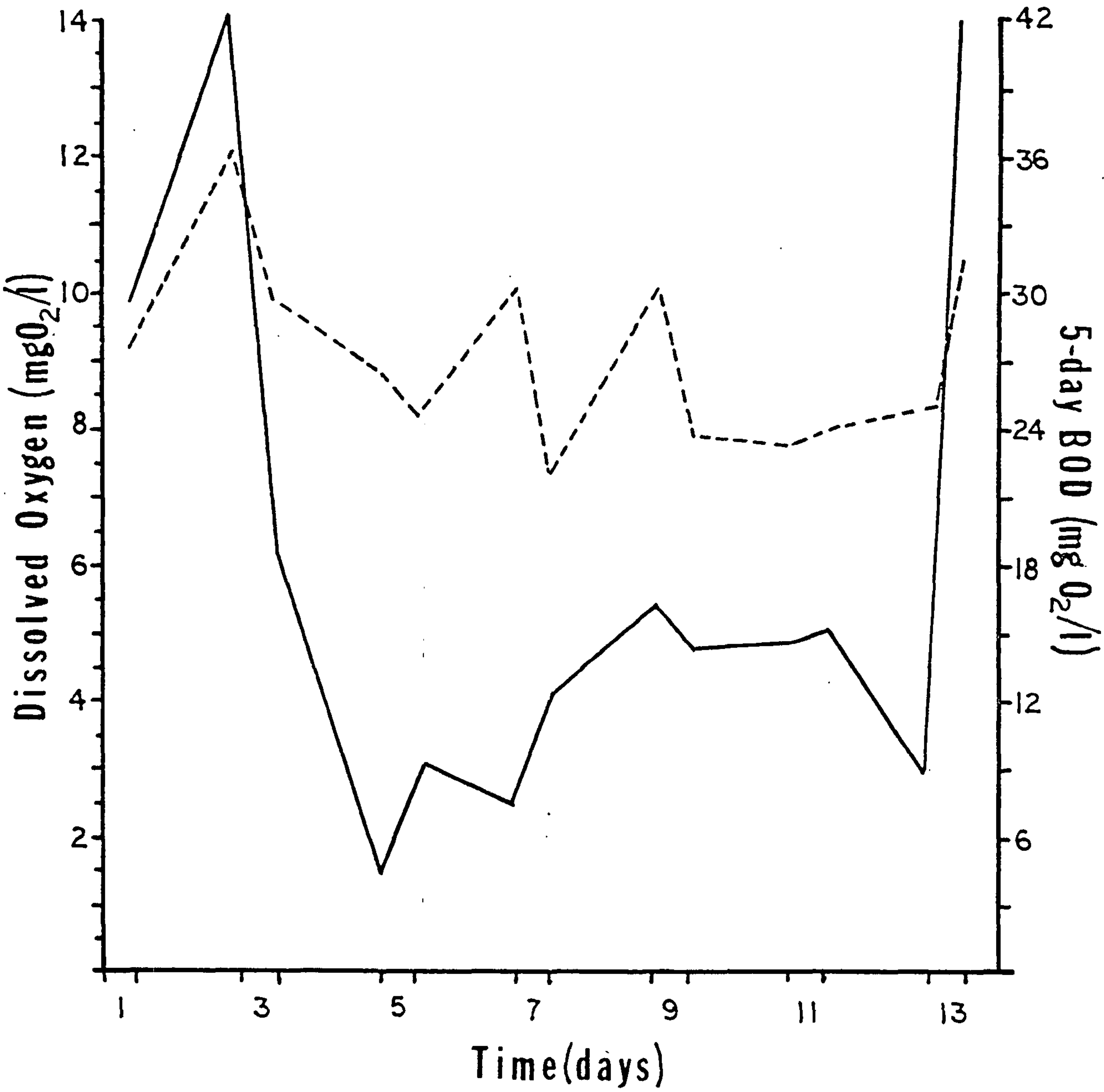


Figure 21. 5-day biochemical oxygen demand (solid line) and dissolved oxygen concentrations (dashed line) in Santa Rosa Sound.

Table 1. TIDE DATA FOR SAMPLING DATES.*

DATE	TIME	HEIGHT	DATE	TIME	HEIGHT
8 Oct. 1977	0644	1.3	20 May 1978	0903	1.2
	1633	0.7		1917	0.0
22 Oct. 1977	0644	1.1	9 June 1978	2321	0.0
	1532	0.7	10 June 1978	1252	1.3
5 Nov. 1977	0345	1.1	23 June 1978	2312	-0.1
	1417	0.5	24 June 1978	1259	1.4
19 Nov. 1977	0231	0.8	7 July 1978	2222	0.1
	1248	0.5	8 July 1978	1208	1.4
3 Dec. 1977	0147	0.9	21 July 1978	2209	0.1
	1218	0.2	22 July 1978	1218	1.4
19 Dec. 1977	0633	0.1	4 Aug. 1978	2118	0.3
	1931	0.9	5 Aug. 1978	1134	1.4
14 Jan. 1978	0106	0.5	18 Aug. 1978	2103	0.4
	1004	0.1	19 Aug. 1978	1148	1.4
4 Feb. 1978	0631	-0.6	22 Sept. 1978	0203	1.6
	2021	1.3		1323	0.4
18 Feb. 1978	0634	-0.3	18 Oct. 1978	2347	1.6
	2012	1.0	19 Oct. 1978	1039	0.2
5 Mar. 1978	0558	-0.4	1 Nov. 1978	2249	1.6
	2006	1.2	2 Nov. 1978	0925	0.0
18 Mar. 1978	0446	-0.1	15 Nov. 1978	2248	1.5
	1823	1.0	16 Nov. 1978	0939	-0.1
7 Apr. 1978	1944	0.2	7 Dec. 1978	0200	0.8
8 Apr. 1978	1103	1.0		1215	0.2
21 Apr. 1978	1835	0.2	19 Dec. 1978	0040	1.0
22 Apr. 1978	1003	1.0		1133	-0.1
5 May 1978	1936	0.1	Jan. 1979	0813	0.5
6 May 1978	1001	1.2		2148	1.1

*Source: U.S. Dept. of Commerce NOAA Tide Table for Pensacola, FL. Heights are reckoned from the datum of soundings on charts of the locality which is mean low water.

Table 1. (Continued)

DATE	TIME	HEIGHT	DATE	TIME	HEIGHT
2 Feb. 1979	0757	0.1	28 Mar. 1979	1924	0.2
	1637	0.6	29 Mar. 1979	1134	0.9
15 Feb. 1979	0046	0.6	25 Apr. 1979	1927	0.1
	0920	0.1	26 Apr. 1979	1024	1.2
1 Mar. 1979	0725	0.4	17 May 1979	0031	-0.2
	1336	0.5		1408	1.4
16 Mar. 1979	2118	0.2	13 June 1979	2321	-0.2
17 Mar. 1979	1301	0.8	14 June 1979	1300	1.5

Table 2. RESULTS OF WATER COLUMN GREASE AND OIL ANALYSIS(mg/1) IN SANTA ROSA SOUND AND LITTLE SABINE BAY.

	STATION			
DATE	3	4	Q	6
7/ 8/78	7.2	7.2	7.5	7.5
7/22/78	3.2	0.8	1.0	0.6
8/ 6/78	-*	1.3	-	-
8/19/78	-	-	-	-
9/22/78	-	-	-	-
10/19/78	-	-	-	-
11/ 2/78	0.6	1.3	1.0	-
11/16/78	2.2	2.4	1.0	9.2
12/ 7/78	-	-	-	-
12/19/78	-	-	-	-
1/11/79	-	-	-	-
2/ 2/79	-	-	-	-
2/14/79	-	-	-	-
3/ 1/79	-	-	-	-
3/17/79	-	-	-	-
3/29/79	-	-	-	-
4/26/79	-	-	-	-
5/17/79	-	-	-	-
6/14/79	-	0.6	-	-

*(dash marks indicate results below detectable limits for analysis)

Table 3: Phytoplankton Numbers at Station 2S in Santa Rosa Sound

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
MICROFLAGELLATES										
3 x 2 μ	9450	16185	13572	3820	4423	6534	7740	13994	6032	2111
5 x 3 μ	2011	1407	503	2011	402	303	402	402	503	603
7 x 5 μ	704	503	503	6		3	3	3	402	6
9 x 7 μ	201	100				3				
12 x 9 μ	201									
Chroomonas		3								
Cryptomonas	603	704	804	402	3	402	1608	3	402	
Rhodomonas	402	3		3		402	6	402	6	
Isochrysis										
Chrysochromulina	304									
Ochromonas										
Dinobryon										
Apedinella										
Calycomonas	704	3016	905	603	905	2312	1005	1508	603	
Ebria						6	6		3	
Eutreptia										
Euglena										
Heteromastix										
Pyramimonas										
Tetraselmis										
Chlamydomonas	503	3								
Chrysophyte sp.(A)		16989	9148			3			3	
Chrysophyte sp.(B)	5630									
Blue-green					4423	804	5428	603		
Anacystis					15					
Coccochloris					603					
Fila. blue-green									3	13
DIATOMS										
Amphipora										
Amphora			3				9	3		3

Table 3: Continued - Station 2S

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
MICROFLAGELLATES								
3 x 2 μ	1106	2011	3317	1910	2714	6333	4423	5831
5 x 3 μ		3	603	104	1106	2714	3	1206
7 x 5 μ	3	3	3	3	6	503	302	1206
9 x 7 μ			3	6				
12 x 9 μ				3	3			3
Chroomonas								
Cryptomonas				4		1810	503	603
Rhodomonas	6	6	3	3				
Isochrysis								
Chrysochromulina								
Ochromonas								
Dinobryon					43	27		3
Apedinella					3			
Calycomonas		3	6	304	302	6	2111	704
Ebria						25	3	
Eutreptia					6	19		
Euglena								
Heteromastix								
Pyramimonas				3		503		
Tetraselmis								
Chlamydomonas								
Chrysophyte sp.(A)	3		3				3016	
Blue-green coccoid								1608
Coccochloris						3	9	
DIATOMS								
Amphipora						3		
Amphora			3	6		6	3	9
Asterionella					44			
Auricula								
Bacteriastrum				3	16			

Table 3: Continued - Station 2S

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Asterionella										
Auricula										
Bacteriastrum									13	
Biddulphia										
Ceratulina										
Chaetoceros	6	25								
Cocconeis				3					3	3
Corethron										
Coscinodiscus				13	3	3		3	13	
Coscinosira				3		13	13		16	
C yclotella	804	10759	3421	502	402	2517	1851	305	921	411
Diploneis										
Dactyliosolen										
Epithemia										
Eucampia										
Fragilaria										
Frustulia										
Grammatophora									3	
Gyrosigma										
Hantszchia										
Leptocylindrus								6		
Licmophora										
Mastigloia										
Melosira			6		3		6		6	
Navicula sp.			9				9		6	6
Nitzschia sp.(A)		4021	3		1307	804	3317	2714	1206	
Nitzschia sp.(B)		11360			10455	5529	9148	5328	3921	402
Nitzschia sp.(C)	3		13				10		6	
Opephora										
Paralia										3
Pinnularia										
Pleurosigma										
Rhabdonema										
Rhaphoneis										

Table 3: Continued - Station 2S

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Biddulphia								
Ceratulina		22	13	94	85	6		
Chaetoceros		44	37		340	348	9	26
Cocconeis				3	3		3	
Corethron								
Coscinodiscus			3	9	3	3	6	6
Coscinosira	6		6	3			6	
Cyclotella	13	1105	1219	9	6	19	2515	2110
Diploneis								
Dactyliosolen								
Epithemia								
Eucampia			9	16	6			3
Fragilaria								
Frustulia								
Grammatophora								
Gyrosigma								
Hantszchia								
Leptocylindrus		1567				69	99	3
Licmophora								
Mastigloia			3	3				3
Melosira			22	3	3	9	3	44
Navicula sp.		9	3	3	3	9	13	9
Nitzschia sp.(A)		3	3			1508	1709	804
Nitzschia sp.(B)	703	1005	6	502		10556	6032	7640
Nitzschia sp.(C)		540	379	204	159	25	34	15
Opephora								
Paralia			3	3				
Pinnularia								
Pleurosigma								
Rhabdonema								
Rhaponeis								
Rhizosolenia		47	138	31	493	6	6	6
Rhopalodia								
Skeletonema		31			22		13	

Table 3: Continued - Station 2S

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Rhizosolenia							3			
Rhopalodia										
Skeletonema				3						
Stauroneis										
Stephanodiscus										
Striatella										
Surirella										
Synedra										
Thalassionema									6	181
Thalassiosira							3	6		
Triceratium										
Centric Diatom	3820			1910						
Achnanthes				3						
SILICOFLAGELLATE										
Dictyochia	3							19	6	
DINOFLAGELLATES										
Amphidinium										
Ceratium										
Dinophysis										
Exuviaella										
Goniaulax	3									
Gymnodinium		25			31	13	13	6		9
Gyrodinium						6				
Katodinium		3		3						
Oxytoxum									9	
Peridinium										
Phalacroma										
Prorocentrum				3	6	3	3	9	13	50
Pyrocystis									13	

Table 3: Continued - Station 2S

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Stauroneis								
Stephanodiscus								
Striatella								
Surirella								
Synedra				3				
Thalassionema			56	25	22		6	31
Thalassiosira		9				3		
Triceratium								
<u>SILICOFLAGELLATE</u>								
Dictyochia	9	6	6					
<u>DINOFLAGELLATES</u>								
Amphidinium								3
Ceratium	3	3					9	3
Dinophysis								
Exuviaella								
Goniaulax						3		
Gymnodinium		6	35	3				9
Gyrodinium								3
Katodinium								
Oxytoxum								3
Peridinium				3	6		9	
Phalacroma								
Prorocentrum	6	34	25	16	47	28	29	3
Pyrocystis								

Table 3: Continued - Station 2B

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
MICROFLAGELLATES										
3 x 2 µ	5630	9249	5630	3418	5630	6736	1005	3116	4725	1910
5 x 3 µ	1106	1206	402		201	3	201		402	503
7 x 5 µ	905	201	3		3	3	3	3		
9 x 7 µ	201				3	9				
12 x 9 µ	201									
Chroomonas		3								
Chryptomonas		1810		6	3	502	3	3	904	
Rhodomonas	503	402				3			3	
Isochrysis										
Chrysochromulina										
Ochromonas	402									
Dinobryon										
Apedinella										
Calycomonas	201	603	1608	704	6	2010	402		502	
Ebria		25		6						
Eutreptia										
Euglena										
Heteromastix										
Pyramimonas										
Tetraselmis	101								3	
Chlamydomonas	202									
Chryosphyte sp.(A)		1506	402		402					
Blue-green						704	1709		9	
Fila. Blue-green						3				
DIATOMS										
Amphipora				3			3			
Amphora	9	35	44	62	13	3	22	18	3	
Asterionella									3	
Auricula										
Bacteriastrum										

Table 3: Continued - Station 2B

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
MICROFLAGELLATES								
3 x 2 µ	6	1206	1609	2513	3820	5529	3619	7540
5 x 3 µ		403	302	1005		804	3	1307
7 x 5 µ		302	3	302	503	603	9	402
9 x 7 µ				3		3	3	6
12 x 9 µ				3			6	
Chroomonas								
Cryptomonas		402	3	6	6	1106	704	302
Rhodomonas		3	3					6
Isochrysis								
Chrysochromulina								
Ochromonas								
Dinobryon					6			
Apedinella								
Calycomonas		302		402	3	704	1910	1106
Ebria					3	6		
Eutreptia					9	3		
Euglena								
Heteromastix								
Pyramimonas				3		703	3	
Tetraselmis				3		6		
Chlamydomonas								
Chrysophyte sp.(A)	3	3					6	603
Coccochloris		6						
Fila. Blue-green		3		3				
Blue-green coccoid				1005				302
DIATOMS								
Amphipora								
Amphora	6	6	3	6	12	6	9	
Asterionella				28	82	9	3	
Auricula								

Table 3: Continued - Station 2B

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Biddulphia			3							
Ceratulina		3								
Chaetoceros									9	
Cocconeis	6	3				3	3	6		
Corethron										
Coscinodiscus	6		44	82		3	35	19	13	16
Coscinosira	3								16	41
Cyclotella	304	10556	7442	9412	3	3619	1533	452	323	9
Diploneis	3		3	6						
Dactyliosolen										
Epithemia			3				3			
Eucampia										
Fragilaria				3	3			9		
Frustulia	3					3				
Grammatophora			3	3				13		
Gyrosigma	3									
Hantszchia										
Leptocylindrus									6	
Licmophora								3		
Mastigloia		9	16	6			6	6		
Melosira				41	47	3	72	9	9	
Navicula	9	9	47	66		9	22	28	3	
Nitzschia sp.(A)	3	905			3	3	503	503	302	
Nitzschia sp.(B)		2413				1810	6	26		13773
Nitzschia sp.(C)	19	6	16	25	3		25	29	22	6
Opephora			6	3						
Paralia			35	19				9		3
Pinnularia		6					3			
Pleurosigma	3		22	19			9	9		
Rhabdonema			13					94		
Rhaphoneis			6							
Rhizosolenia		13		3			3	116		
Rhopalodia		3		3				3	3	
Skeletonema	22	3		19				94	60	

Table 3: Continued - Station 2B

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Bacteriastrum								
Biddulphia								
Ceratulina			3	603	22	3		3
Chaetoceros		32	19	53	72	82		9
Cocconeis		3			6		6	6
Corethron								
Coscinodiscus			31	13	13	9	21	
Coscinosira	9	22	6	6			6	
Cyclotella	22	310	318	805	25	16		4926
Diploneis								
Dactyliosolen							3	
Epithemia						3		
Eucampia			3	6				3
Fragilaria								
Frustulia								
Grammatophora			9	6				3
Gyrosigma								
Hantszchia								
Leptocylindrus		38				56	38	31
Licmophora								
Mastigloia			3	3		3	13	
Melosira			29	3	9	19	28	16
Navicula	3	3		9	16	6	28	19
Nitzschia sp.(A)	603		3			302	603	1810
Nitzschia sp.(B)	302	1106				5630	3116	6635
Nitzschia sp.(C)	3	503	138	599	130	6	113	34
Opephora								
Paralia		6	9	9			6	
Pinnularia			3					
Pleurosigma			6		6		9	
Rhabdonema	6						6	
Rhaponeis	6							
Rhizosolenia	9	6	104	50	63		53	22
Rhopalodia	3							

Table 3: Continued - Station 2B

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Stauroneis		6								
Stephanodiscus										
Striatella							3			
Surirella			3	6				3		
Synedra				3			3			
Thalassionema			9	60		6	22	19	3	273
Thalassiosira										
Triceratium							3			
Cymatosira	3		54	107			72	63		
Centric Diatom	1508				6					
Hemiaulus							3	3		
Ditylum								3		
SILICOFLAGELLATE										
Dictyochia		3	6					9		
DINOFLAGELLATES										
Amphidinium										
Ceratium		13								
Dinophysis			6							9
Exuviaella										
Goniaulax										
Gymnodinium		6			3			3	3	
Gyrodinium										
Katodinium										
Oxytoxum									6	
Peridinium										
Phalacroma										
Prorocentrum	41	25	3		3			9	38	198
Pyrocystis										

Table 3: Continued - Station 2B

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Skeletonema		25	63		25	3	110	
Stauroneis								
Stephanodiscus							3	
Striatella						3	6	
Surirella								
Synedra		3						
Thalassionema	22	28		50	22		31	60
Thalassiosira						6		
Triceratium			6					
Cymatosira	25	3	19	3	9		13	
Hemiaulus					3			
<u>SILICOFLAGELLATE</u>								
Dictyochia	6	6	3			3		
<u>DINOFLAGELLATES</u>								
Amphidinium							3	
Ceratium	14					3		3
Dinophysis		3						
Exuviaella								
Goniaulax								3
Gymnodinium		3	13	13	6			9
Gyrodinium								3
Katodinium								
Oxytosum								
Peridinium								3
Phalacroma								
Prorocentrum	21	195	79	26	87	65	28	9

Table 3: Continued - Station 4S

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
MICROFLAGELLATES										
3 x 2 μ	14175	10355	10656	5831	11762	11963	13270	7439	8042	7640
5 x 3 μ	1608	1407	503	503	1005	1508	603	804	402	905
7 x 5 μ	3	503	3	3	704	402	6		603	503
9 x 7 μ				3						3
12 x 9 μ		3								
Chroomonas										
Cryptomonas	1608	905	905	2513	704	2513	1407	302	402	
Rhodomonas	6					704	804	6	6	402
Isochrysis										
Chrysochromulina								3		
Ochromonas	6									
Dinobryon										
Apedinella										
Calycomonas	6	1206	4021	1508	3	5228	2011	1206	1608	
Ebria	13					3			9	
Eutreptia										
Euglena										
Heteromastix										
Pyramimonas			3	6	3	3		3		3
Tetraselmis			603			6	9	3		
Chlamydomonas										
Chrysophyte sp.(A)	3	8344	8646	402				3		
Spirulina	3			3				6		
Blue-green				4122		10254	1206	3519	804	
Anacystis				3		22		42		
Agmenellum				3		9				
DIATOMS										
Amphipora	6	6	3	19				3		
Amphora	28	44	51		19	18	19	28	3	13
Asterionella										
Auricula								3		
Bacteriastrum										

Table 3: Continued - Station 4S

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
MICROFLAGELLATES								
3 x 2 μ	4815	2412	1106	2614		2614	4725	5328
5 x 3 μ	603	402	3	804		1106	704	1005
7 x 5 μ		3	13			1206	905	703
9 x 7 μ				3		3	402	3
12 x 9 μ						3	3	3
Chroomonas								
Cryptomonas		3		4		905	402	503
Rhodomonas	3		3	3		302	3	
Isochrysis								
Chrysochromulina								
Ochromonas								
Dinobryon				19		9	6	3
Apedinella								
Calycomonas		3		503		503	3317	905
Ebria						3		
Eutreptia								
Euglena								
Heteromastix								
Pyramimonas								
Tetraselmis								
Chlamydomonas								
Chrysophyte sp.(A)	3		6				2815	402
Blue-green								3
Coccochloris								503
DIATOMS								
Amphipora				6		6		
Amphora	16	13	3			12	25	22
Asterionella						4		
Auricula								
Bacteriastrum			3					
Biddulphia								

Table 3: Continued - Station 4S

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Biddulphia										
Ceratulina									6	
Chaetoceros							9	13		
Cocconeis				3		3		3		3
Corethron										
Coscinodiscus	3			6			6			
Coscinosira								6		6
Cyclotella	1810	10961	8445	4926	2614	5429	2841	813	5127	1023
Diploneis										
Dactyliosolen										
Epitehmia										
Eucampia										
Fragilaria		3			6					
Frustulia		6								
Grammatophora		3					3			
Gyrosigma										
Hantszchia										
Leptocylindrus										
Licmophora										
Mastigloia	9	6	31	13		6	13	31		9
Melosira			6			13				
Navicula	33	9	34	37		41	3	44	16	9
Nitzschia sp.(A)	302	2513	905	6	6233	603	4122	704	804	1105
Nitzschia sp.(B)	16990	14376	4624	1608	16185	7640	10455	1307	5027	4624
Nitzschia sp.(C)	102	36	13			6	9	6	6	6
Opephora								3		
Paralia										
Pinnularia		6	3		3	3	3			3
Pleurosigma	6			3						
Rhabdonema				3						
Rhaphoneis										
Rhizosolenia		16					9	6		
Rhopalodia										
Skeletonema		3								
Stauroneis										

Table 3: Continued - Station 4S

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Ceratulina		11259		38				3
Chaetoceros						374	6	35
Cocconeis								3
Corethron								
Coscinodiscus	9	9					6	9
Coscinosira	13	6	9			9	16	
Cyclotella	629	524	515			314	3518	4222
Diploneis								
Dactyliosolen								
Epithemia								
Eucampia		9	1005	3				
Fragilaria				3				
Frustulia								
Grammatophora	3			3				
Gyrosigma								
Hantszchia								
Leptocylindrus			3	3		16	28	3
Licmophora						3		
Mastigloia	3		13			9	9	13
Melosira	16						21	36
Navicula	41	3	9			13	13	13
Nitzschia sp.(A)		301				603	905	303
Nitzschia sp.(B)		704				4323	7942	10556
Nitzschia sp.(C)	25	634	706	233		16	15	19
Opephora								
Paralia								
Pinnularia		6				6		
Pleurosigma			9				3	
Rhabdonema								
Rhaponeis								
Rhizosolenia		16	2237	20			3	
Rhopalodia			3				3	
Skeletonema			22				13	
Stauroneis								

Table 3: Continued - Station 4S

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Stephanodiscus										
Striatella										
Surirella			9							
Synedra	19	9		3	3	3				
Thalassionema		16	28	9		31	19	6	9	418
Thalassiosira		6					16	6	3	
Triceratium										
Centric Diatom	1215									
Fila. Blue-green				22		3		13	3	9
Coccochloris					503	60				
SILICOFLAGELLATE										
Dictyochia								3	6	3
DINOFLAGELLATES										
Amphidinium										
Ceratium	6	16					6			6
Dinophysis										3
Exuviaella										
Goniaulax										
Gymnodinium	13		40	47	9	211	138	38	41	9
Gyrodinium			3							
Katodinium										
Oxytoxum										
Peridinium			3							
Phalacroma										
Prorocentrum	266	73	3	32	6	9		6	3	79
Pyrocystis									3	
Pyrophacus										

Table 3: Continued - Station 4S

	11/2/78	11/16	12/7	12/17	1/11/79	3/29	4/26	5/17
Stephanodiscus								
Striatella								
Surirella								
Synedra			9					
Thalassionema	22		19				22	53
Thalassiosira								
Triceratium								
Hemiaulus			25	19				
SILICOFLAGELLATE								
Dictyochia	9	6	6					
DINOFLAGELLATES								
Amphidinium								
Ceratium	3						19	
Dinophysis		3						
Exuviaella								
Goniaulax				6				3
Gymnodinium	9	13	9	9		6		13
Gyrodinium				3				
Katodinium								
Oxytoxum								
Peridinium		3		3		3		
Phalacroma								
Prorocentrum	170	21	13	22		16	34	19
Pyrocystis								

Table 3: Continued - Station 4B

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
MICROFLAGELLATES										
3 x 2 µ	8042	15582	22619	4725	19201	12566	10254	4926	8545	4725
5 x 3 µ	1508	1005	603	402	905	1910	704	503	1005	804
7 x 5 µ	6	302		3	3	1005	3	402	402	6
9 x 7 µ	3				301					3
12 x 9 µ						3				
Chroomonas										
Cryptomonas	302	2111	34180	2010		2111	2915	1508	302	
Rhodomonas	3					1005		3	6	905
Isochrysis										
Chrysochromulina				3		3				
Ochromonas										
Dinobryon										
Apedinella										
Calycomonas	1005	1307	1809	1709		2915	2412	1106	2815	
Ebria		35	3						6	
Eutreptia										
Euglena								3		
Heteromastix										
Pyramimonas			6	6		503	302	3		
Tetraselmis			3	3						
Chlamydomonas						3				
Chrysophyte sp.(A)	3	6836	1608	6				6	3	
Spirulina		6		3				3		
Fila. Blue-green				6			9		9	6
Agmenellum						3				
Coccochloris							6		6	
DIATOMS										
Amphipora	12			3	37	28				
Amphora	37	38	31	38			6	16	16	6
Asterionella										

Table 3: Continued - Station 4B

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
MICROFLAGELLATES								
3 x 2 μ	4222	2413	2111	2011		4122	6434	7640
5 x 3 μ	503	6	302	3		204	9	1106
7 x 5 μ	6		9			302	503	1307
9 x 7 μ	402	3	3				6	
12 x 9 μ							3	6
Chroomonas								
Cryptomonas		704	302			1005	402	3
Rhodomonas	704	905	503					3
Isochrysis								
Chrysochromulina								
Ochromonas								
Dinobryon						9		
Apedinella								
Calycomonas		402		503		704	2212	804
Ebria								
Eutreptia				3				
Euglena								
Heteromastix								
Pyramimonas						3		
Tetraselmis								3
Chlamydomonas								
Chrysophyte sp.(A)	3		3			3	3619	302
Coccochloris								
Fila. Blue-green	15	3						3
Blue-green Coccoid								
Agmenellum		3						
DIATOMS								
Amphipora							25	22
Amphora	6	28	4	6		19		
Asterionella						3		
Auricula								

Table 3: Continued - Station 4B

	4/8/78	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Auricula			6			3		3		
Bacteriastrum	3									
Biddulphia										
Ceratulina									9	
Chaetoceros		13					3			
Cocconeis		6					3			
Corethron										
Coscinodiscus	9	3		6	6	25	19	6	3	9
Coscinosira							3		3	34
Cyclotella	1809	13370		5630	1005	6132	2516	2315	4835	423
Diploneis										
Dactyliosolen										
Epithemia										
Eucampia										
Fragilaria	6			6						
Frustulia	3									
Grammatophora		3		3	13				3	3
Gyrosigma										
Hantszchia						3				
Leptocyindrus										
Licmophora										
Mastigloia	16	31		13	18	13	16	31		
Melosira	19			22	28	38	19	13		
Navicula		41	22	31	31	13	9	6	13	
Nitzschia sp.(A)	6	2714	1910	905	1608		1709	704	804	804
Nitzschia sp.(B)	4624	22820	26942	4122	6233		2111	1307	5529	2011
Nitzschia sp.(C)	18	25	6	147		19	13	9		
Opephora										
Paralia								3		
Pinnularia	9		3		13	9				
Pleurosigma	12	3		3						
Rhabdonema			19		119					
Rhaphoneis										
Rhizosolenia	21	31							53	

Table 3: Continued - Station 4B

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Bacteriastrum				3				
Biddulphia								
Ceratulina		11058		223				3
Chaetoceros		3	160	283		446		9
Cocconeis								3
Corethron								
Coscinodiscus	3		3				16	3
Coscinosira	35	25	35				13	
Cyclotella	820	1121	1118	405		18	4728	4633
Diploneis								
Dactyliosolen								
Epithemia							3	
Eucampia		6	804	6				
Fraiglaria								
Frustulia								
Grammatophora	3		3					
Gyrosigma								
Hantszchia								
Leptocylindrus		9	3			3	38	
Licmophora								
Mastigloia		9	28	3			12	13
Melosira			6	13		25	47	19
Navicula	66	9	3	6			19	16
Nitzschia sp.(A)	6	402	3			3	18	905
Nitzschia sp.(B)	1709	704				4222	7238	7741
Nitzschia sp.(C)	47	730	1366	454		6	24	12
Opephora								
Paralia								
Pinnularia	3					3	3	
Pleurosigma								3
Rhabdonema	3							
Rhaponeis								
Rhizosolenia		19	1457	66			37	3
Rhopalodia								

Table 3: Continued - Station 4B

	4/8/79	4/22	5/20	6/10	6/24	7/8	7/22	8/19	9/22	10/19
Rhopalodia		3			6					
Skeletonema		3								
Stauroneis		6			26					
Stephanodiscus										
Striatella	3									
Surirella				6						
Synedra		6		9	3					
Thalassionema		6	41	22		16	25	3	16	407
Thalassiosira		25	28			9	6		16	
Triceratium										
Centric Diatom	1715									
Plaziogramma	3									
Blue-green							38905	302	503	
Cymatosira							28			
Anacystis								3		
<u>SILICOFLAGELLATE</u>										
Dictyochia									22	3
<u>DINOFLAGELLATES</u>										
Amphidinium			6			3				
Ceratium	16	16								
Dinophysis										
Exuviaella										
Goniaulax										
Gymnodinium	13	6	63	3			9	19	40	16
Gyrodinium							3			
Katodinium										
Oxytoxum								57	6	
Peridinium			3						3	
Phalacroma										
Prorocentrum	34	44	28	9			6		6	25

Table 3: Continued - Station 4B

	11/2/78	11/16	12/7	12/19	1/11/79	3/29	4/26	5/17
Skeletonema				6		13	22	
Stauroneis								
Stephanodiscus								
Striatella								
Surirella								
Synedra			3	3				
Thalassionema	19	25	41				3	56
Thalassiosira								
Triceratium								
Hemiaulus			28	9				
Guindardia							6	
SILICOFLAGELLATE								
Dictyochia	22	9	3					
DINOFLAGELLATES								
Amphidinium		3	3					
Ceratium							9	
Dinophysis								
Exuviaella								
Goniaulax								
Gymnodinium	6	38	13	6		3		6
Gyrodinium							3	3
Katodinium								
Oxytoxum								
Peridinium	3	3	13					
Phalacroma								
Prorocentrum	44	41	31	54			66	19
Pyrocystis								

Appendix I. Data from red-tide study conducted 8/15-8/27/79. (AM samples collected at 11:00 AM; PM samples collected at 11:00 PM)

Station 1: From Sound waters near Ft. Pickens entrance gate.

Parameter	Sample day and time 1 AM	1 PM	3 AM	3 PM	5 AM	5 PM	7 AM	7 PM	9 AM	9 PM	11 AM	11 PM	13 AM	13 PM
Temperature(^{o}C)	-	28.5	30.5	28.6	30.0	29.2	29.0	29.7	29.1	29.0	28.2	28.0	27.5	27.8
Salinity (ppt)	-	16.0	16.0	14.8	15.3	14.0	15.1	18.0	15.5	15.7	19.2	-	14.9	14.0
D.O. (ppm)	-	9.2	12.1	9.8	8.8	8.2	10.2	7.4	10.3	8.2	8.0	8.2	8.5	10.5
pH	-	8.8	8.5	8.3	8.5	8.3	8.6	8.4	7.9	8.4	8.3	8.1	8.3	8.6
B.O.D.(mg/1/5 d)	-	29.8	44.5	18.7	4.5	9.3	7.5	12.7	16.5	14.7	14.9	15.4	9.0	42.8
Organic C (ppm)	-	6.7	4.5	2.7	4.3	4.5	5.6	5.5	4.2	4.8	5.2	5.1	10.1	3.9
NO_3-N (ppm)	-	.008	.011	.008	0.0	.001	.003	.003	.041	0.0	0.0	0.0	0.0	0.0
PO_4-P (ppb)	-	0.0	0.0	0.0	0.0	0.0	2.8	0.0	2.8	4.2	2.0	1.3	9.2	5.3
Bacterial biomass (mg/mlX10^{-4})	-	14.7	17.6	7.2	8.6	10.3	11.2	8.6	8.2	7.2	4.7	5.1	11.4	6.5
Gonyaulax monilata (cells/ml)	-	384	42	48	109	26	7	19	30	58	1	7	14	240

Appendix I. (continued)

Station 2: Gulf Breeze boat ramp at 3-mile bridge.

Parameter	Sample day and time 1 AM	1 PM	3 AM	3 PM	5 AM	5 PM	7 AM	7 PM	9 AM	9 PM	11 AM	11 PM	13 AM	13 PM
Temperature(^{o}C)	30.1	30.2	29.9	29.2	29.0	29.0	29.3	29.8	29.0	29.5	28.3	28.8	28.0	28.0
Salinity (ppt)	13.2	12.3	14.0	10.8	12.8	16.8	12.3	14.0	12.2	13.5	14.8	17.0	14.8	14.2
D.O. (ppm)	10.6	10.5	9.4	9.0	10.0	8.2	8.2	7.9	8.3	8.5	7.2	6.6	6.5	8.6
pH	7.5	8.9	8.2	7.7	7.7	8.3	7.5	8.1	7.3	8.3	8.3	7.9	8.0	8.3
B.O.D. (mg/1/5d)	9.5	35.7	14.5	16.9	31.3	6.7	11.7	12.3	24.7	11.0	19.0	20.5	13.0	31.8
Organic C (ppm)	5.8	6.5	4.7	3.4	5.4	4.5	5.5	4.8	4.6	10.8	6.5	14.1	6.8	8.0
NO_3-N (ppm)	.008	.014	.014	.011	0.0	.020	-	.070	.026	0.0	0.0	.005	0.0	0.0
PO_4-P (ppb)	0.0	0.0	0.0	0.0	0.0	0.0	5.5	0.0	16.7	1.2	2.0	6.2	4.8	1.2
Bacterial biomass (mg/ml X 10^{-4})	16.4	15.0	12.4	15.8	9.8	7.3	8.9	6.6	7.3	8.4	8.1	7.8	9.8	8.7
Gonyaulax monilata (cells/ml)	15	490	89	40	27	7	26	44	237	24	8	1	8	26

Appendix I. (continued)

Station 3: EPA intake dock.

Parameter	Sample time and day 1 AM	1 PM	3 AM	3 PM	5 AM	5 PM	7 AM	7 PM	9 AM	9 PM	11 AM	11 PM	13 AM	13 PM
Temperature(^{o}C)	29.1	30.0	30.0	29.9	29.4	29.8	30.0	29.9	29.0	29.8	28.8	27.5	28.0	28.3
Salinity (ppt)	18.1	13.7	17.0	17.1	17.5	19.5	14.5	17.8	17.6	17.0	18.7	25.0	18.0	15.9
D.O. (ppm)	9.8	12.0	11.6	7.0	8.1	7.8	10.4	7.2	8.0	8.0	7.3	8.2	6.8	9.4
pH	8.0	8.5	8.2	8.1	8.2	8.1	8.1	8.3	7.8	8.2	8.4	8.0	8.3	8.6
B.O.D.(mg/1/5d)	12.7	28.7	26.2	10.6	21.3	8.0	10.3	14.2	17.7	11.8	16.5	14.9	10.7	15.6
Organic C (ppm)	4.3	5.6	3.5	5.8	7.7	6.9	4.6	4.2	6.3	8.3	7.5	6.6	8.9	4.8
NO_3-N (ppm)	.090	.020	.011	.011	.003	.014	-	.031	0.0	0.0	0.0	.010	0.0	0.0
PO_4-P (ppb)	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.0	3.0	2.3	20.0	10.7	4.0	0.3
Bacterial biomass (mg/ml X 10^{-4})	10.0	16.2	7.0	5.3	9.6	9.7	7.4	7.4	4.5	7.6	4.2	6.1	8.7	6.6
Gonyaulax monilata (cells/ml)	69	306	157	94	34	40	58	21	72	23	27	1	20	15

Appendix I. (continued)

Station 4: Unfiltered intake water from EPA wet lab.

Parameter	Sample day and time 1 AM	1 PM	3 AM	3 PM	5 AM	5 PM	7 AM	7 PM	9 AM	9 PM	11 AM	11 PM	13 AM	13 PM
Temperature(^oC)	29.0	29.7	29.1	29.3	29.0	29.8	29.0	29.5	29.3	29.4	29.5	28.8	28.3	28.4
Salinity (ppt)	21.2	21.0	24.0	18.0	25.0	26.1	19.5	22.3	22.5	21.9	20.9	22.5	18.9	17.5
D.O. (ppm)	5.5	7.2	5.0	7.5	5.0	5.2	5.6	4.7	4.7	4.3	5.6	8.0	5.9	8.6
pH	7.9	8.4	7.5	8.1	7.9	8.1	8.0	8.1	7.4	8.2	8.3	8.2	8.1	8.5
B.O.D.(mg/1/5d)	13.8	25.8	28.1	24.3	34.1	16.7	13.9	17.1	11.9	15.5	19.4	17.7	13.0	14.3
Organic C (ppm)	7.1	6.6	5.9	4.5	6.1	6.1	4.6	6.1	4.9	6.8	5.4	5.4	6.9	9.1
NO_3-N (ppm)	0.0	.020	.011	.008	.003	.006	-	.014	0.0	0.0	0.0	0.0	0.0	0.0
PO_4-P (ppb)	5.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	3.0	2.0	3.5	5.3	1.2
Bacterial biomass (mg/ml X 10^{-4})	4.1	11.4	4.5	5.7	4.9	6.7	5.5	3.5	4.6	3.5	5.4	5.3	8.1	5.2
Gonyaulax monilata (cells/ml)	13	214	109	27	38	92	60	404	27	382	71	4	14	8

Appendix I. (continued)

Station 5: From Sound behind last convenience store on beach road heading toward Navarre.

Parameter	Sample day and time 1 AM	1 PM	3 AM	3 PM	5 AM	5 PM	7 AM	7 PM	9 AM	9 PM	11 AM	11 PM	13 AM	13 PM
Temperature(^{o}C)	29.8	28.4	31.0	28.2	30.3	28.3	30.3	29.0	29.8	28.7	29.0	26.8	27.9	28.0
Salinity (ppt)	14.1	16.2	17.5	18.7	15.3	16.0	17.0	17.4	18.3	17.1	18.0	-	17.8	17.7
D.O. (ppm)	9.9	8.3	12.2	7.8	9.0	7.4	9.6	6.4	9.0	7.1	8.7	9.0	7.5	8.0
pH	8.6	8.6	8.1	8.0	8.5	8.3	8.4	8.4	8.0	8.2	8.4	8.1	8.0	8.5
B.O.D.(mg/1/5d)	11.6	14.9	22.5	19.7	34.7	10.7	10.9	10.9	11.1	13.5	14.1	18.2	11.3	14.9
Organic C (ppm)	3.3	6.0	3.0	4.1	4.3	7.0	7.7	6.7	5.2	9.9	8.1	4.2	12.5	3.6
NO_3-N (ppm)	.011	.033	0.0	.008	.017	.011	-	.031	0.0	0.0	0.0	0.0	0.0	0.0
PO_4-P (ppb)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	2.5	2.0	3.7	3.3	0.3
Bacterial biomass (mg/ml X 10^{-4})	14.0	20.0	10.4	7.5	9.8	10.9	13.1	7.6	10.3	7.2	13.4	8.7	7.9	7.0
Gonyaulax monilata (cells/ml)	43	7	2	2	148	0	8	16	0	16	1	21	2	0

Appendix IIa. Diel study (12/14-12/15/78)

	Station 2S				Station 2M			
	Time				Time			
Parameter	1500	2100	0300	0900	1500	2100	0300	0900
Temperature(°C)	12.0	11.2	10.7	10.8	11.0	9.7	9.8	10.1
Salinity (ppt)	5.8	7.2	10.5	12.1	8.9	18.5	16.0	16.8
D.O. (ppm)	12.8	13.3	12.6	11.8	13.2	12.4	12.3	11.7
pH	7.6	7.9	-	7.8	7.9	8.0	-	7.7
B.O.D.(mg/1/5 d)	1.2	0.7	3.1	11.0	5.6	0.0	3.1	11.0
Poly-PO_4 (ppb)	0.0	7.4	2.3	8.1	0.1	7.5	3.9	9.4
PO_4-P (ppb)	4.2	0.0	0.0	0.8	1.8	4.2	0.3	2.3
NH_3-N (ppb)	0.0	0.0	0.0	1.3	36.2	0.0	0.0	0.0
NO_3-N (ppm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Station 2B				Station 4S			
	Time				Time			
Parameter	1500	2100	0300	0900	1500	2100	0300	0900
Temperature(°C)	11.2	11.2	11.3	11.3	14.0	12.2	11.7	12.2
Salinity (ppt)	25.1	31.2	24.0	28.0	11.5	10.4	11.0	12.7
D.O. (ppm)	9.6	8.8	9.0	8.5	12.6	11.8	11.6	10.8
pH	8.0	8.1	-	7.8	8.0	7.8	-	7.7
B.O.D.(mg/1/5 d)	6.8	0.7	0.7	10.0	4.4	2.0	0.7	8.3
Poly-PO_4 (ppb)	6.7	0.0	1.9	3.9	0.4	0.0	0.0	4.7
PO_4-P (ppb)	2.2	5.5	0.0	0.0	0.0	0.0	0.7	0.0
NH_3-N (ppb)	0.0	15.1	0.0	0.0	0.0	46.7	0.0	0.0
NO_3-N (ppm)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

	Station 4B			
	Time			
Parameter	1500	2100	0300	0900
Temperature(°C)	9.2	11.3	9.2	9.2
Salinity (ppt)	16.2	16.2	15.8	17.8
D.O. (ppm)	13.0	12.2	12.3	11.8
pH	8.0	8.1	-	7.8
B.O.D.(mg/1/5 d)	9.2	3.4	4.1	9.7
Poly-PO_4 (ppb)	0.0	-	0.0	11.2
PO_4-P (ppb)	0.0	-	0.0	0.0
NH_3-N (ppb)	0.0	-	0.0	0.0
NO_3-N (ppm)	0.0	-	0.0	0.0

Appendix IIb. Diel study (6/13-6/14/79)

Parameter	Station 2S 1500	2100	0300	0900	Station 2M 1500	2100	0300	0900
Temperature (^oC)	26.3	25.7	25.2	26.0	26.0	25.7	25.2	26.0
Salinity (ppt)	22.7	25.3	22.0	20.8	23.2	26.1	22.2	22.7
D.O. (ppm)	8.4	8.0	6.8	7.4	8.1	7.8	6.8	7.0
pH	-	8.5	8.5	8.4	-	8.5	8.5	8.4
B.O.D. (mg/1/5 d)	0.9	1.1	3.9	0.3	0.0	2.0	0.0	0.0
Poly-PO_4 (ppb)	0.0	0.0	9.3	2.6	1.9	1.5	3.7	22.2
PO_4-P (ppb)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH_3-N (ppb)	92.9	52.9	2.4	163.5	25.9	23.5	56.5	63.5
NO_3-N (ppm)	0.0	0.0	0.0	.012	0.0	0.0	0.0	.025

Parameter	Station 2B 1500	2100	0300	0900	Station 4S 1500	2100	0300	0900
Temperature (^oC)	25.3	25.3	24.8	26.1	26.0	25.2	24.3	24.9
Salinity (ppt)	27.8	24.6	24.3	25.8	23.5	21.0	20.3	20.6
D.O. (ppm)	5.8	5.5	4.6	4.8	8.2	8.3	7.8	7.6
pH	8.4	8.4	8.4	8.4	8.5	8.3	7.8	7.6
B.O.D. (mg/1/5 d)	6.3	7.1	3.3	0.6	0.9	0.9	3.6	1.7
Poly-PO_4 (ppb)	4.1	4.4	11.1	0.0	0.0	0.0	7.4	0.0
PO_4-P (ppb)	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
NH_3-N (ppb)	87.1	43.5	35.3	85.9	169.4	0.0	108.2	52.9
NO_3-N (ppm)	0.0	0.0	0.0	.035	0.0	0.0	0.0	.160

Parameter	Station 4B 1500	2100	0300	0900
Temperature (^oC)	25.1	24.7	24.3	25.5
Salinity (ppt)	23.9	21.7	20.5	21.9
D.O. (ppm)	7.9	7.5	7.8	6.4
pH	8.5	8.5	8.5	8.4
B.O.D. (mg/1/5 d)	5.1	1.1	0.3	2.0
Poly-PO_4 (ppb)	0.0	0.0	7.4	0.0
PO_4-P (ppb)	0.0	0.0	0.0	0.0
NH_3-N (ppb)	60.0	15.3	81.2	9.4
NO_3-N (ppm)	0.0	0.0	0.0	0.0