WATER-COLUMN AND BENTHIC INVERTEBRATE AND PLANT ASSOCIATIONS AS AFFECTED BY THE PHYSICO-CHEMICAL ASPECTS IN A MESOTROPHIC BAYOU ESTUARY, PENSACOLA, FLORIDA

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ABSTRACT

Water column samples were collected every two weeks over a one-year period from three stations in mesotrophic Bayou Texar, Pensacola, Florida. The samples were analyzed for $-NO_3$, $-NH_3$, $-PO_4$, and total organic carbon against a background of physical parameters. Phytoplankton and zooplankton populations present during the study period were identified and enumerated. Benthic core samples were collected to assess the macroinvertebrate populations; however, analysis indicated a paucity of organisms in general. Data was subjected to appropriate statistical analysis to indicate possible relationships among aspects studied. Negative correlations appeared between salinity and nitrates, between ammonia and dissolved oxygen (at some stations), between *Brachionus plicatilus* and dissolved oxygen, and between Cryptophytes and dissolved oxygen. Positive correlations were indicated between total organic carbon and ammonia, between *Brachionus* and Cryptophytes, and between *Brachionus* and *Oithona colcarva*.

INTRODUCTION

Years of abuse and degradation have severely damaged the estuarine waters of Northwest Florida. As a result, many areas have been closed to the public, while others have suffered as the result of fish kills. Innumerable factors contributing to this lowering of water quality have so altered the natural energy flow of these systems that established procedures for recovery, which usually attack the superficial symptoms, now often prove ineffective. Recovery of these systems therefore depends upon developing an understanding of their altered energy flow. Such an understanding requires first a knowledge of pertinent physico-chemical relationships of the system in question followed by an investigation of its trophic dynamics. From this base, an elucidation of the biotic-abiotic interactions can be made and an energy flow pattern thereby determined.

Over the past four years, the principal investigator and his associates have studied nutrient-productivity relationships in three Northwest Florida estuaries with major emphasis on mesotrophic Bayou Texar, Pensacola, where investigation has progressed steadily toward a comprehensive profile of the trophic status of the system (Hannah, Simmons, and Moshiri, 1973; Moshiri _et al_, 1974). As knowledge of the system has grown, it has become possible to incorporate the sufficiently explored parameters into a monitoring regimen while at the same time gathering detailed information on new parameters. Thus, from preliminary investigations of inorganic nutrient inputs, the regimen has expanded to assess inorganic and organic nutrient flow, producer trophic dynamics, and heterotrophic uptake of dissolved carbohydrates by bacteria and algae.

The current project was proposed to investigate the consumer trophic levels in relation to regularly monitored parameters (nutrient status, primary production, and quantitative and qualitative primary producer distribution). The intent was, therefore, to assess the effects of water quality of degraded systems such as Bayou Texar, on the producer-consumer food webs--a natural and final phase to the studies of these waters. The enthusiastic public response, coupled with the wealth of background information, the extensive monitoring regimen now established, and the logic of conducting this final phase, made Bayou Texar ideal for the proposed study.

Generally, the approach taken was in three segments: primary producers, decomposer-transformers, and consumers. The first two levels constitute the autotrophic and heterotrophic producers of the system respectively. The recognition of decomposer-transformers as producers is important due to the enormous amount of substrate available to this level (Kormondy, 1969; Odum, 1971). In nutrified systems such as Bayou Texar, where high concentrations of dissolved and particular organics exist, heterotrophic uptake by decomposer-transformers must be assessed. The third level, the consumers, is by definition, based upon the previous levels and is therefore the logical conclusion of any trophic investigation. In addition, the possible uptake of dissolved organics by invertebrates (Stephens and Schinske, 1961) makes the investigation of these "consumers" necessary to explain satisfactorily the energy flow at the producer level.

The work on heterotrophic uptake was reported elsewhere (Moshiri, et al, 1976; Moshiri, Crumpton, and Aumen, Manuscript). The study reported here was aimed at the performance of consumer studies necessary for a trophic profile of the Bayou Texar system, and the possible effects of pollutants on the biotic community.

OBJECTIVES

The objectives of the proposed study were to gather quantitative and qualitative information on water column and benthic populations as related to the nutrient status of the system.

Tc satisfactorily obtain and treat this data, it was necessary to:

1. Quantitatively and qualitatively investigate the flora and fauna of Bayou Texar water column and benthic regions.
2. Continue monitoring nutrients in conjunction with (1).
3. Monitor total organics in the water column with relation to possible uptake by producers and consumers.
4. Correlate past and present data in order to determine the relationships of physico-chemical parameters to the status of producer and consumer populations.

METHODOLOGY

Three sites were selected for the collection of water and sediment samples (Fig. 1). Water column samples were taken once every two weeks at the surface and the sediment-water interface. All samples were analyzed to determine the quantitave and qualitative distribution of flora and invertebrate fauna.

Most of the collection techniques for the quantification of planktic samples are useful only when such organisms are found in high concentrations, as exemplified by phytoplankton populations. When higher trophic levels are sampled, present devices are unsatisfactory. In fact, problems of avoidance (Lloyd and Ghelardi, 1964; McGowan and Fraundorf, 1966), and escape (Saville, 1958) are of such magnitude that available devices were believed to be inadequate for the purpose of the present study. It has been indicated that techniques employing the large capacity pumps are most nearly quantitative (Aron, 1958). Due to these considerations, a modified pumping device was developed which removes a known volume of water from a specific stratum and passes it through a standard 64 micron mesh size plankton net. Although the device does not solve all the problems associated with water column sampling, for zooplankton analysis it proved satisfactory in the shallow, protected waters of Bayou Texar.

The 30 cm depth chosen for the present work has been shown to be sufficient for the collection of the majority of benthic macroinvertebrates (Wells, 1971; Rosenberg, 1974). Unfortunately, benthic sampling presents problems comparable to those stated for planktic forms since many of the readily available devices are not sufficiently quantitative (Wells, 1971). It is generally believed that coring techniques most nearly meet the requirements for adequate quantitative sampling.

Benthic macrofauna, when present, were retained and separated using standard sieves and flotation techniques (Birkett, 1957). Identification was confined to those organisms retained by a 1.0 mm. mesh sieve, as described by Bloom, Simon, and Hunter (1972), and Rosenberg (1974). Reish (1959) has shown that this mesh size retains nearly 95% of the total biomass.

Water samples for phytoplankton determinations were taken from each station and immediately fixed with neutralized 5% glutaraldehyde. Zooplankton samples were also collected at each station by filtering 25 liters of water through a plankton net and immediately fixing the sample with neutralized glutaraldehyde. Both phytoplankton and zooplankton were later identified and enumerated using settling chamber techniques in conjunction with whole mount microscopy. Samples, once identified and enumerated, were subjected to appropriate statistics. The data were computerized and correlated with already computerized physico-chemical and primary productivity data collected during the past four years.

All experimentation was conducted against a background of physico-chemical data including pH, salinity, temperature, dissolved oxygen, and inorganic nitrogen, phosphorus and carbon.

RESULTS & DISCUSSION

Benthic Invertebrates:

In the first survey, a set of five cores was taken from each station shown in figure 1. Subsequent examination of these samples suggested that no significant numbers of macroinvertebrates occur at these stations. In order to determine if a spatial distribution of macroinvertebrates exists according to depth from shore to the center of the bayou, a transect consisting of sixty cores was established at station 4 (Fig. 1). Again, examination indicated a paucity of macroinvertebrates in the substrate, and further benthic sampling was considered inappropriate.

It should be noted that the design of the coring device employed in this study did not permit collection of cores from sandy substrates as exist in the nearshore areas within an approximate distance of 10 meters from shore in Bayou Texar. It is possible that colonization by macroinvertebrates occurs only in this sandy habitat and not in the organic-rich ooze of the three mid-bayou sites as originally suggested in our proposal.

The consistent presence of polychaete larvae in the water column suggests that these larvae are transported by tidal inflow from Escambia Bay, or are the result of colonization within the bayou. A possible explanation for the observed paucity of adult polychaetes, and benthic macroinvertebrates in general, lies in the inherent nature of the benthic substrates of Bayou Texar. These substrates are characterized by a graded suspension of particles and a subsequent absence of a sharply delineated bottom. This extended water column/substrate interface, which is probably related to turbulent mixing by tidal flow (Rhoads, 1974), could present an effective barrier to inhabitation by macroinvertebrates. It has also been suggested that in estuaries, the alternate exposure of the bottom to fresh and salt water is a major factor responsible for the apparent absence of benthic flora and fauna (Campbell, 1973).

Phytoplankton:

Phytoplankton in Bayou Texar were sampled once every two weeks from November, 1976 through September, 1977. Both cell numbers and sizes were recorded to determine the total volume per milliliter for each genus enumerated. Volumes were converted to carbon values using Strathman's (1967) conversion equations.

The phytoplankton components were identified to genus and categorized into five major groups. These include dinoflagellates, diatoms, cryptophytes, chlorophytes, and microflagellates (Figs. 2-6). One chrysophyte genus, (Calycomonas), was present throughout the year; however, carbon values for this genus were insignificant (Fig. 7). The dinoflagellates were prodominant in biomass all year except at the lower stations in the spring, at which point in time they were succeeded by diatoms and certain genera of chlorophytes (Figs. 2-6). Following the spring bloom of diatoms and green algae, a major increase in dinoflagellate biomass occurred lasting into the early fall months (Figs. 2-6), but the total carbon values for this group were insignificant in comparison to the vlues for the dinoflagellates. The microflagellates were not found in appreciable volumes during any period of the year (Figs. 2-6). Diatoms and chlorophytes were found in greater numbers and volumes in the spring (Figs. 2-6), due primarily to the blooms of two genera. These included the diatom *Chaetoceros* sp. (Fig. 8) and an unidentified (due to the actions of the fixative) green alga (Fig. 9).

Zooplankton:

Although zooplankton diversity was found to be low throughout the sampling period, seasonally, numbers and biomass of individual species were very high. This low diversity/high biomass characteristic has been reported elsewhere and is characteristic of many estuaries (Darnell, 1961). The most frequently occurring groups of zooplankton in the bayou were copepods (adults and nauplii), rotifers, polychaetes (larvae), and a composite group of miscellaneous zooplankton (tintinnids, infrequent rotifer species, and barnacle nauplii) which, at times, was important in terms of numbers.

The principal grazers in the zooplankton population were *Acartia tonsa* (Dana), *Oithona colcarva* (Bowman), *Brachionus plicatilus*, and *Synchaeta* sp., which occurred throughout the study in rather high numbers. *A. tonsa*, the consistently dominant copepod, showed peaks in the early spring and late summer (Fig. 10). *O. colcarva* occurred somewhat less frequently, but in the late summer did show a peak that exceeded that of *A. tonsa* at some of the stations (Fig. 11). The rotifers, *Synchaeta* sp. and *B. plicatilus*, were found to be almost totally asympatric. *Synchaeta*, which feeds largely on living algae (Pejler, 1957) was present throughout the winter and spring and declined at the onset of summer (Fig. 12). This abundance early in the year could correspond to the rising numbers of algae in the spring. By early summer *Synchaeta* had totally disappeared from all stations and *B. plicatilus*, a detritivore (Pejler, 1957), was present in increasing numbers. *B. plicatilus* peaked in the late summer when organics, in the form of detritus, were high, and was itself beginning to decline by late August (Fig. 13).

Although no adult polychaetes were found during the regular sampling regimen, polychaete larvae were found to be consistently present in the bayou throughout the year (Fig. 14). These larvae were present at all stations in low but consistent numbers.

The final category of zooplankton found in Bayou Texar was the miscellaneous group. This category was clearly dominated by tintinnids, which showed an uncharacteristic high degree of diversity and low species numbers for Bayou Texar, with ten species occurring. The two dominant species, Tintinnopsis turbo and Favella sp., were the major constituents of an extreme peak at all bottom stations in the late summer (Fig. 15).

CONCLUSIONS

To determine whether or not any correlations exist between nutrient, phytoplankton, and zooplankton data gathered throughout the study period in Bayou Texar, a test was conducted using a Statistical Analysis System (SAS) program developed by Barr, Goodnight, Sall, and Hellwig (1976). A list of the significant correlation coefficients is given in Table 1.

A notable negative correlation is exhibited between salinity and nitrates at all stations, while ammonia concentrations were negatively correlated with dissolved oxygen at all three bottom stations. This is presumably due to the utilization of oxygen by decomposers in the decomposition of organics releasing ammonia. Total carbon values also correlated closely with those of ammonia, suggesting that low dissolved oxygen concentrations and high total carbon values may be due to high bacterial numbers. As an inverse relationship appears to exist between Cryptophytes and nitrate concentrations at bottom stations, the similar negative correlation between salinity and nitrates mentioned earlier may indicate a strong dependence of the cryptophytes upon salinity-nitrate interactions.

A correlation between *Brachionus* and *Oithona* and *Brachionus* and *Cryptophytes* suggest the possibility that both of these filter-feeding zooplanktons utilize these phytoplankters as food sources. Although Cryptophytes displayed low biomass, their rapid turnover rate and high productivity render them favorable as an excellent food source for a substantial population of grazers. The negative correlations between both *Brachionus* and *Cryptophytes*, and *Brachionus* and dissolved oxygen, strengthen the hypothesis suggested above.

APPENDIX

Table 1 Correlation Coefficients

Top no. in each box - correlation coefficient

Bottom no. in each box - significance probability

CRYPTOPHYTES						
	2S	2B	4S	4B	6S	6B
<u>Oithona</u> <u>colcarva</u>	0.32420 0.1516	0.75171 0.0001	0.49044 0.0240	0.50938 0.0183	0.61110 0.0033	0.59645 0.0043
<u>Brachionus</u> <u>plicatilus</u>	0.69767 0.0004	0.67195 0.0008	0.41997 0.0580	0.85274 0.0001	0.55627 0.0088	0.48736 0.0250
NO_3-N	-0.58254 0.0056	-0.39813 0.0739	-0.55953 0.0084	-0.33476 0.1380	-0.50661 0.0191	-0.56237 0.0080
D.O.	-0.40218 0.0707	-0.62506 0.0024	-0.32421 0.1516	-0.69311 0.0005	-0.46578 0.0333	-0.70053 0.0004

DISSOLVED OXYGEN						
	2S	2B	4S	4B	6S	6B
<u>Synchaeta</u> sp.	0.50307 0.0201	0.36581 0.1029	0.64235 0.0017	0.47656 0.0290	0.58036 0.0058	0.56087 0.0082
<u>Brachionus</u> <u>plicatilus</u>	-0.40110 0.0715	-0.46580 0.0333	-0.42899 0.0523	-0.53347 0.0128	-0.53722 0.0120	-0.40720 0.0669
NH_3-N	-0.07849 0.7352	-0.50947 0.0183	-0.13404 0.5624	-0.57154 0.0068	-0.22576 0.3251	-0.66739 0.0009

SALINITY						
	2S	2B	4S	4B	6S	6B
NO_3-N	-0.73471 0.0001	-0.50742 0.0189	-0.55583 0.0089	-0.74157 0.0001	-0.55216 0.0096	-0.73927 0.0001

	TOTAL ORGANIC CARBON					
	2S	2B	4S	4B	6S	6B
NH_3-N	0.52793 0.0139	0.42491 0.0548	0.60599 0.0036	0.41763 0.0596	0.48152 0.0271	0.49816 0.0215

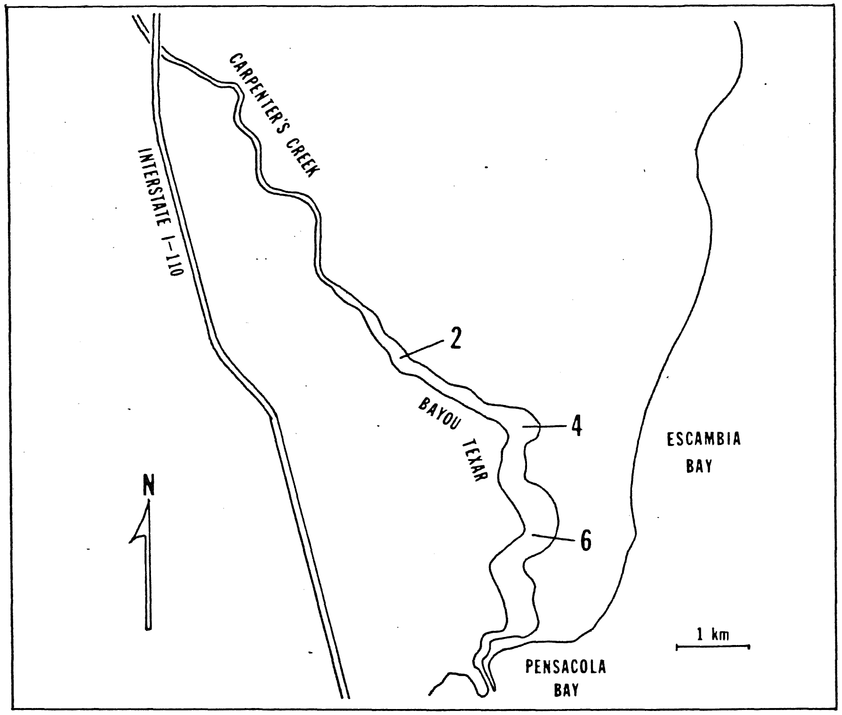


Figure 1. Bayou Texar Sampling Stations

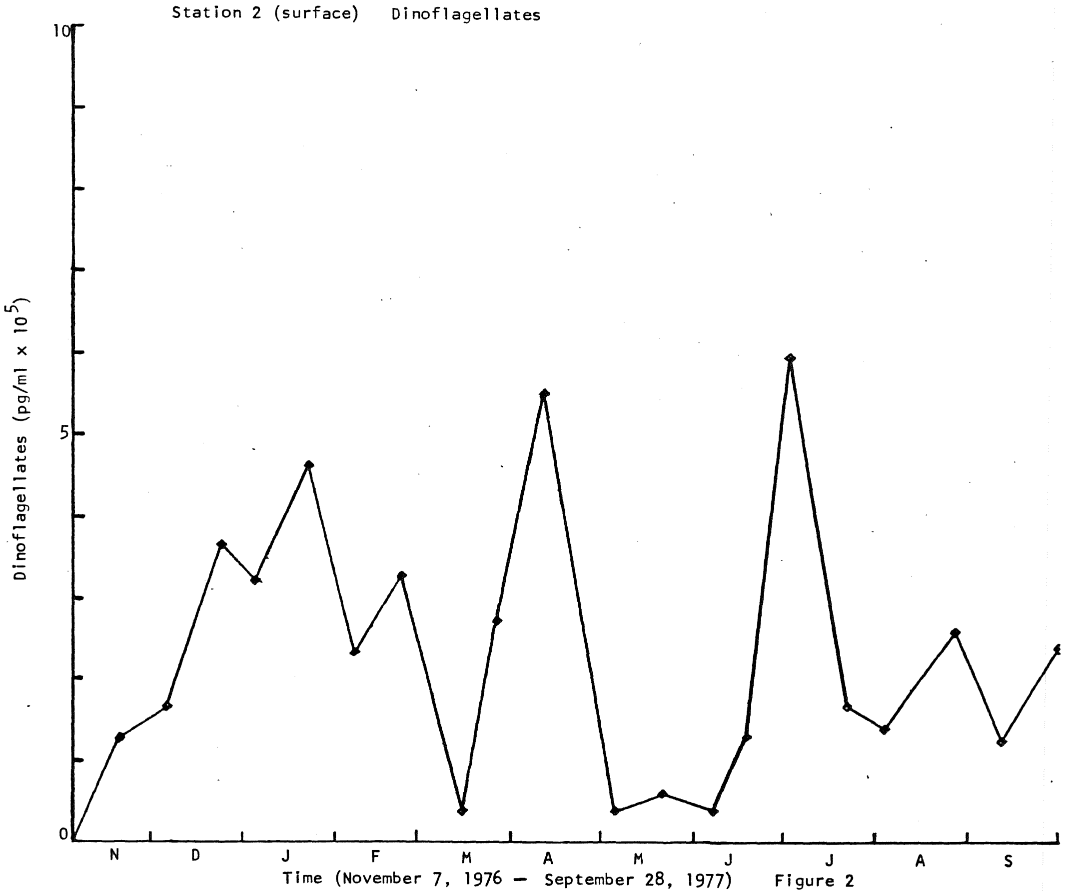
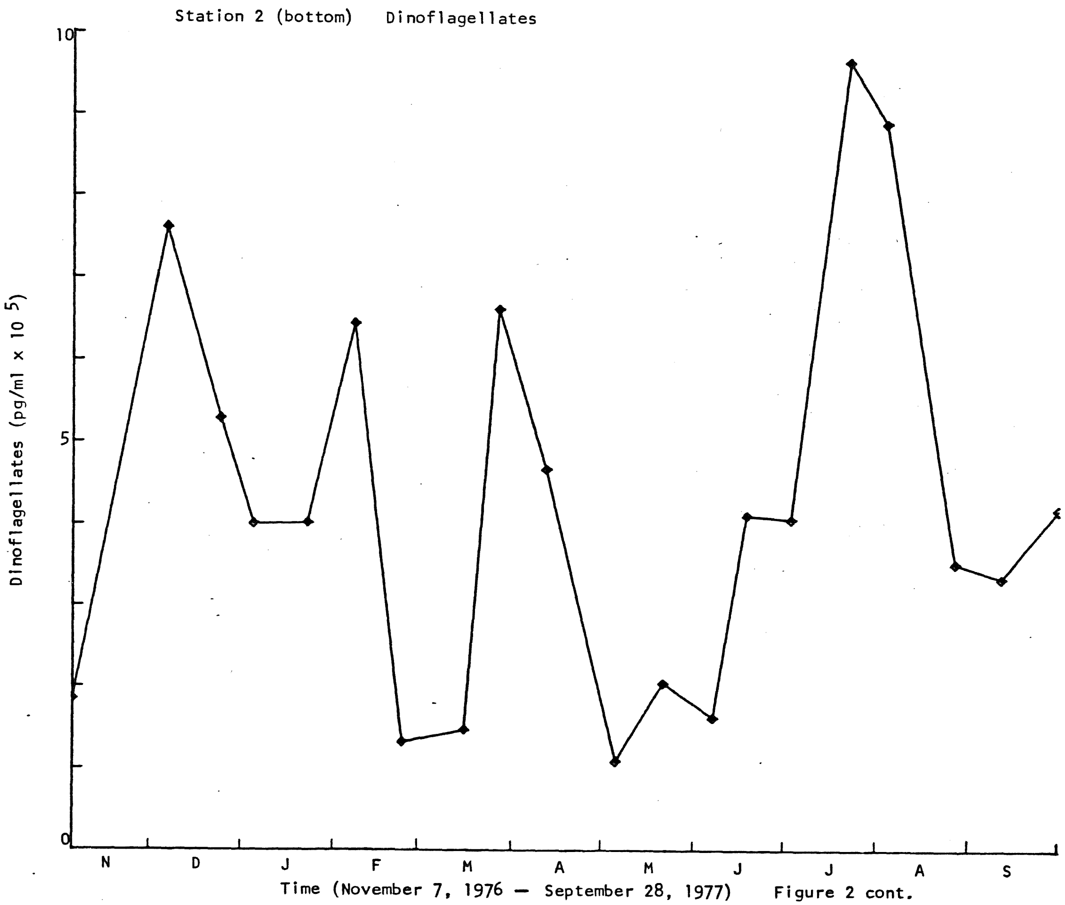

Station 2 (surface) Dinoflagellates
10
5
0
Dinoflagellates (pg/ml x 10^5)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 — September 28, 1977)

Figure 2



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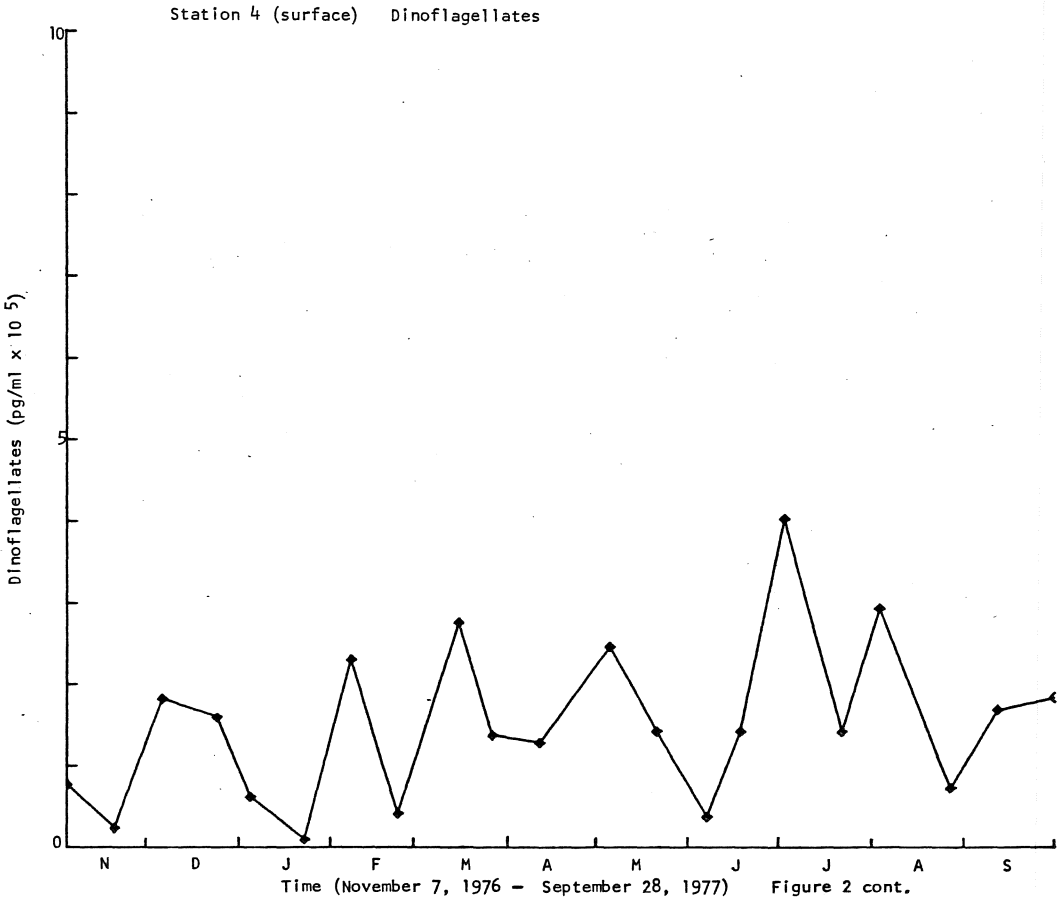
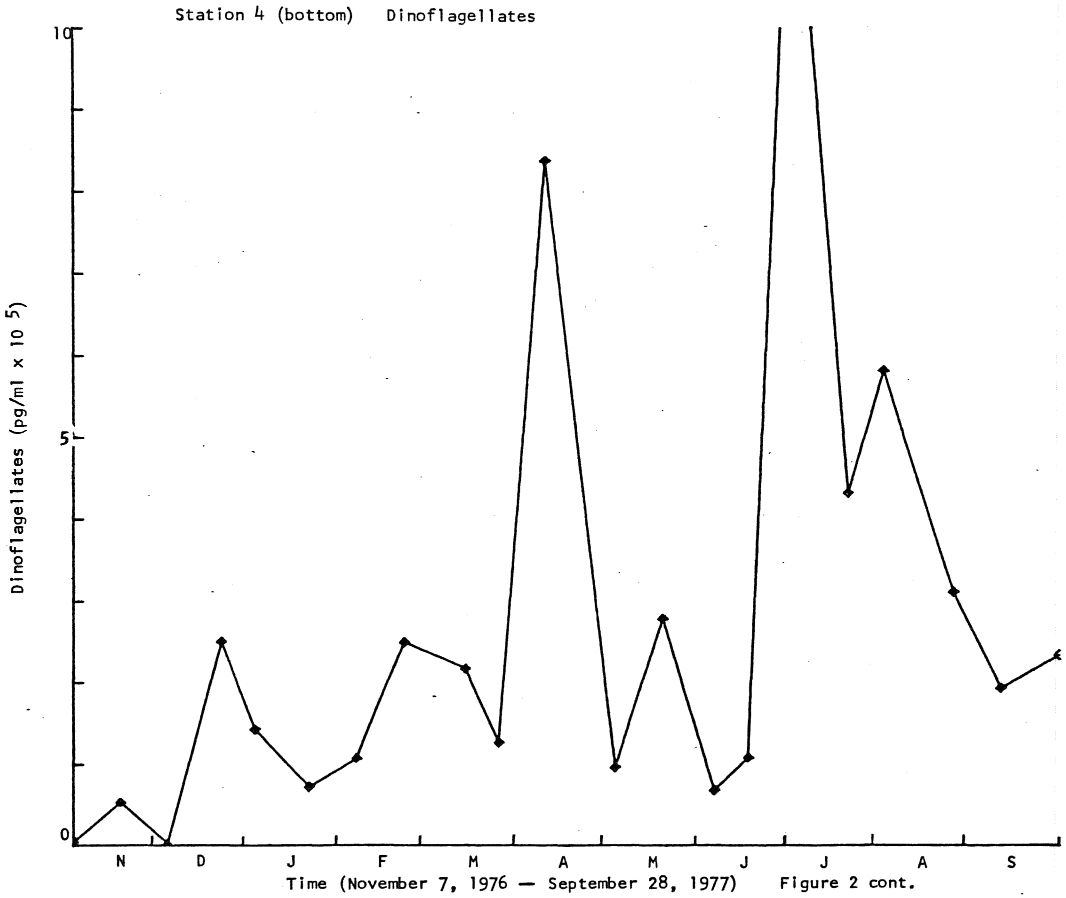


Figure 2 cont.

Station 4 (bottom) Dinoflagellates



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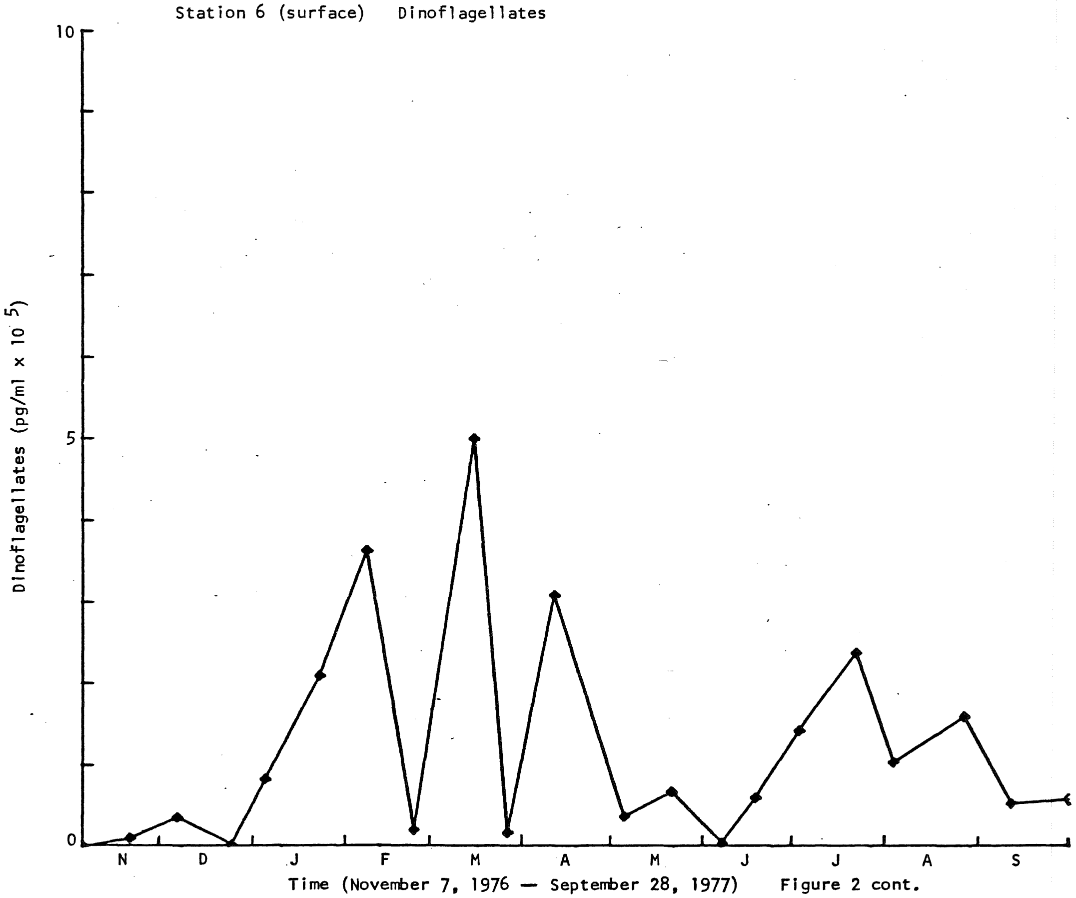

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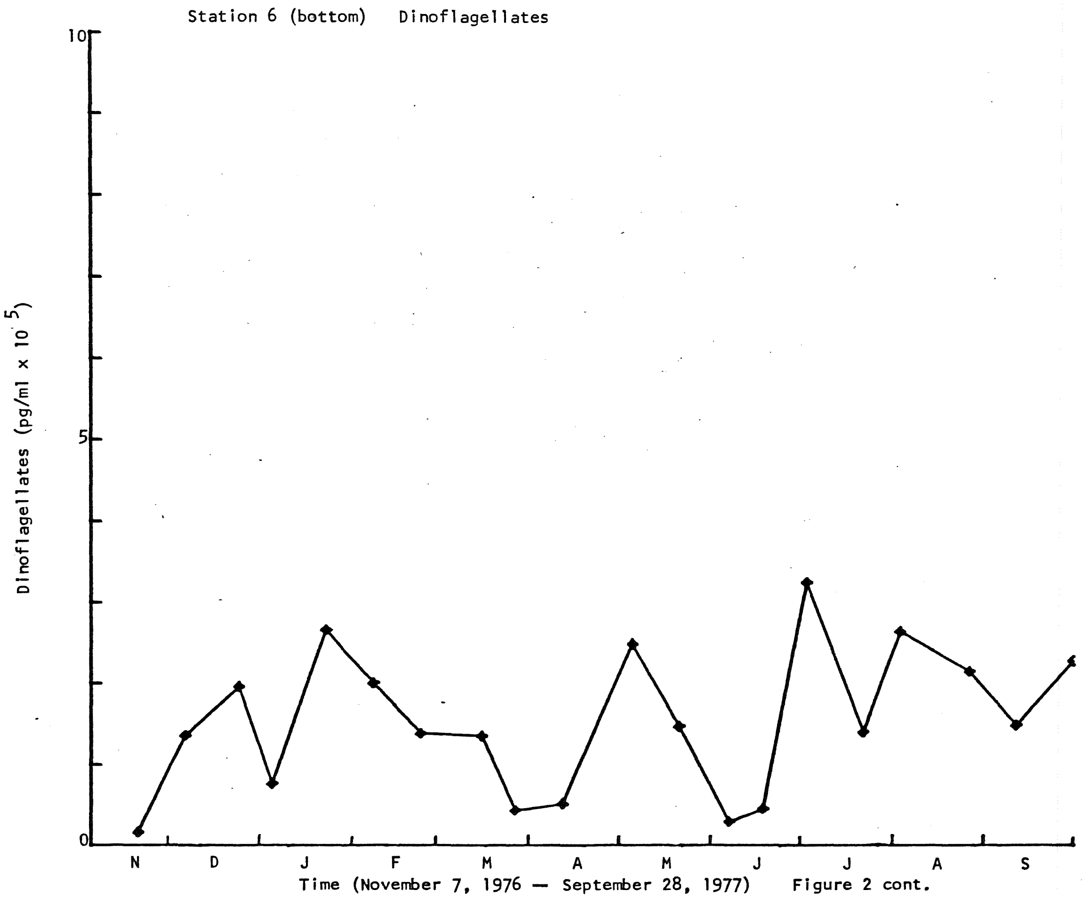

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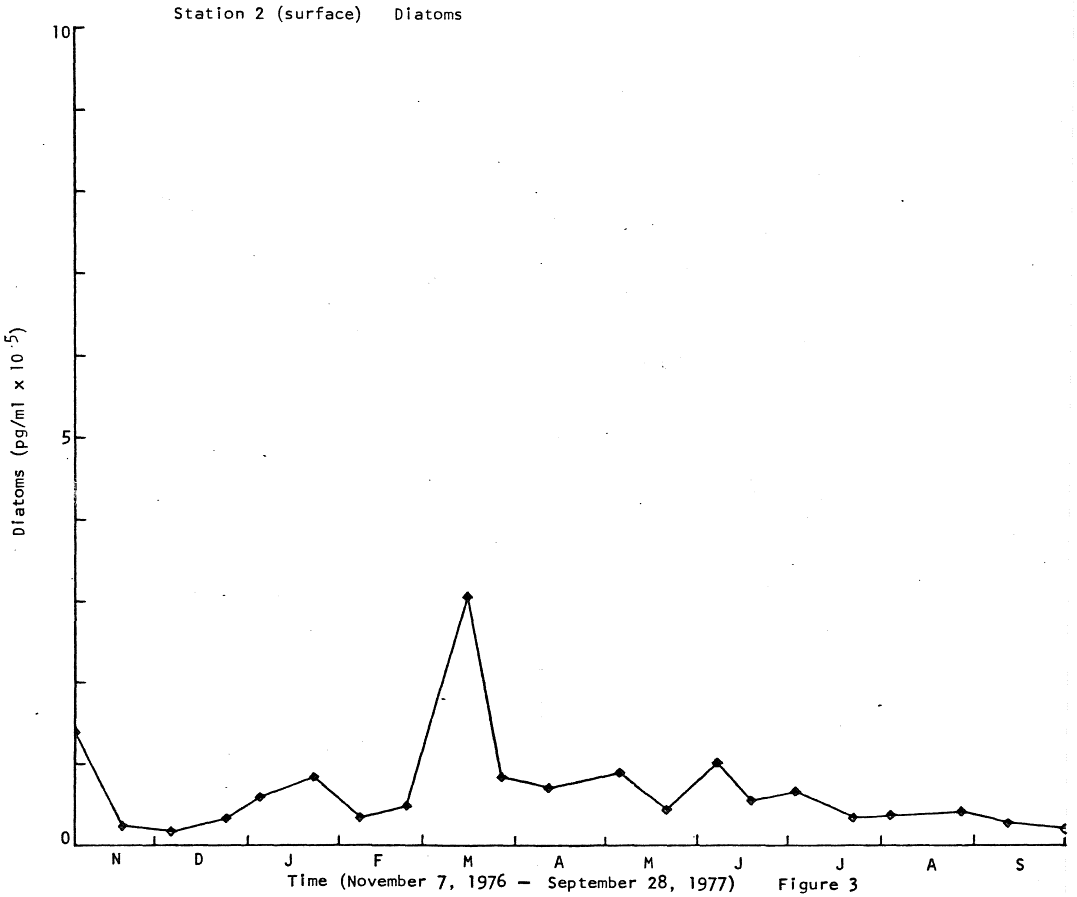
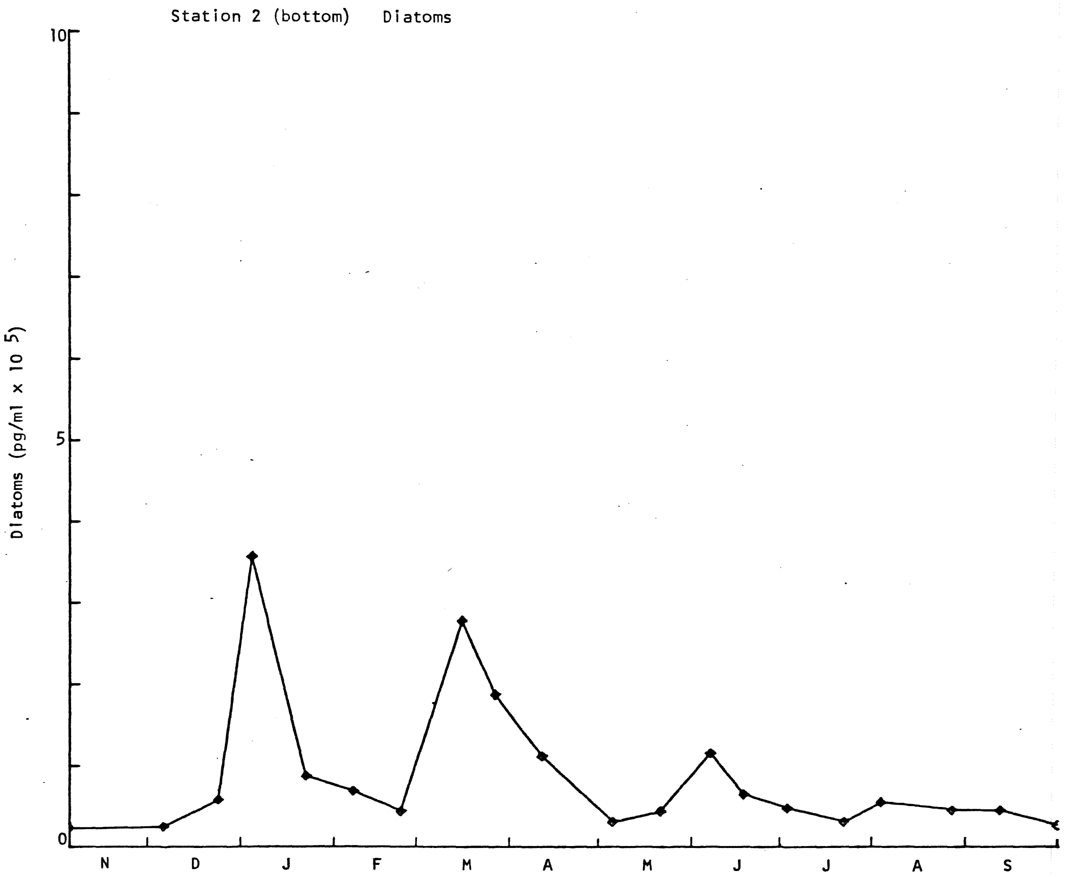

Station 2 (surface) Diatoms
10
5
0
Diatoms (pg/ml x 10⁻⁵)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 — September 28, 1977)

Figure 3



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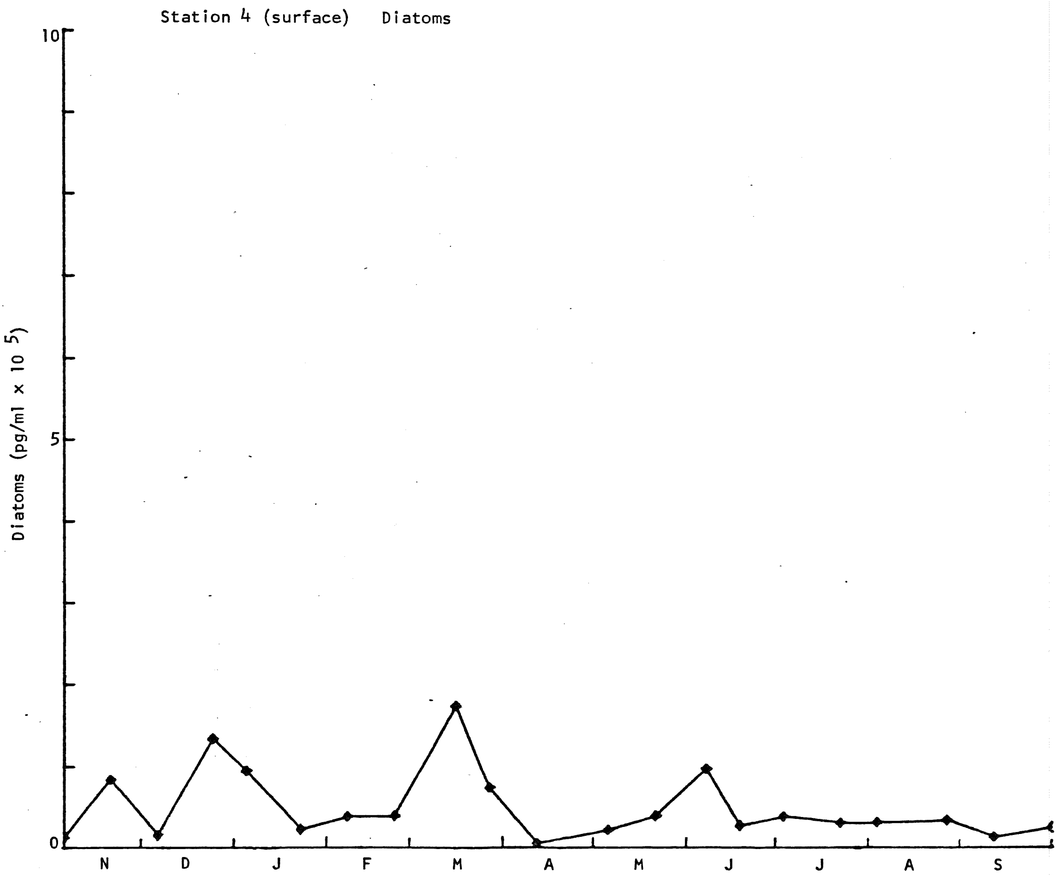

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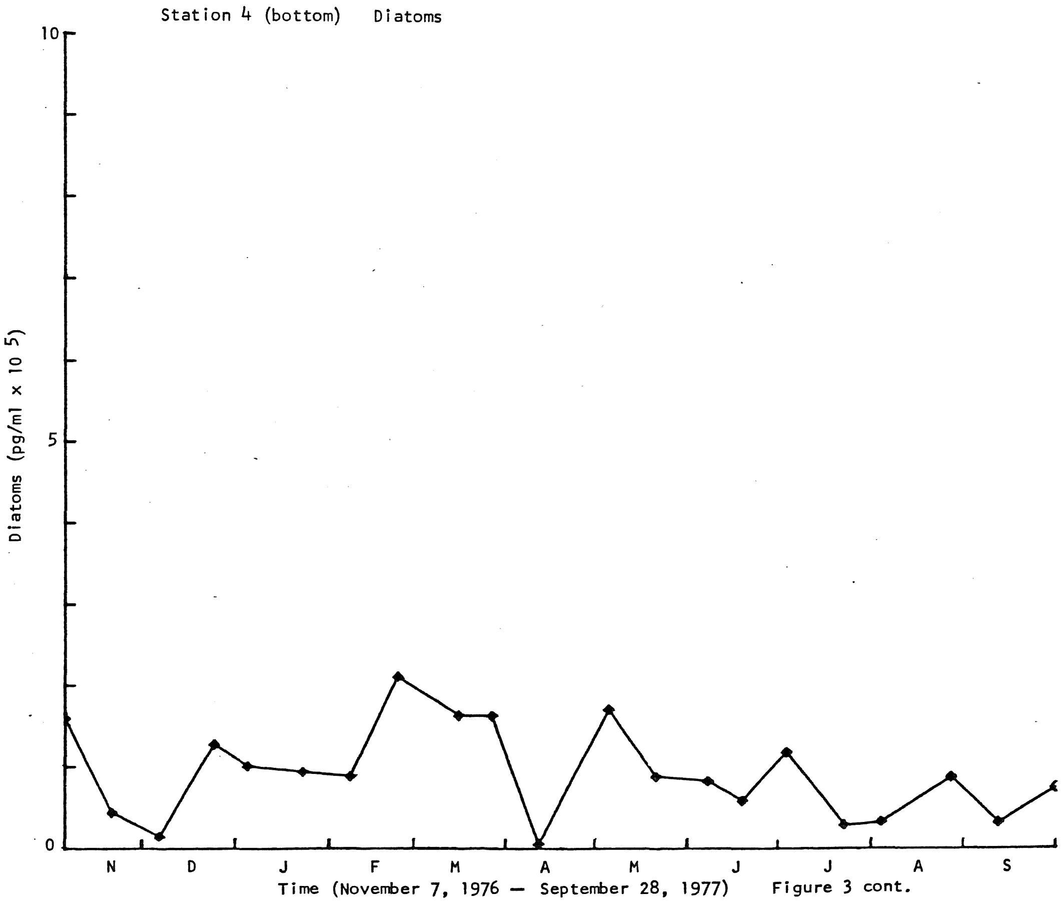

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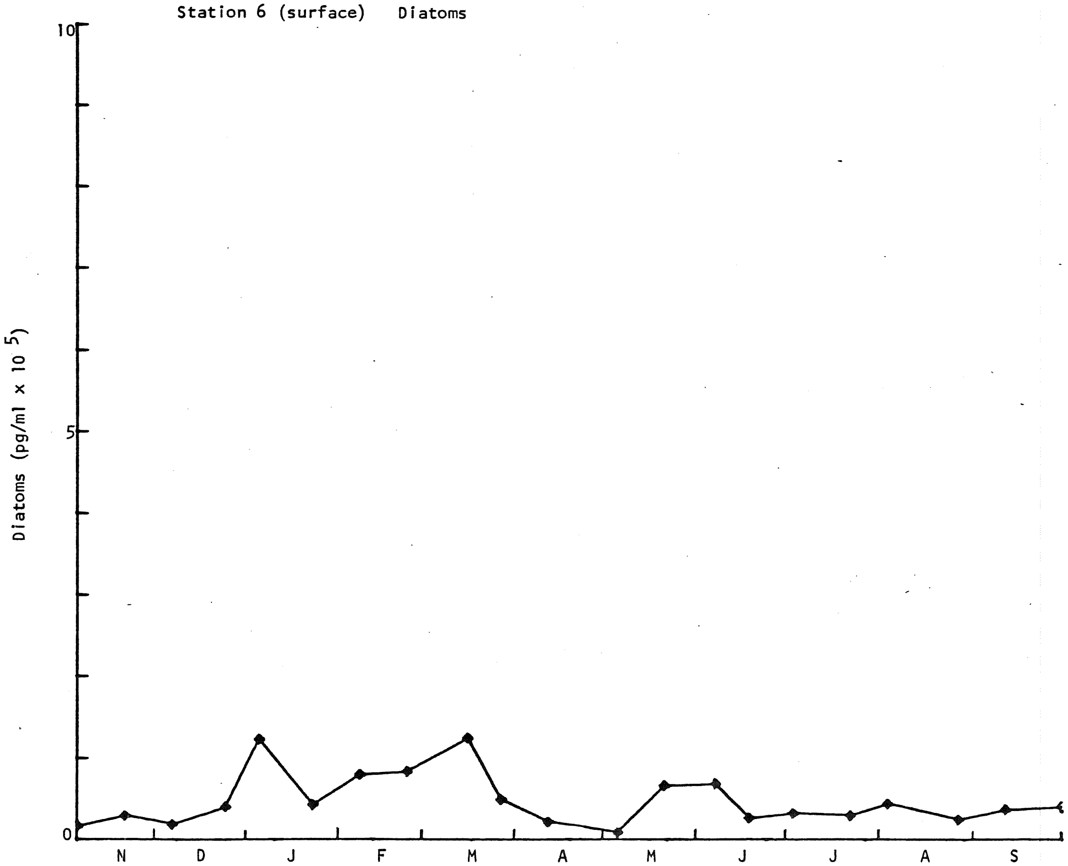
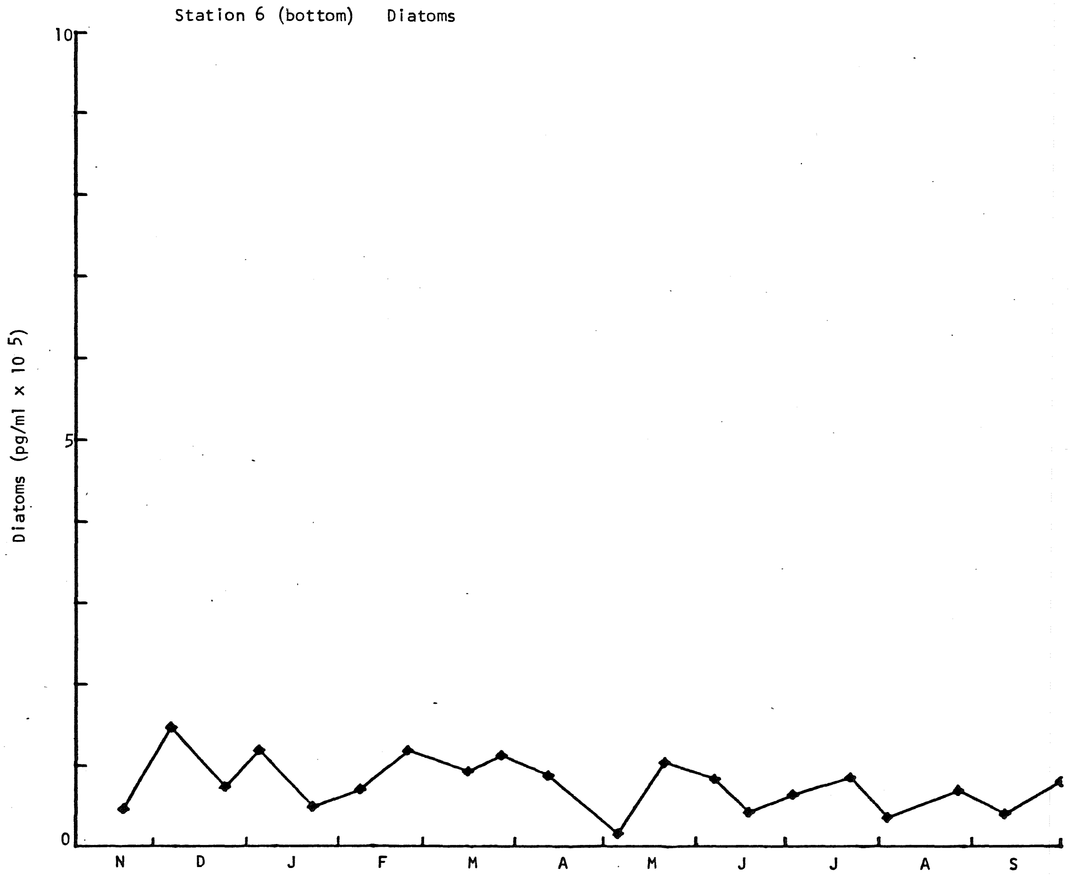
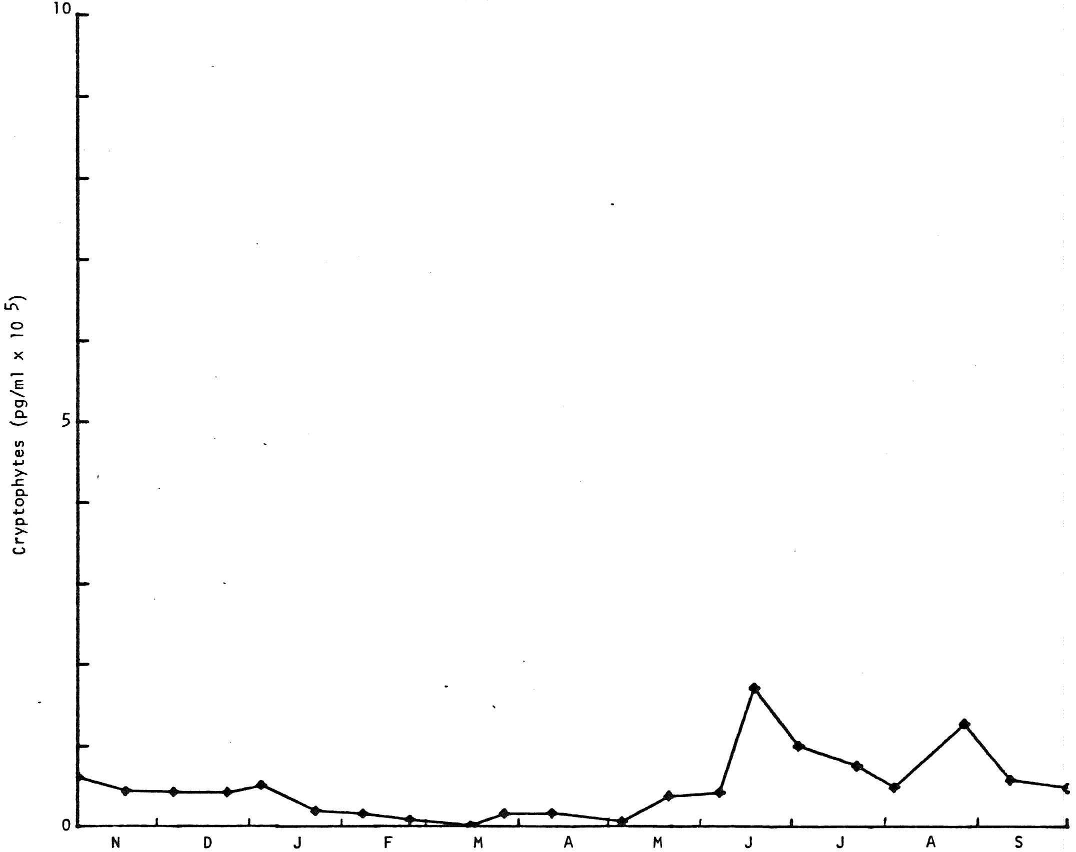


Time (November 7, 1976 — September 28, 1977) Figure 3 cont.

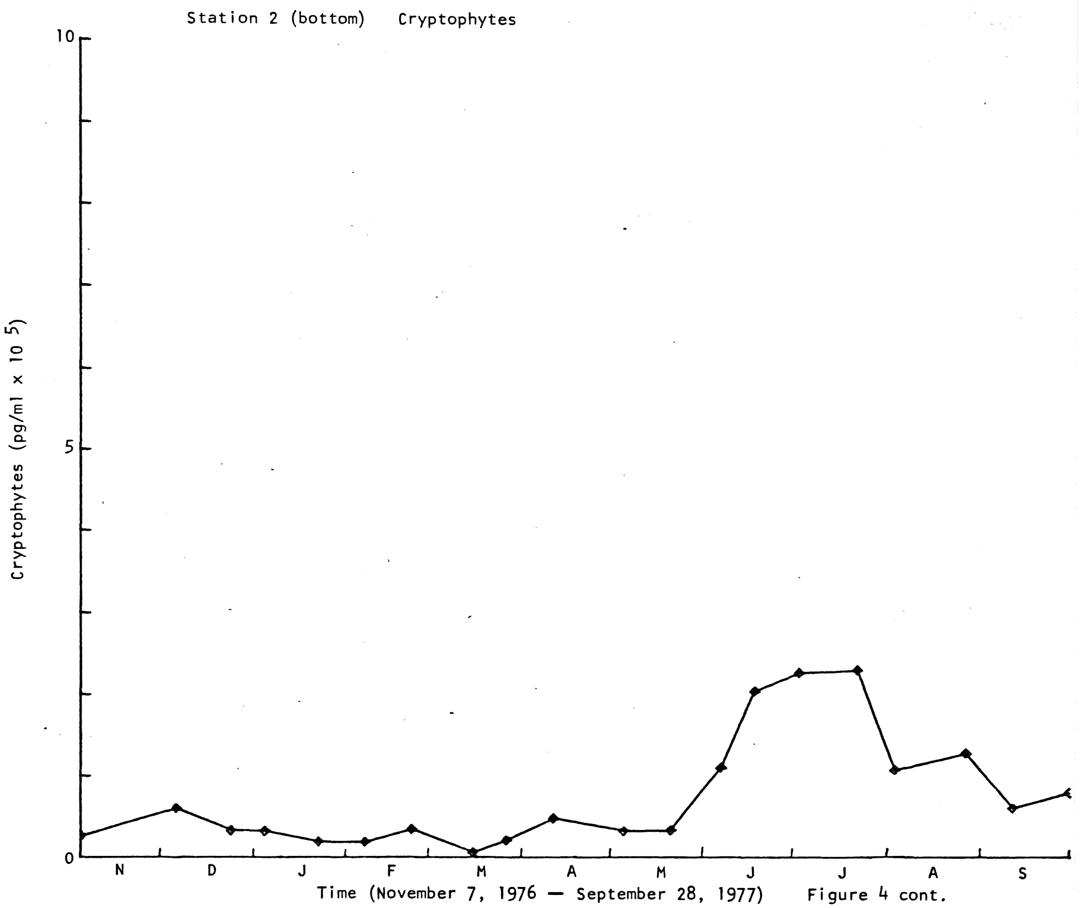


Time (November 7, 1976 - September 28, 1977) Figure 3 cont.



Station 2 (surface) Cryptophytes

Figure 4



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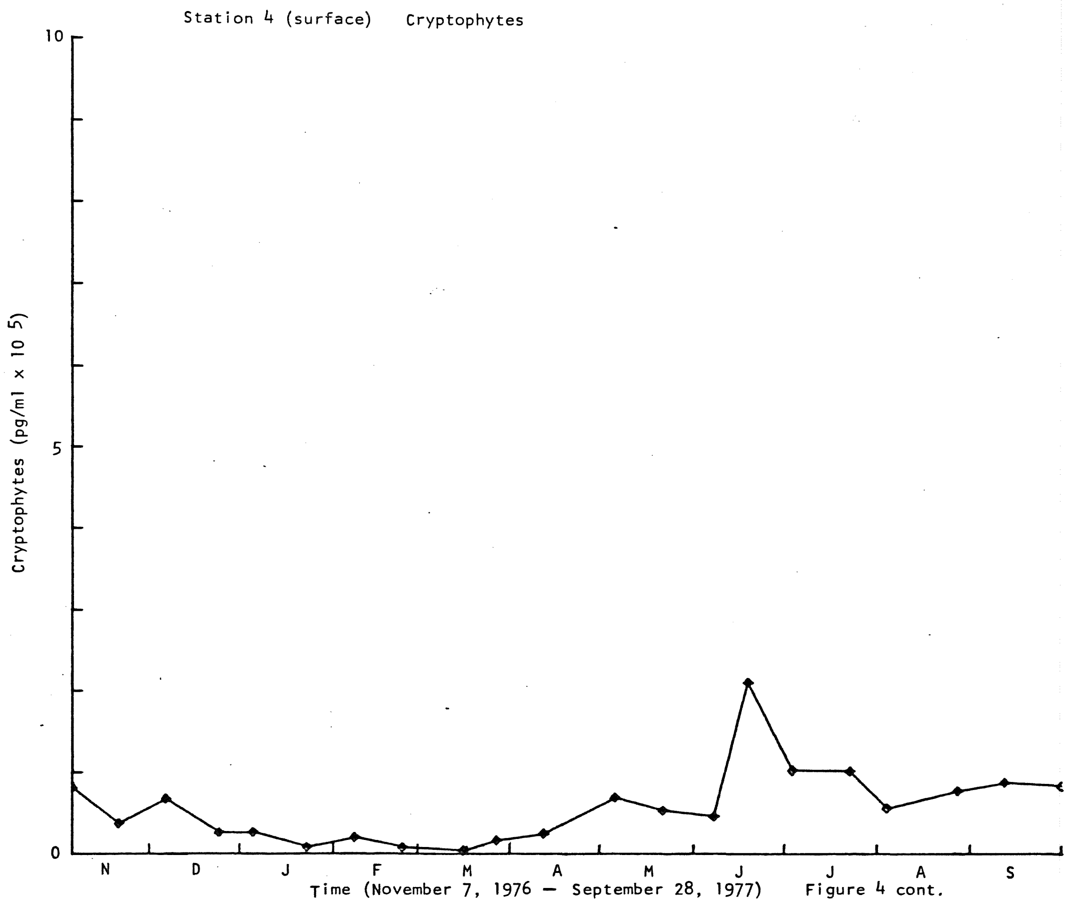

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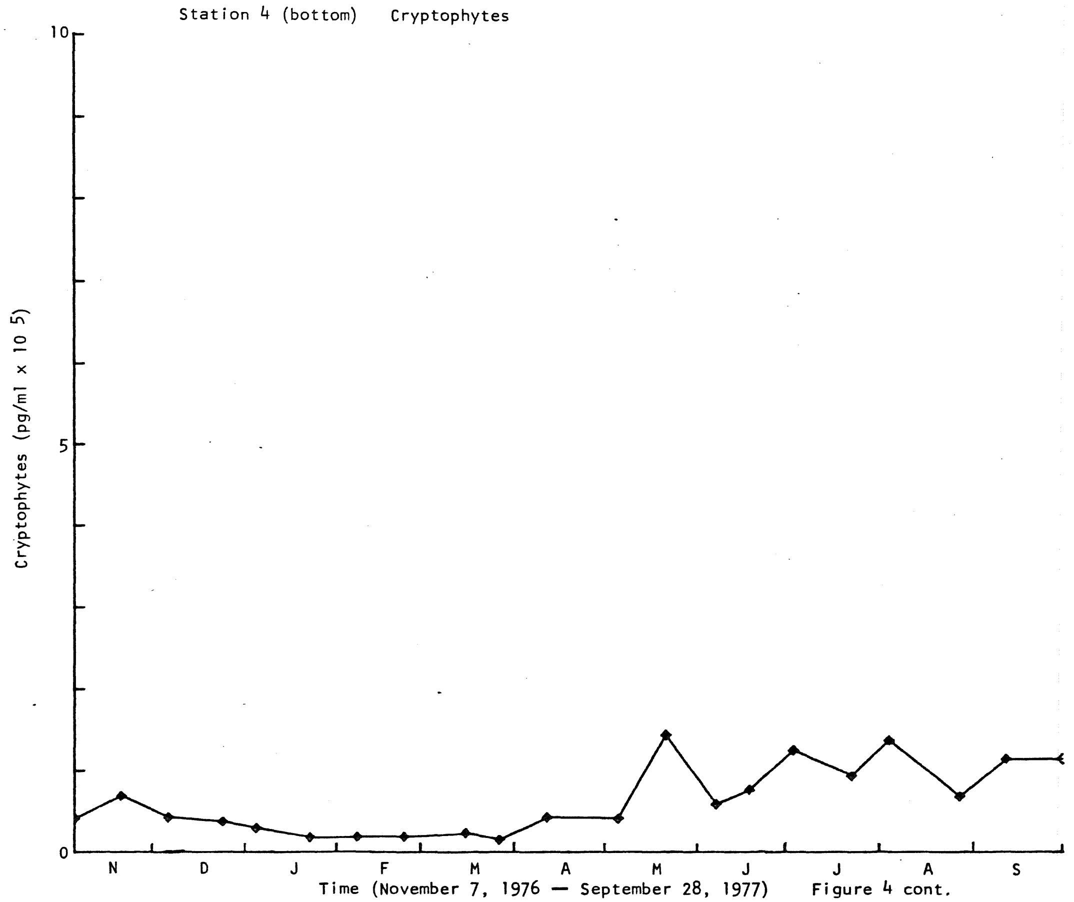

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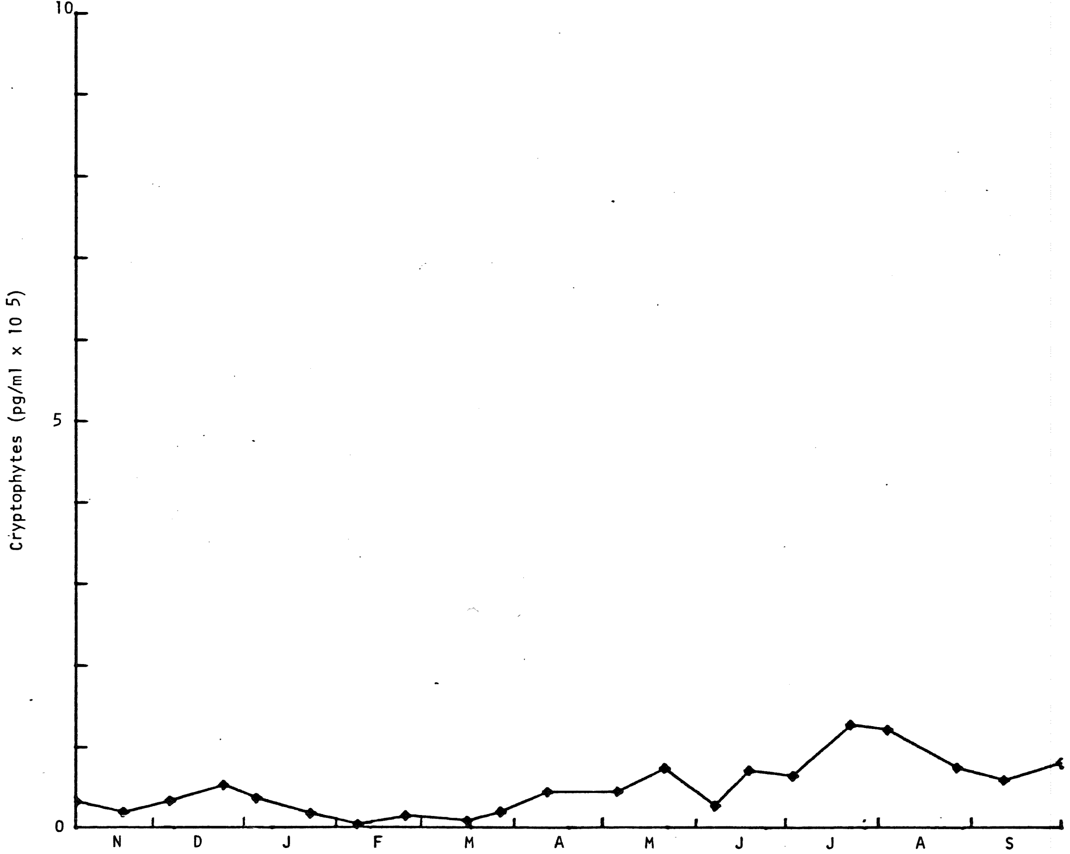
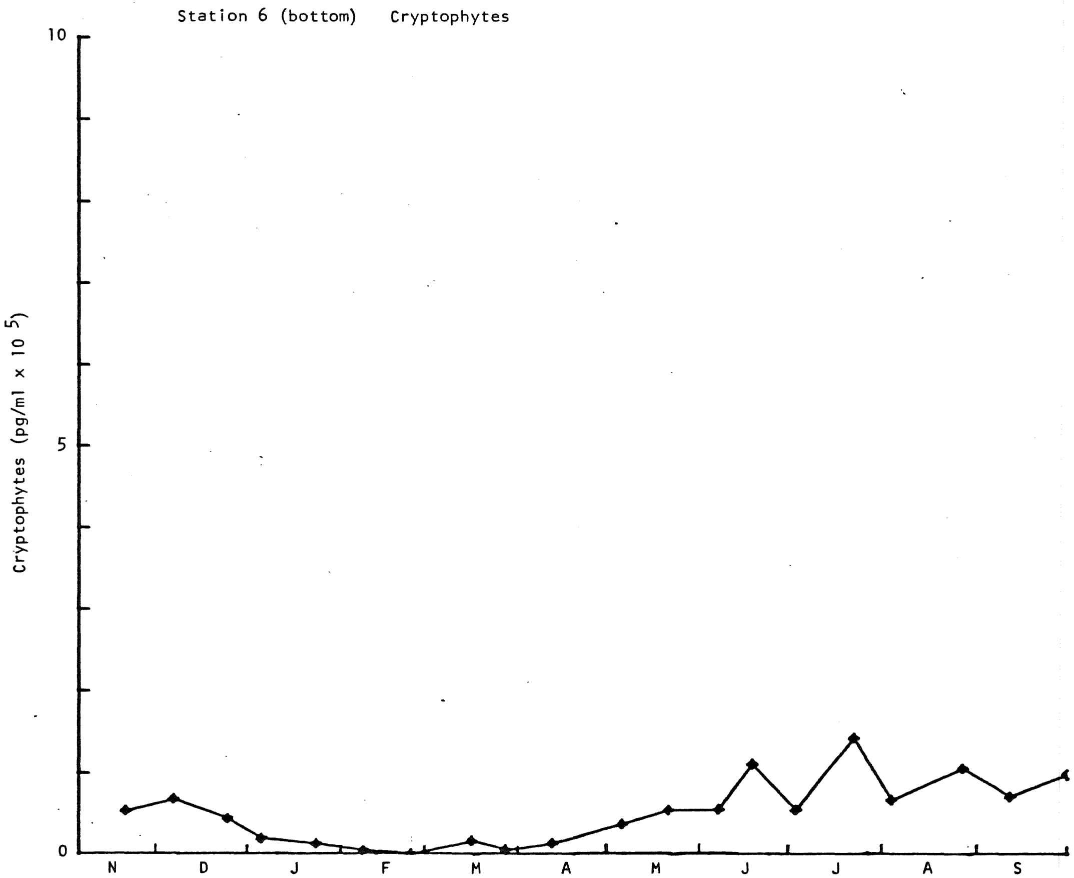
Station 6 (surface) Cryptophytes



Time (November 7, 1976 — September 28, 1977) Figure 4 cont.



Time (November 7, 1976 — September 28, 1977) Figure 4 cont.

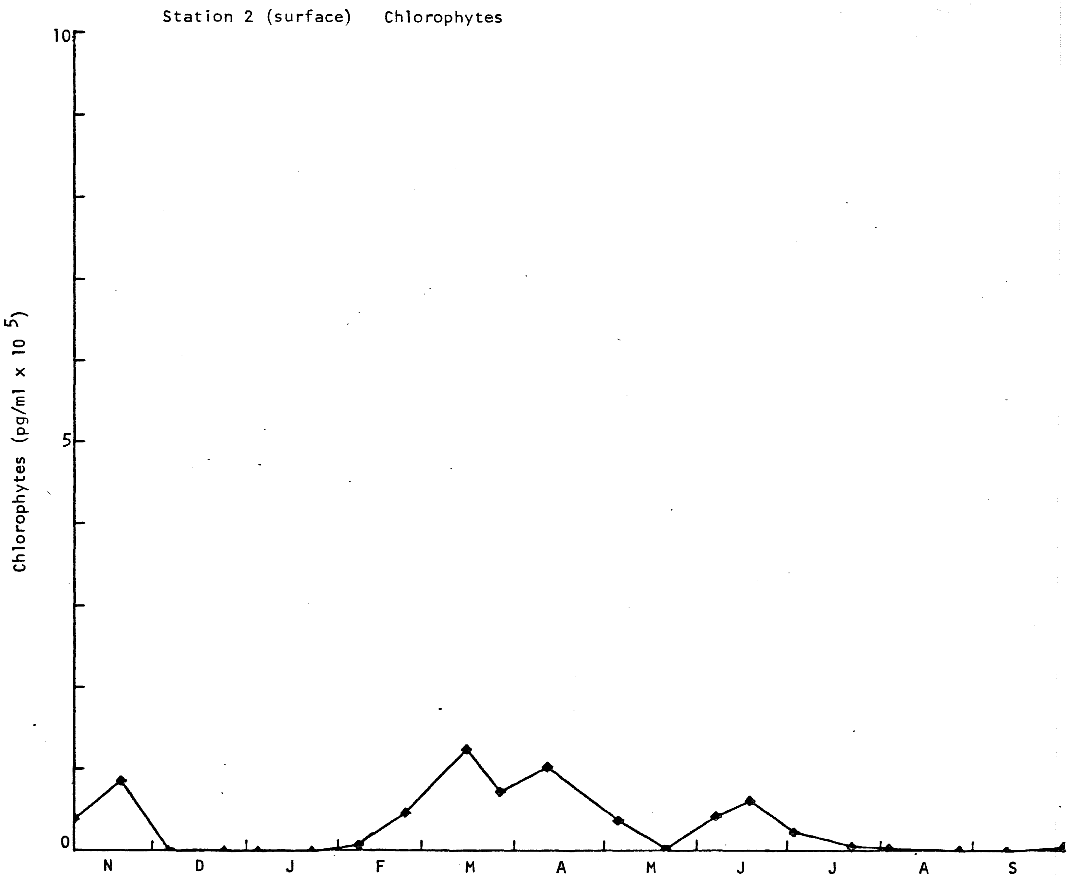
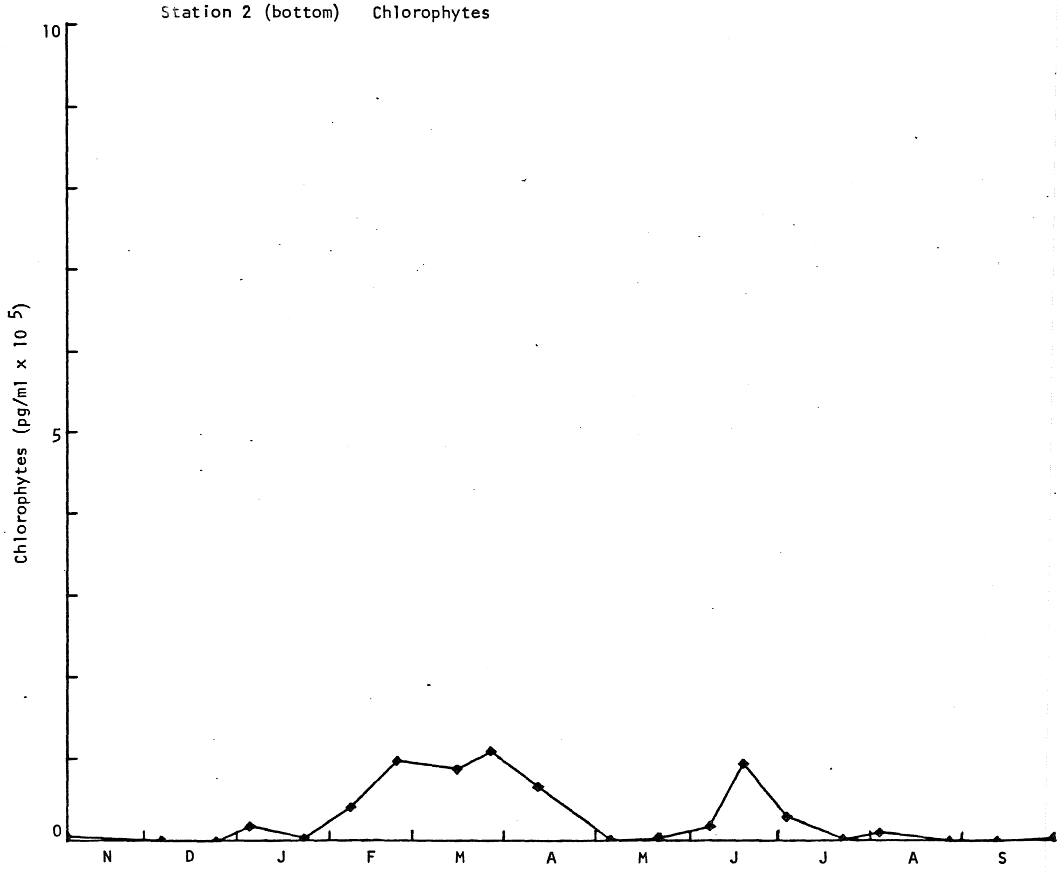

Station 2 (surface) Chlorophytes
Chlorophytes (pg/ml x 10 5)
10
5
0
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 — September 28, 1977)

Figure 5

Station 2 (bottom) Chlorophytes



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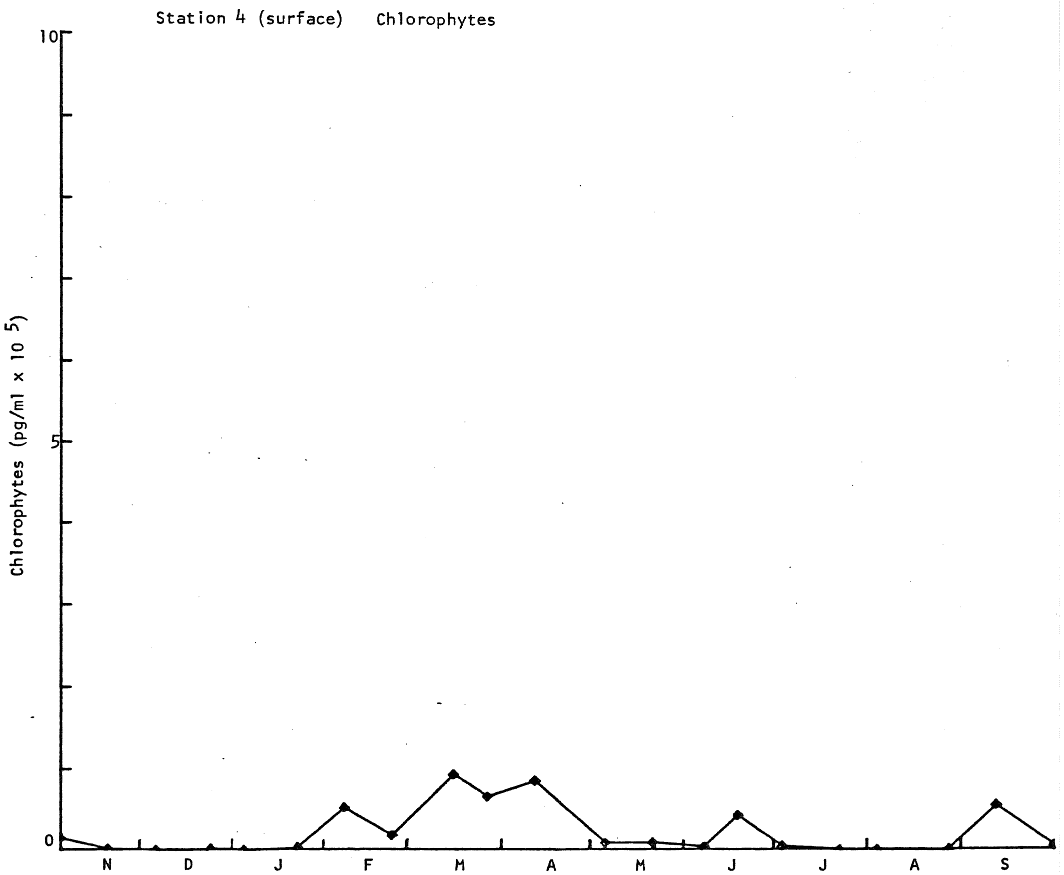


Time (November 7, 1976 — September 28, 1977) Figure 5 cont.

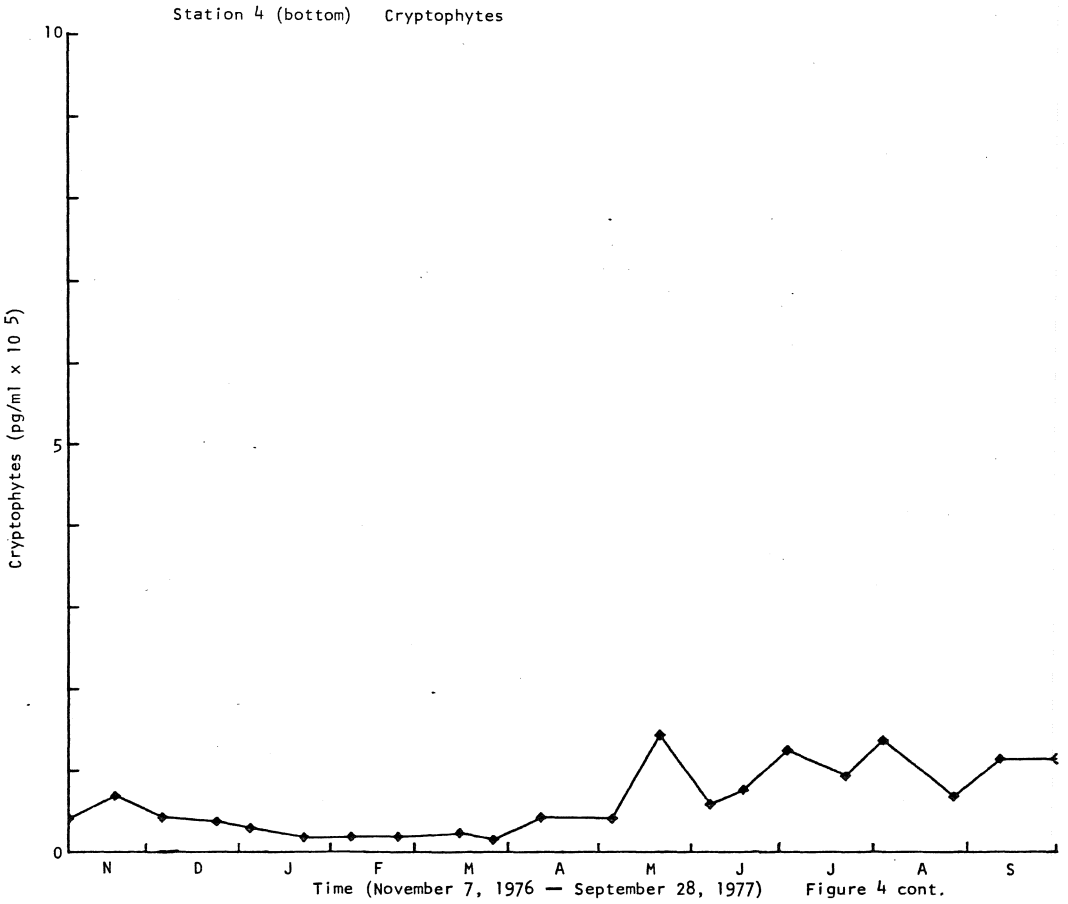


Figure 4 cont.

Station 6 (bottom)   Cryptophytes

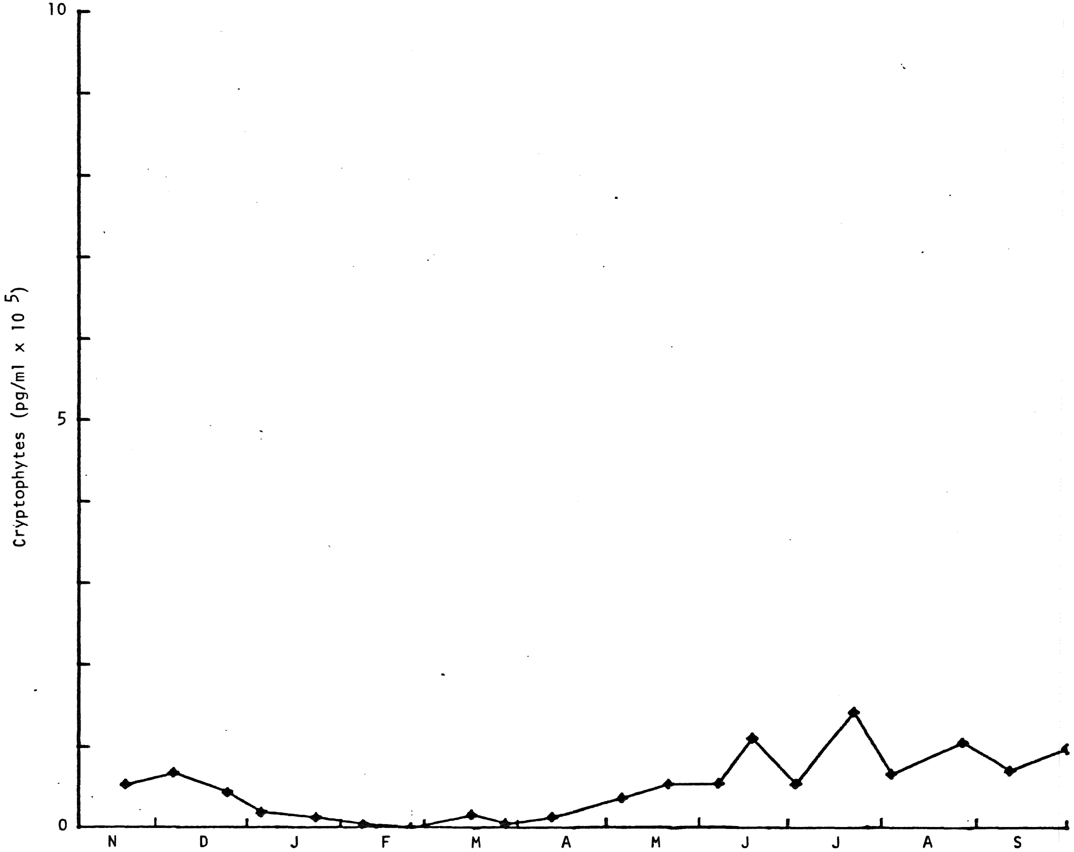
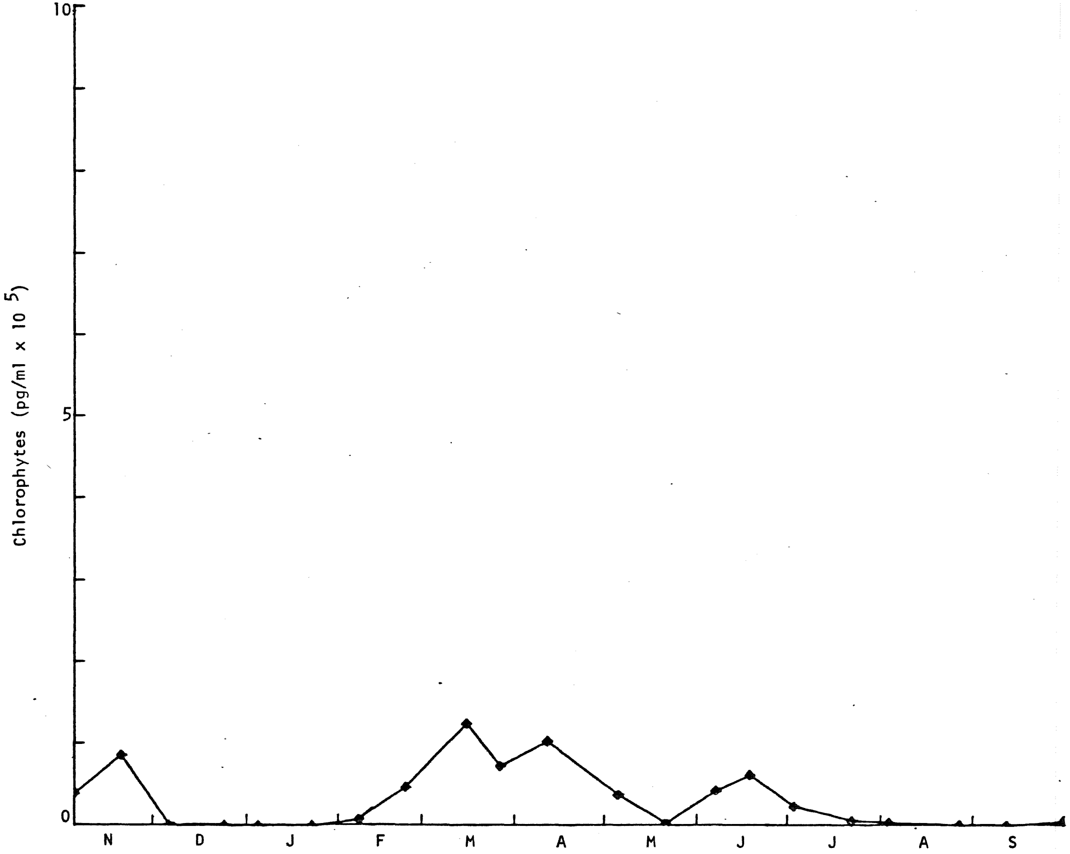
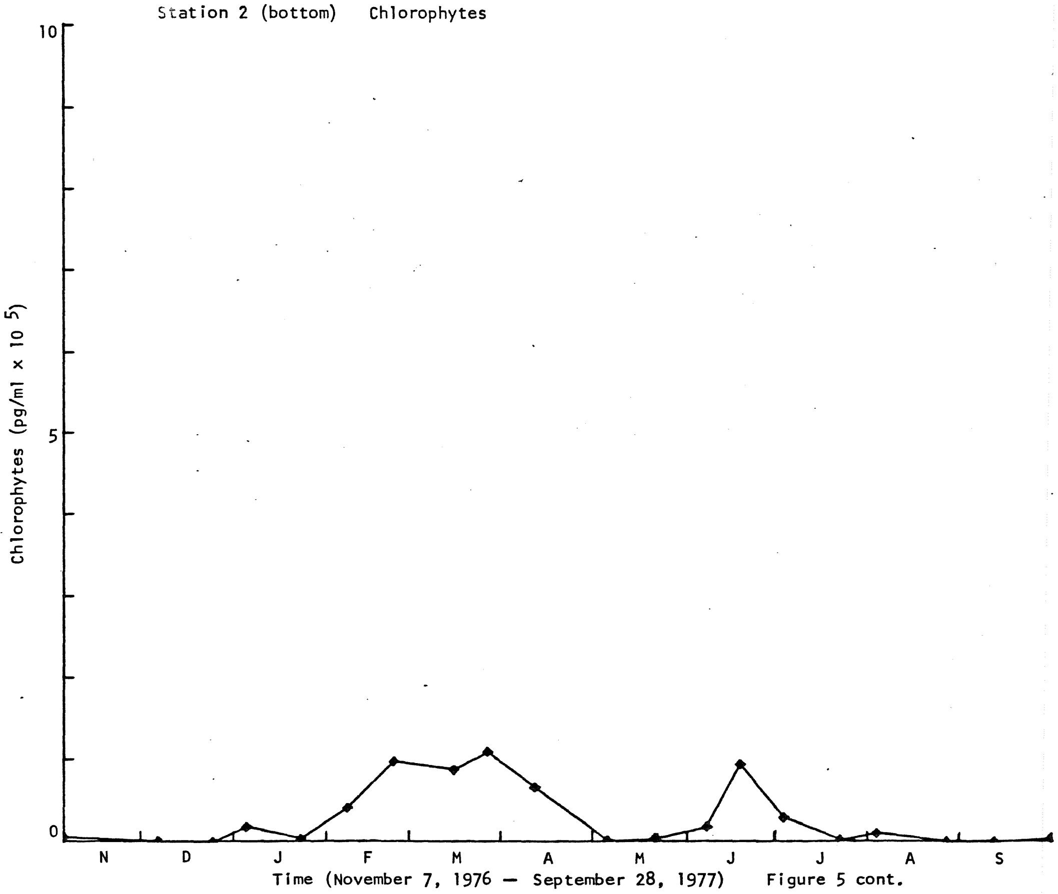


Figure 4 cont.

Station 2 (surface) Chlorophytes



Time (November 7, 1976 — September 28, 1977) Figure 5



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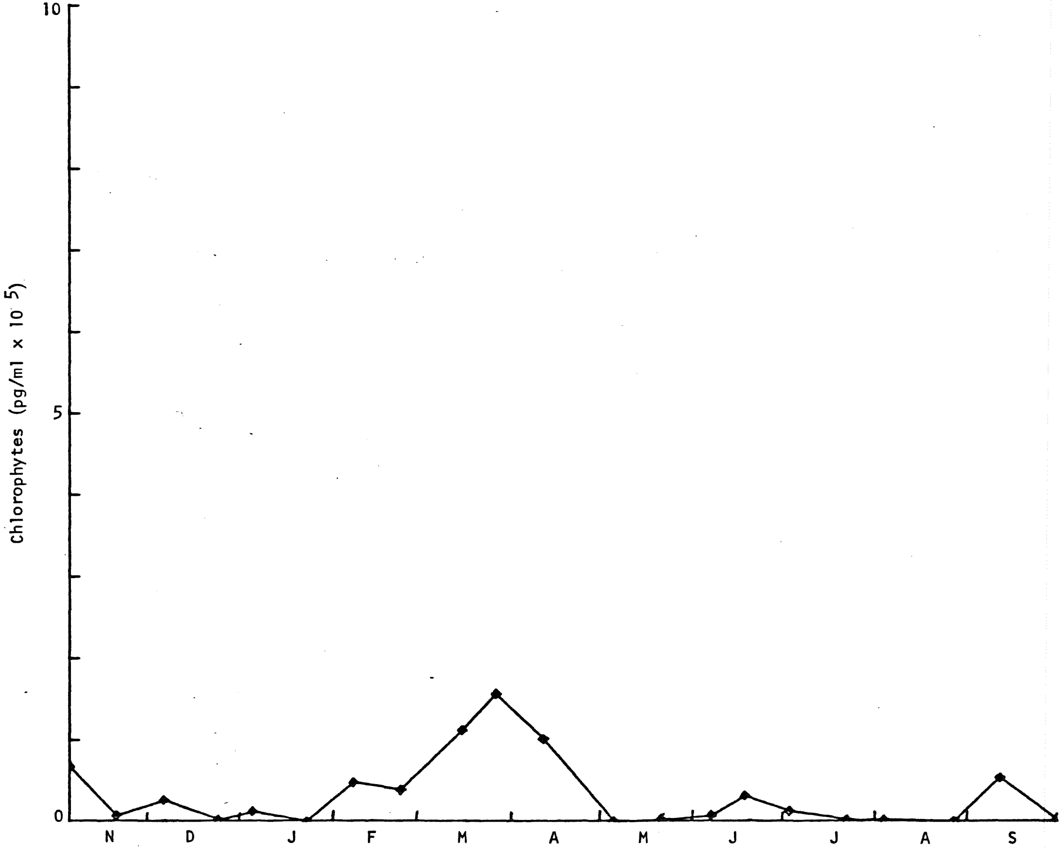
Station 4 (bottom) Chlorophytes



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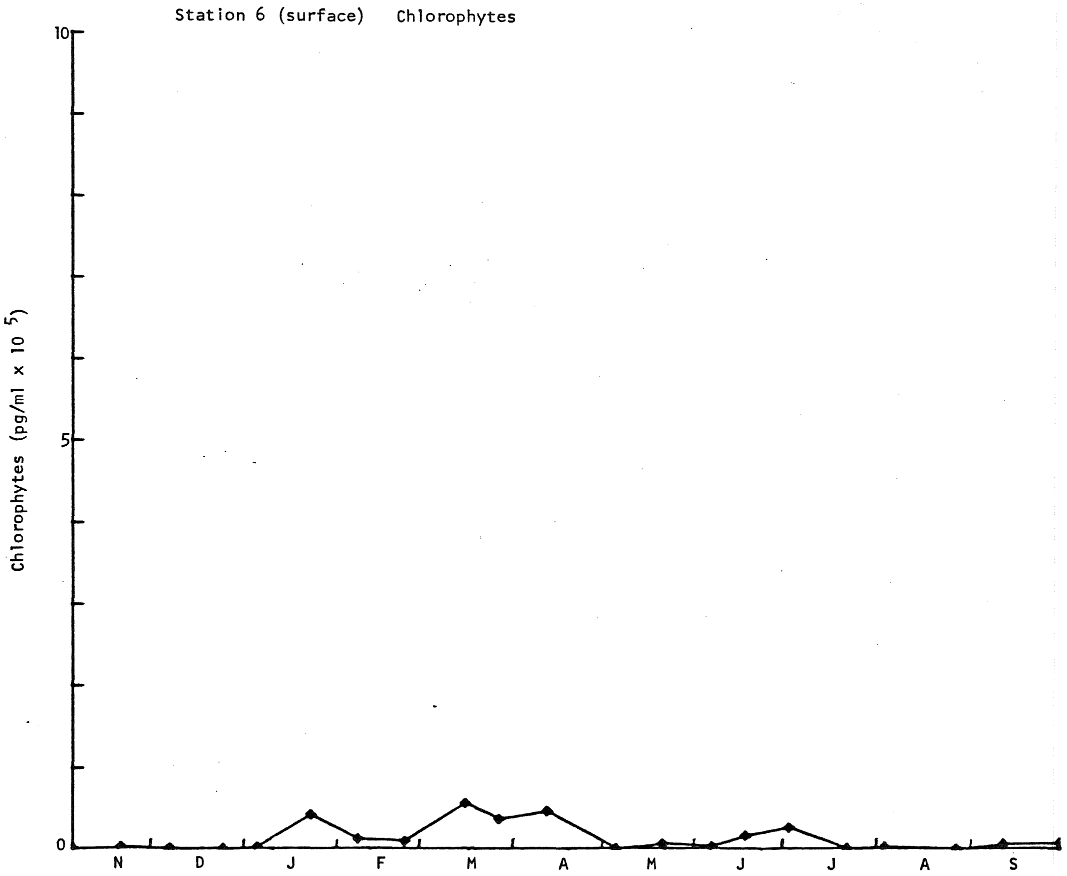
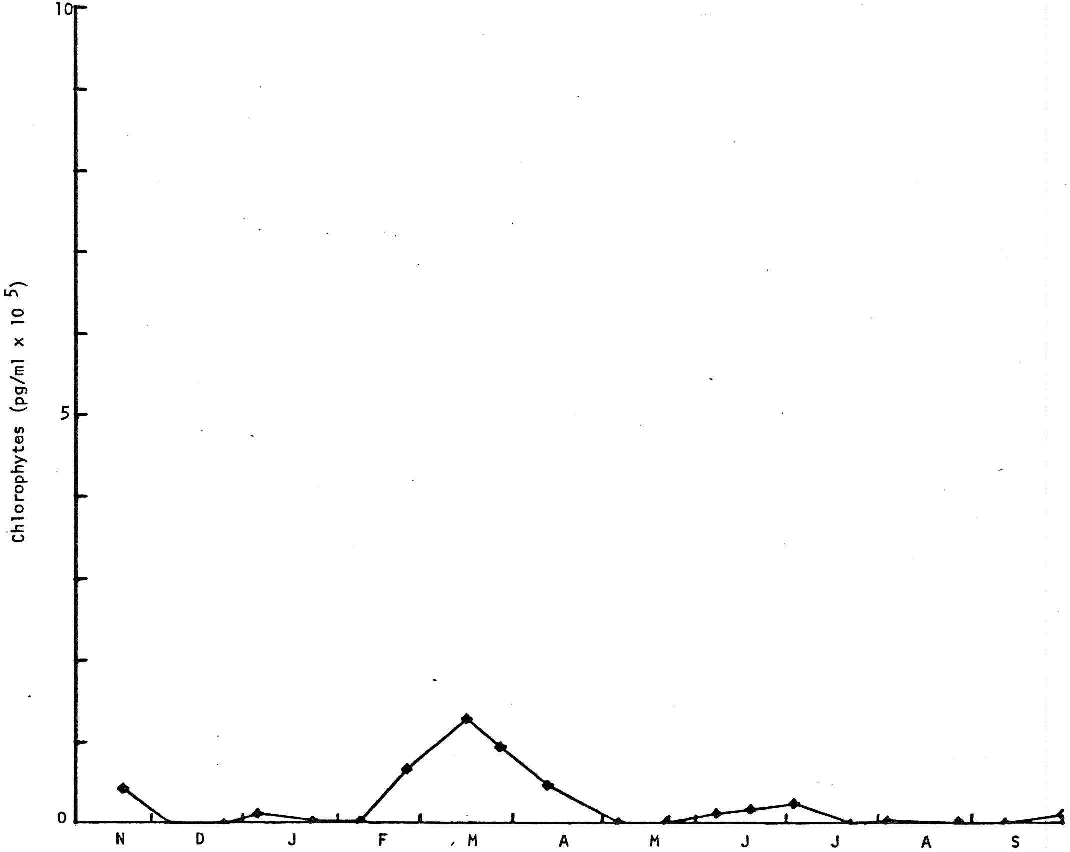


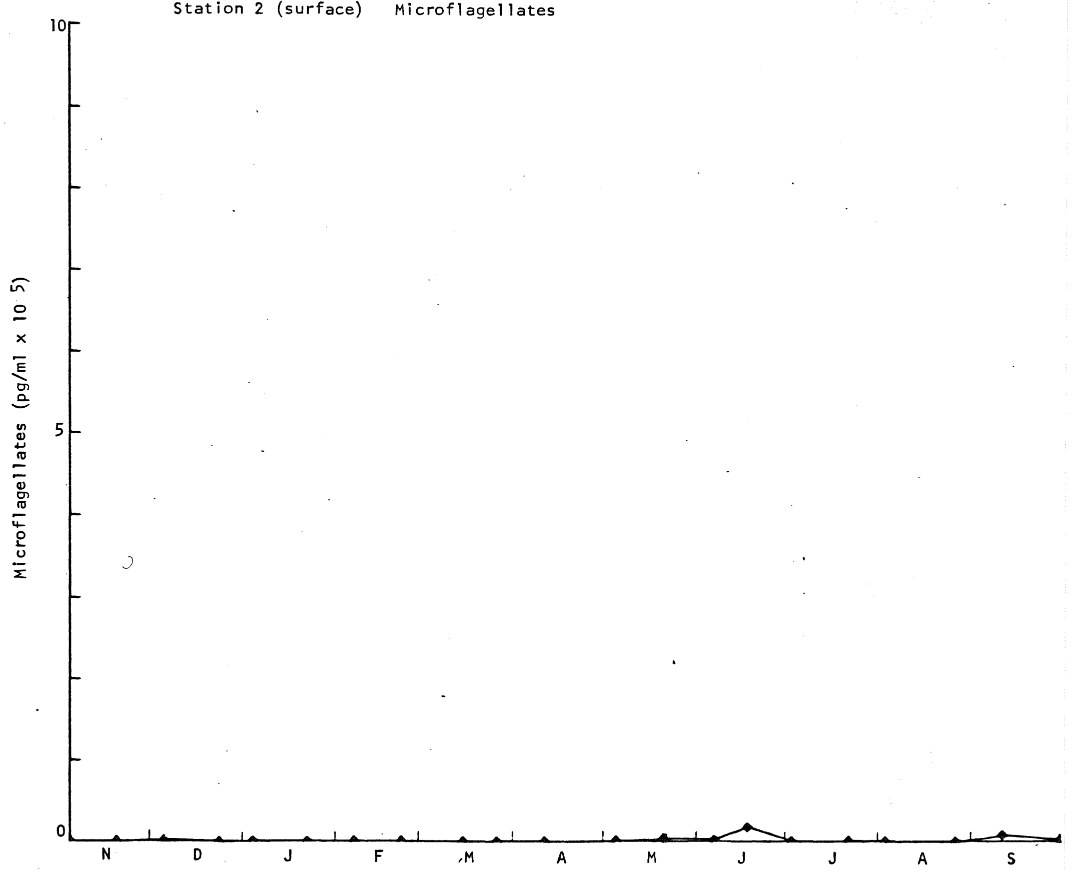
Time (November 7, 1976 — September 28, 1977) Figure 5 cont.

Station 6 (bottom) Chlorophytes



Time (November 7, 1976 – September 28, 1977) Figure 5 cont.

Station 2 (surface) Microflagellates



Time (November 7, 1976 — September 28, 1977) Figure 6

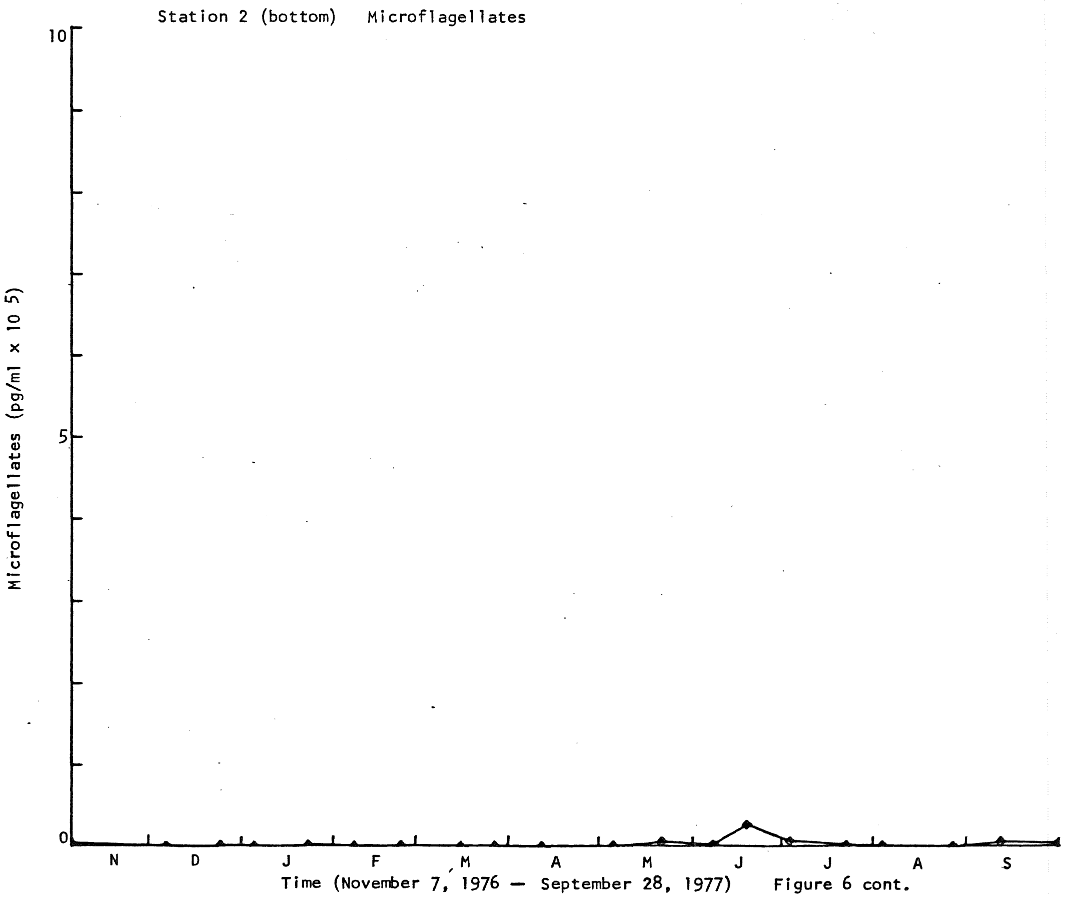


Figure 6 cont.

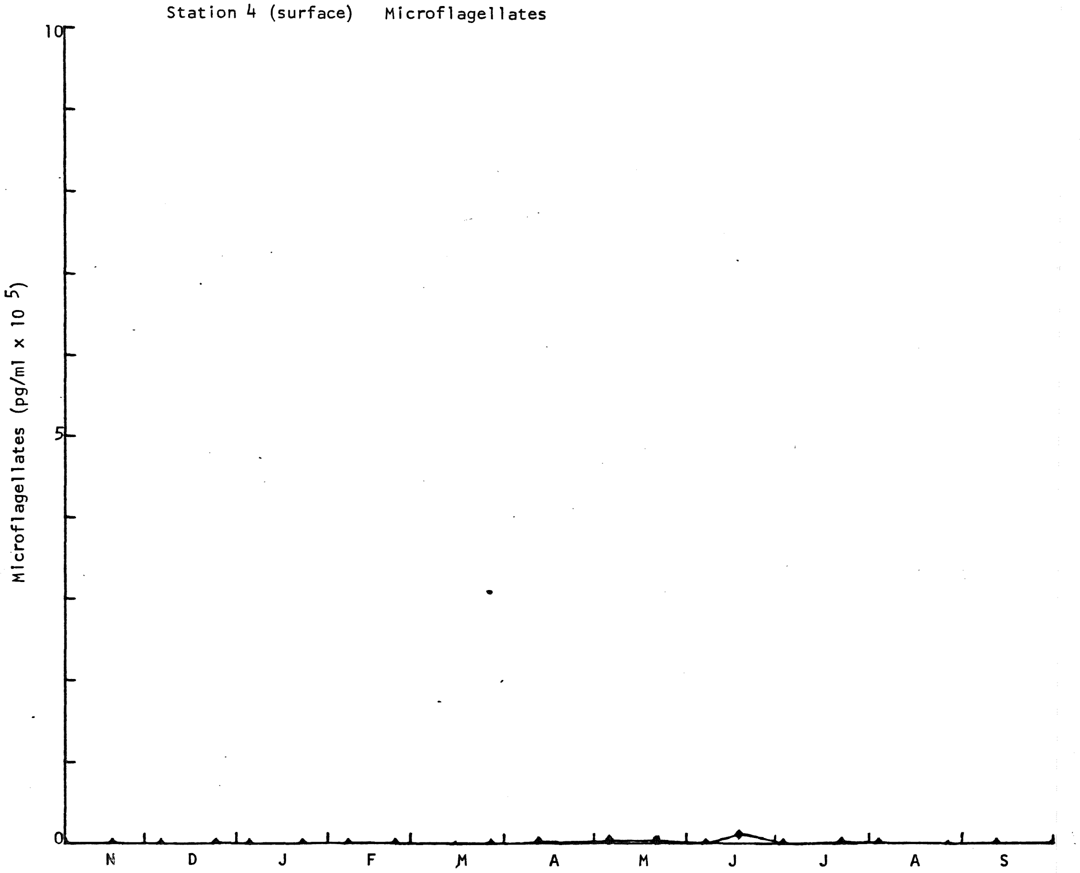
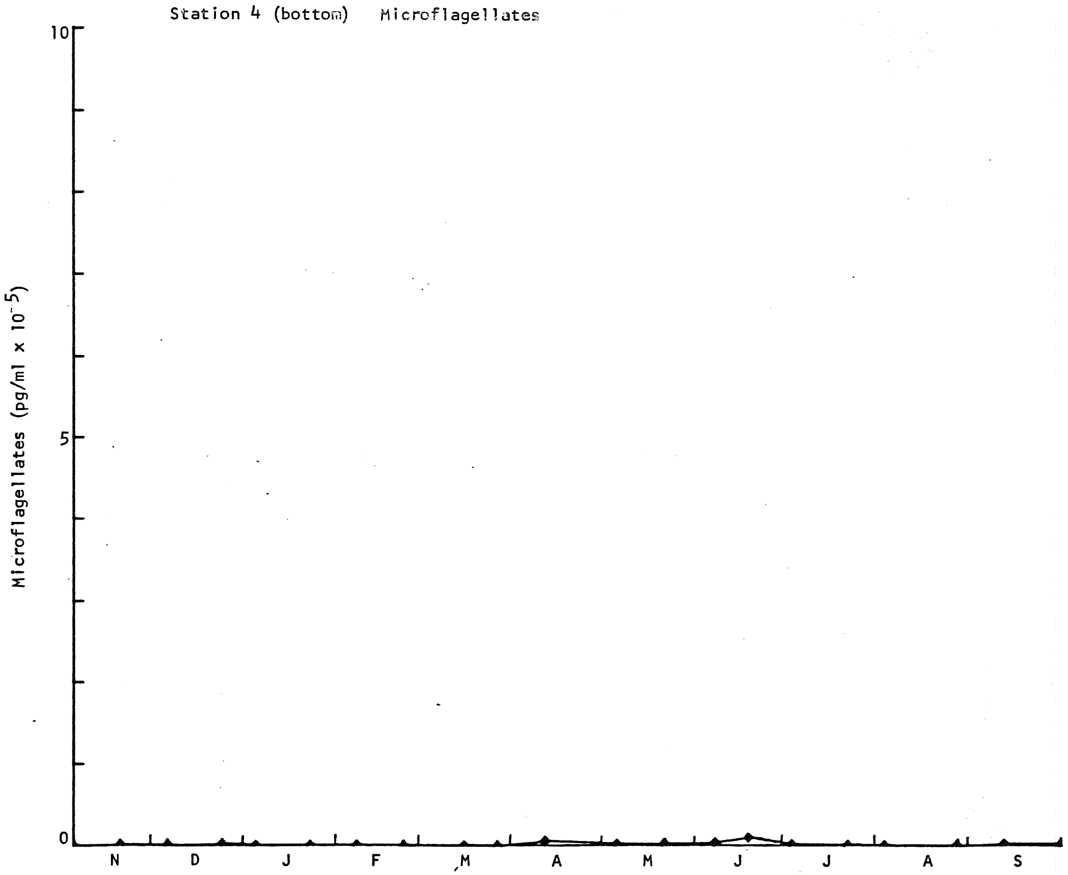
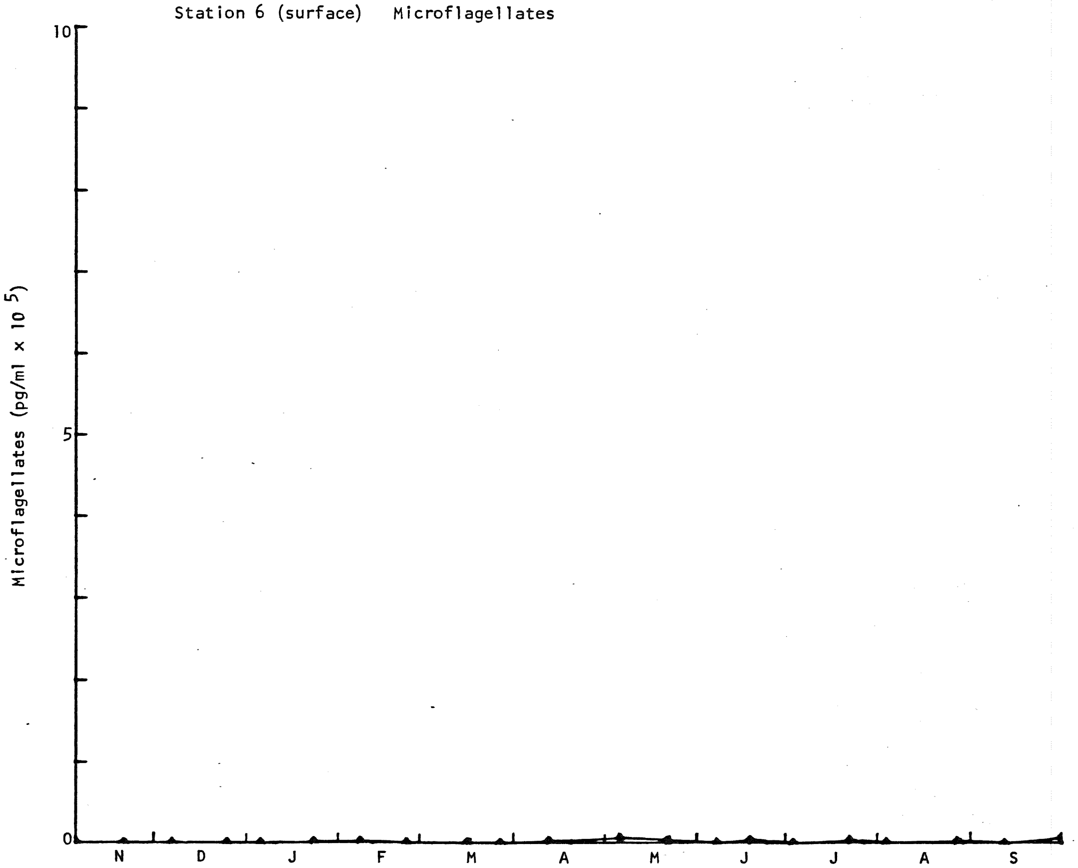


Figure 6 cont.



Time (November 7, 1976 — September 28, 1977) Figure 6 cont.



Time (November 7, 1976 — September 28, 1977) Figure 6 cont.

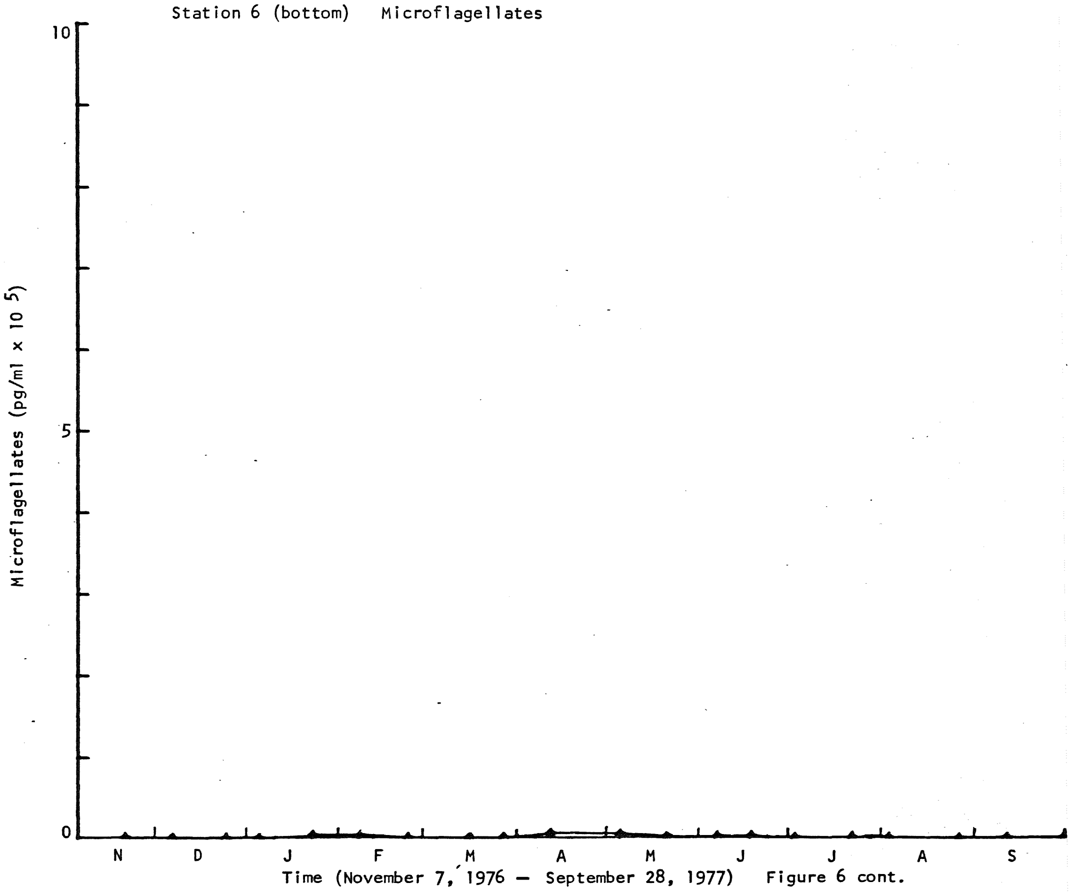


Figure 6 cont.

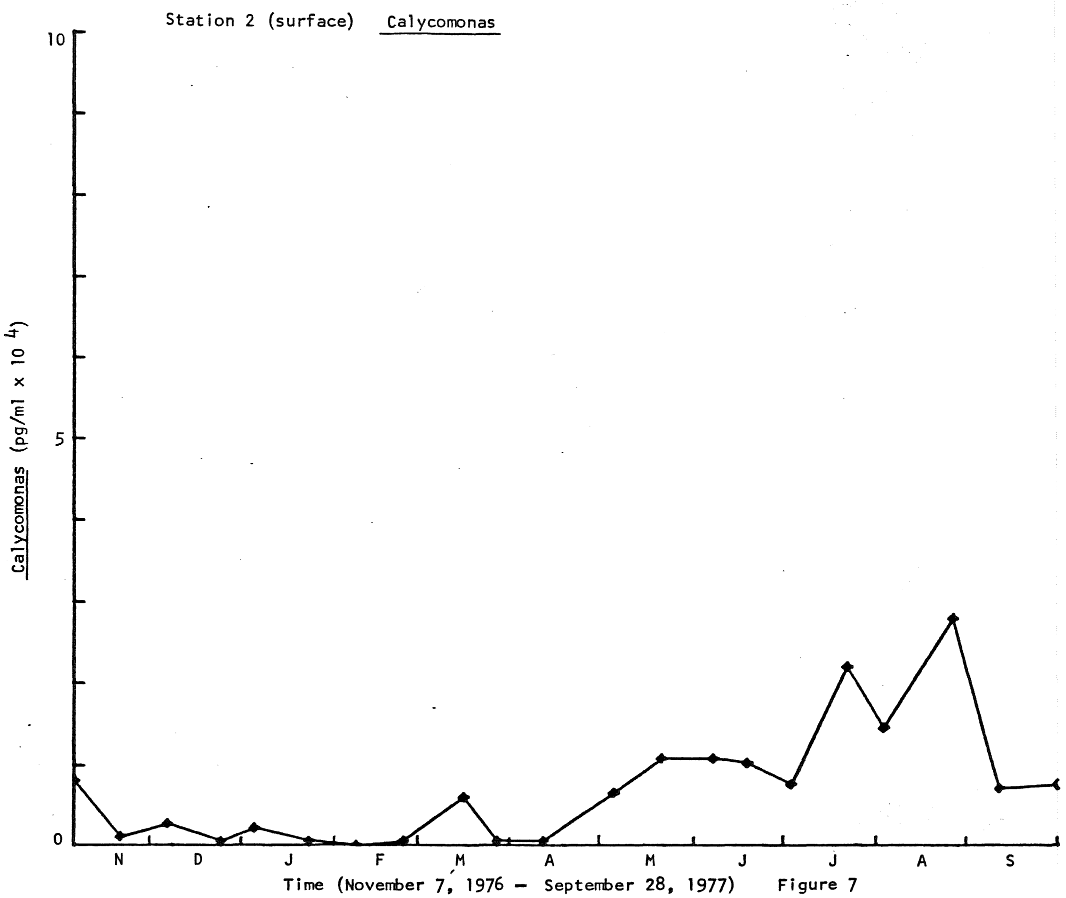

Station 2 (surface) Calycomonas
10
5
0
Calycomonas (pg/ml x 10 ^{4})
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 – September 28, 1977)

Figure 7

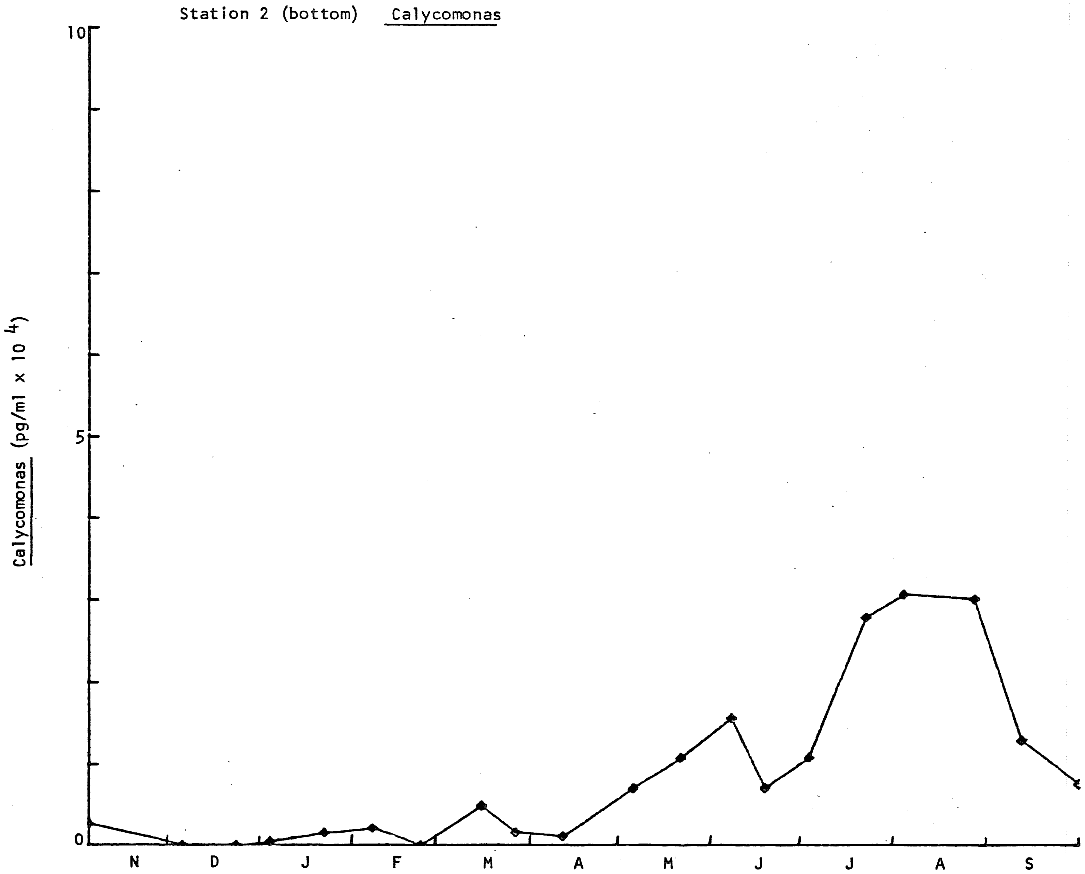


Figure 7 cont.

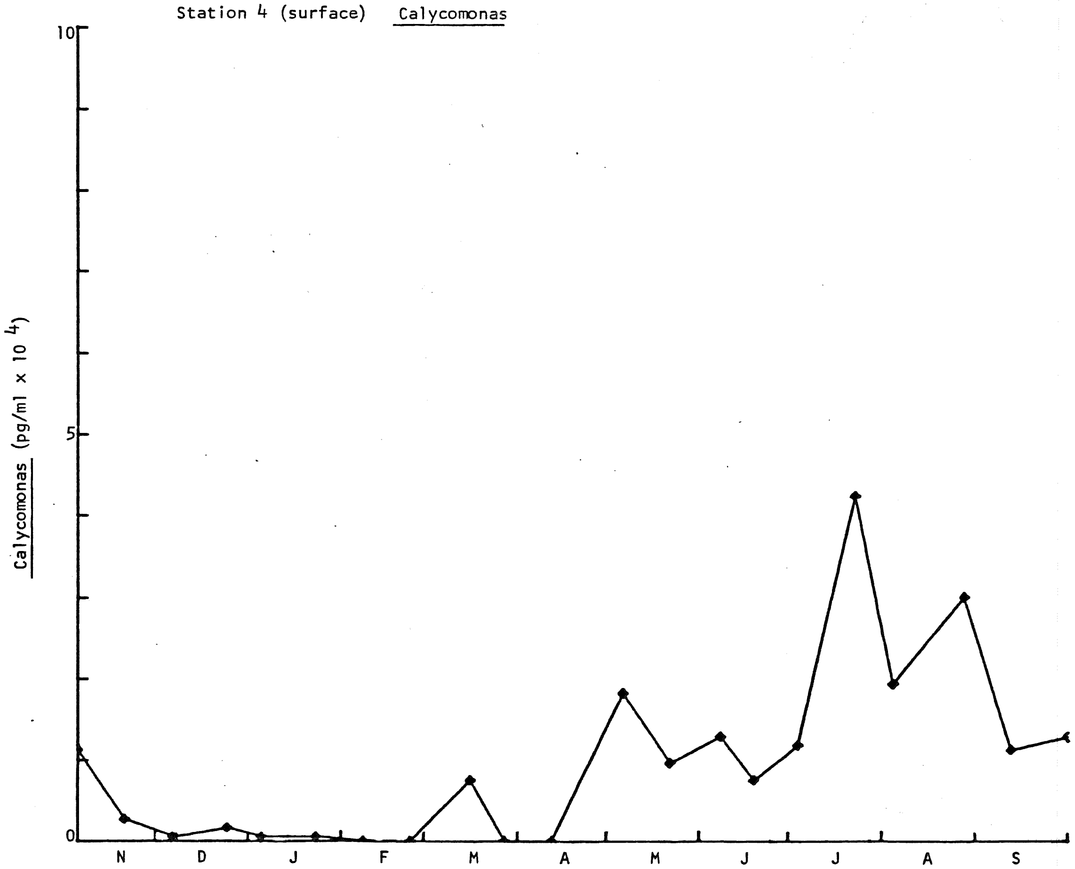


Figure 7 cont.

Station 4 (bottom) Calycomonas

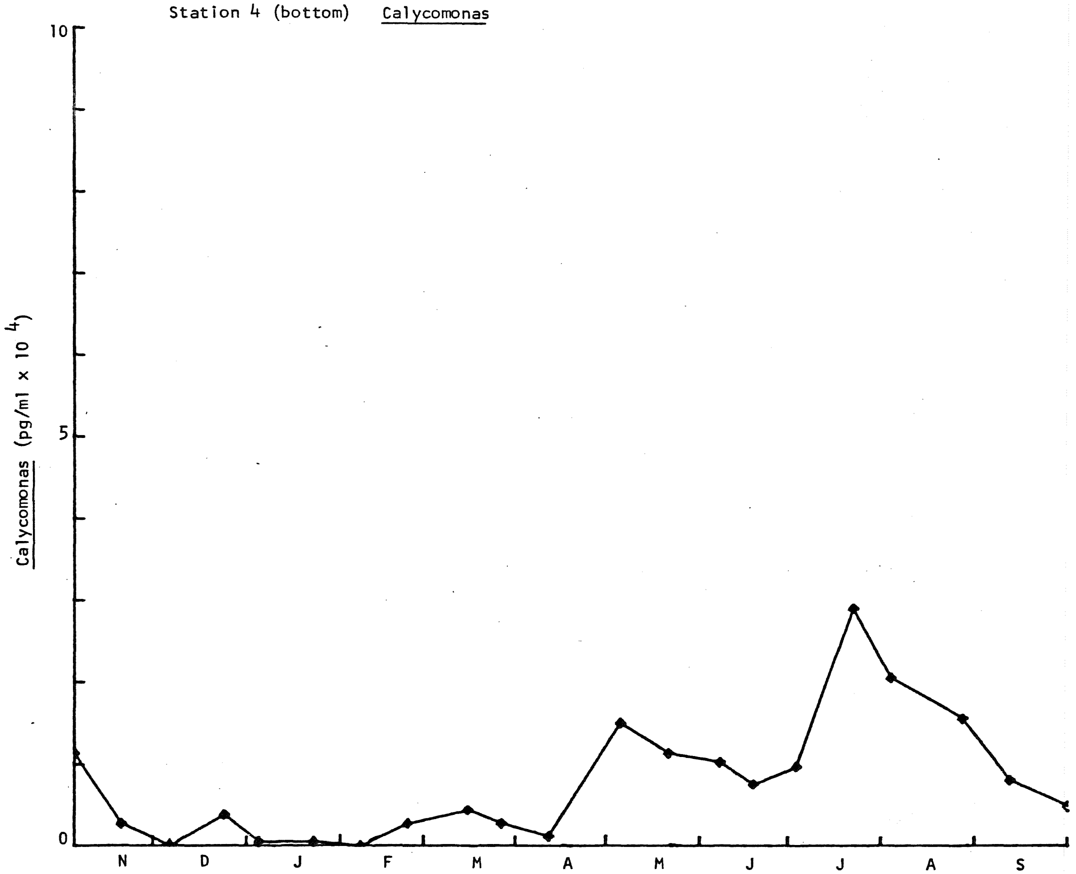


Figure 7 cont.

Station 6 (surface) _Calycomonas_

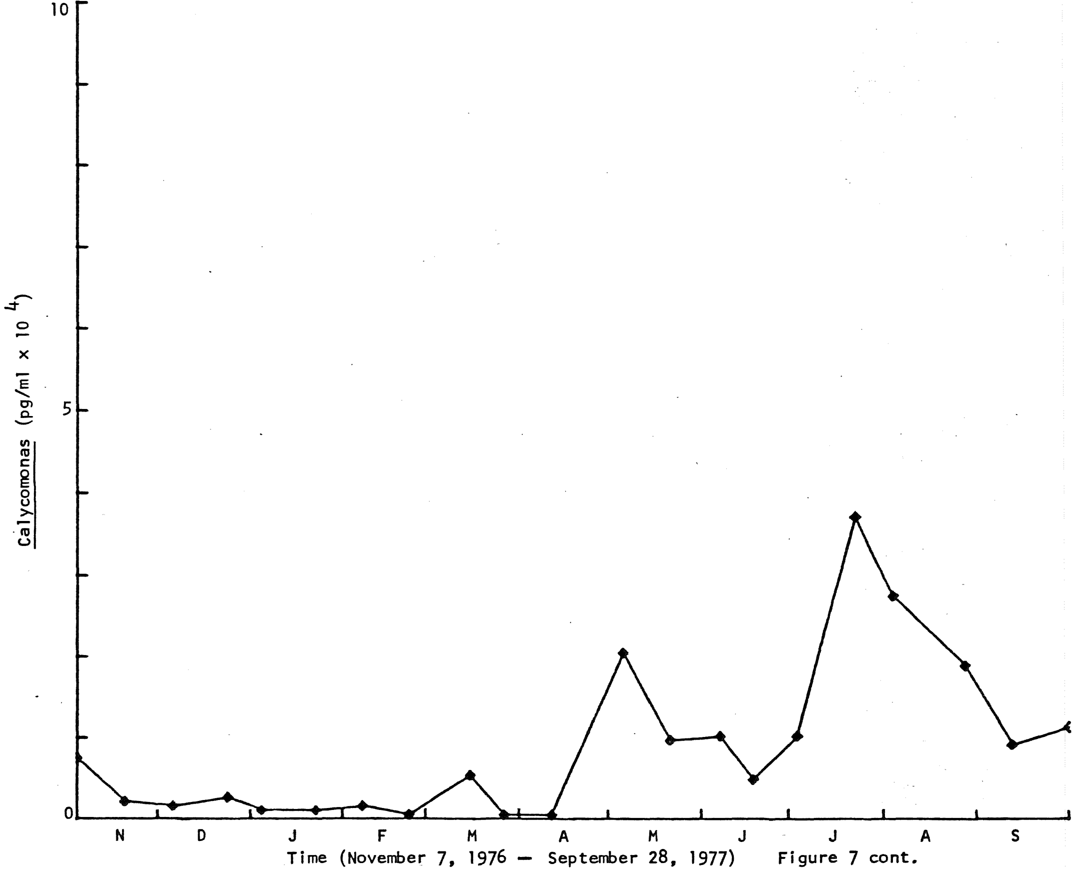


Figure 7 cont.

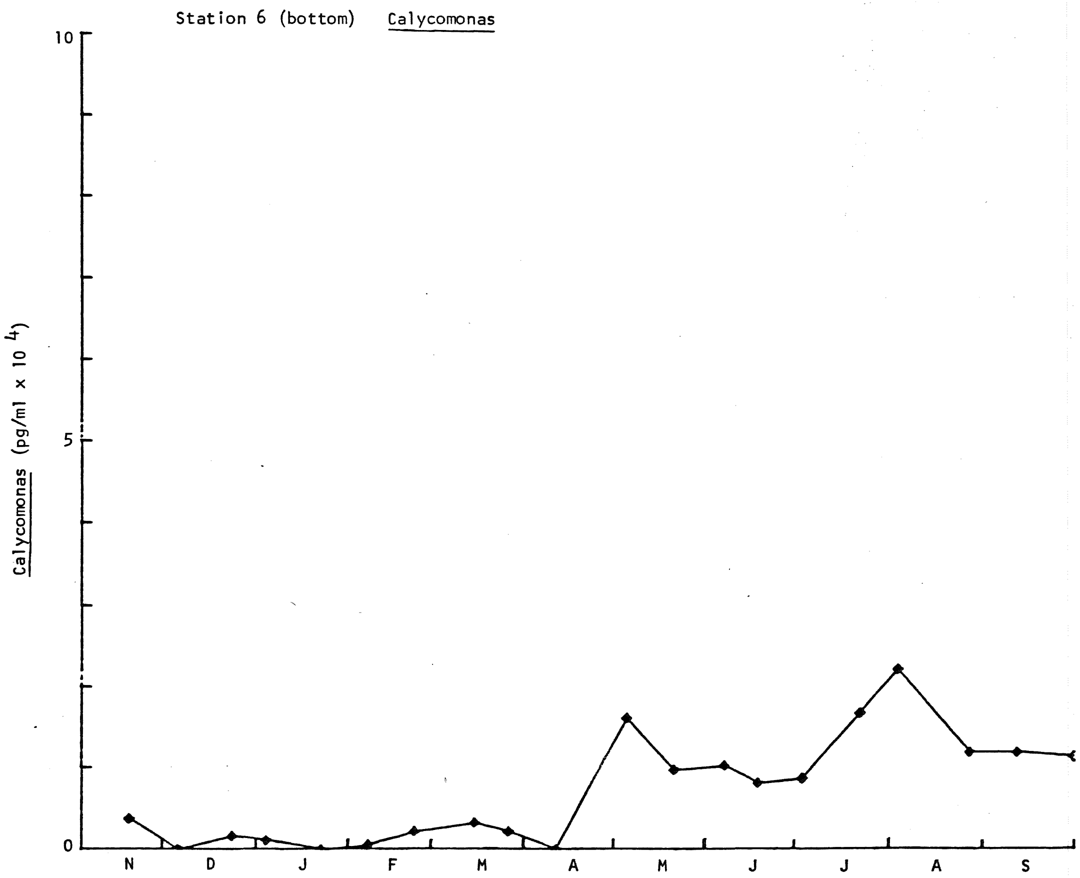


Figure 7 cont.

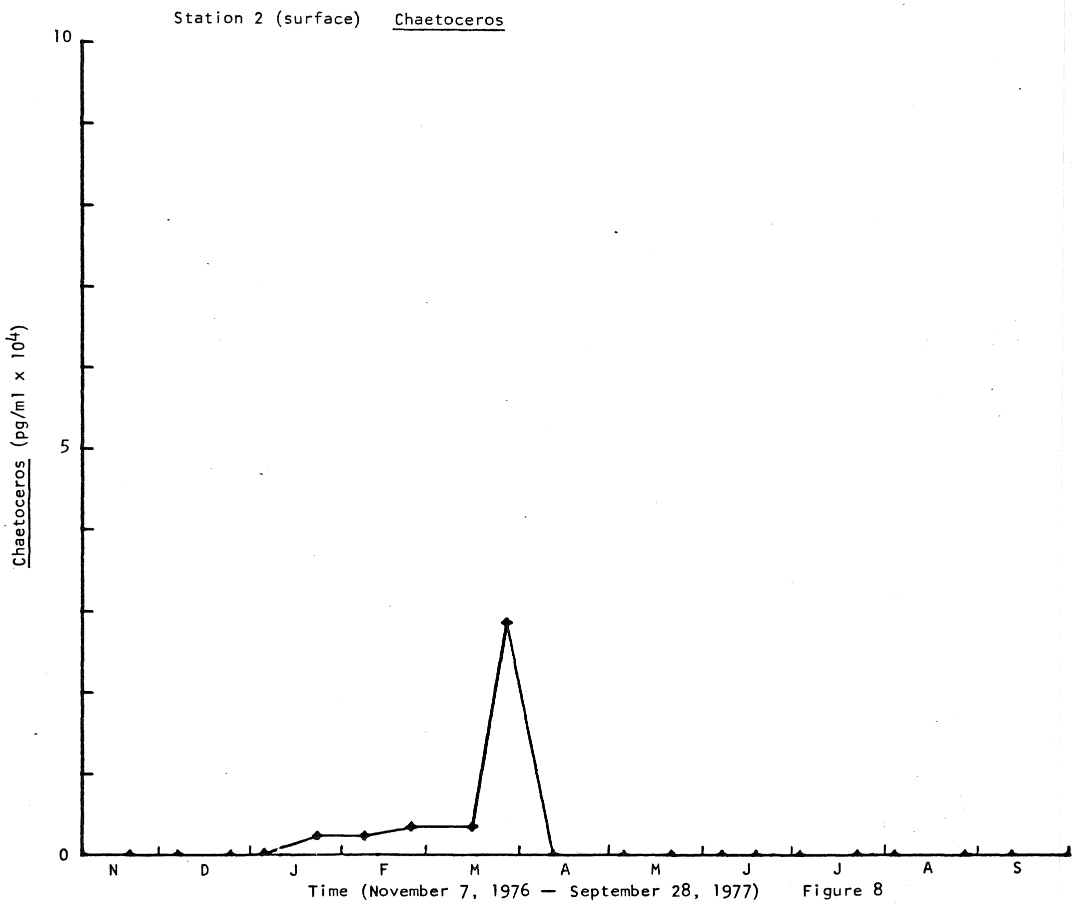

Station 2 (surface) *Chaetoceros*
10
5
0
Chaetoceros (pg/ml x 10^4)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 — September 28, 1977)

Figure 8

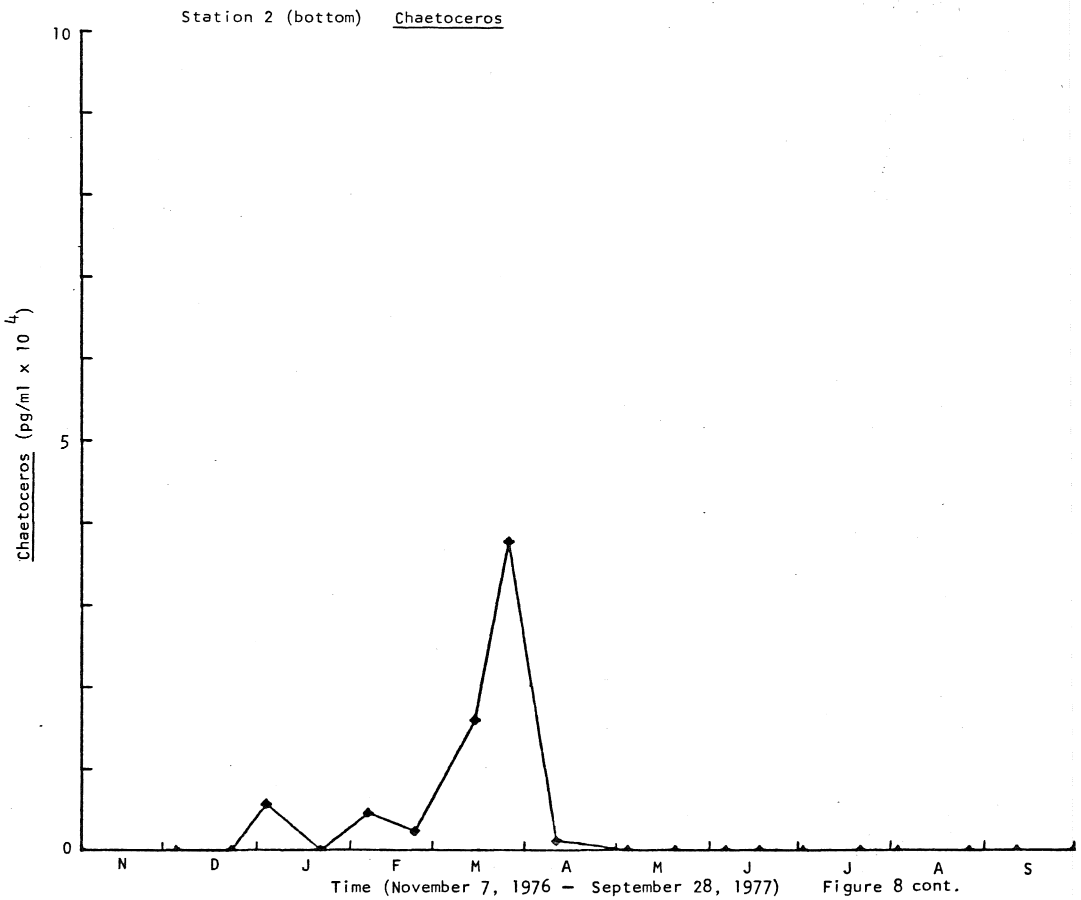


Figure 8 cont.

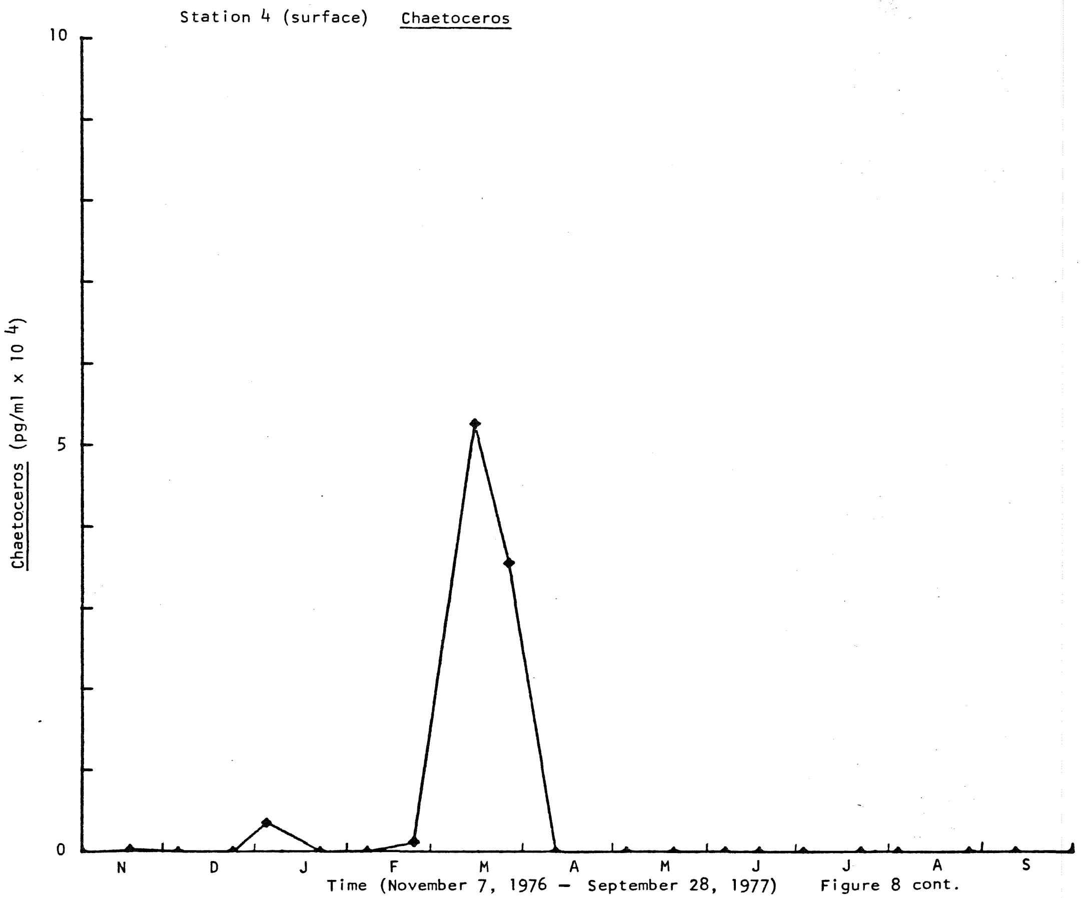


Figure 8 cont.

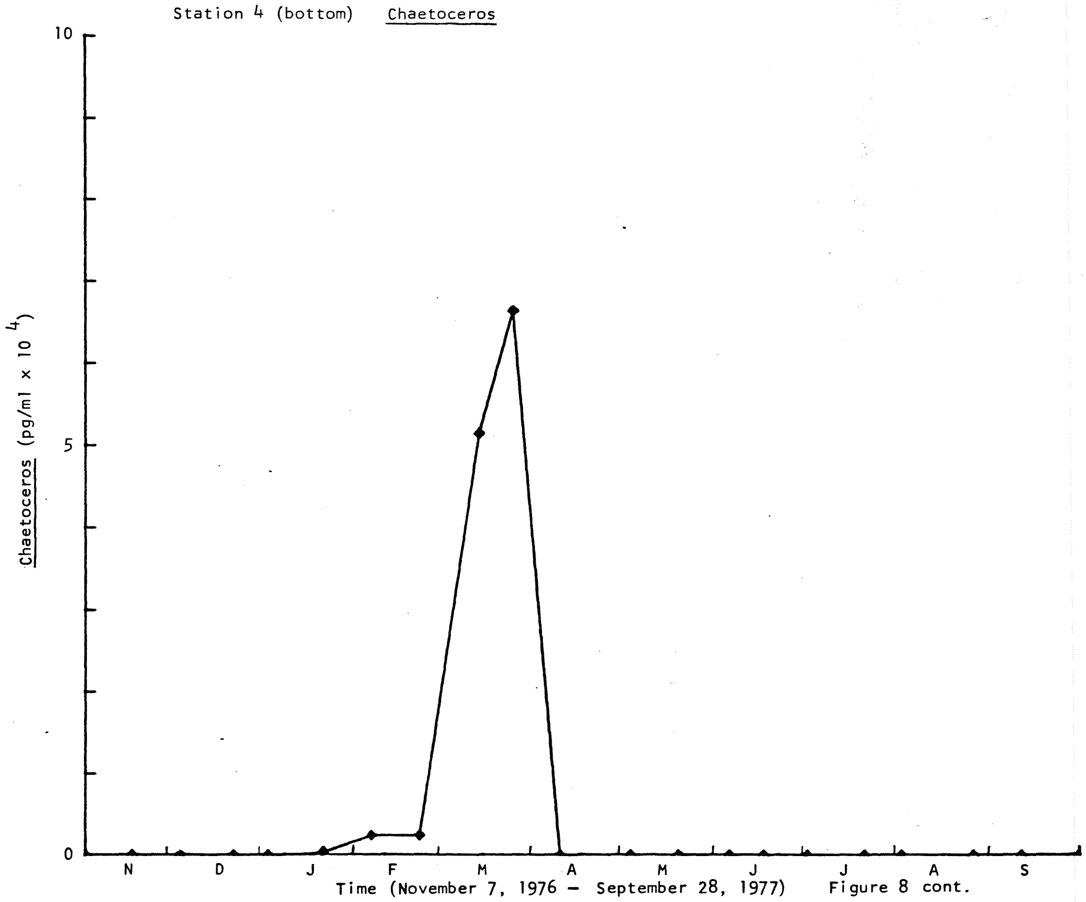


Figure 8 cont.

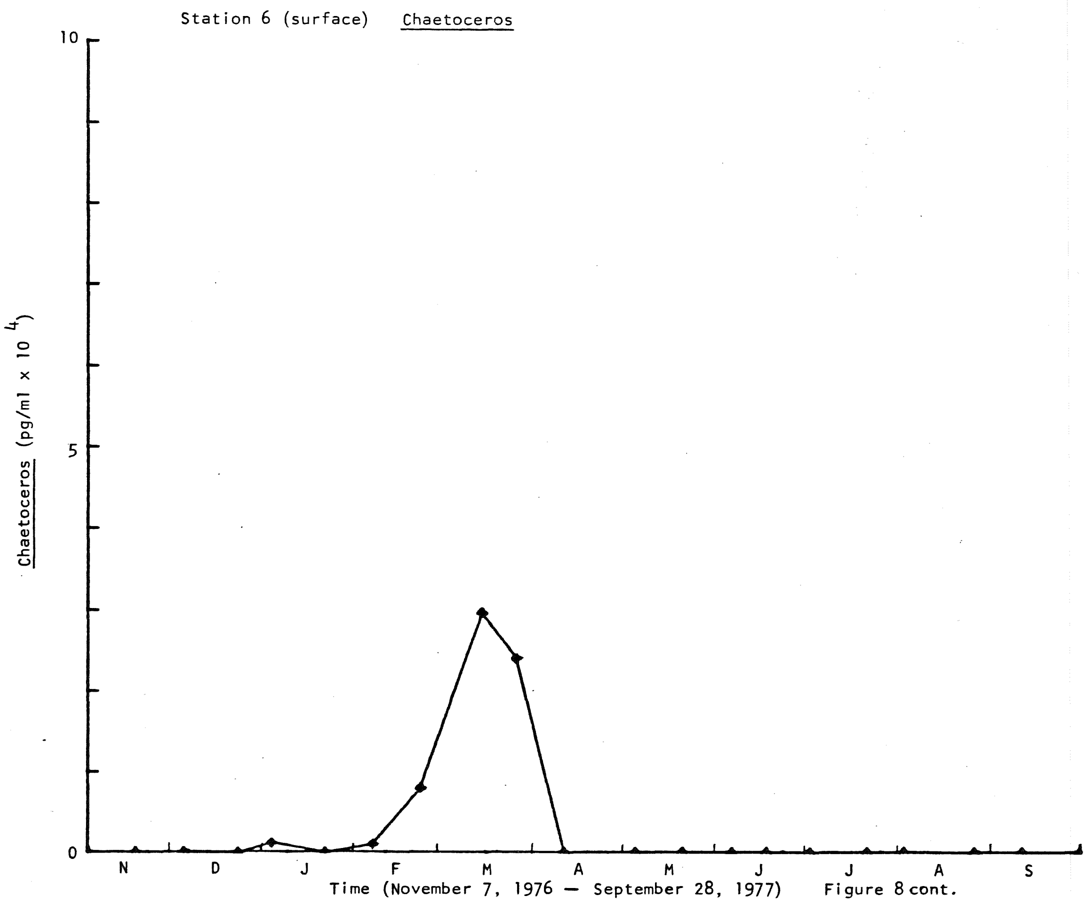

Station 6 (surface) Chaetoceros

Figure 8 cont.

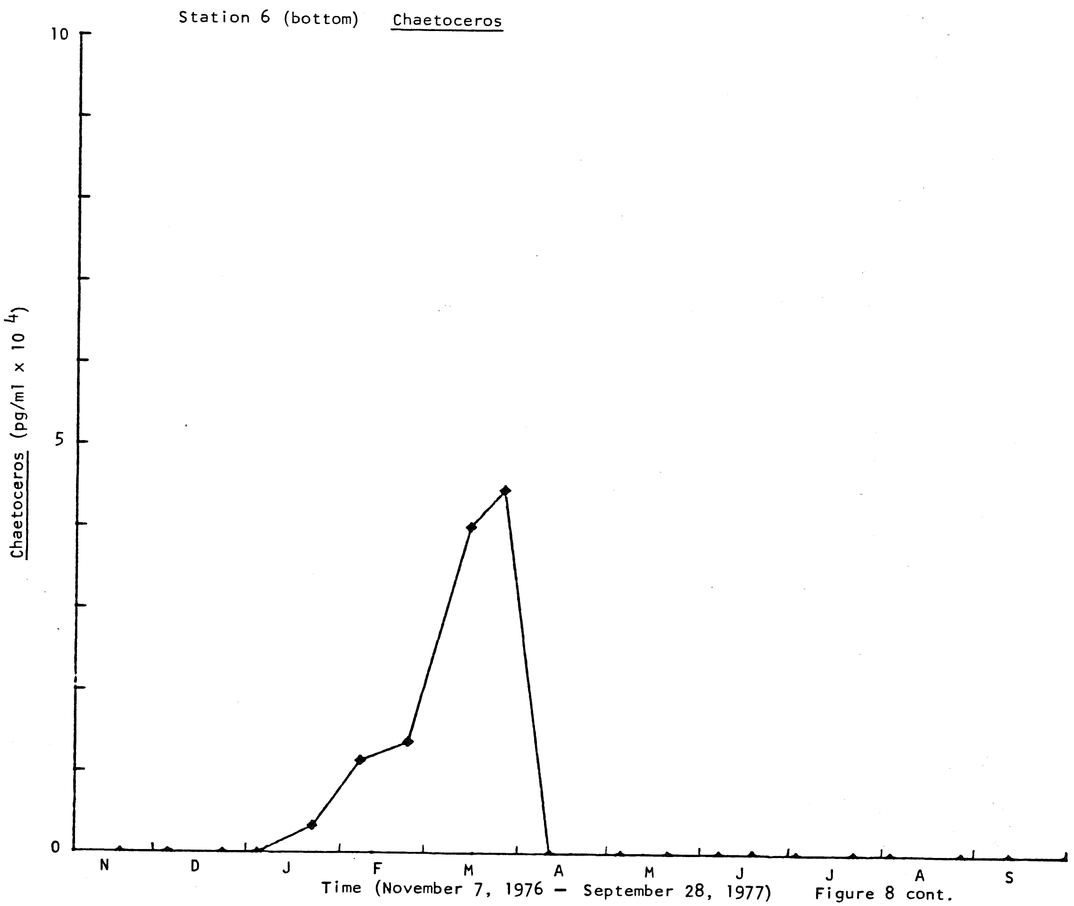
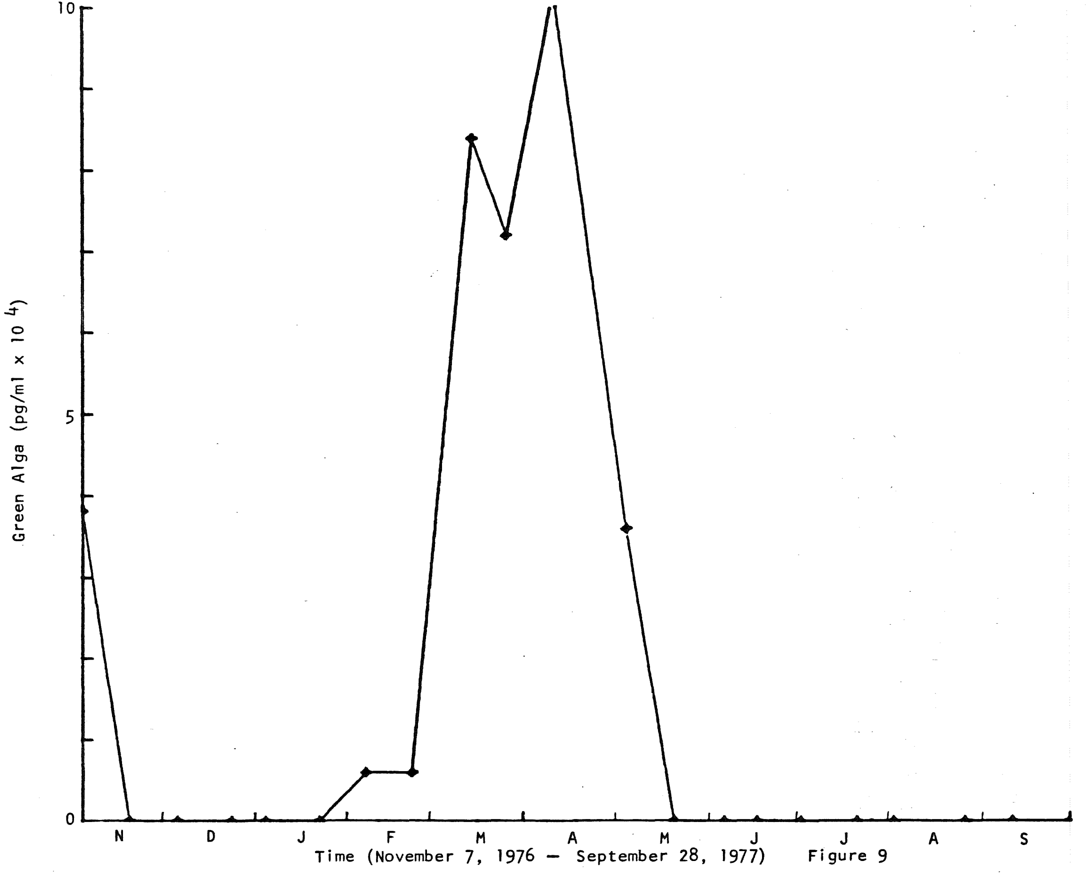


Figure 8 cont.



Station 2 (surface) Unidentified Green Alga

Figure 9

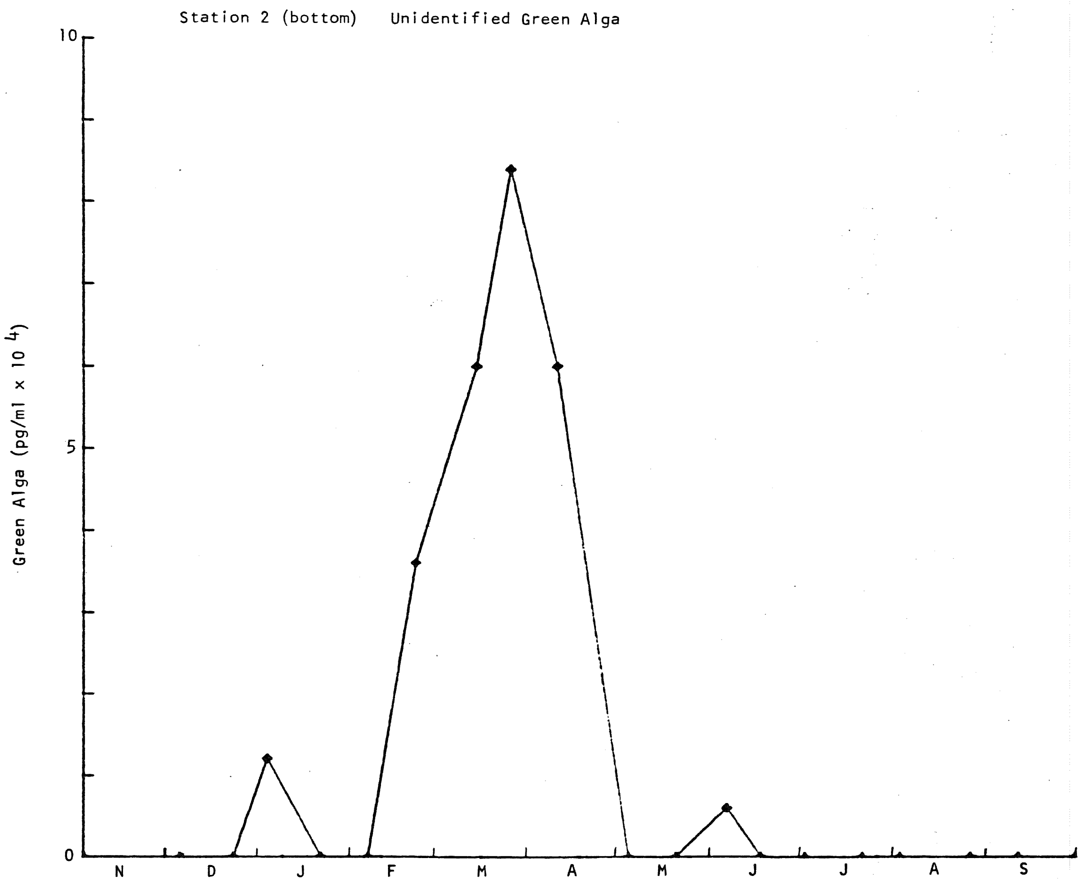

Station 2 (bottom) Unidentified Green Alga

Figure 9 cont.

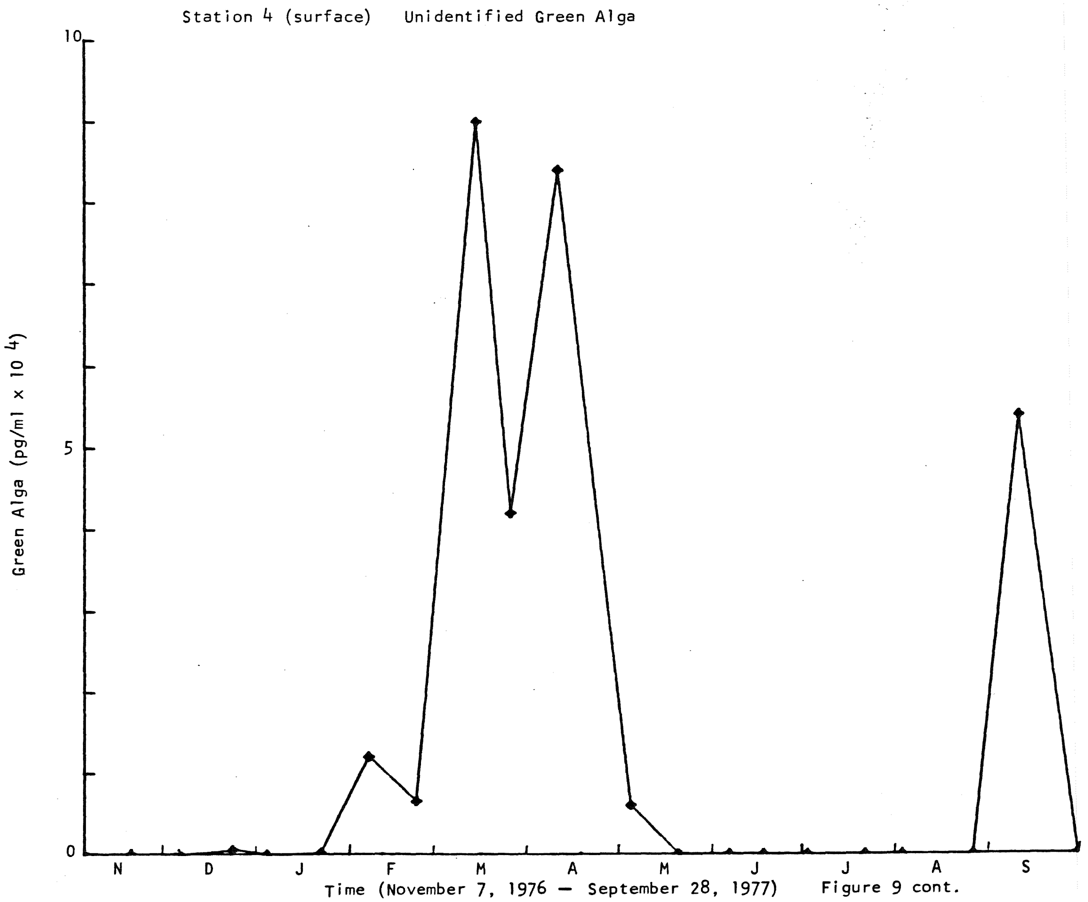
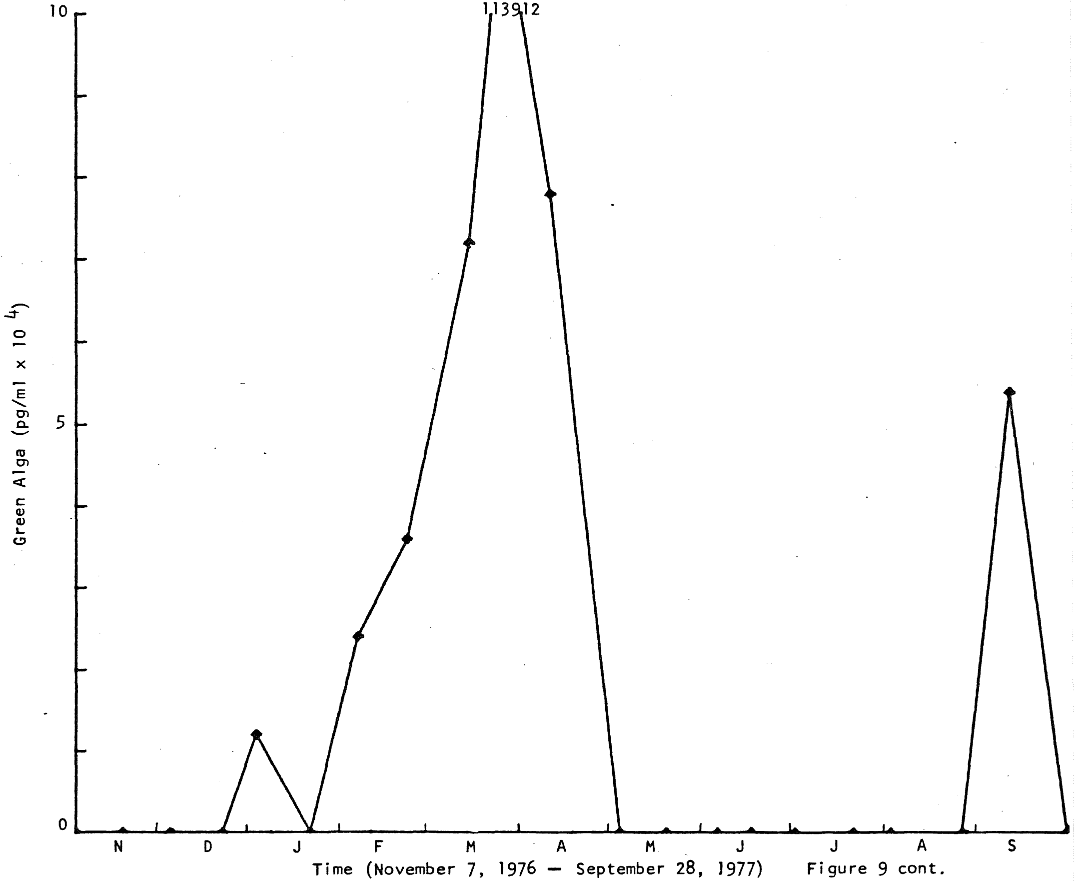


Figure 9 cont.



Station 4 (bottom) Unidentified Green Alga

Figure 9 cont.

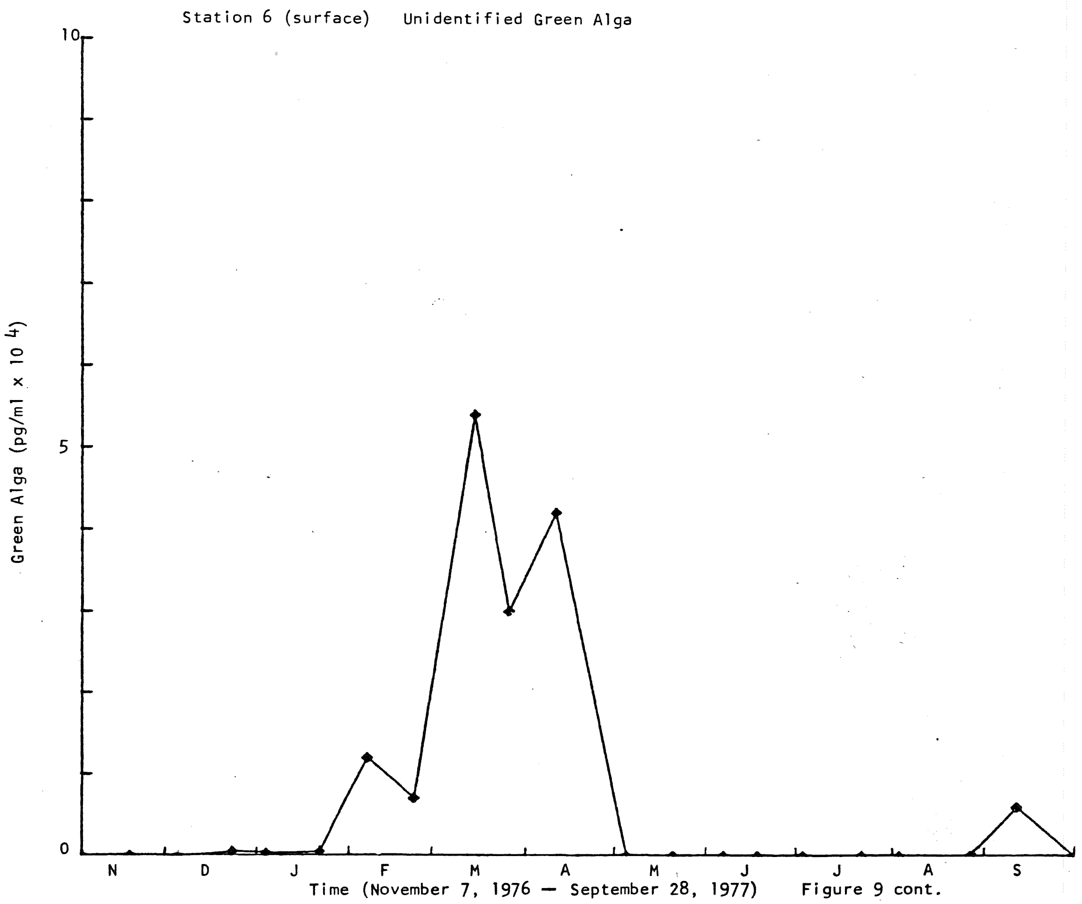


Figure 9 cont.

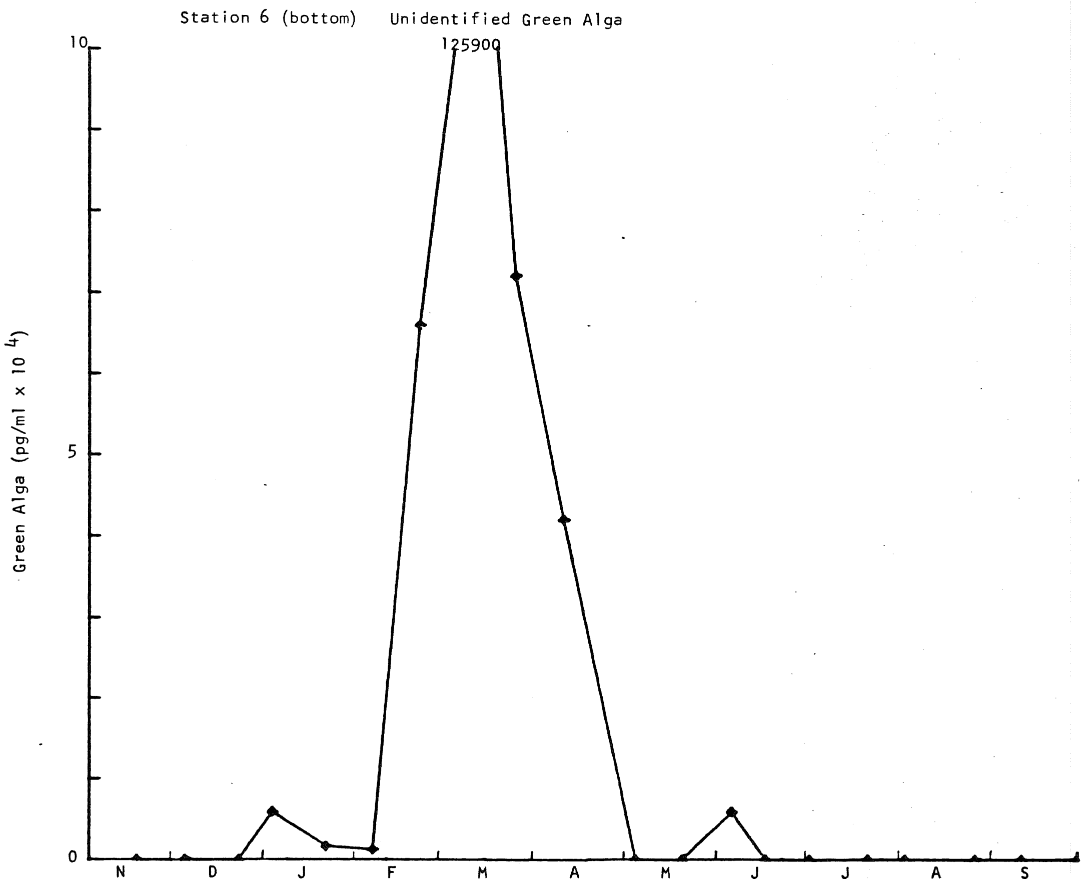


Figure 9 cont.

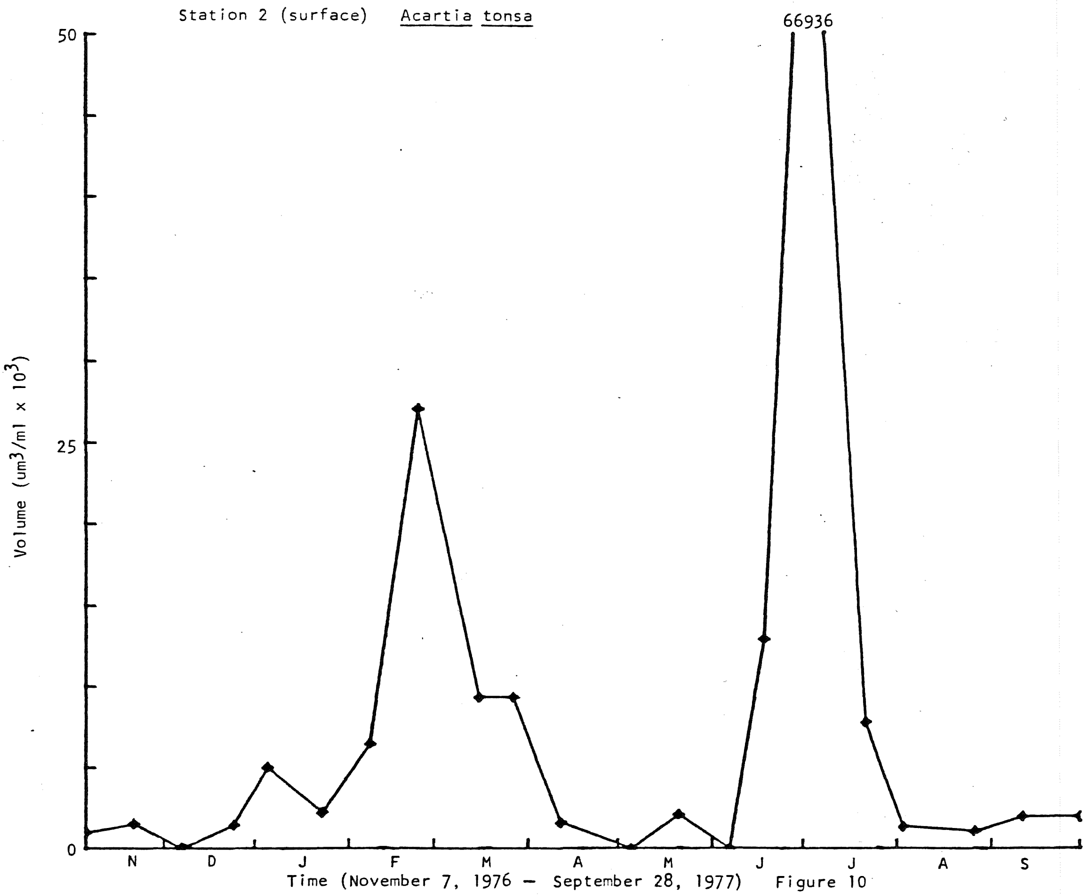

Station 2 (surface) Acartia tonsa
66936
50
25
0
Volume (um^3/ml x 10^3)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 — September 28, 1977)

Figure 10

Station 2 (bottom) <u>Acartia tonsa</u>

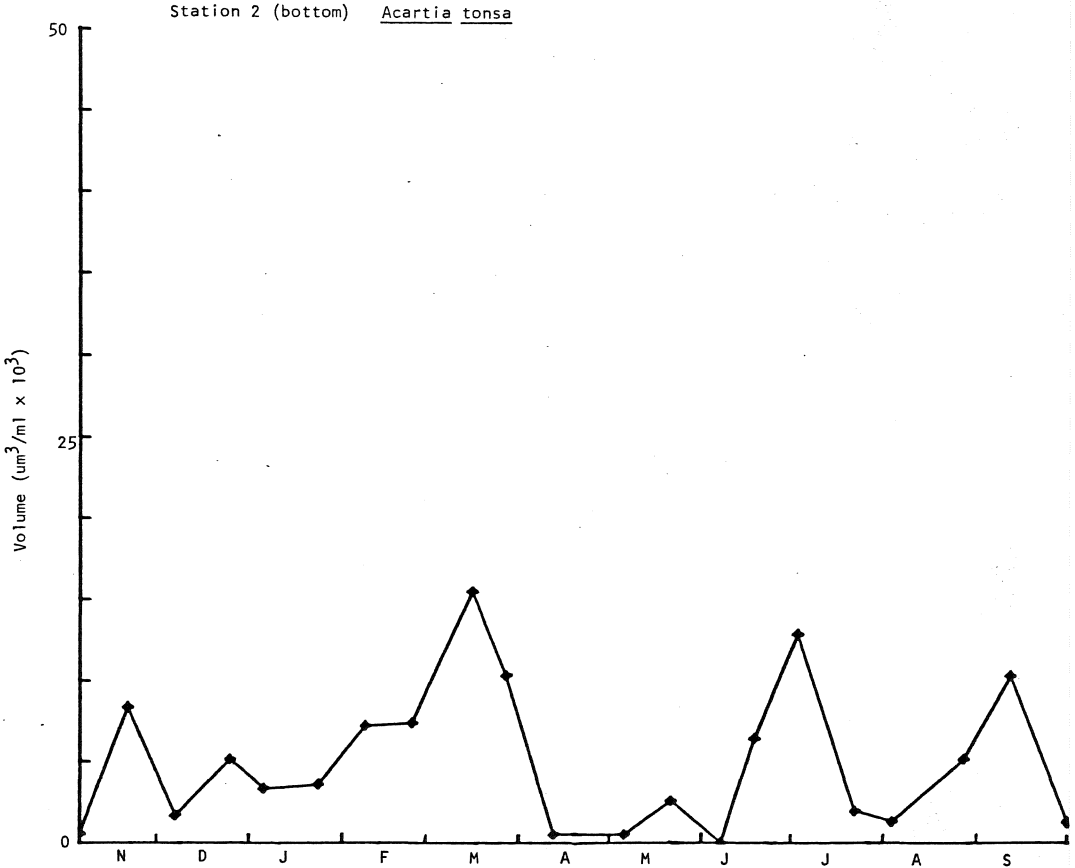


Figure 10 (cont.)

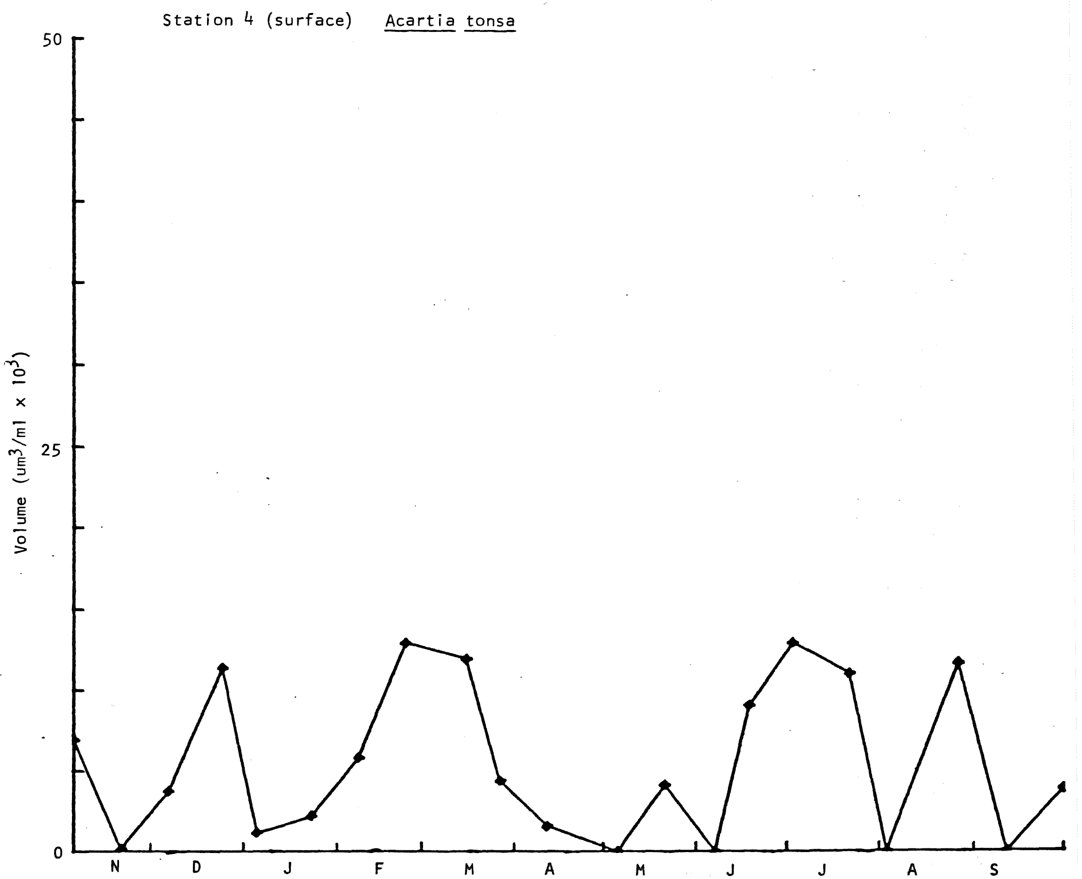


Figure 10 (cont.)

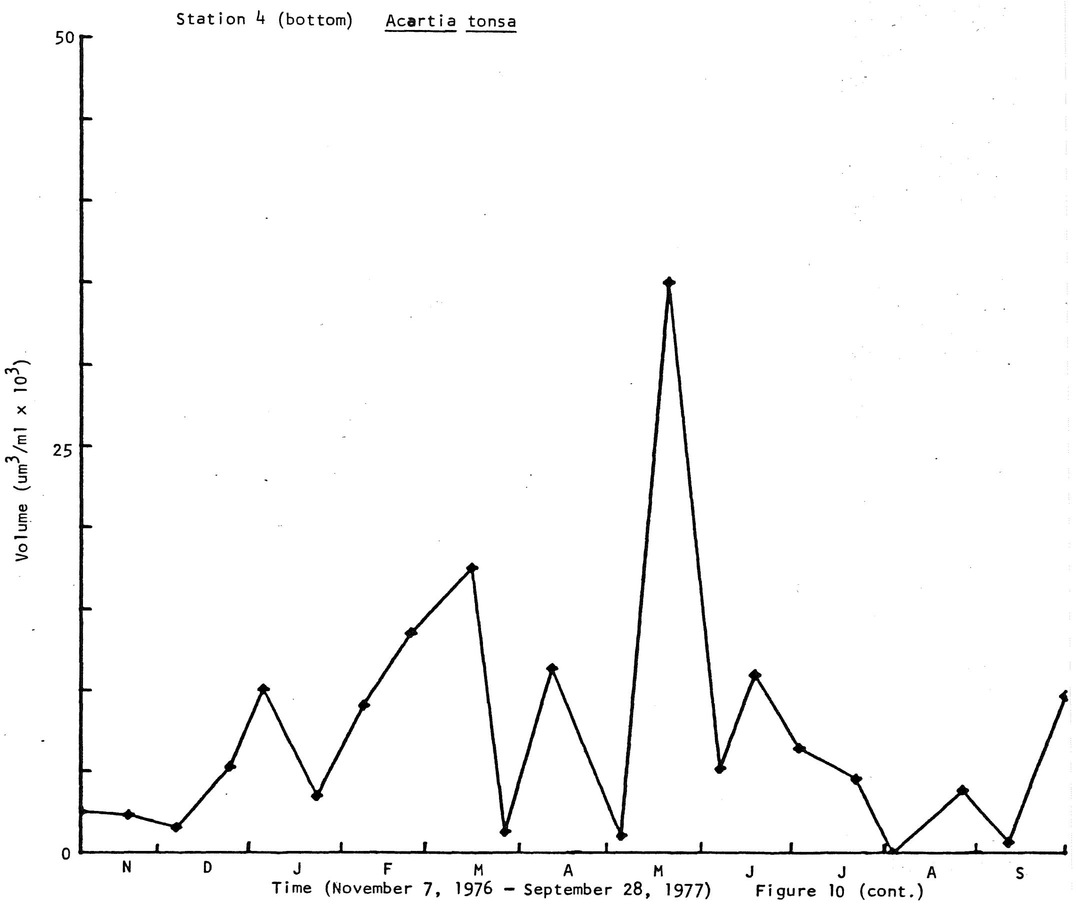


Figure 10 (cont.)

Station 6 (surface) Acartia tonsa

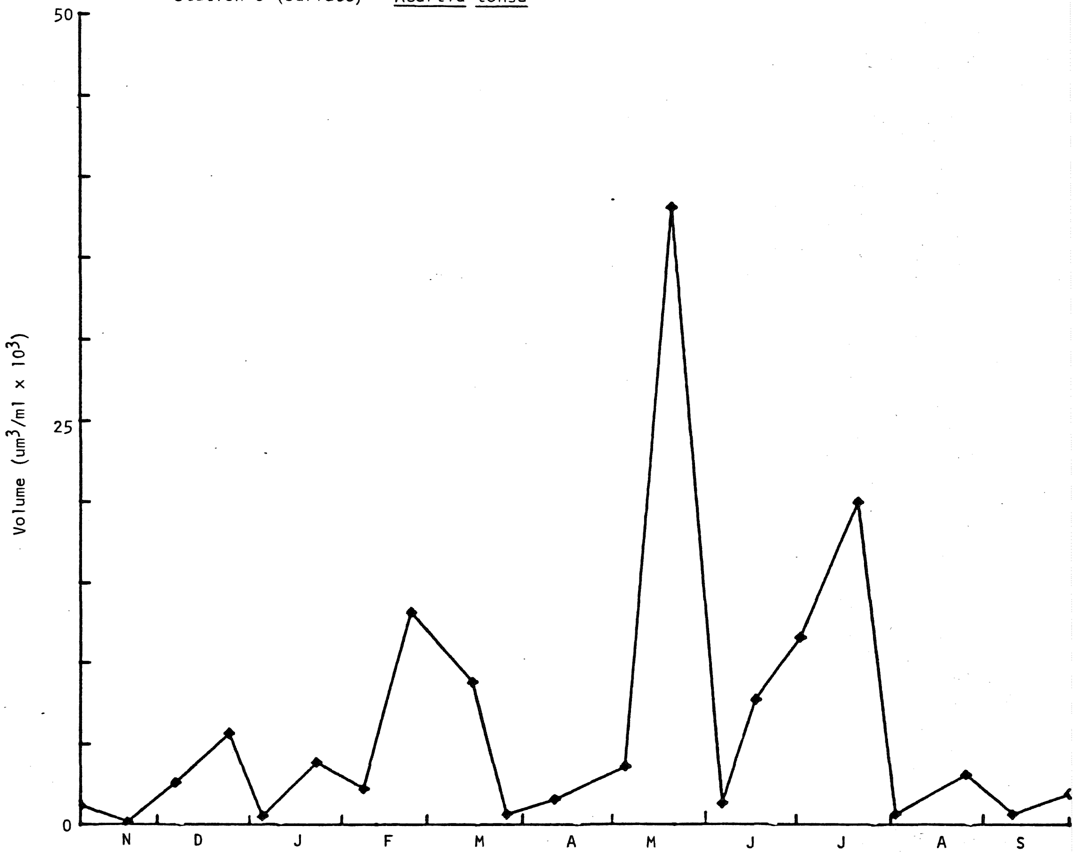


Figure 10 (cont.)

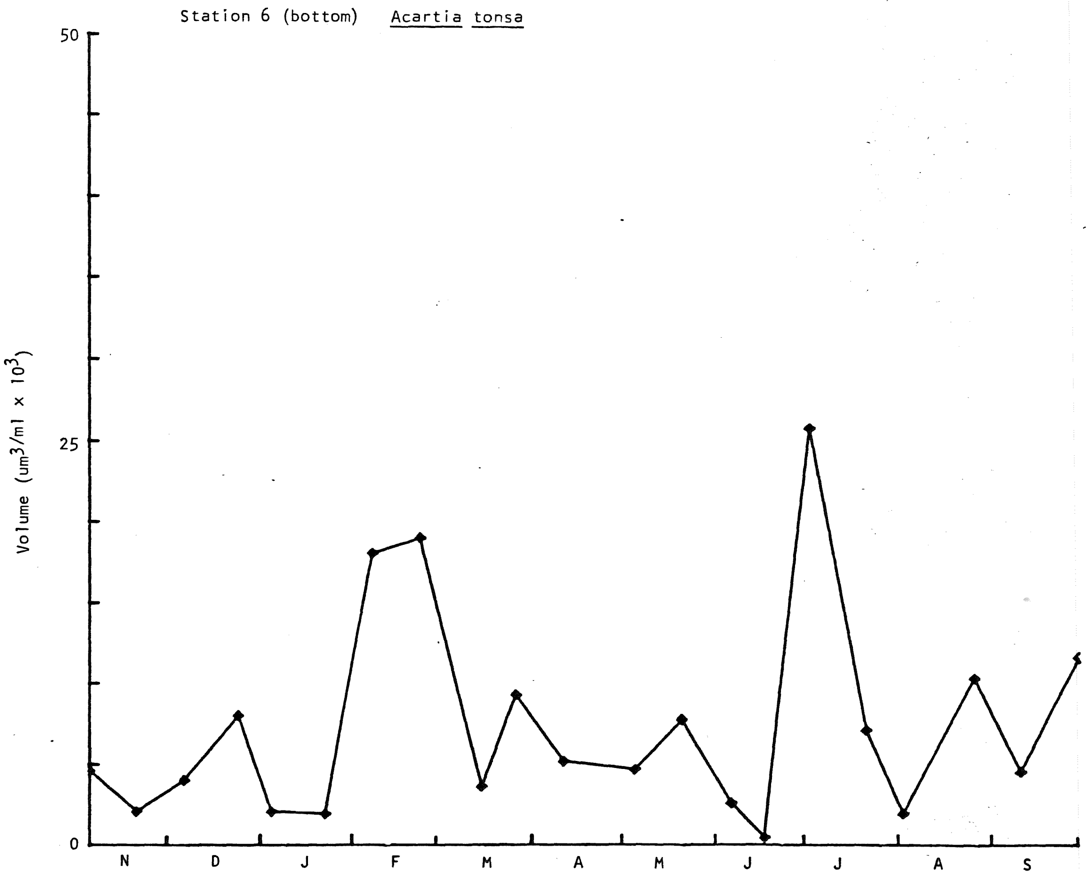


Figure 10 (cont.)

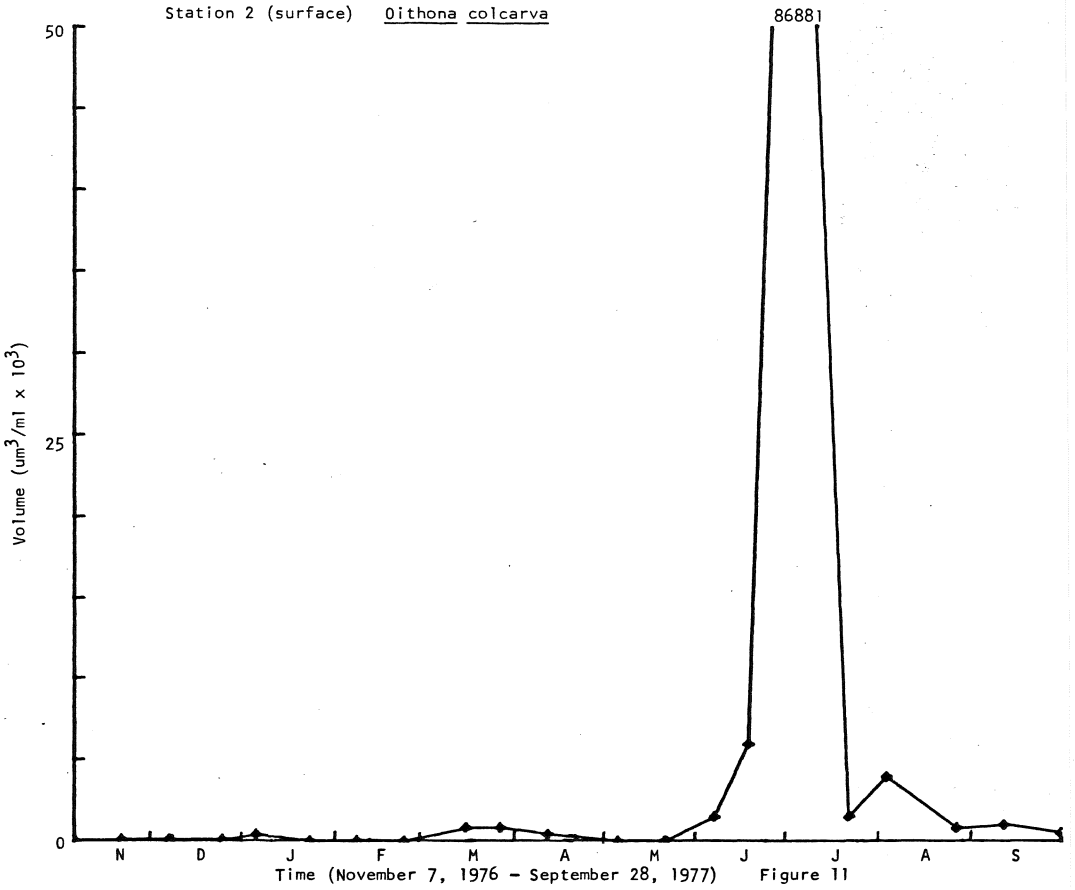

Station 2 (surface) Oithona colcarva
86881
50
25
0
Volume (um^3/ml x 10^3)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 – September 28, 1977)

Figure 11

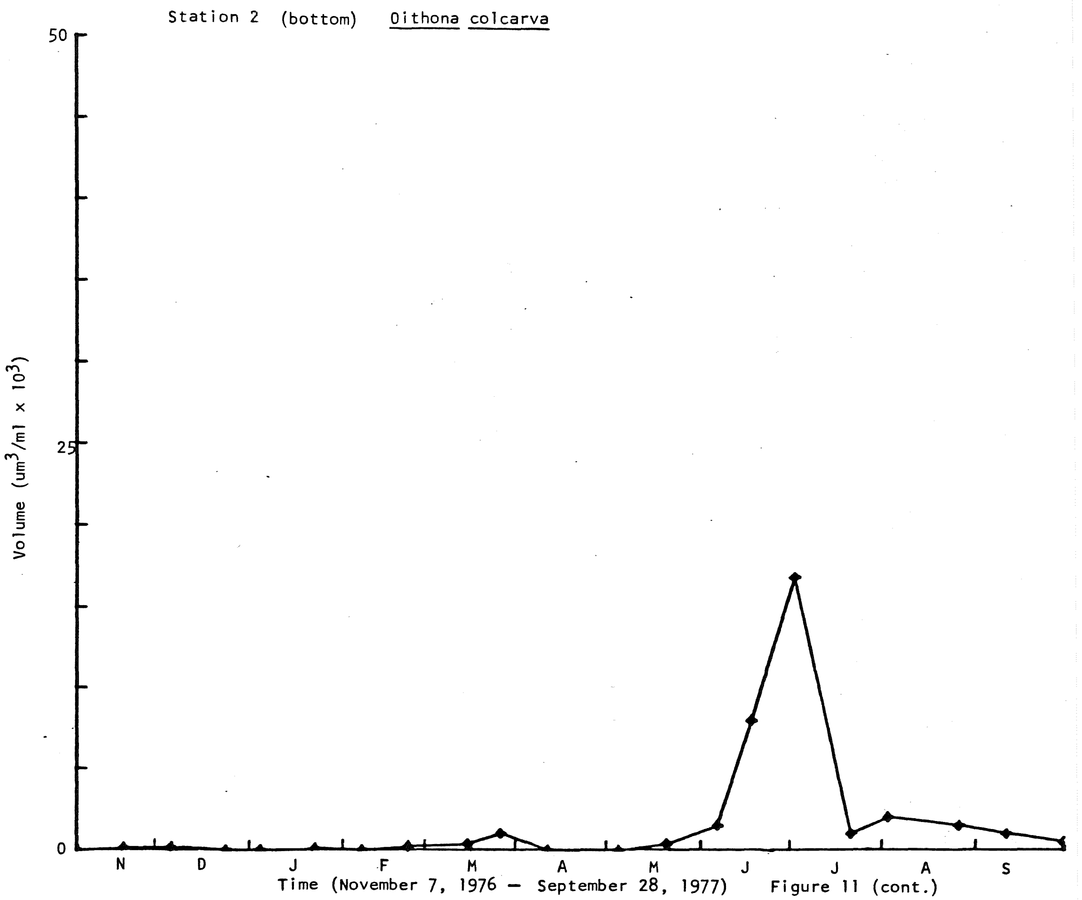


Figure 11 (cont.)

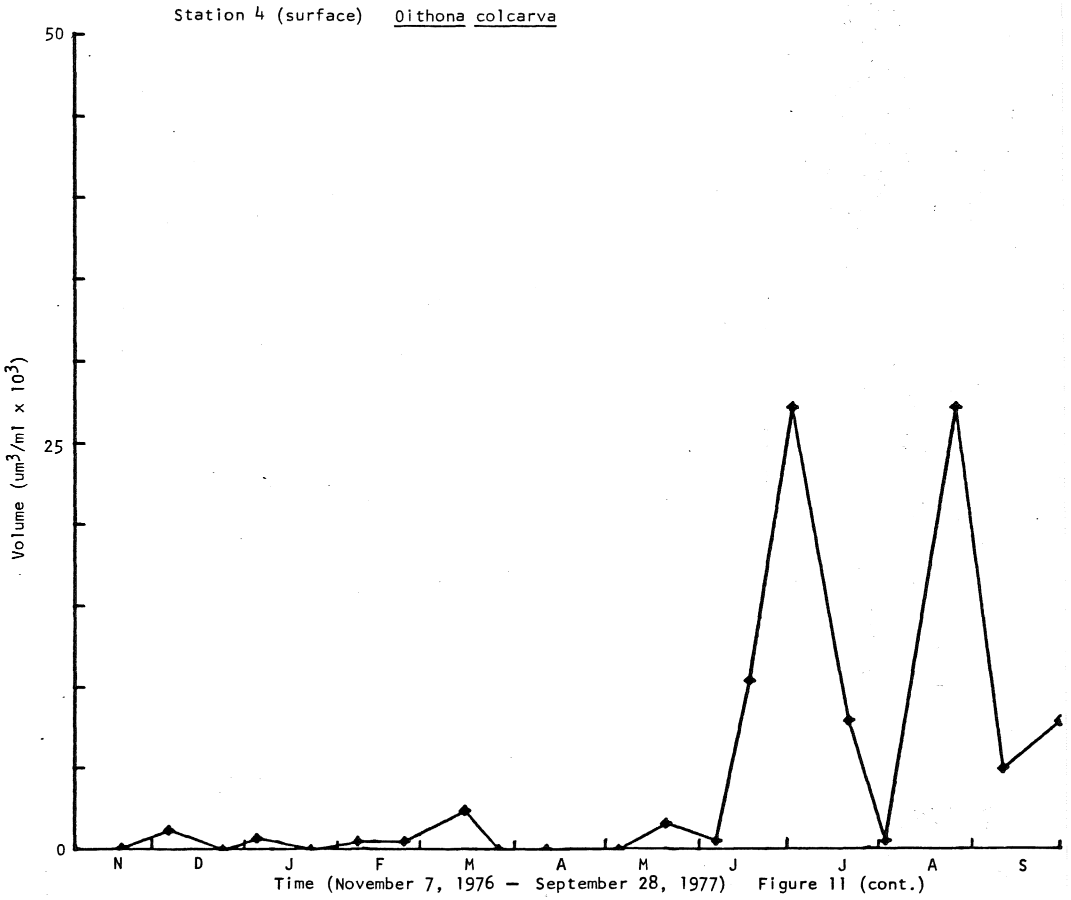


Figure 11 (cont.)

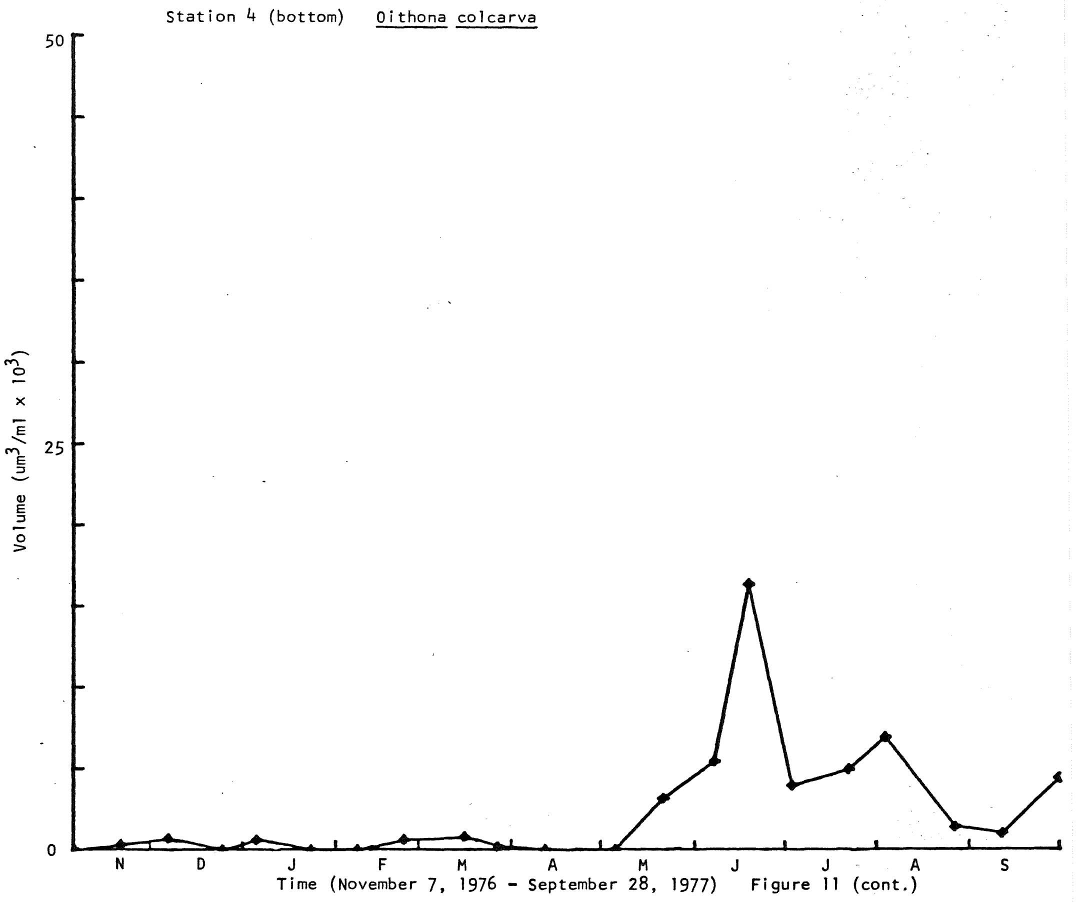


Figure 11 (cont.)

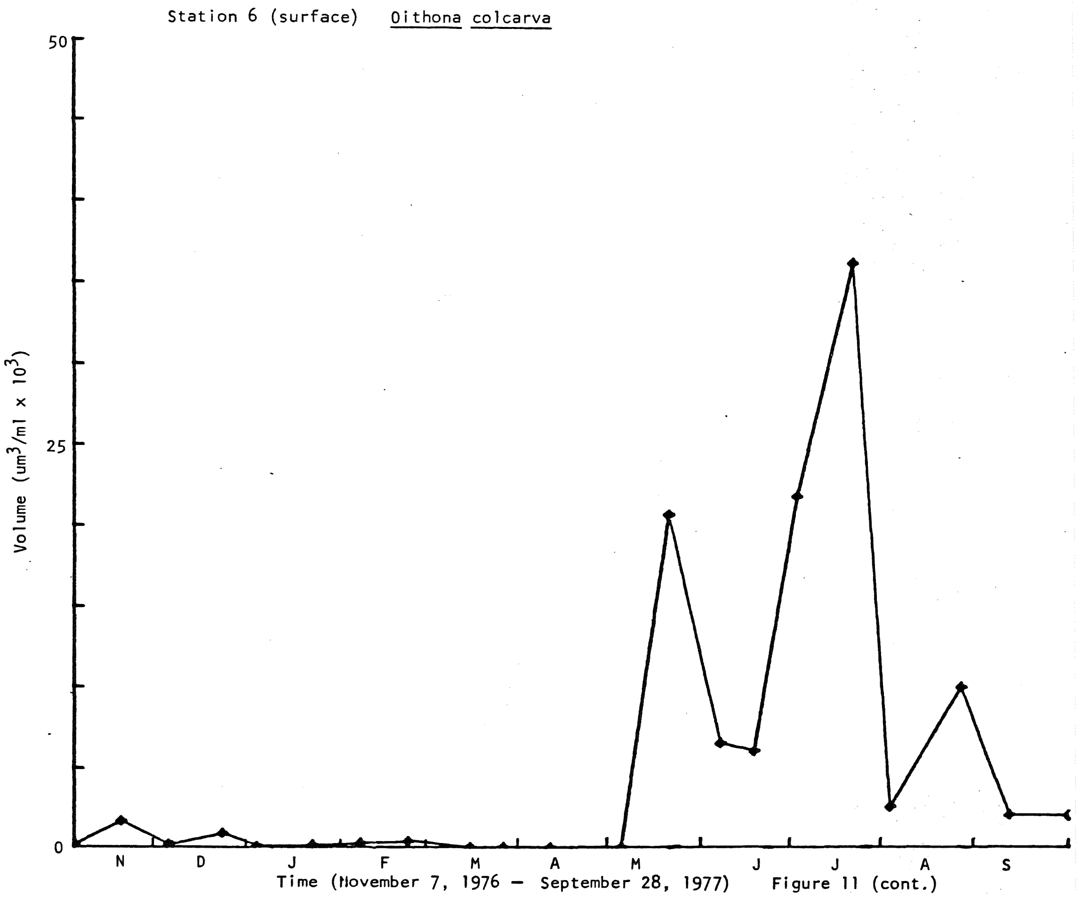


Figure 11 (cont.)

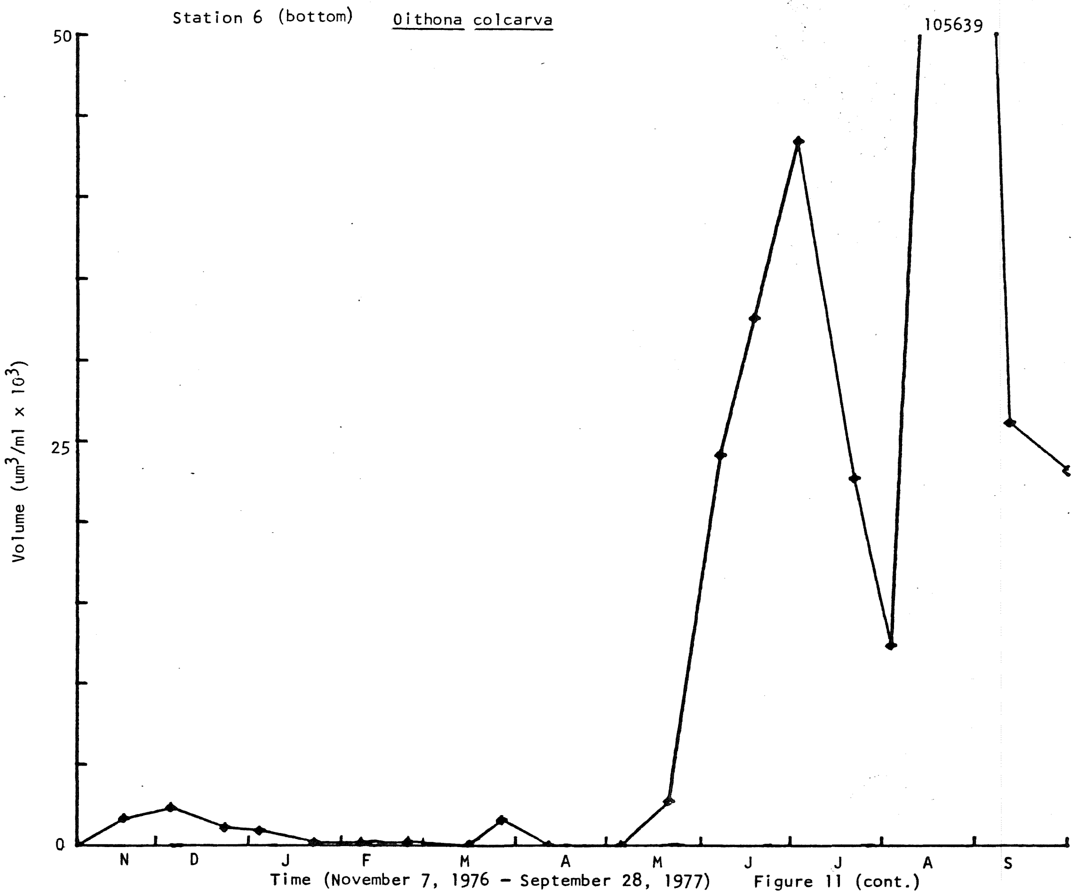


Figure 11 (cont.)

Station 2 (surface) <u>Synchaeta</u> sp.

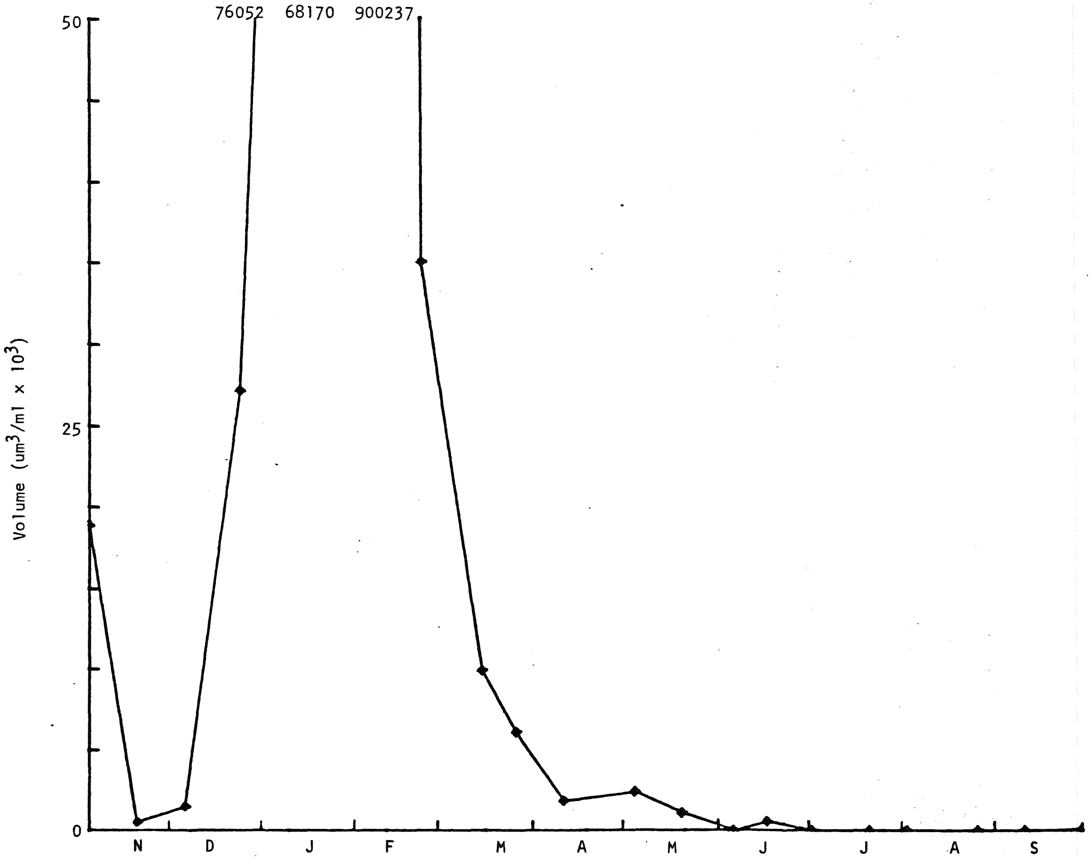
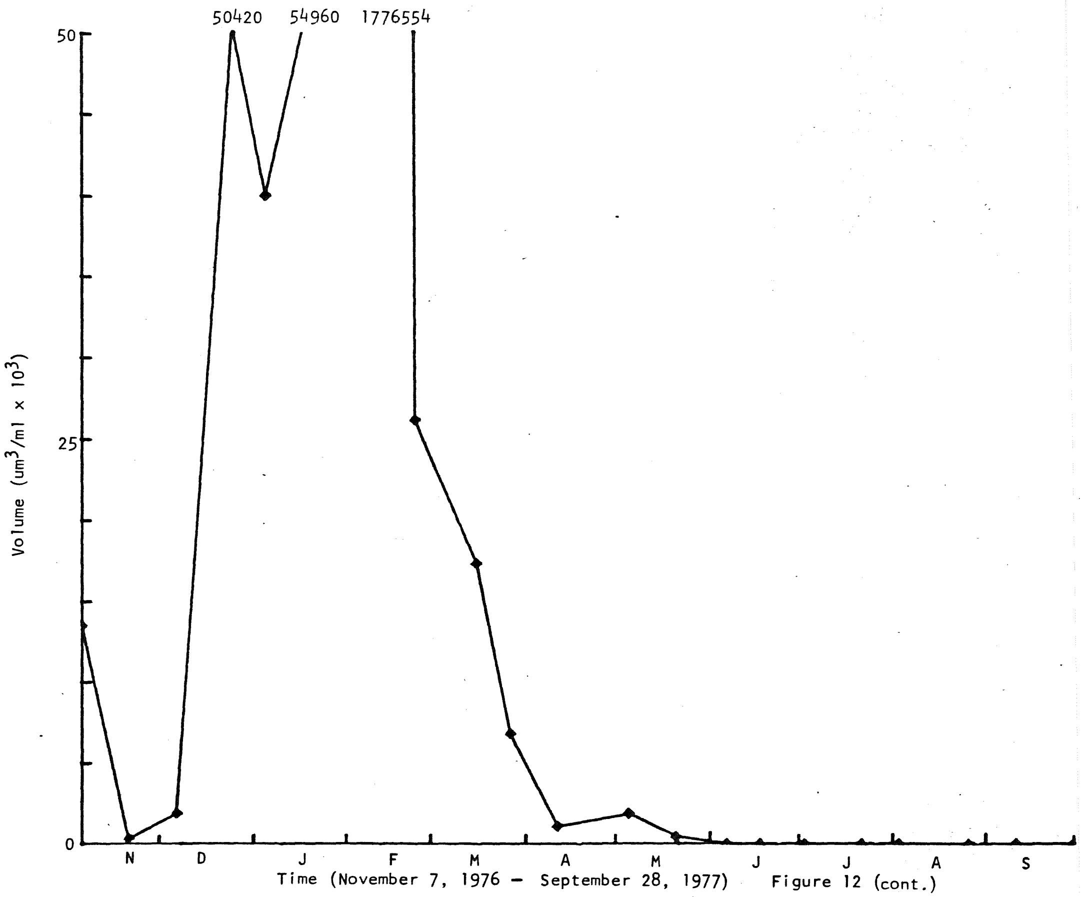


Figure 12



Station 2 (bottom) *Synchaeta* sp.

Figure 12 (cont.)

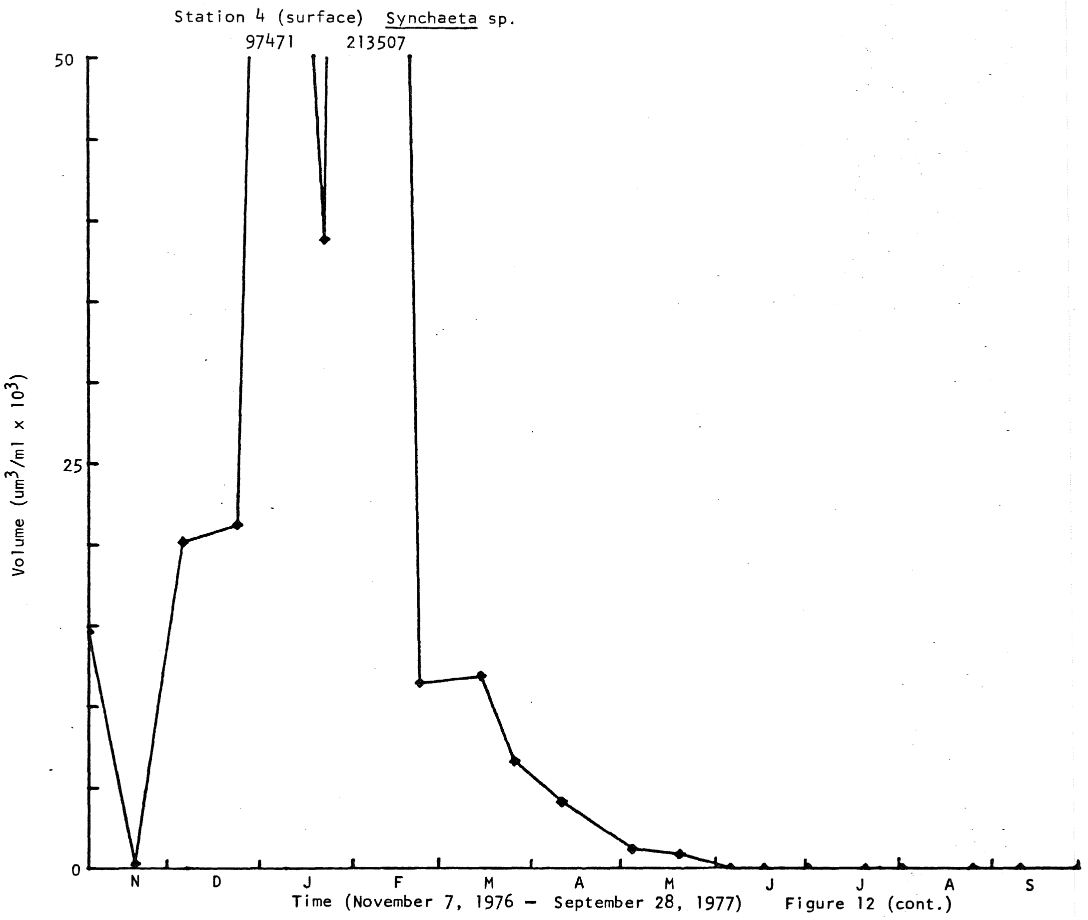


Figure 12 (cont.)

Station 4 (bottom) *Synchaeta* sp.

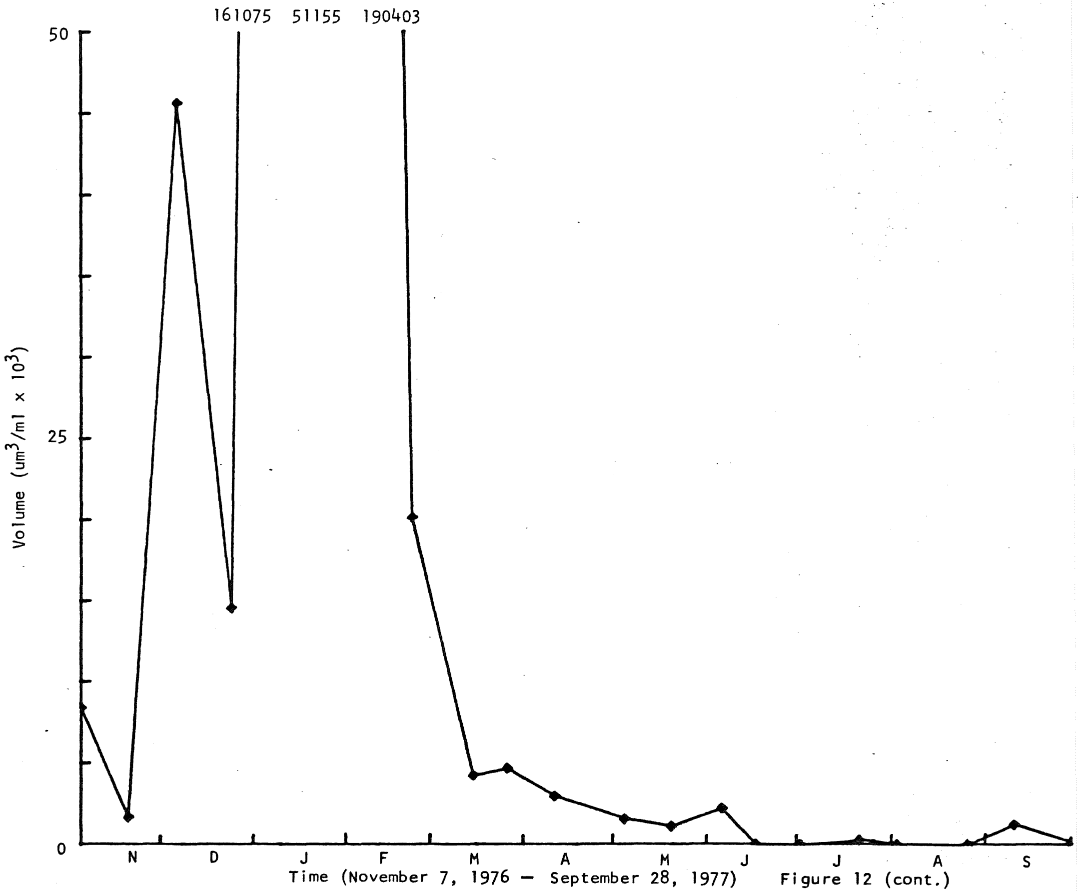
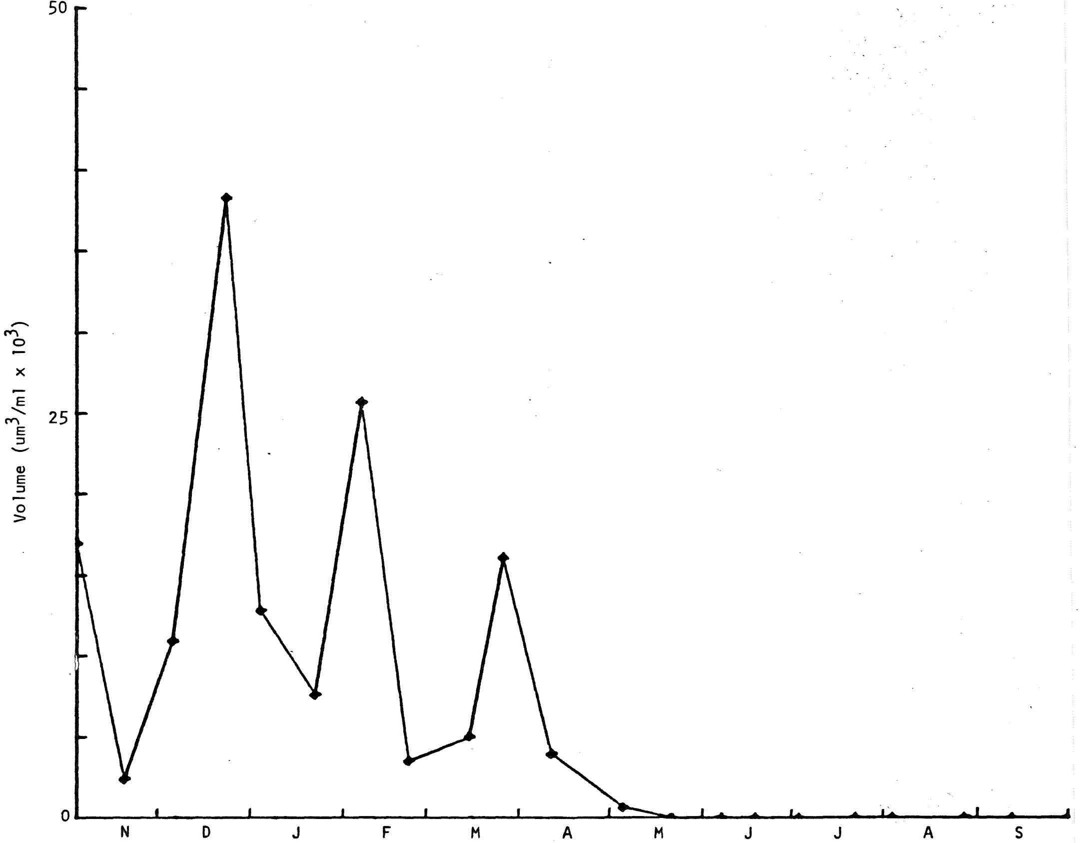


Figure 12 (cont.)



Station 6 (surface) _Synchaeta_ sp.

Time (November 7, 1976 — September 28, 1977) Figure 12 (cont)

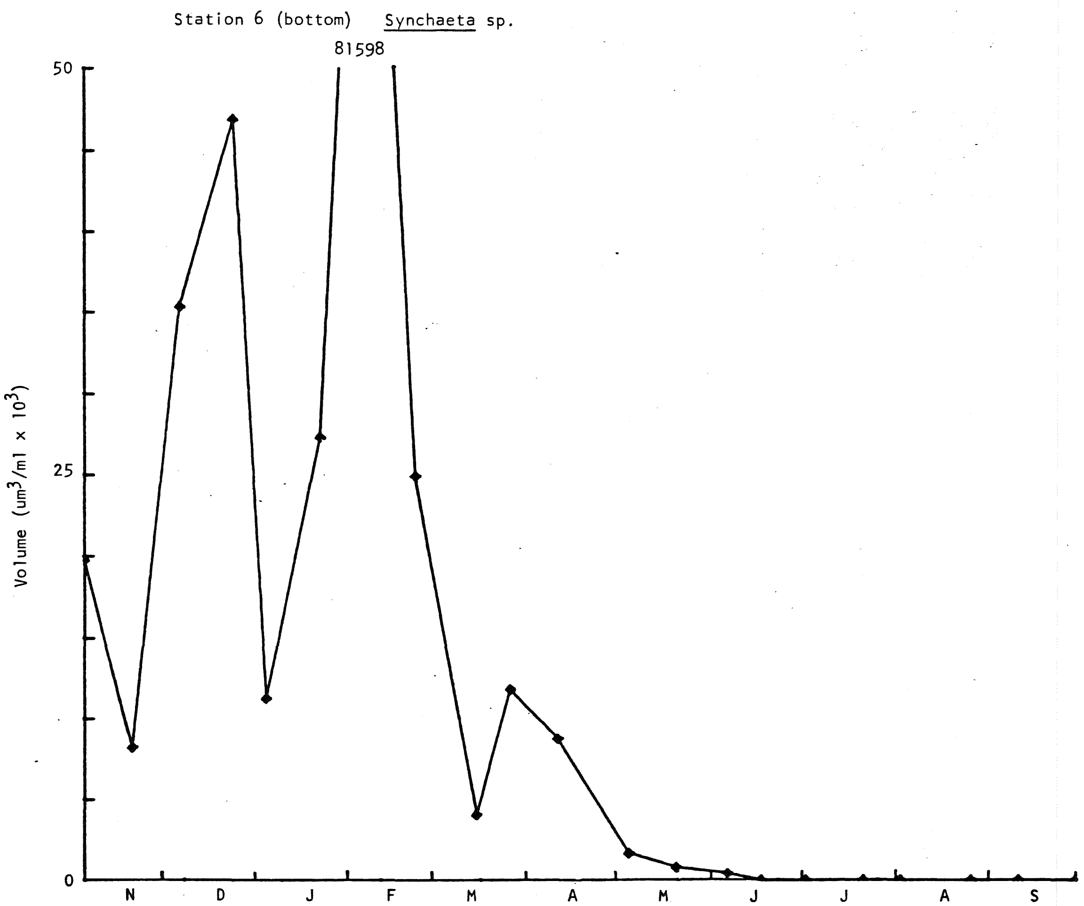


Figure 12 (cont.)

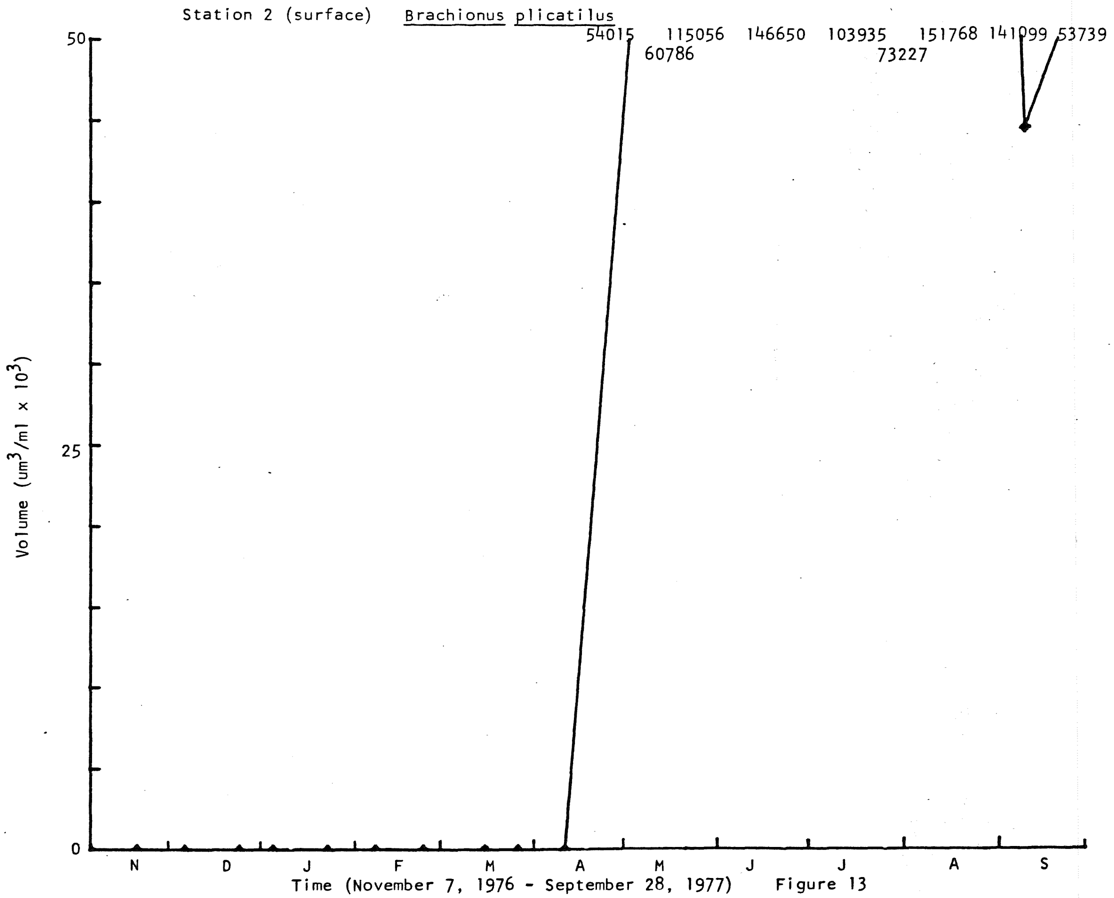

Station 2 (surface) Brachionus plicatilus
54015
60786
115056
146650
103935
73227
151768
141099
53739
50
25
0
Volume (um^3/ml x 10^3)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 - September 28, 1977)

Figure 13

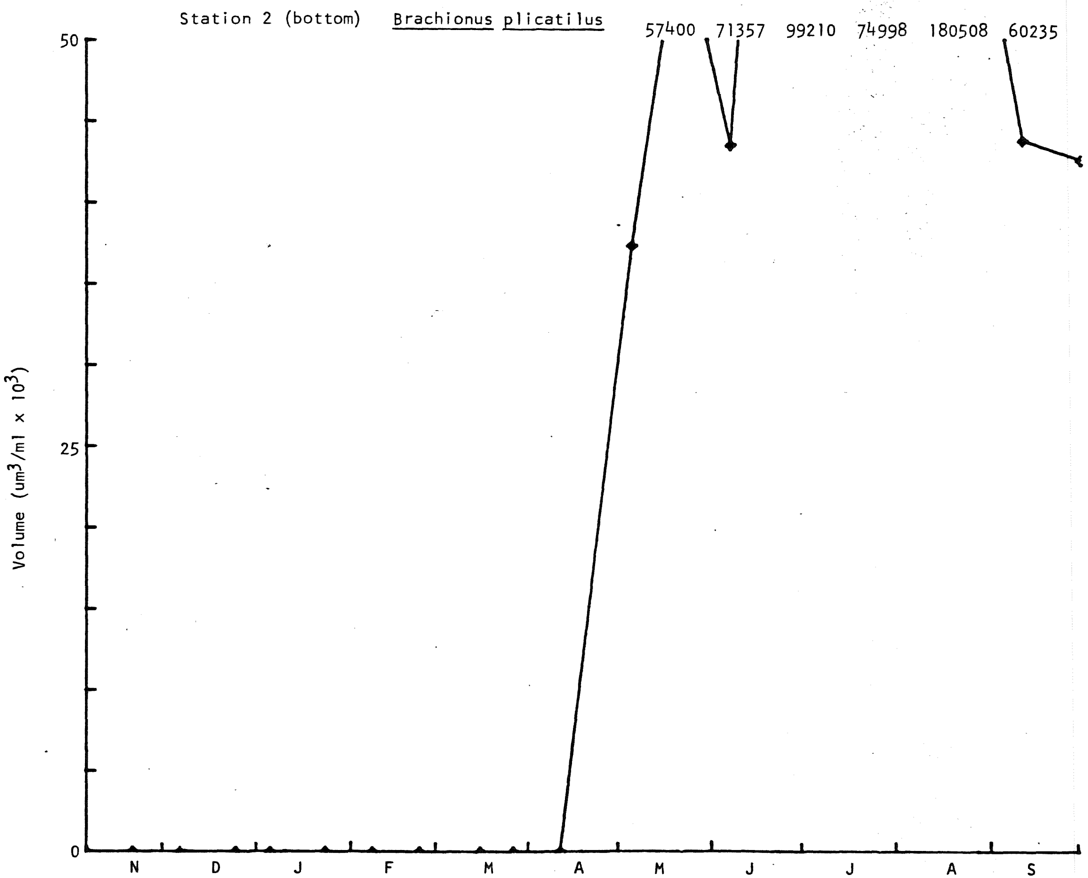


Figure 13 (cont.)

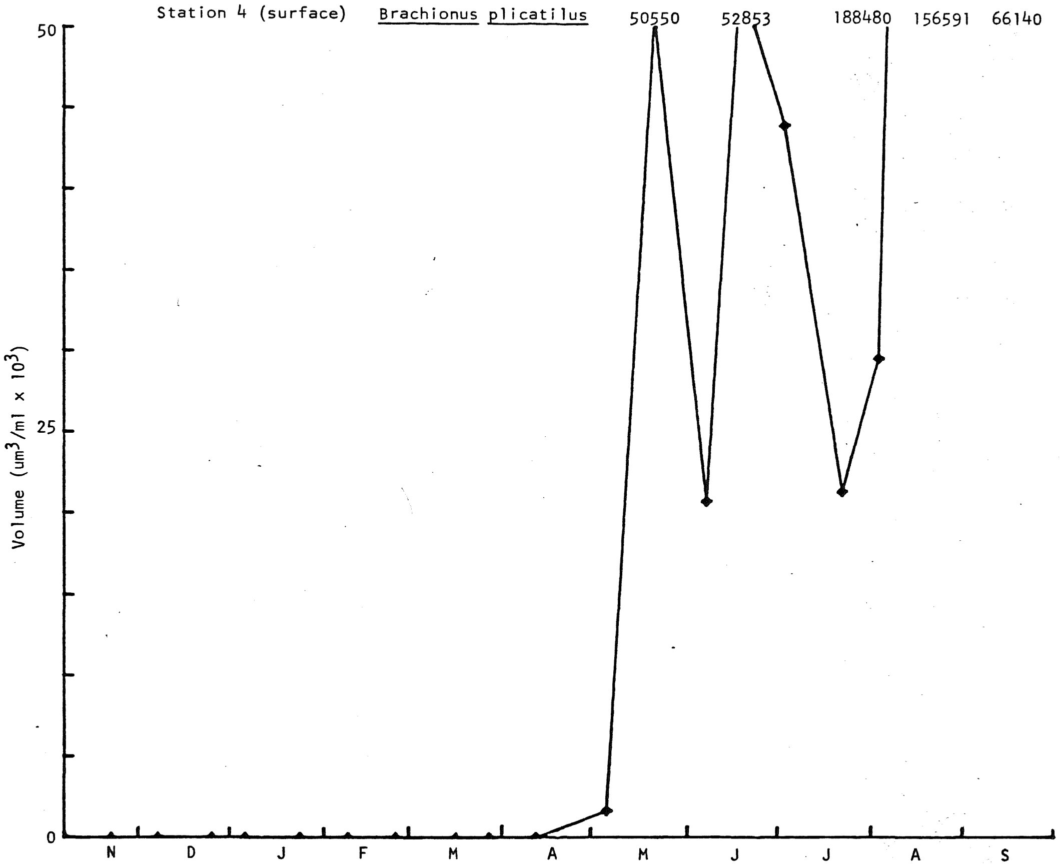
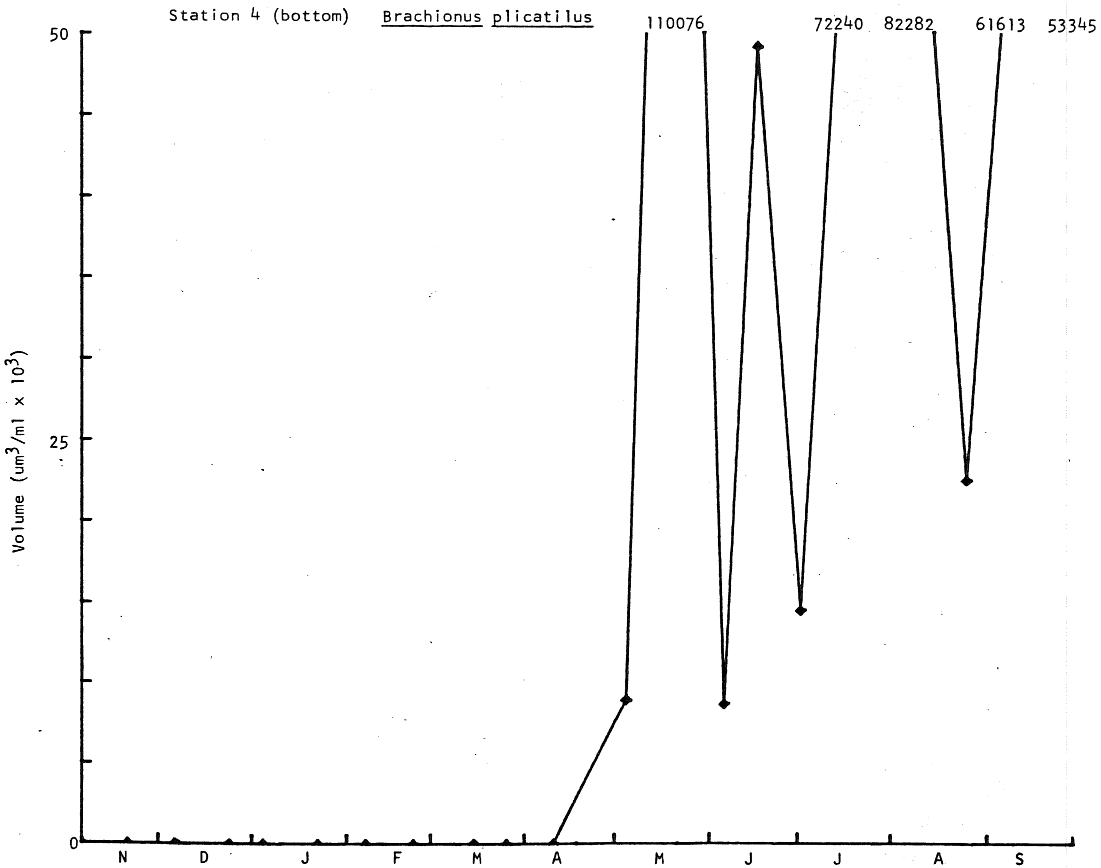


Figure 13 (cont.)


Station 4 (bottom) Brachionus plicatilus

Time (November 7, 1976 — September 28, 1977) Figure 13 (cont.)

Station 6 (surface) <u>Brachionus plicatilus</u>

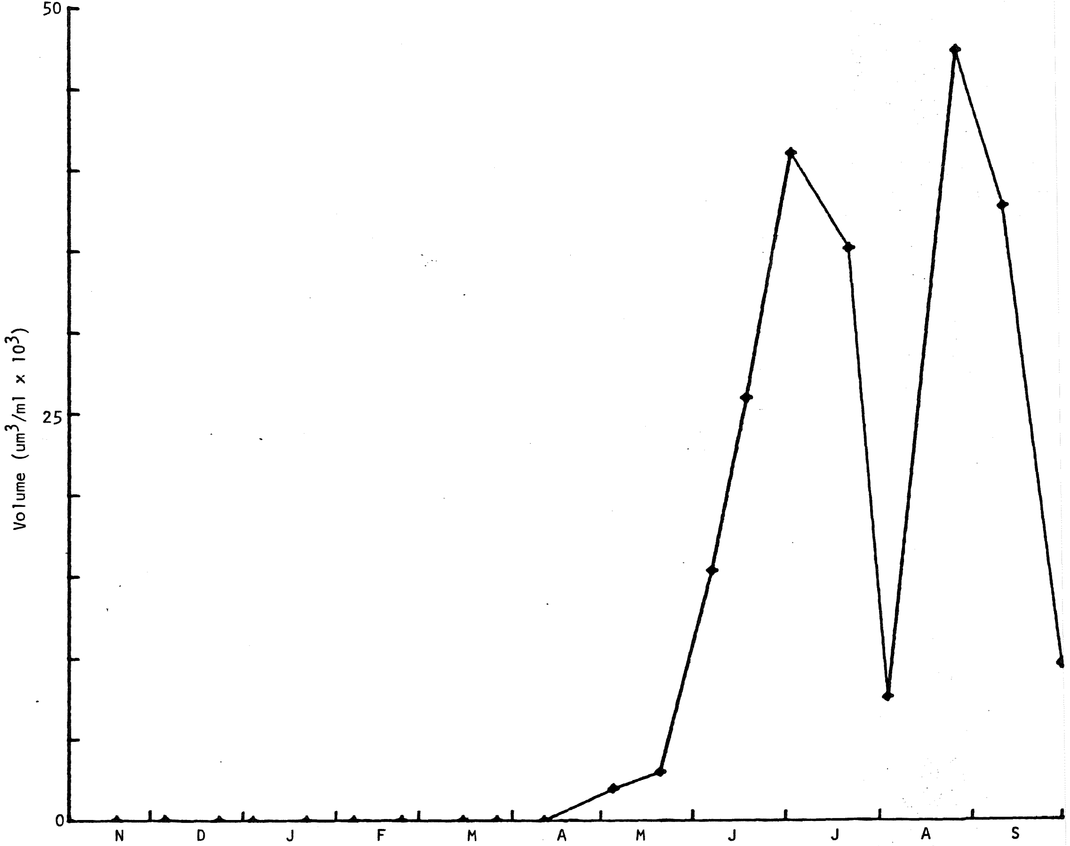


Figure 13 (cont.)

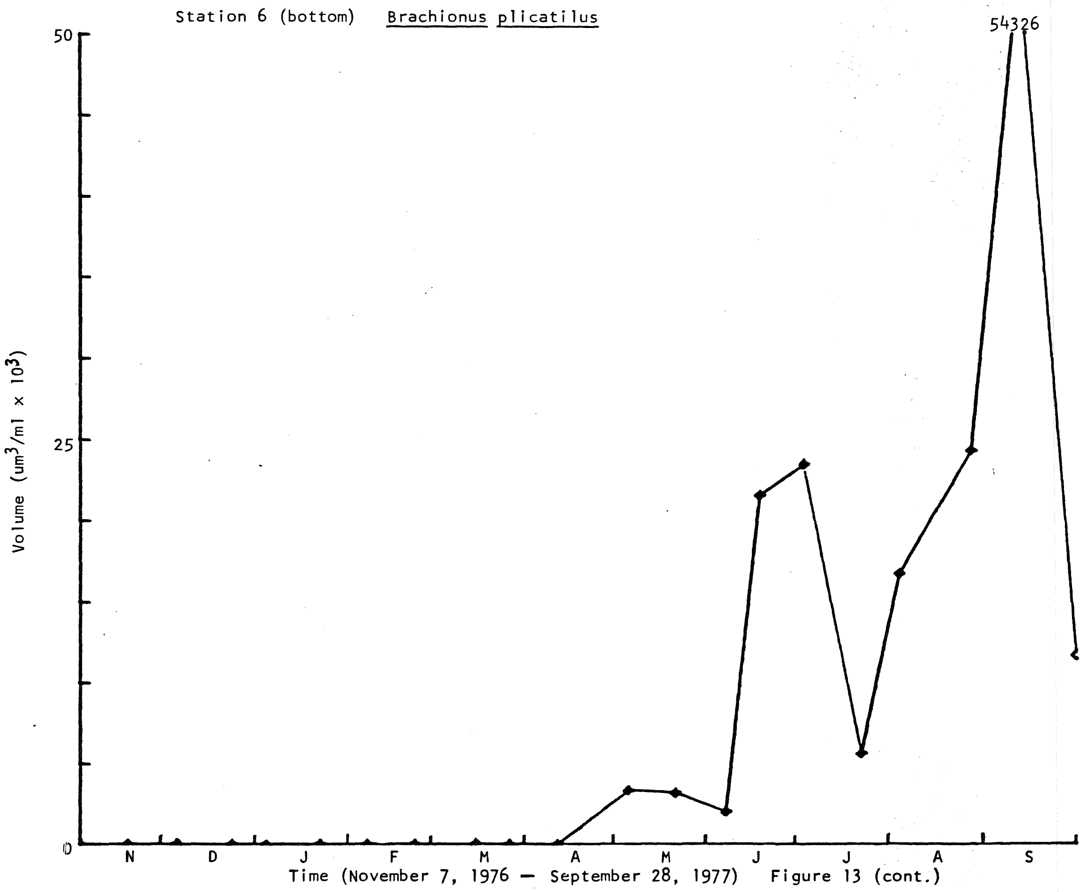
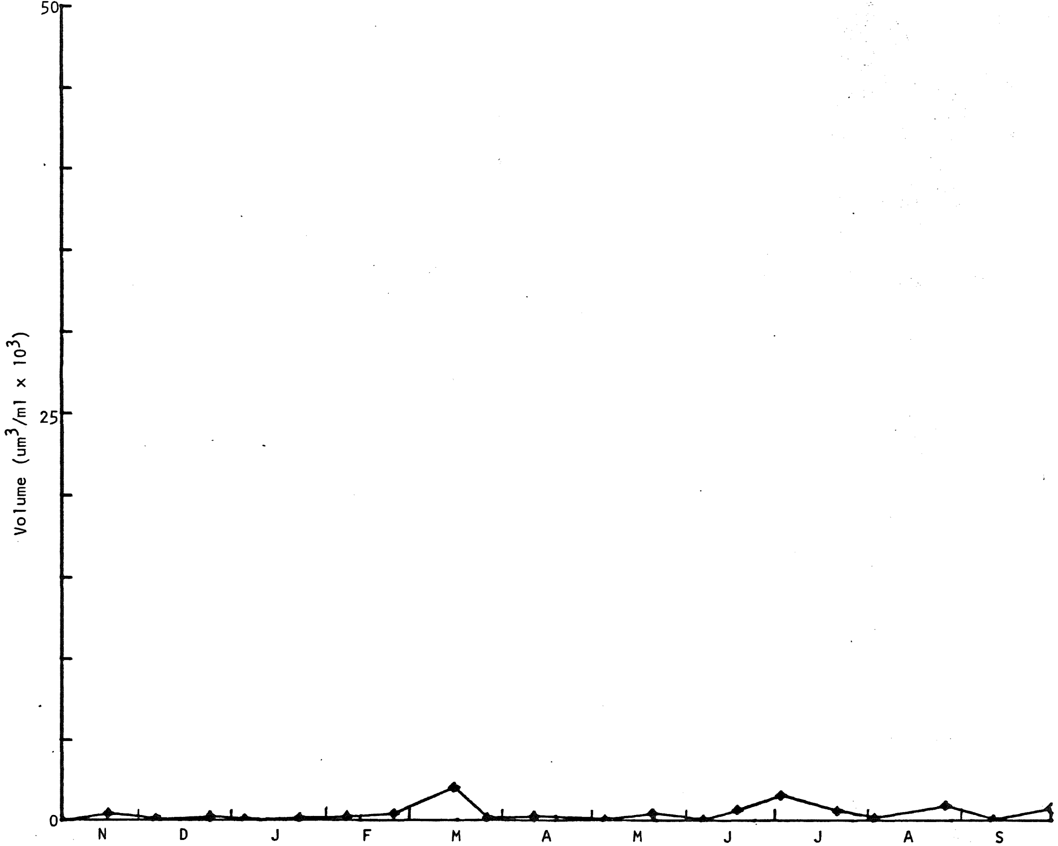


Figure 13 (cont.)

Station 2 (surface) Polychaete Larvae (early)



Time (November 7, 1976 — September 28, 1977) Figure 14

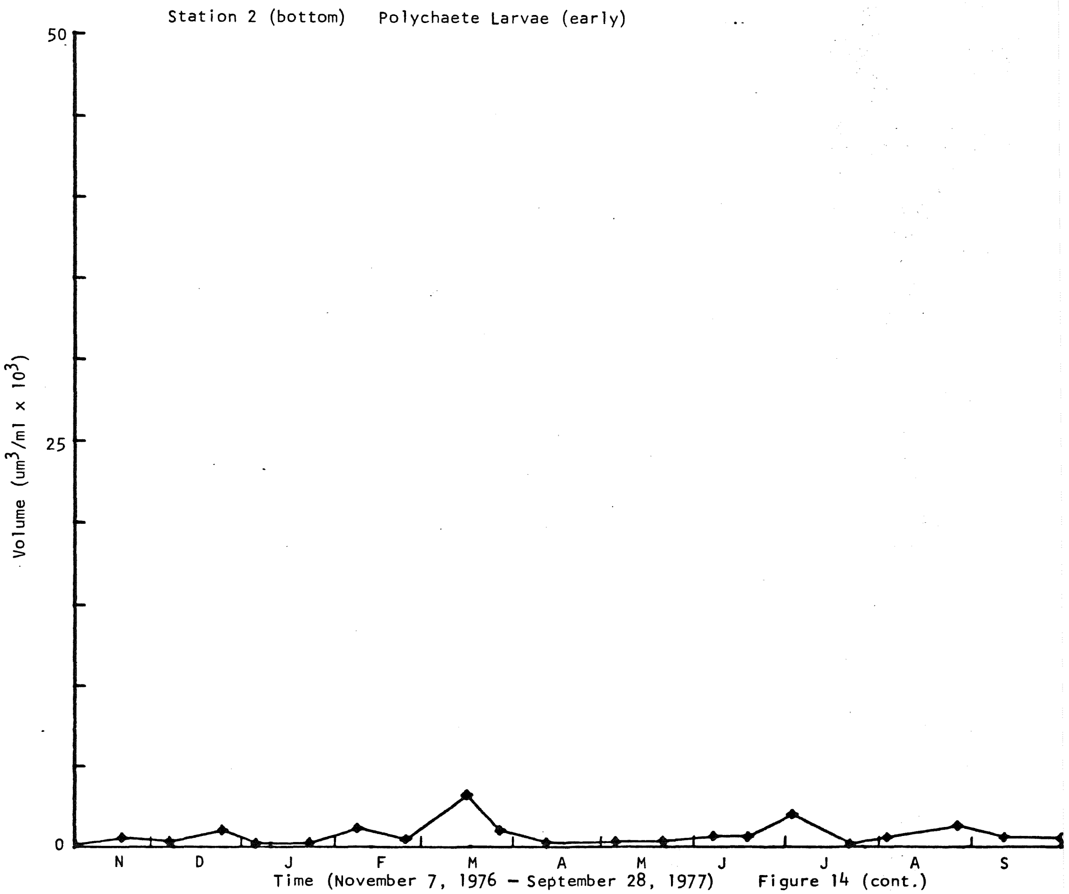


Figure 14 (cont.)

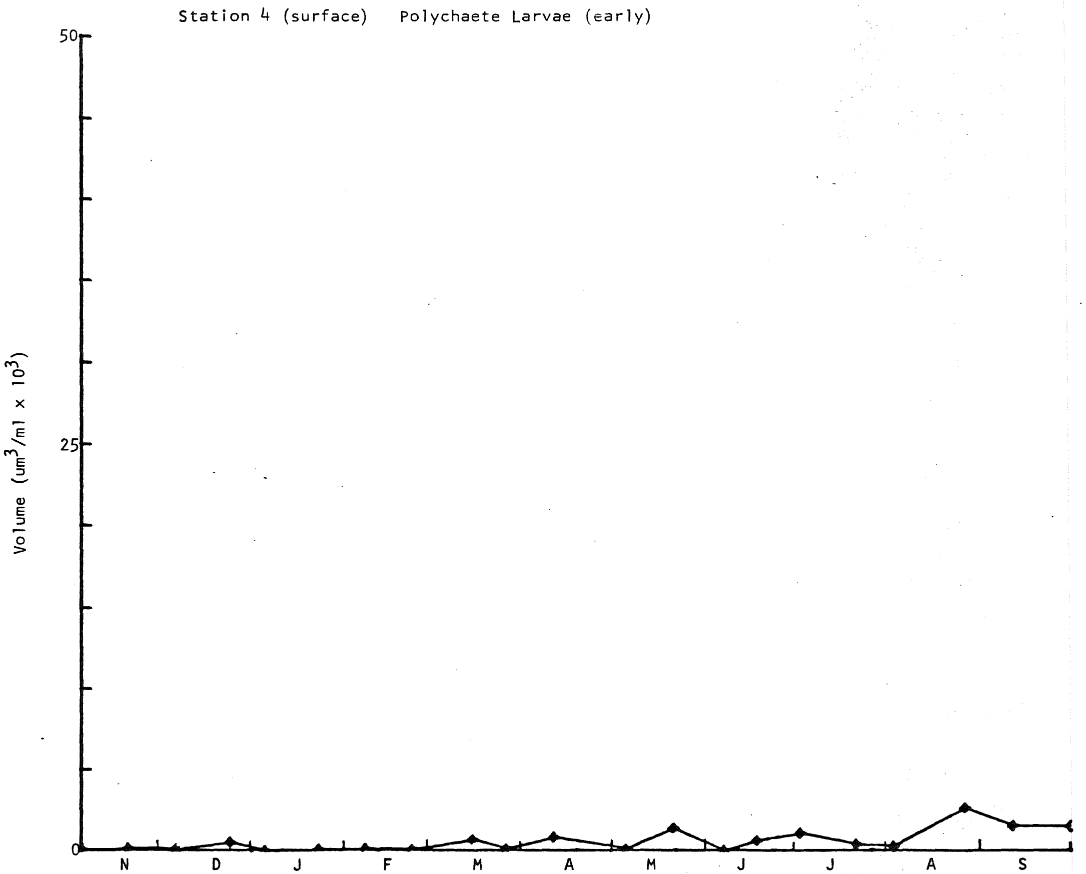


Figure 14 (cont.)

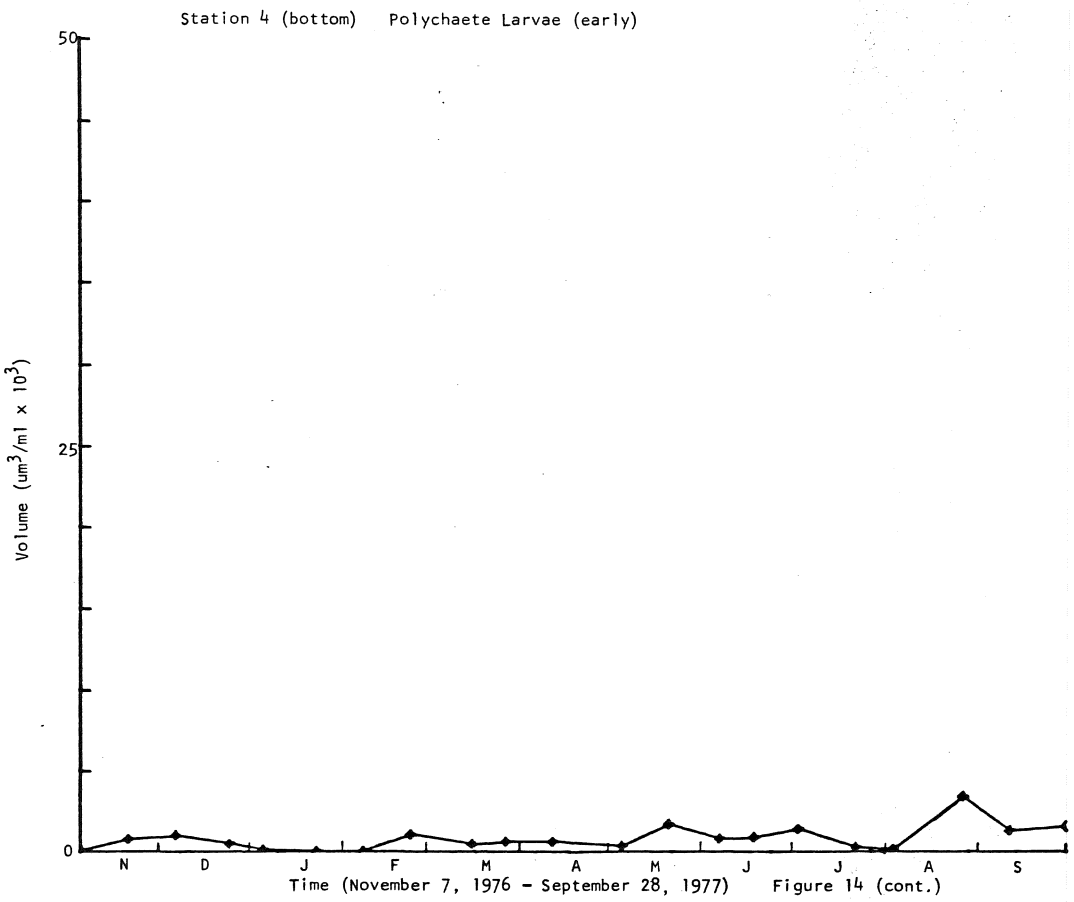


Figure 14 (cont.)

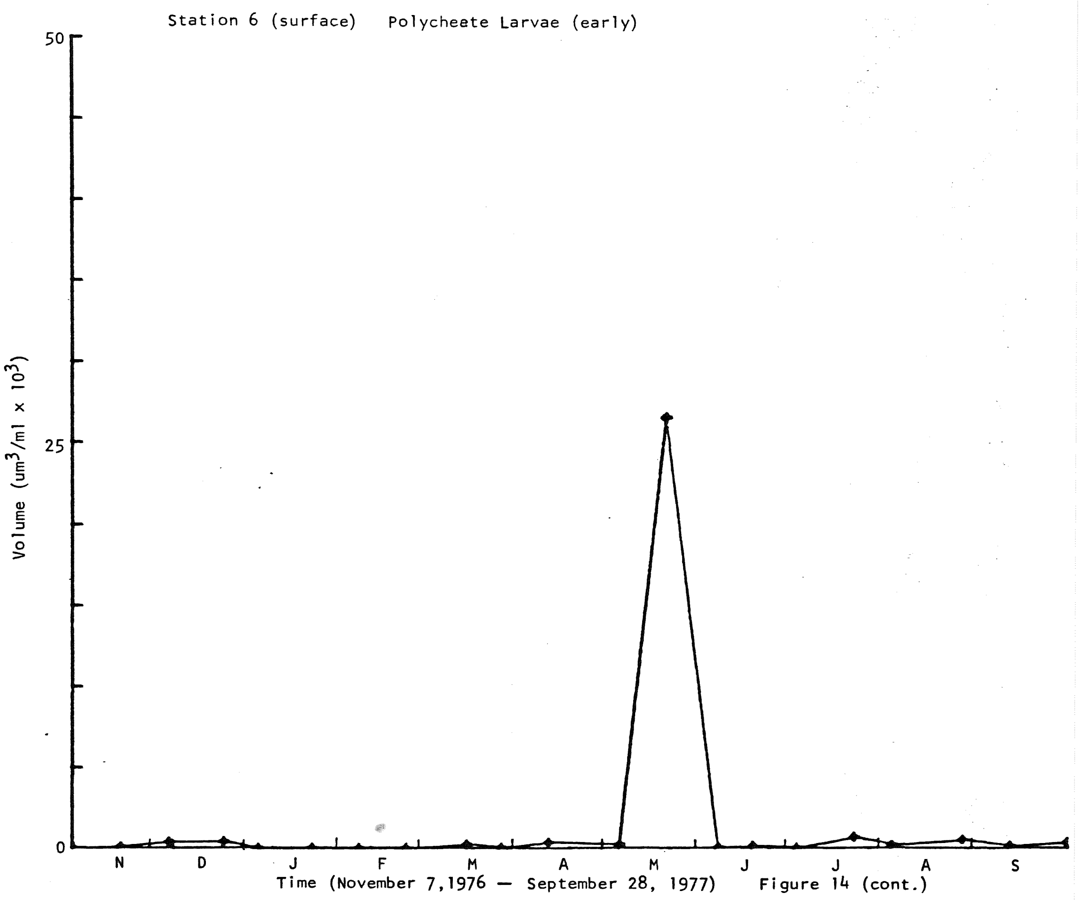


Figure 14 (cont.)

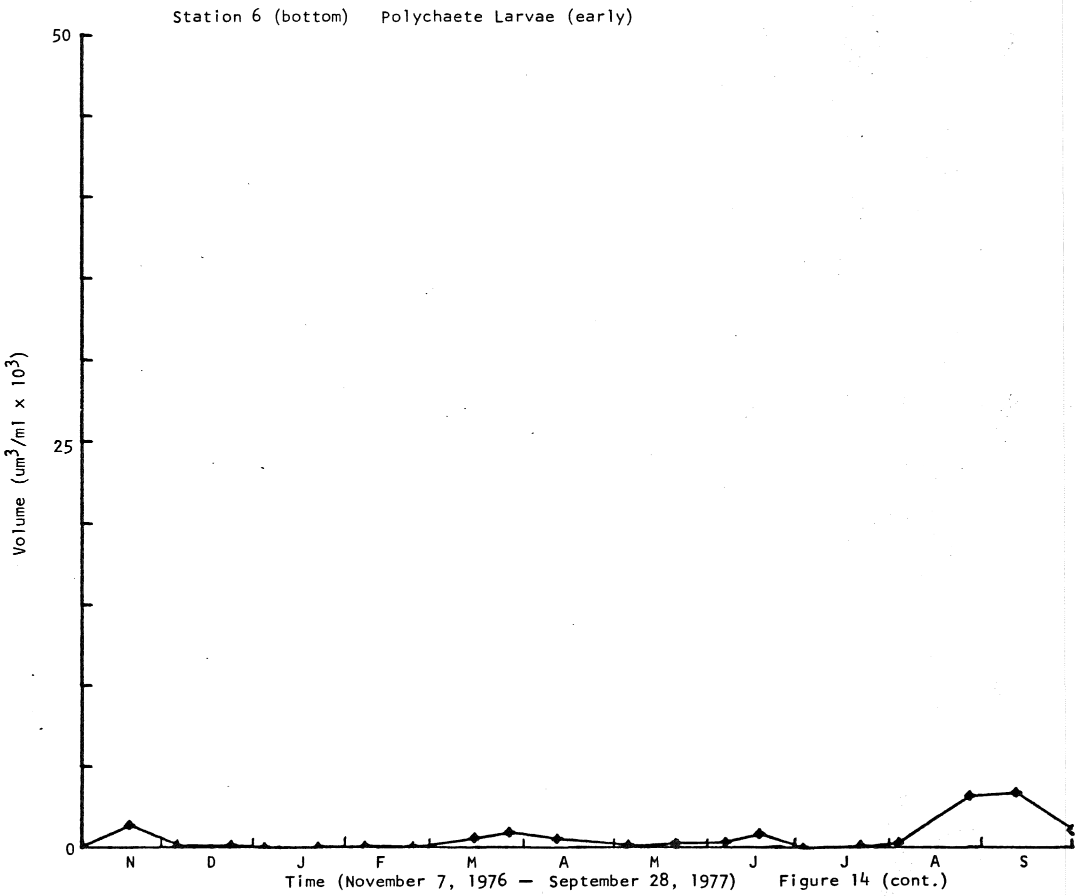


Figure 14 (cont.)

Station 2 (surface) Polychaete Larvae (late)

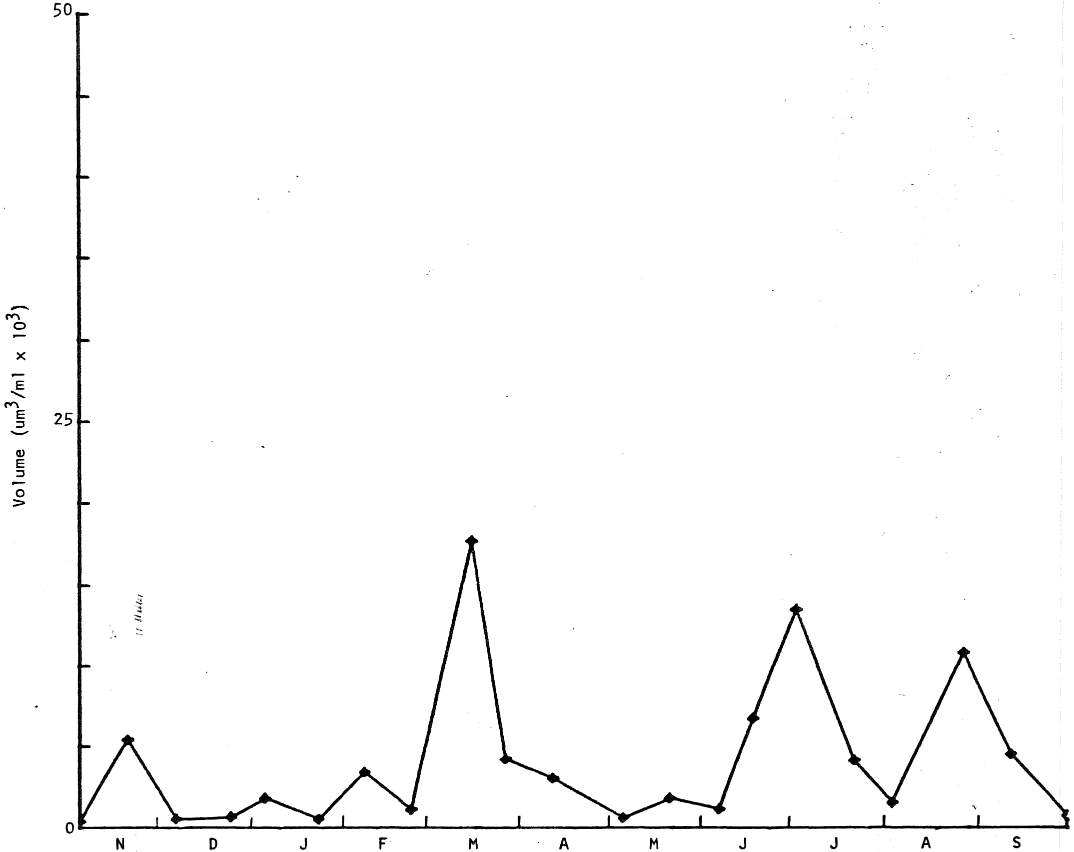


Figure 14 (cont.)

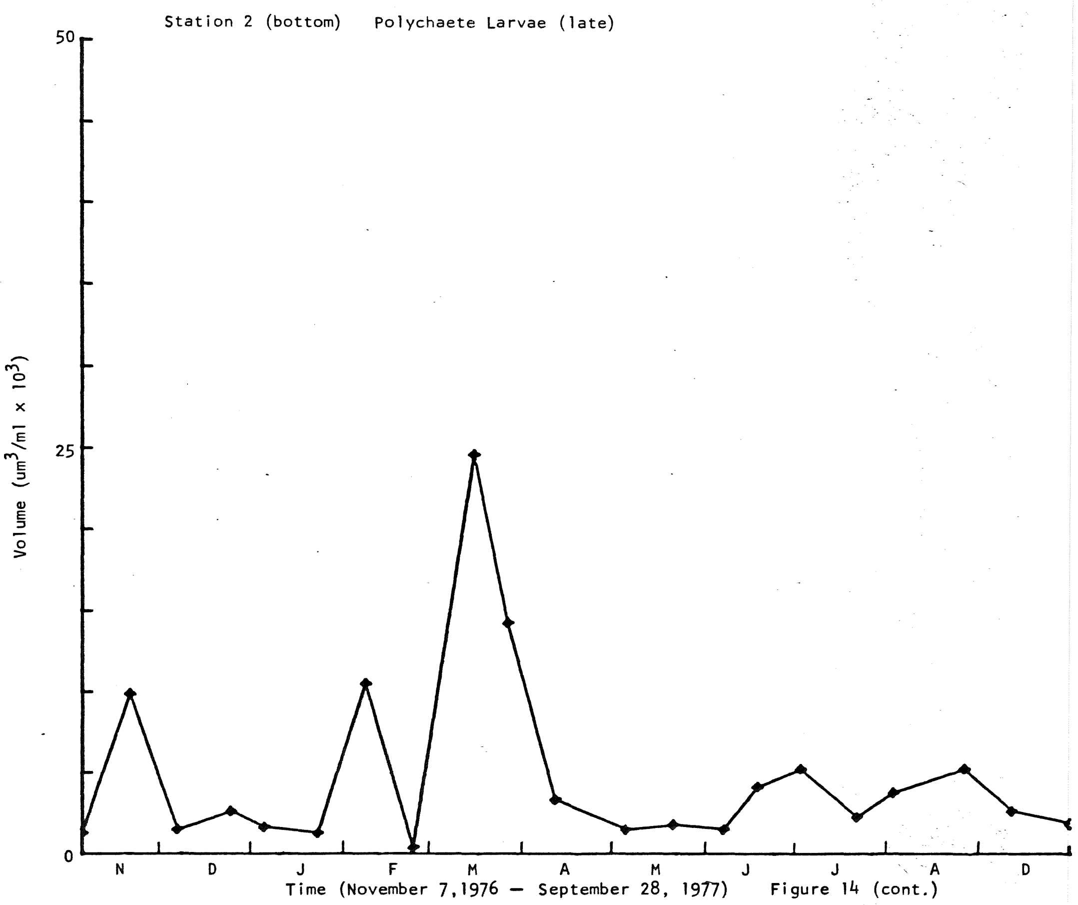
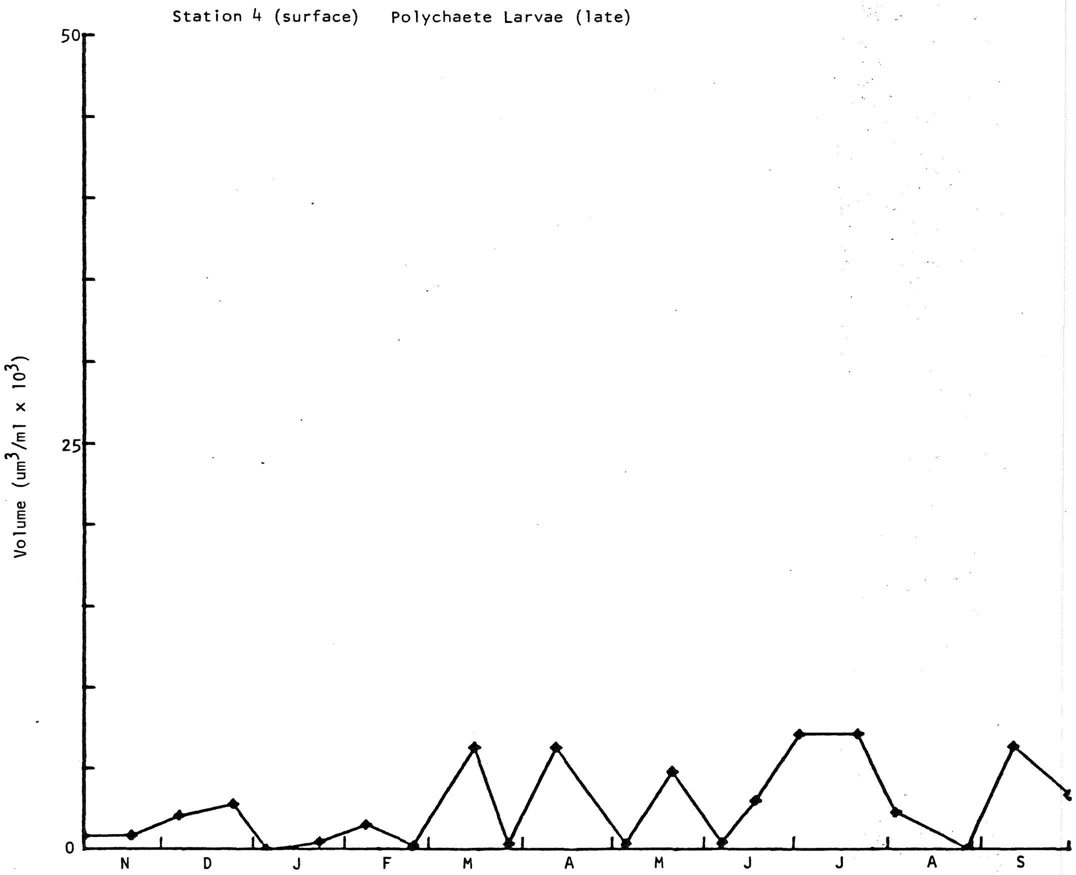
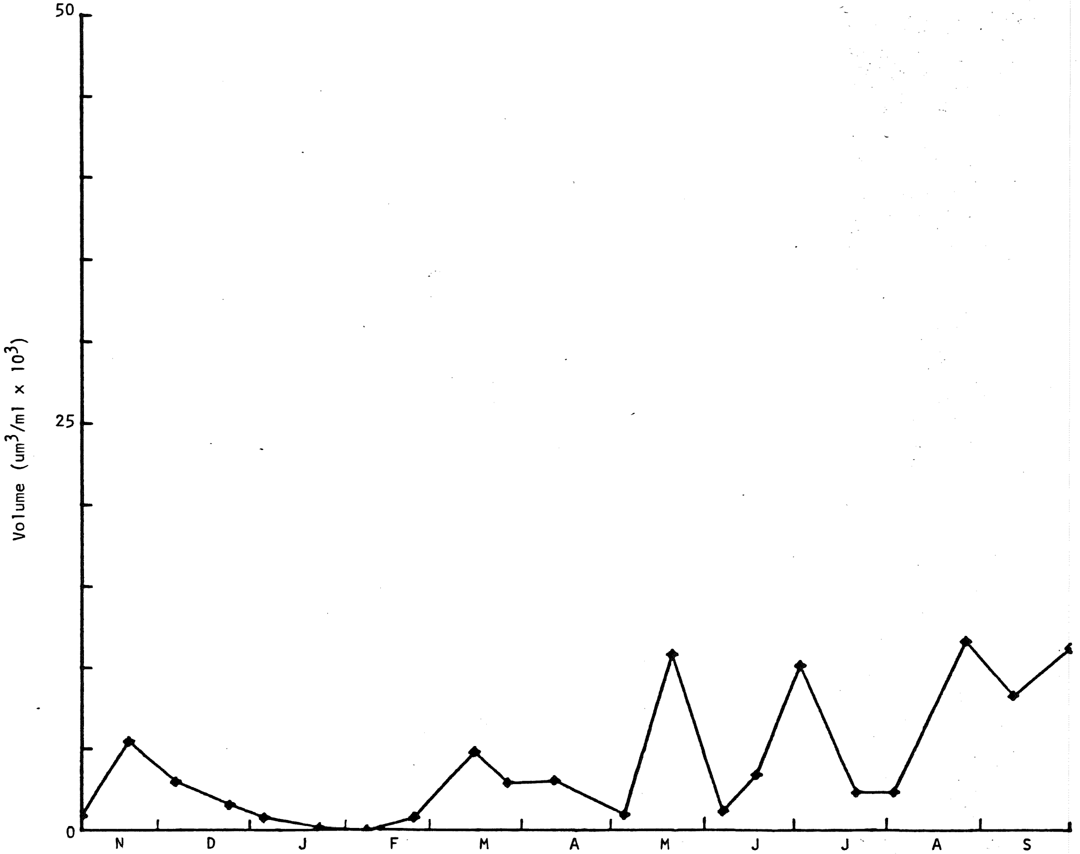


Figure 14 (cont.)



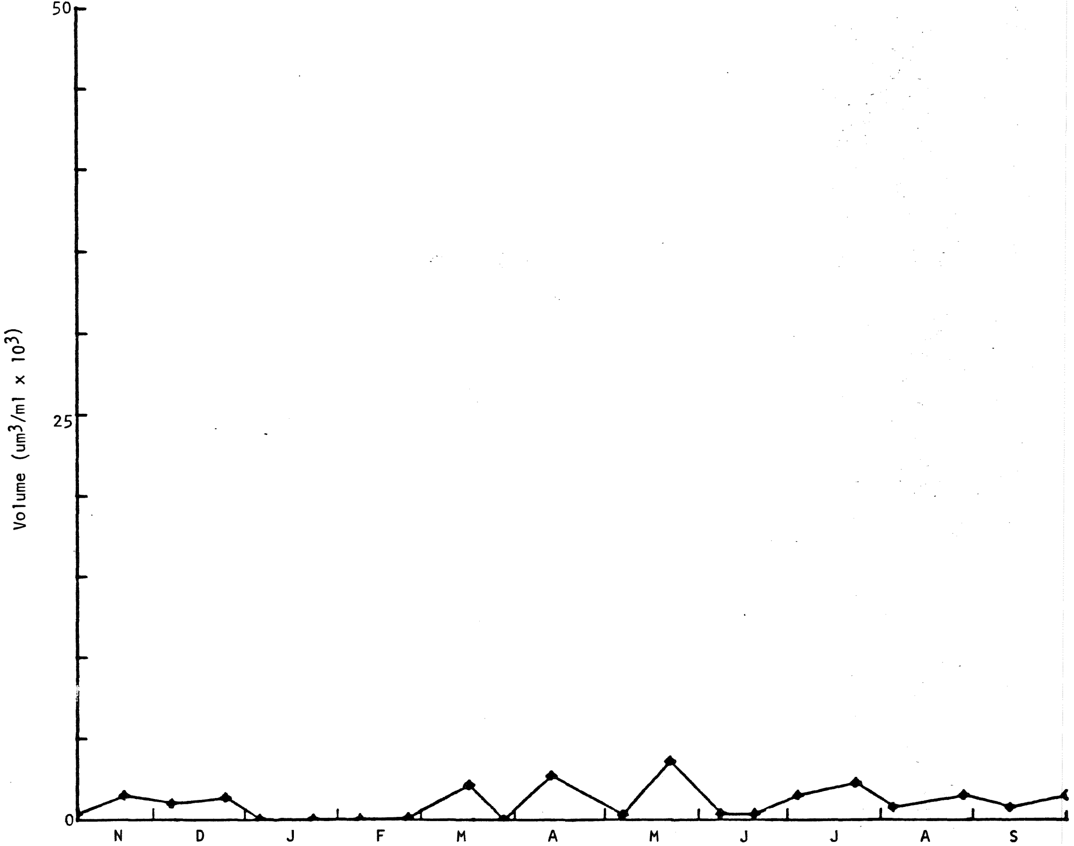
Time (November 7, 1976 — September 28, 1977) Figure 14 (cont.)

Station 4 (bottom) Polychaete Larvae (late)



Time (November 7, 1976 — September 28, 1977) Figure 14 (cont.)

Station 6 (surface) Polychaete Larvae (late)



Time (November 7, 1976 – September 28, 1977) Figure 14 (cont.)

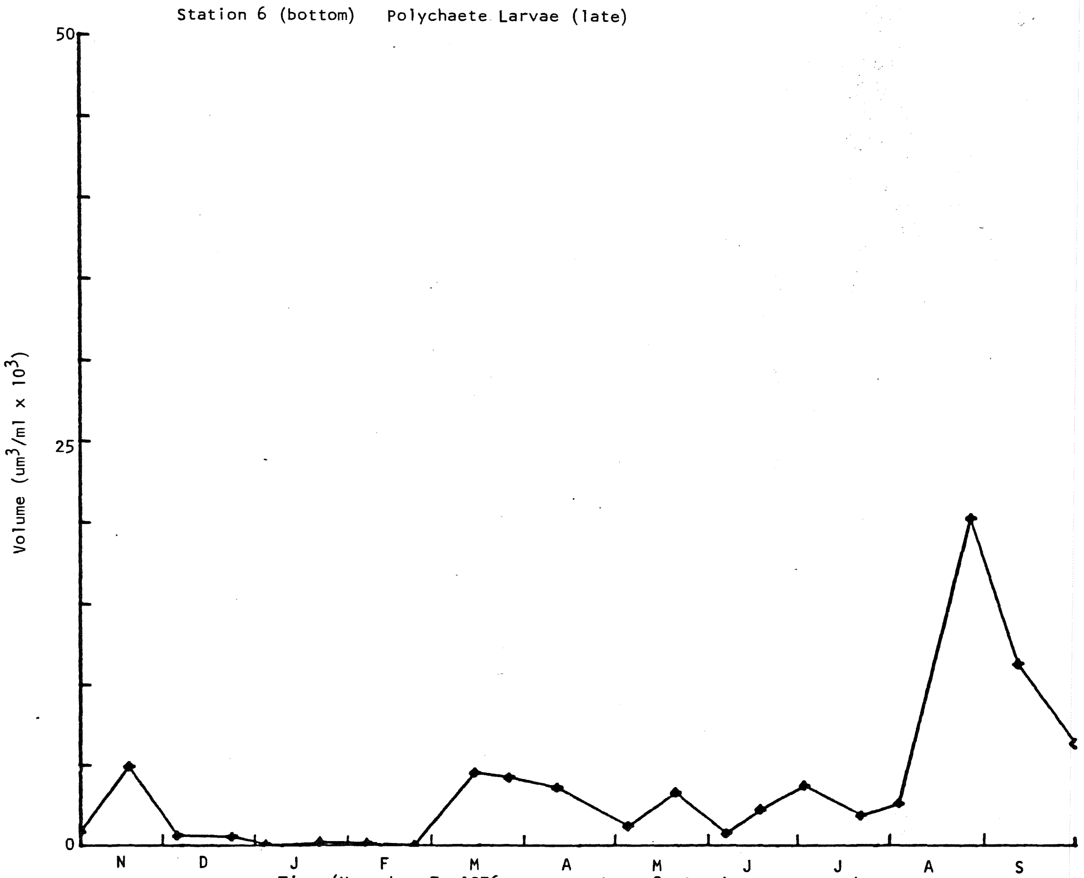
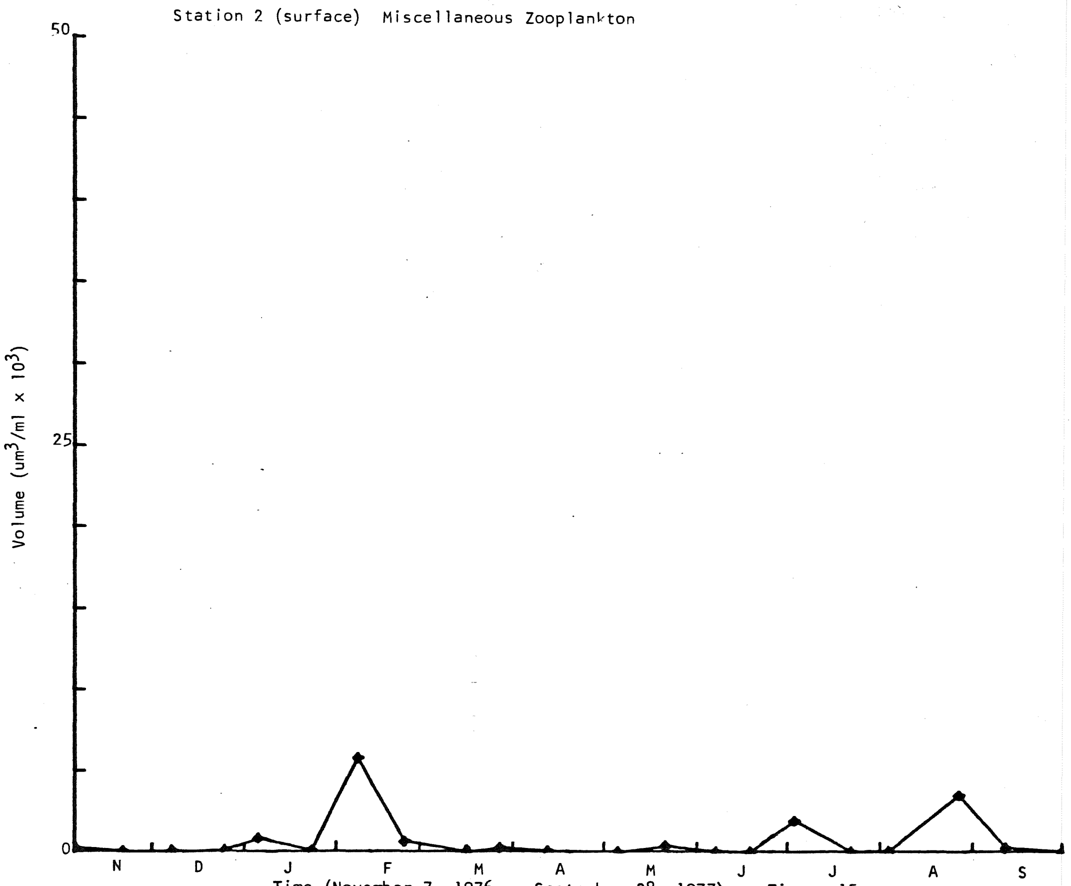


Figure 14 (cont.)



Time (November 7, 1976 — September 28, 1977) Figure 15

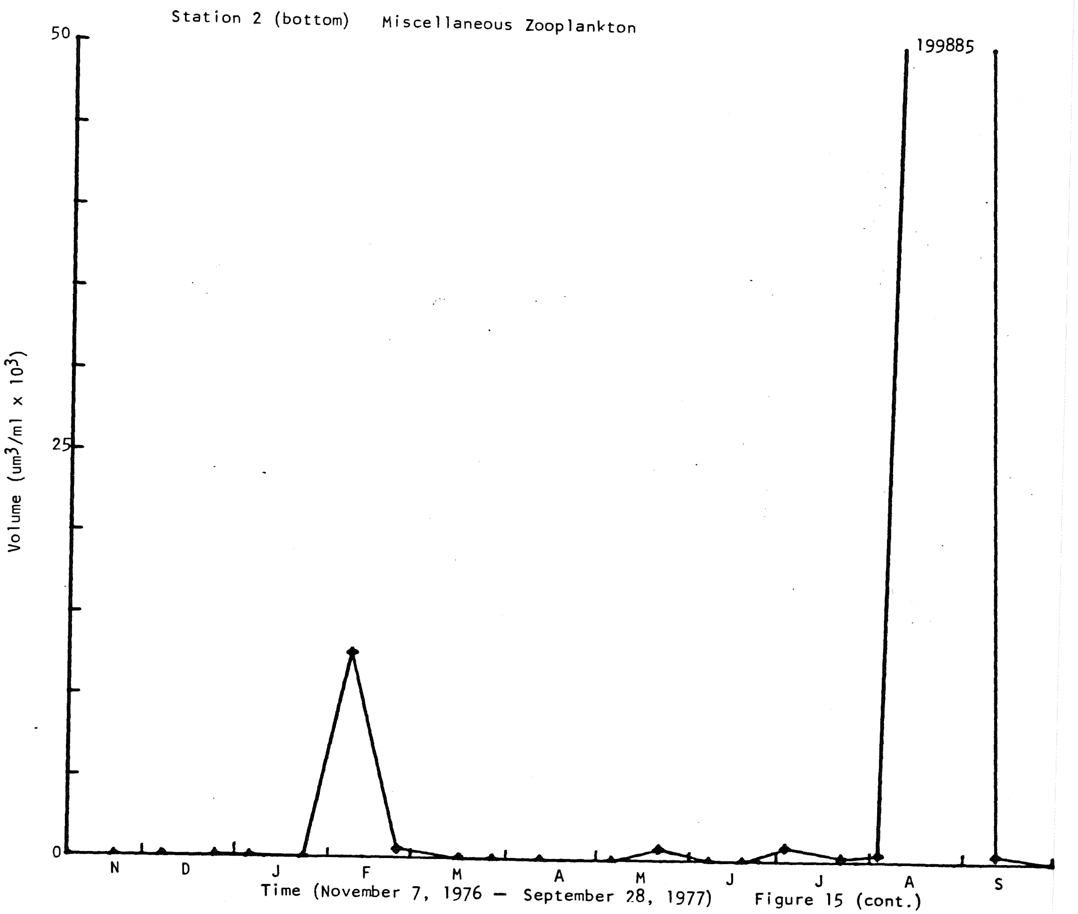


Figure 15 (cont.)

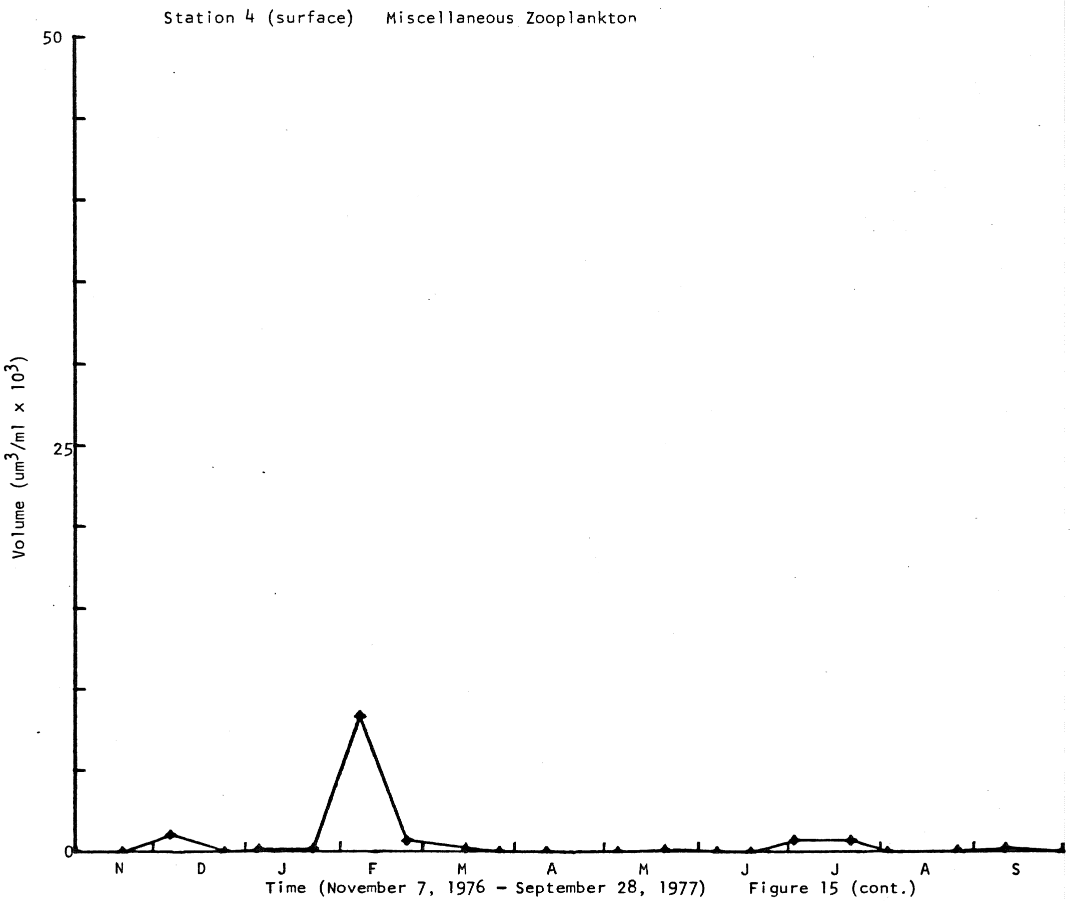


Figure 15 (cont.)

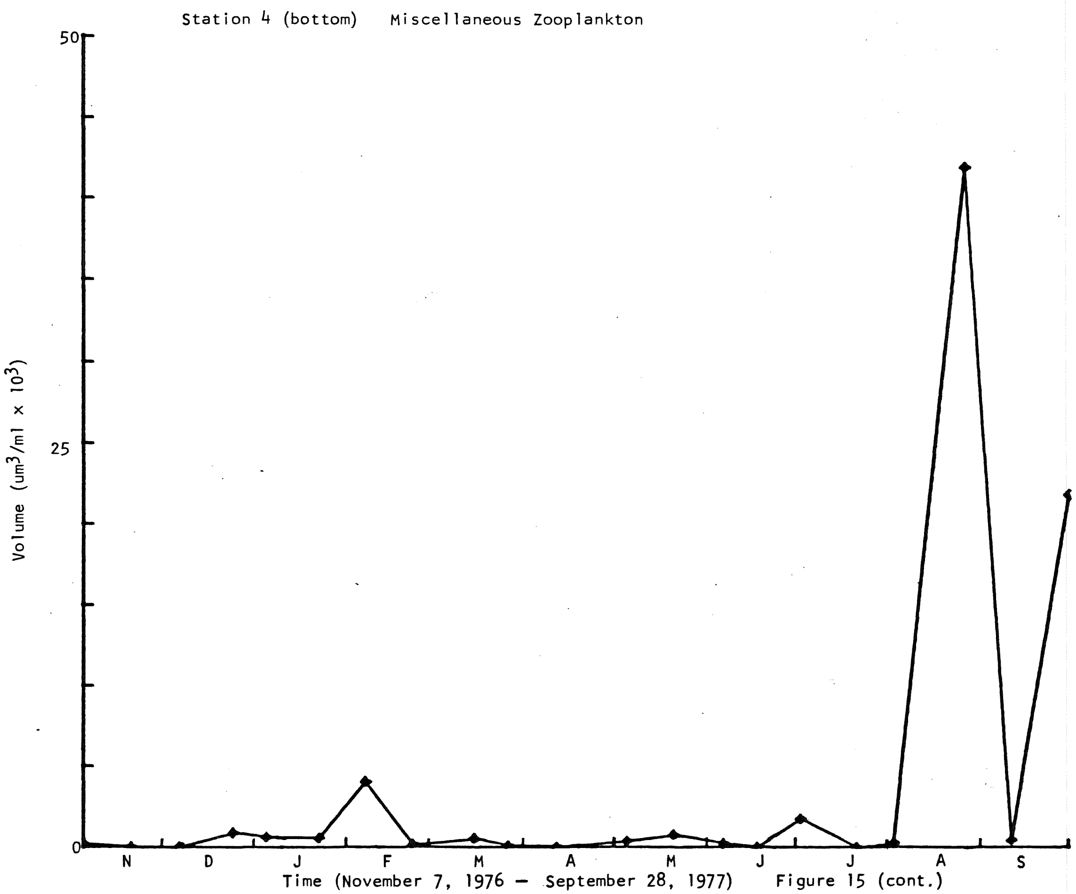
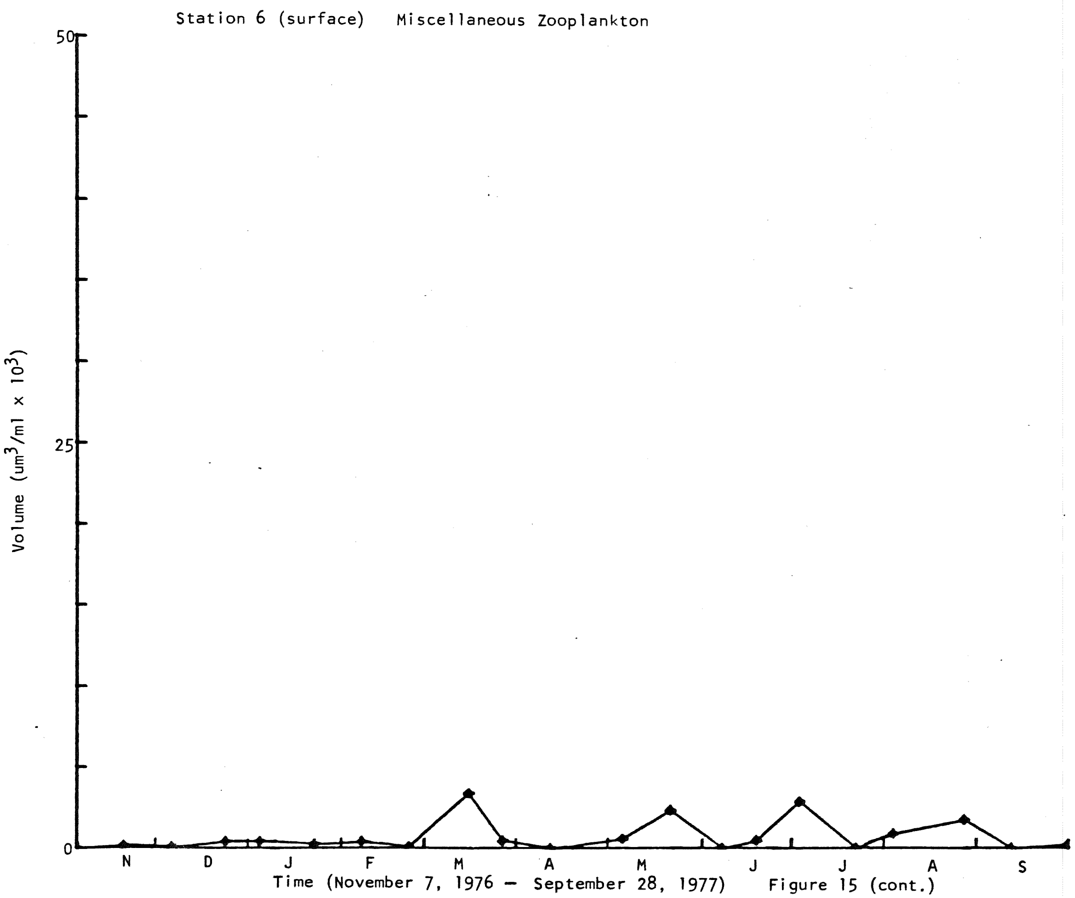


Figure 15 (cont.)



Station 6 (surface) Miscellaneous Zooplankton

Figure 15 (cont.)

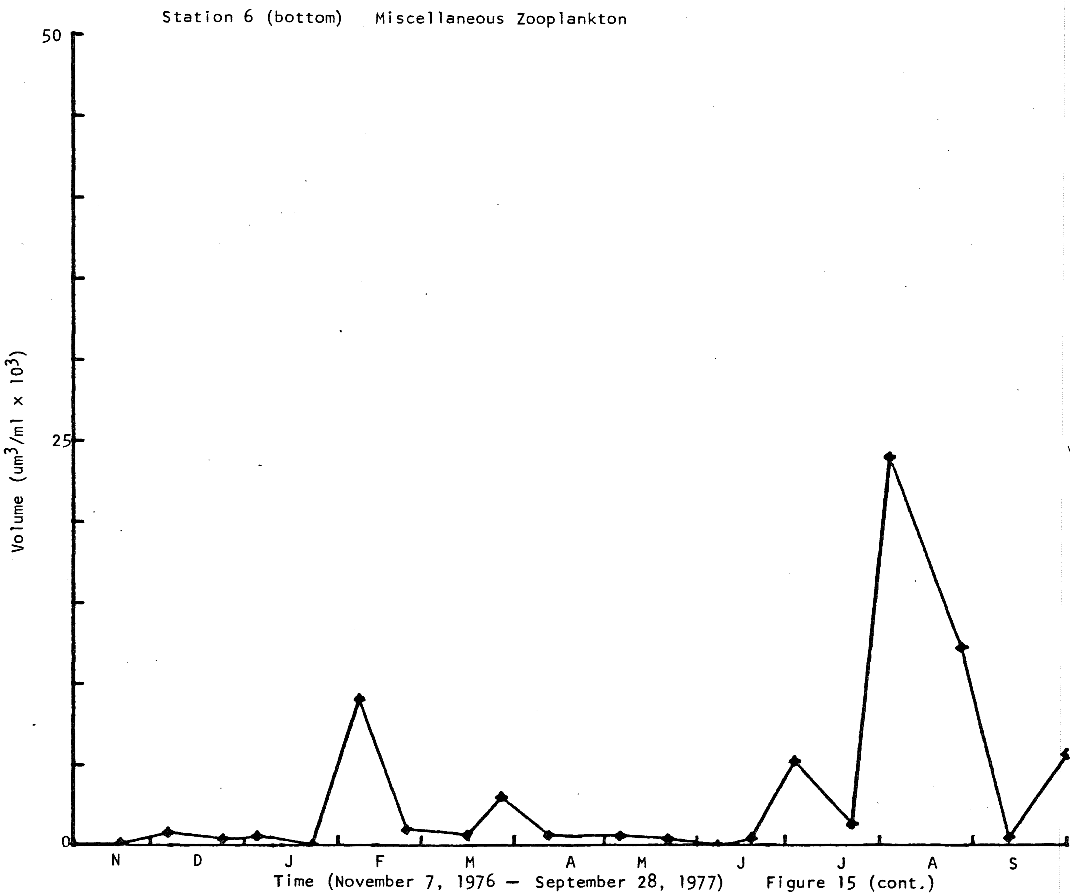


Figure 15 (cont.)

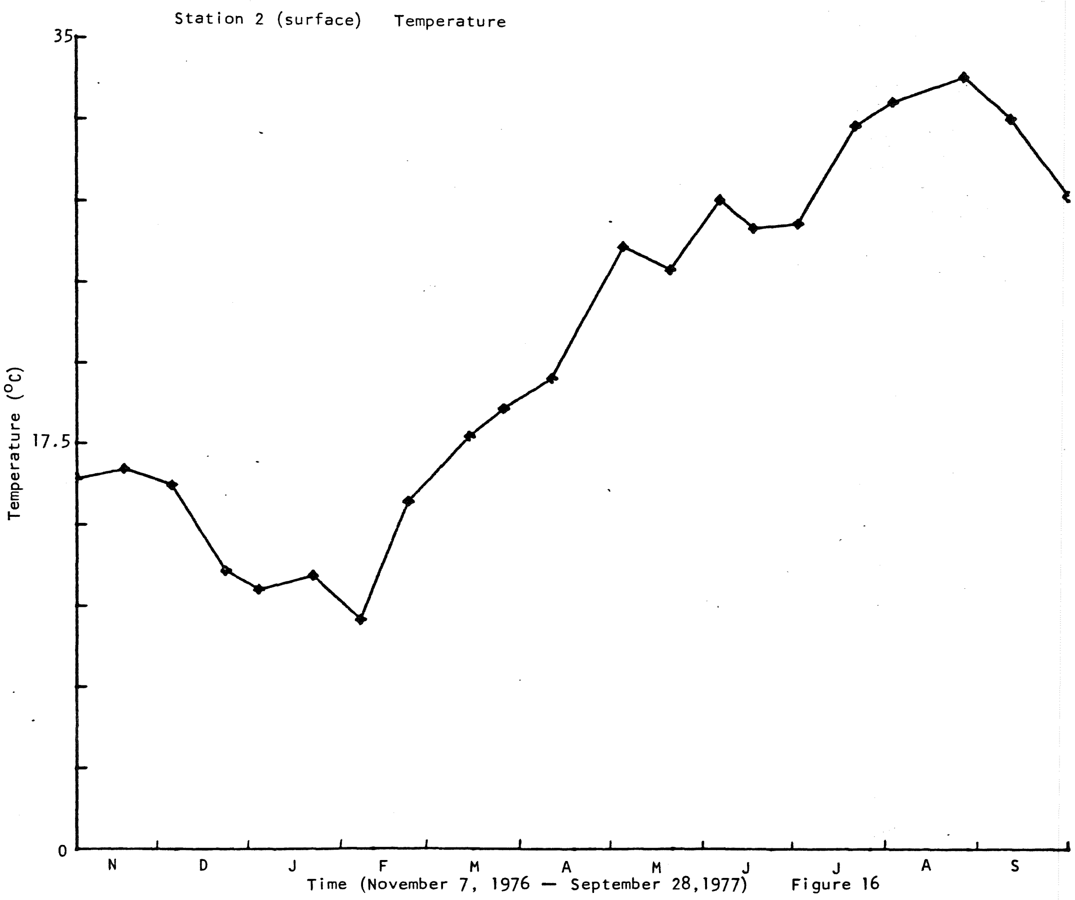
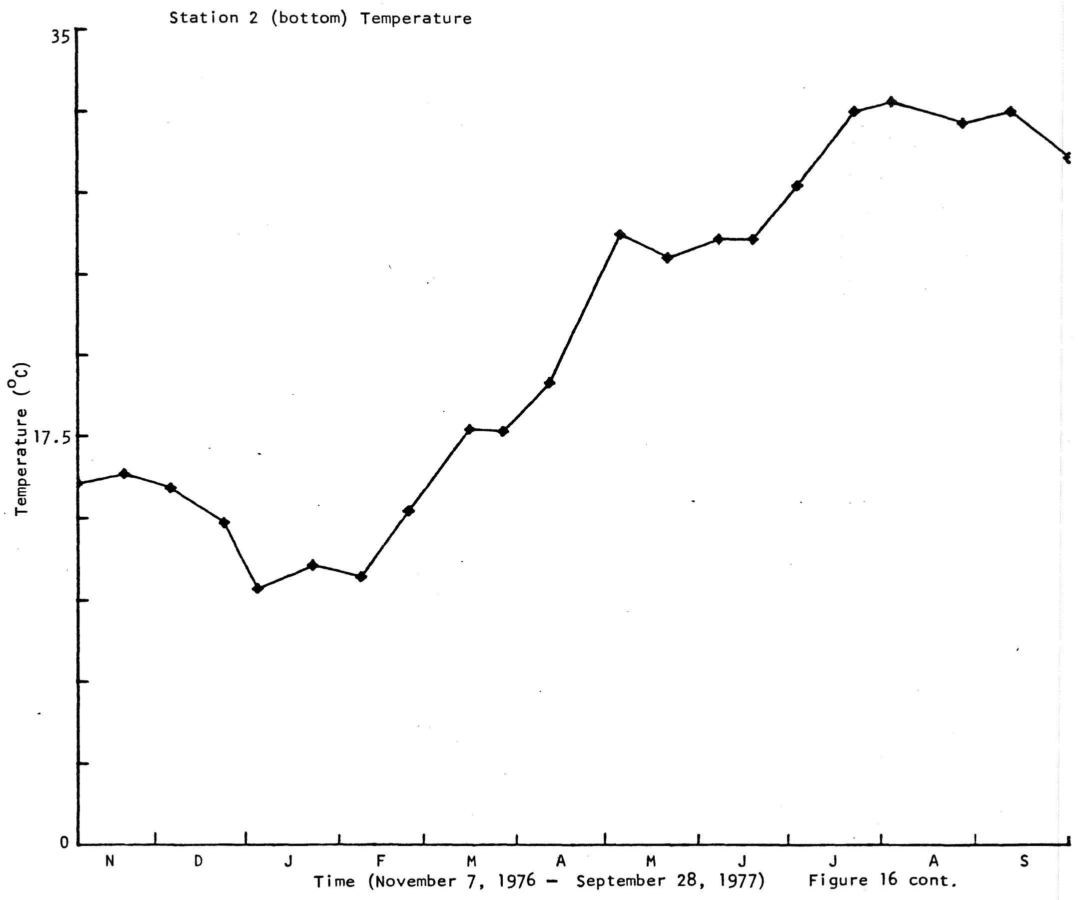
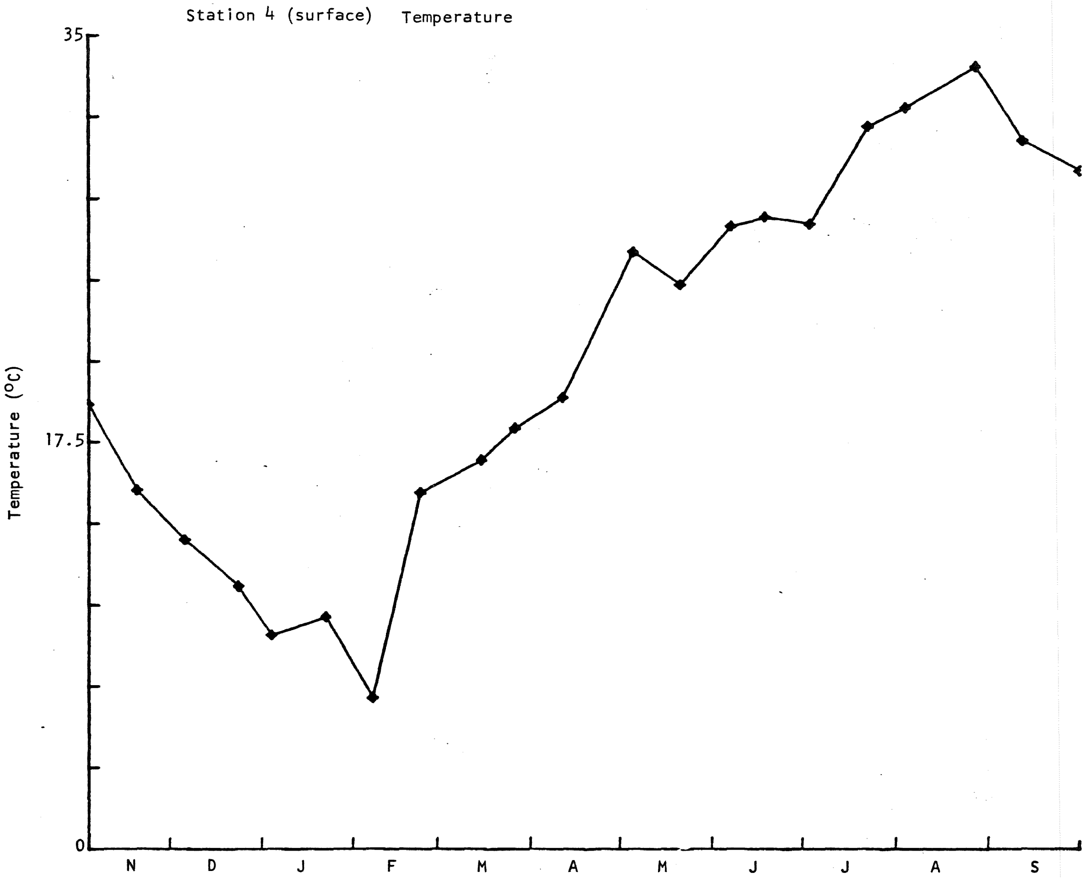

Station 2 (surface) Temperature
35
17.5
0
Temperature (°C)
N
D
J
F
M
A
M
J
J
A
S
Time (November 7, 1976 — September 28,1977)

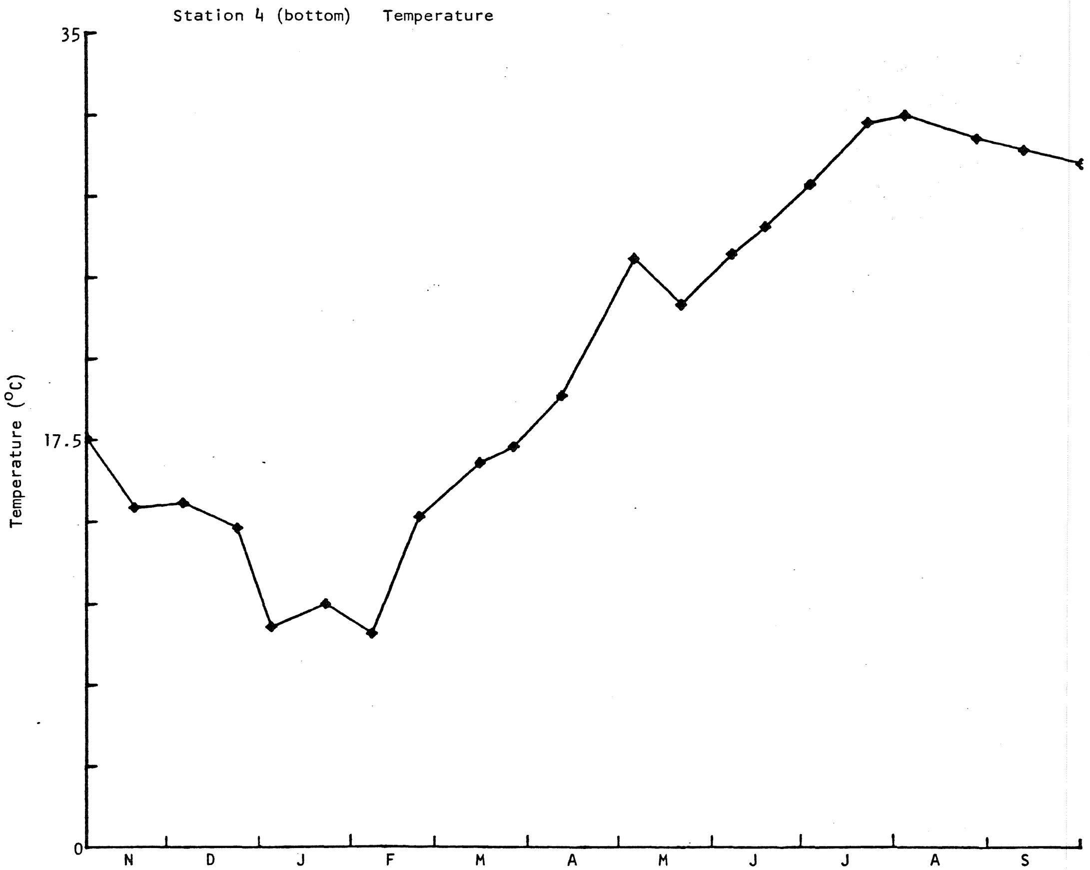
Figure 16



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.

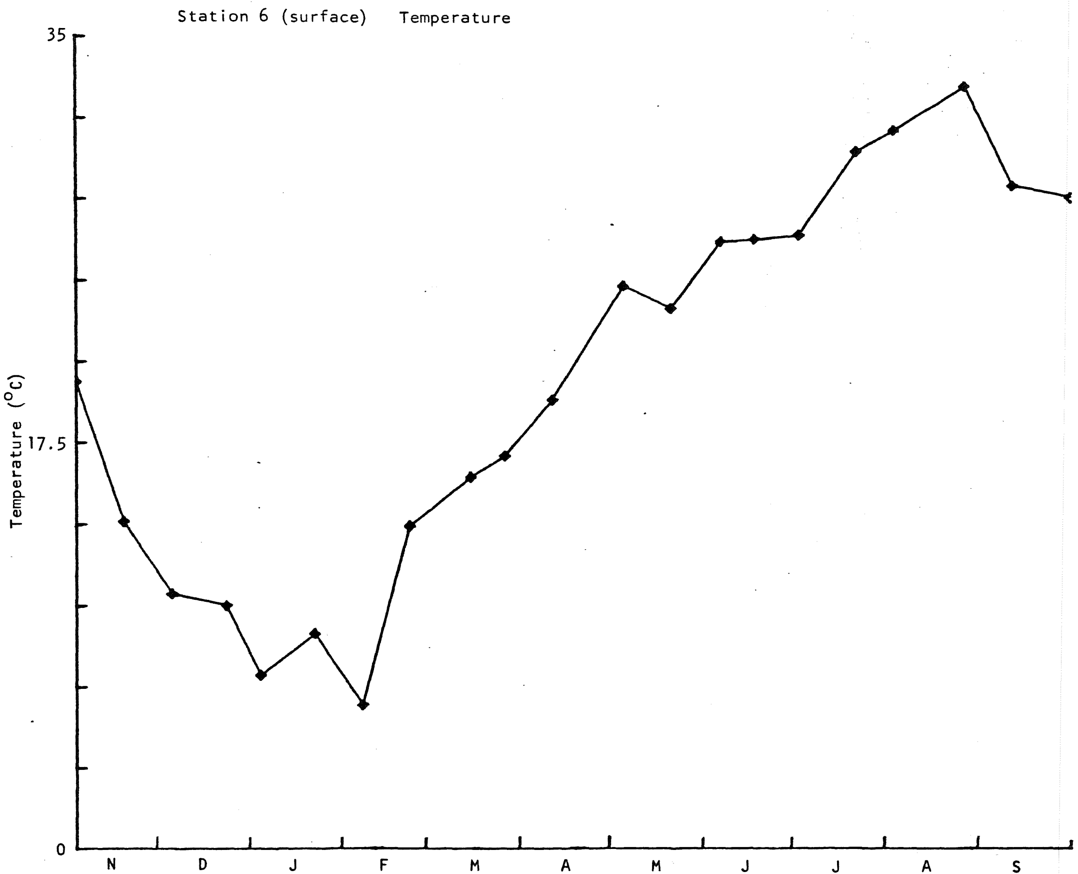


Figure 16 cont.

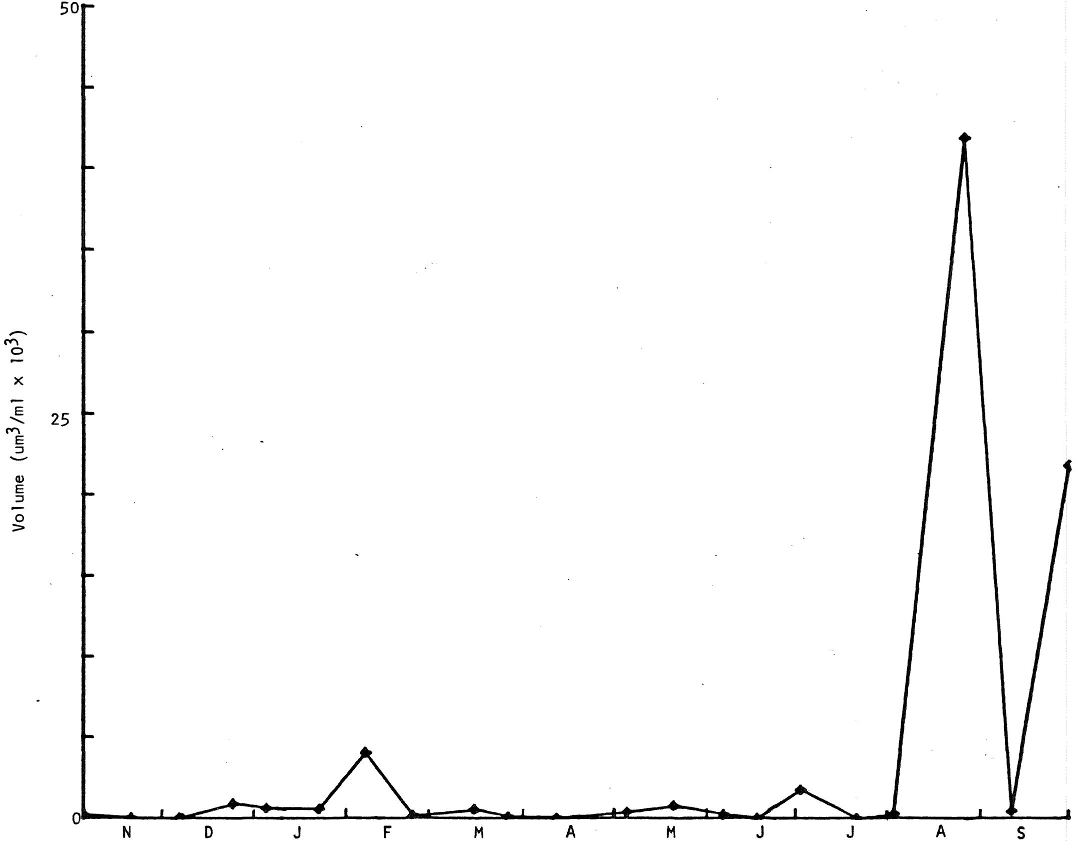
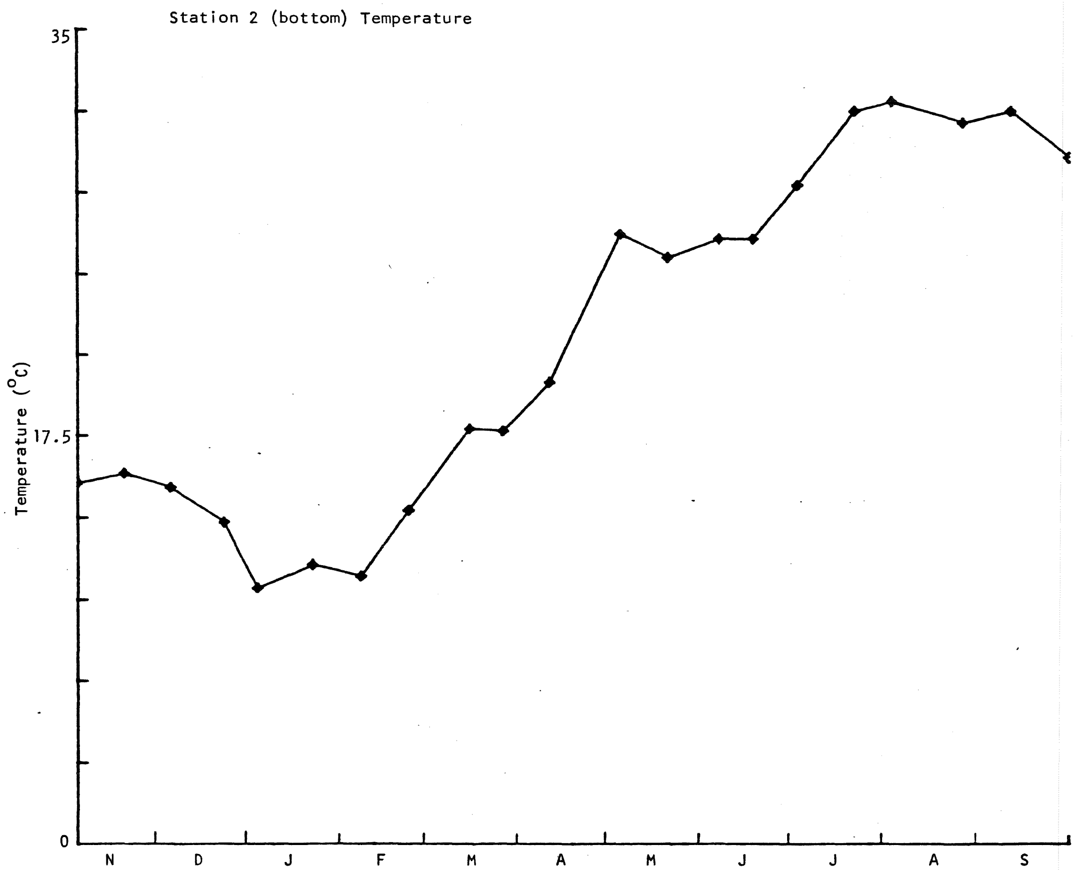

Station 4 (bottom) Miscellaneous Zooplankton

Figure 15 (cont.)



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.

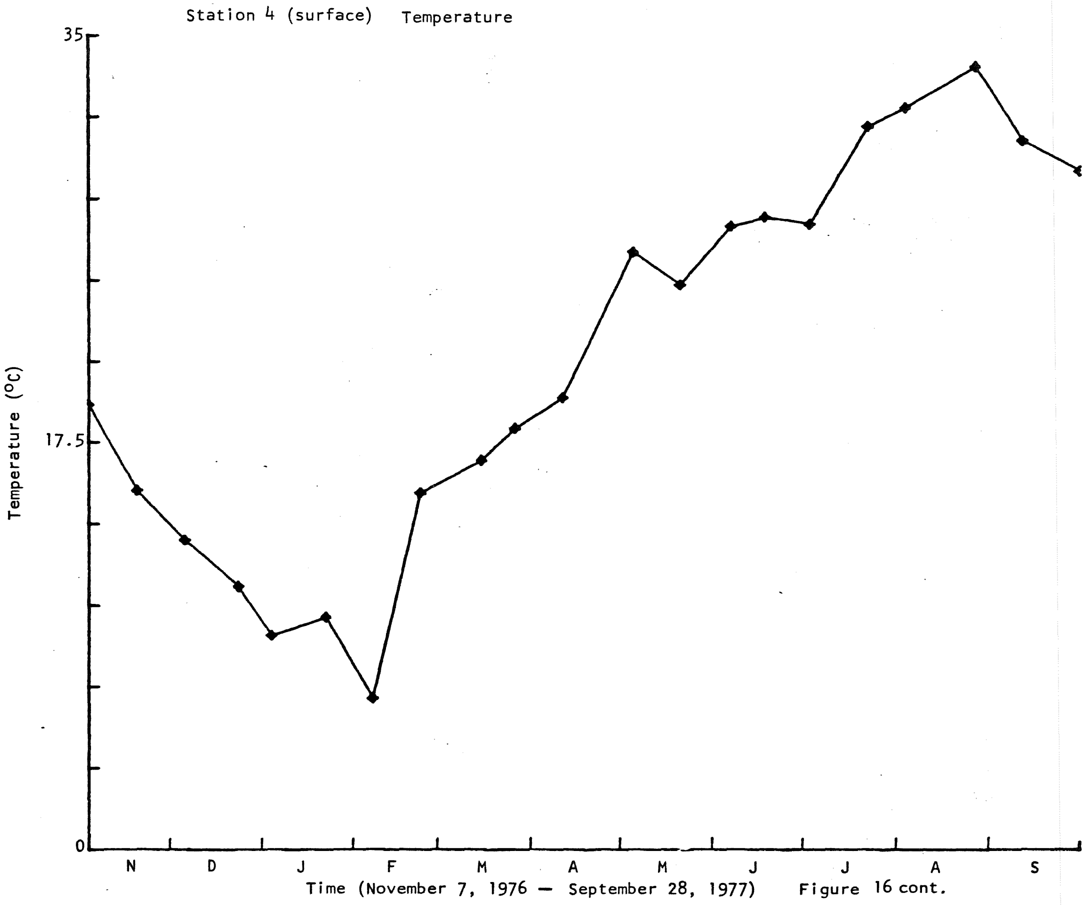
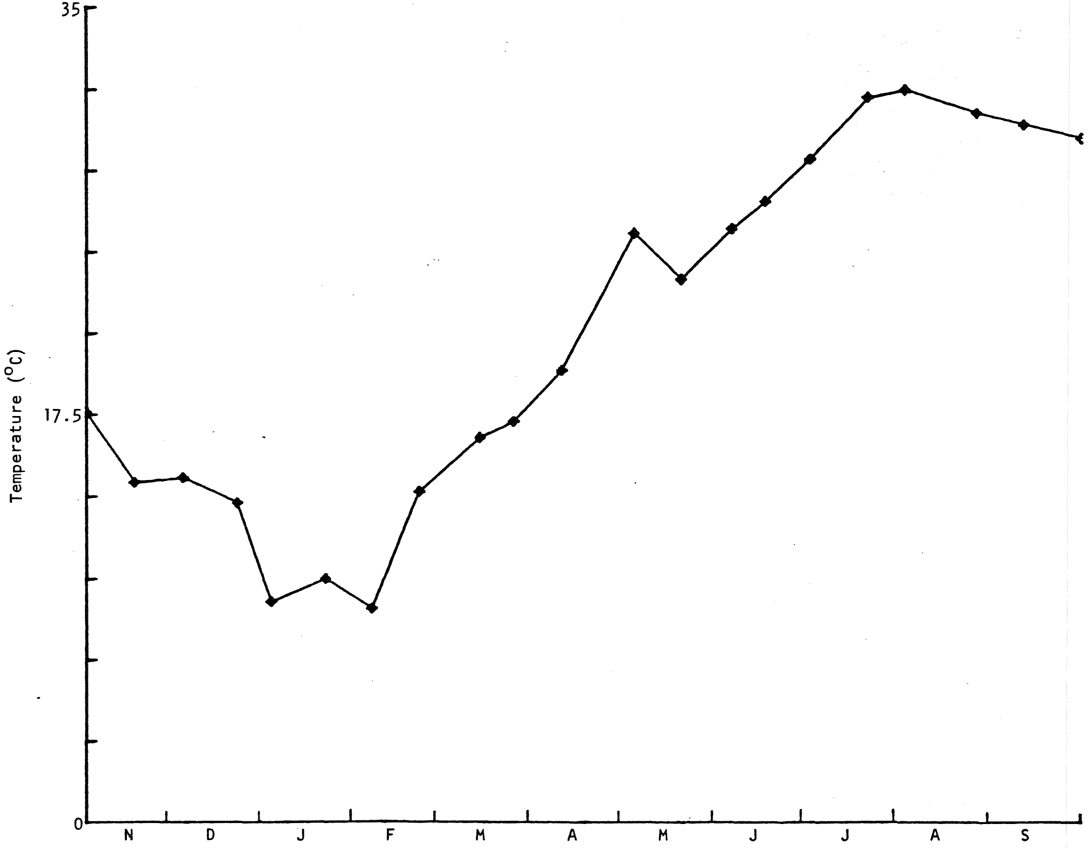


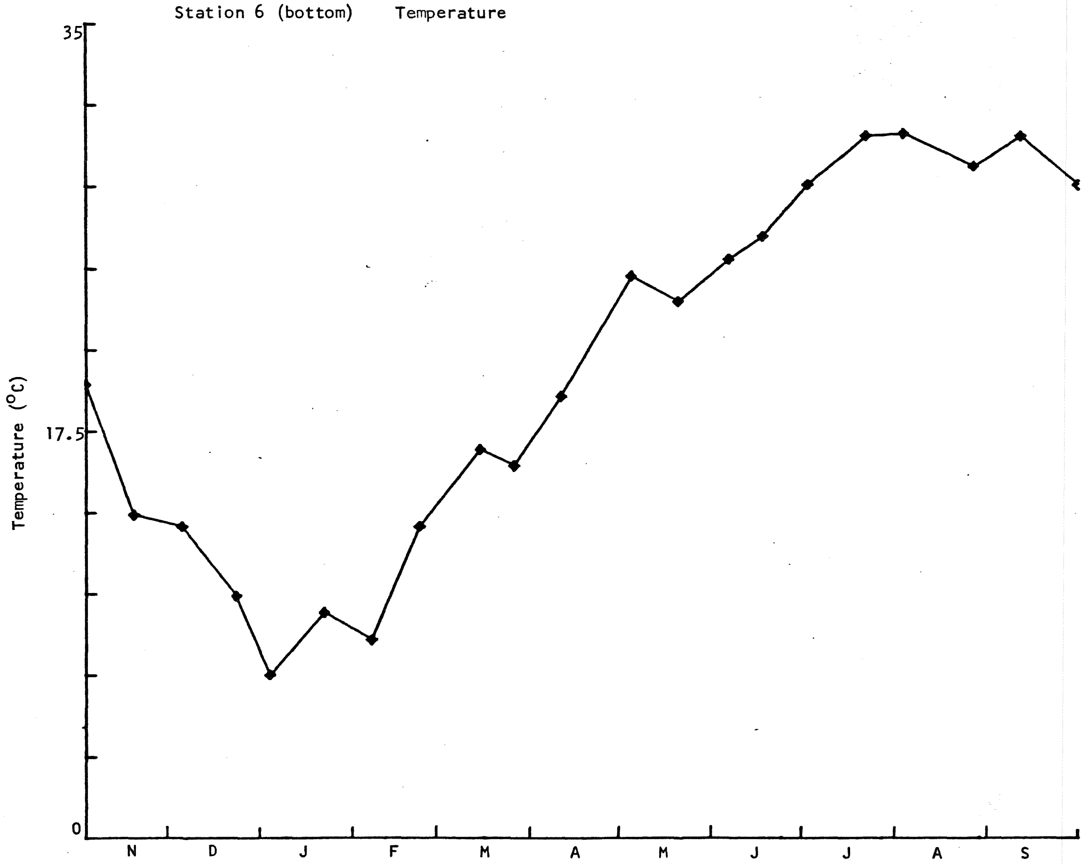
Figure 16 cont.



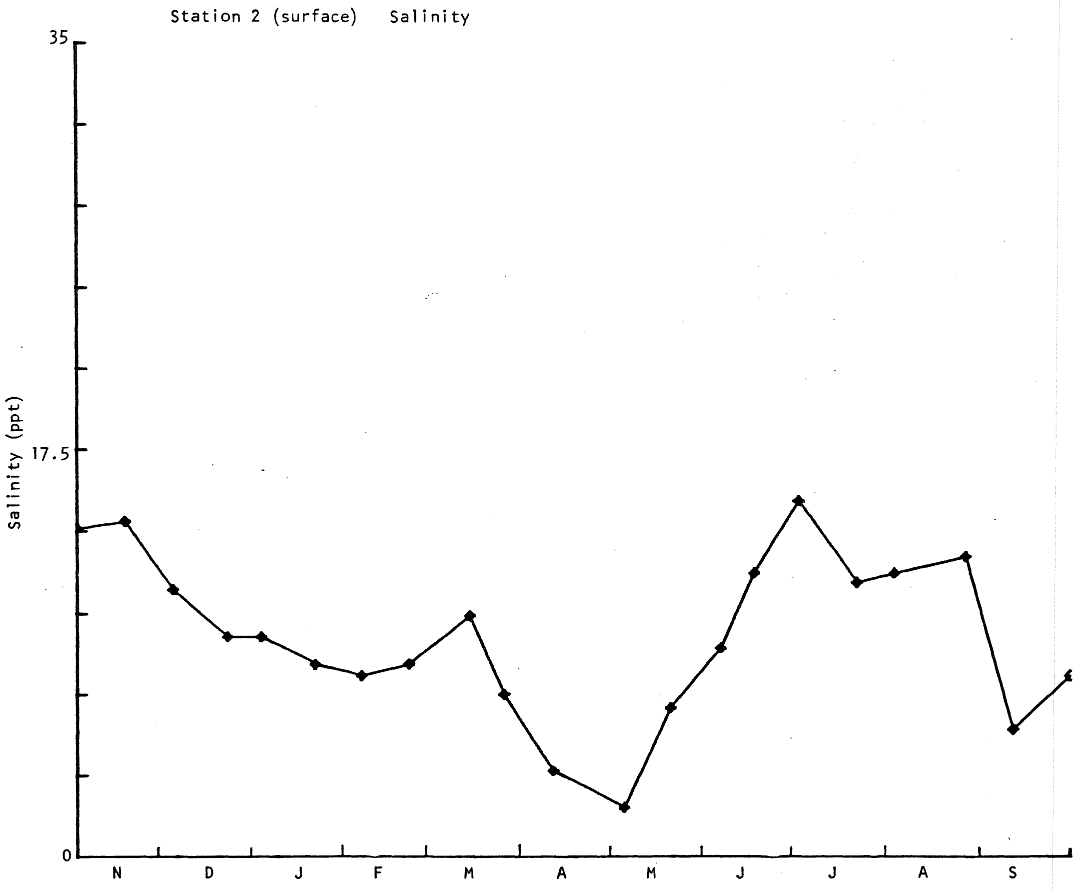
Station 4 (bottom) Temperature

Time (November 7, 1976 – September 28, 1977) Figure 16 cont.

Station 6 (bottom) Temperature



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

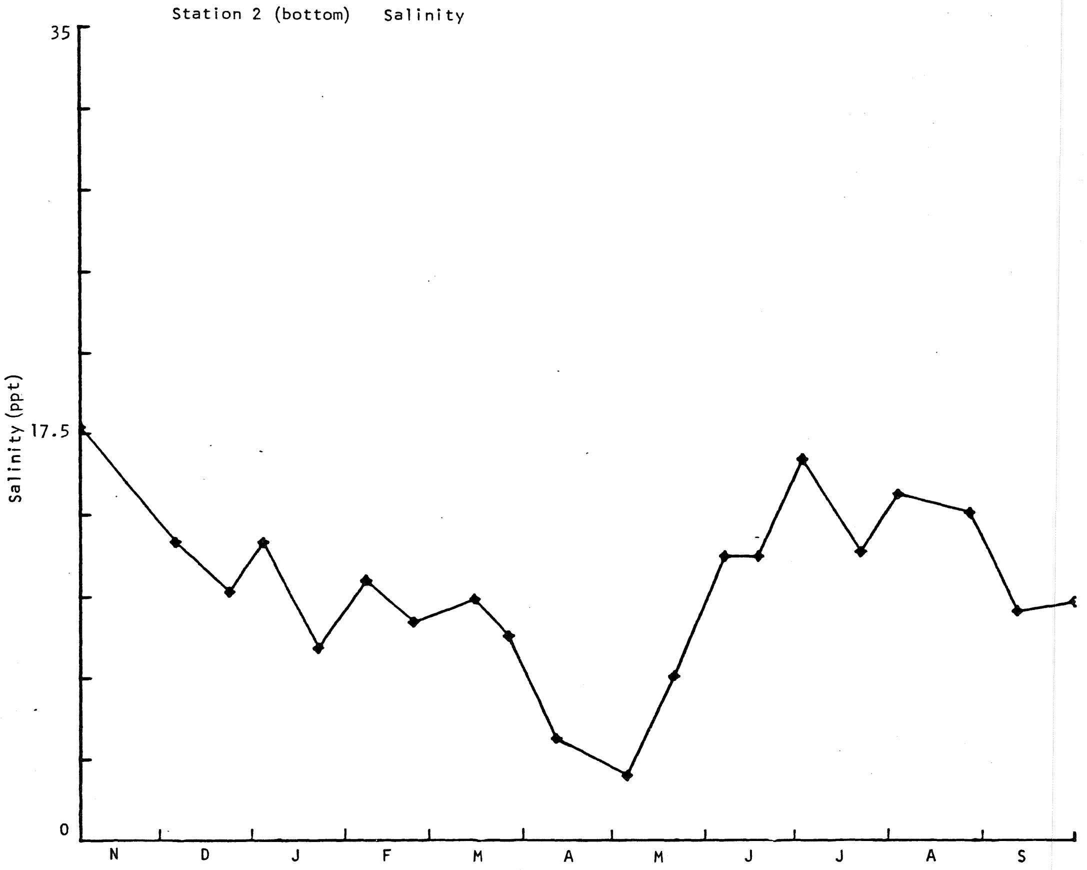
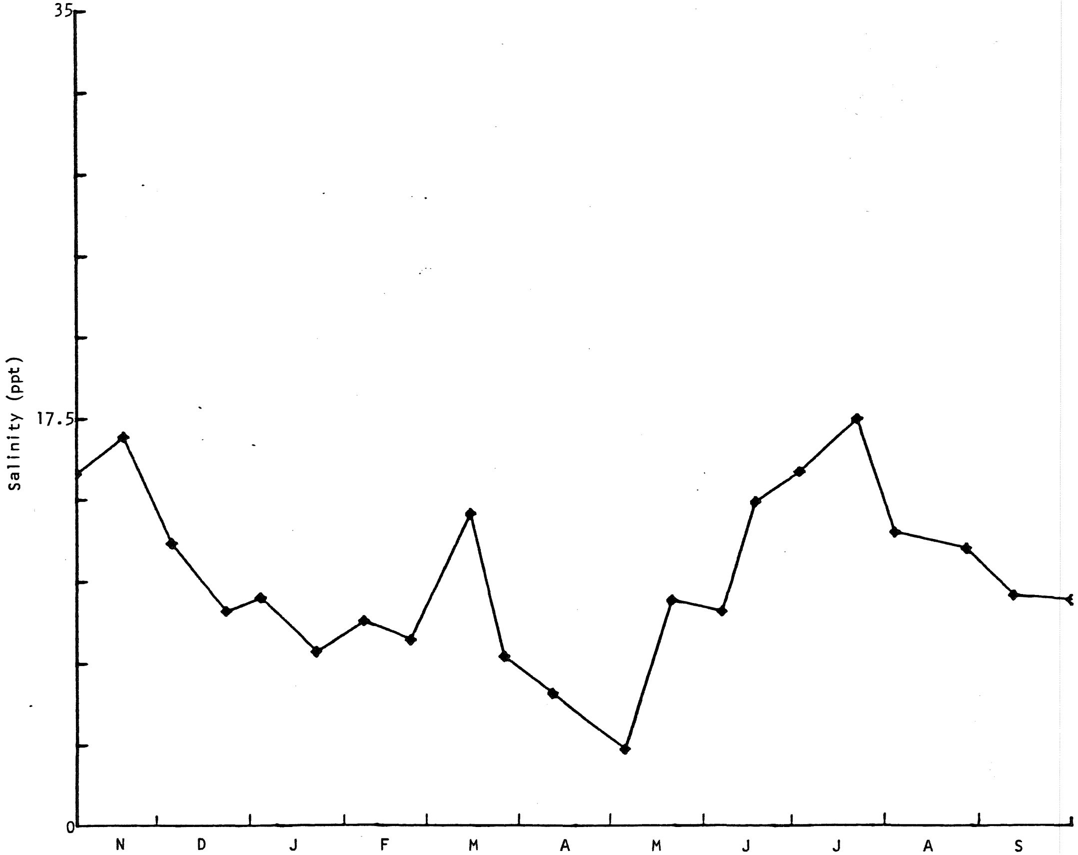


Figure 16 cont.

Station 4 (surface) Salinity



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

Station 4 (bottom) Salinity

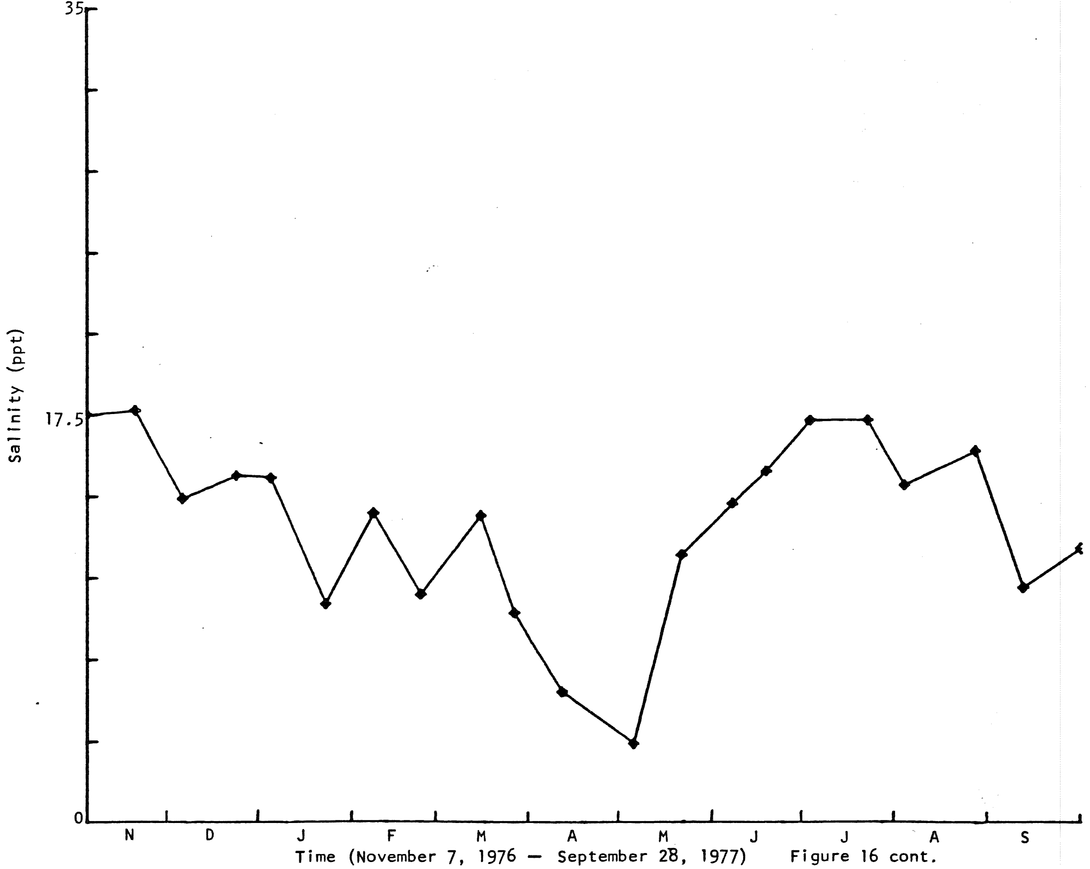


Figure 16 cont.

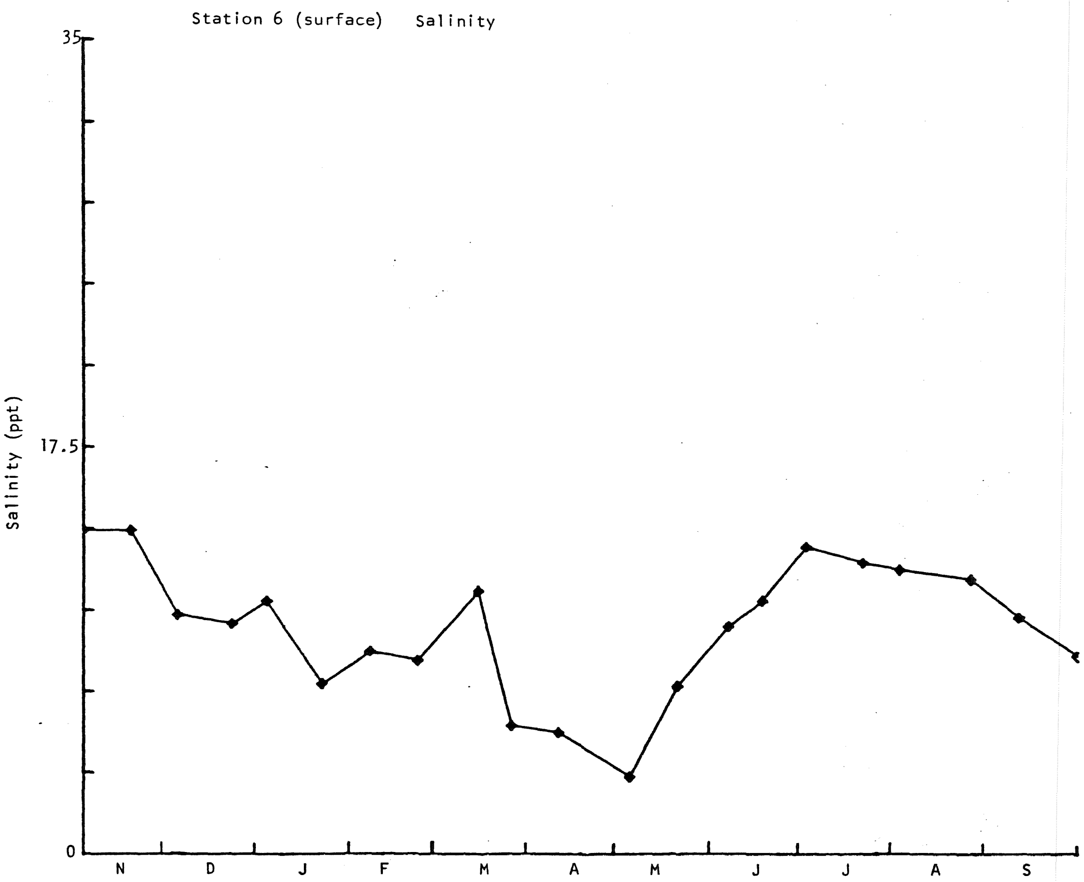


Figure 16 cont.

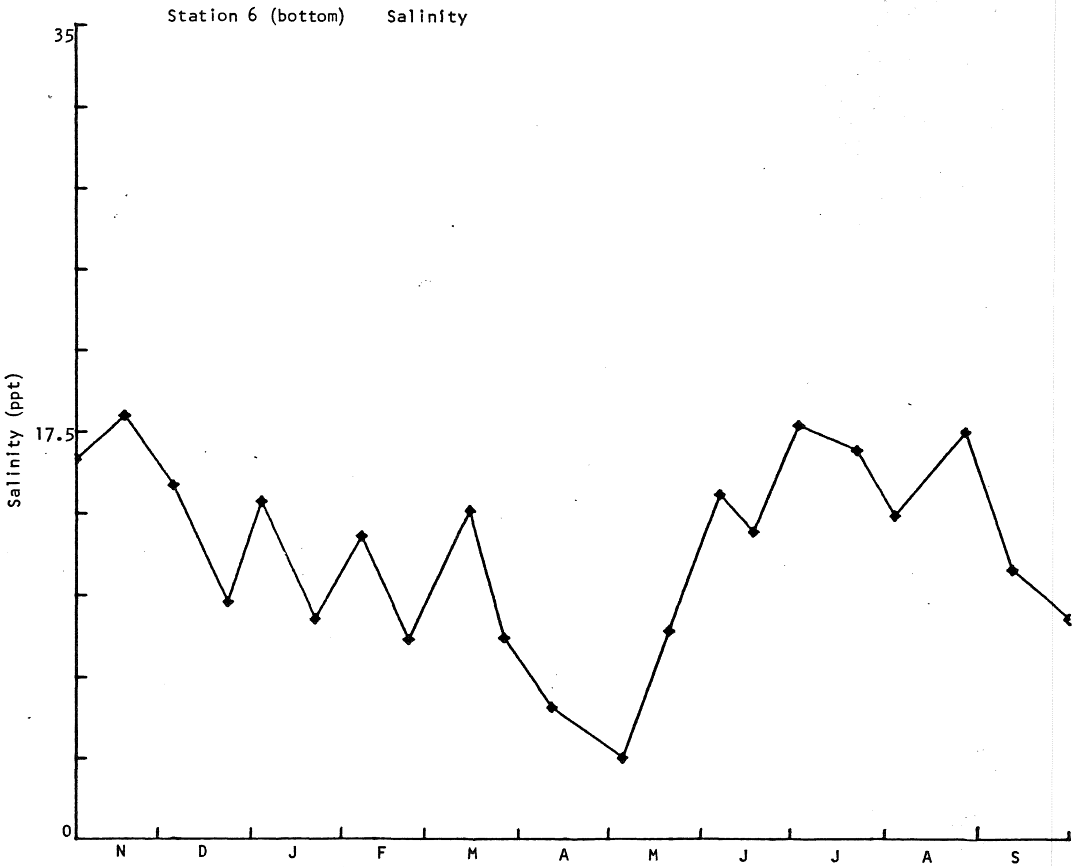
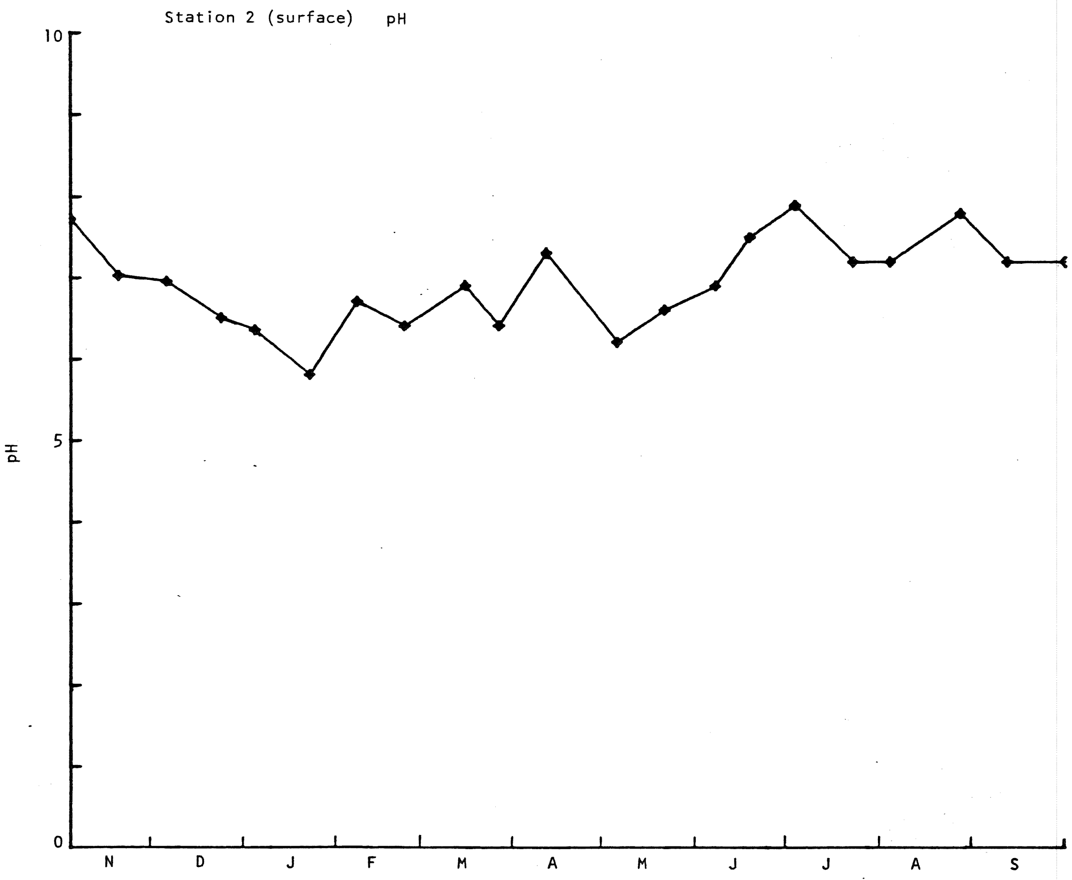

Station 6 (bottom) Salinity

Figure 16 cont.



Time (November 7, 1976 – September 28,1977) Figure 16 cont.

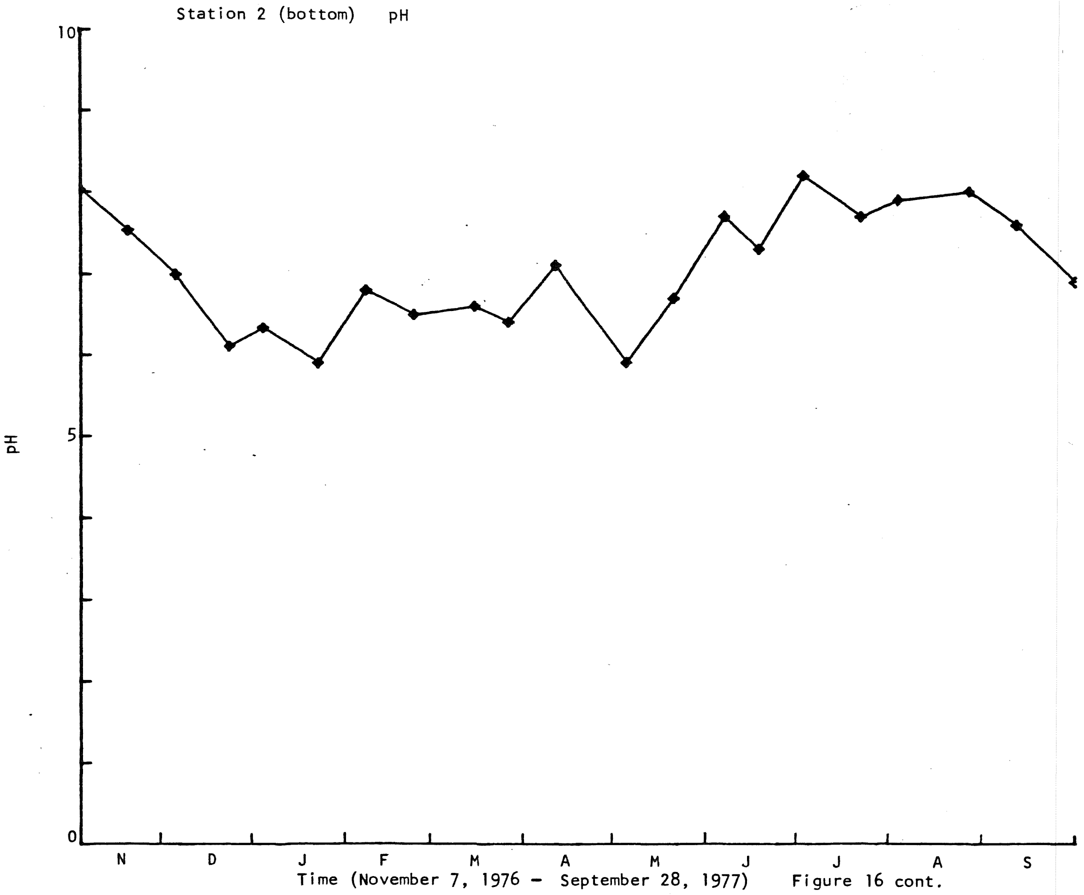
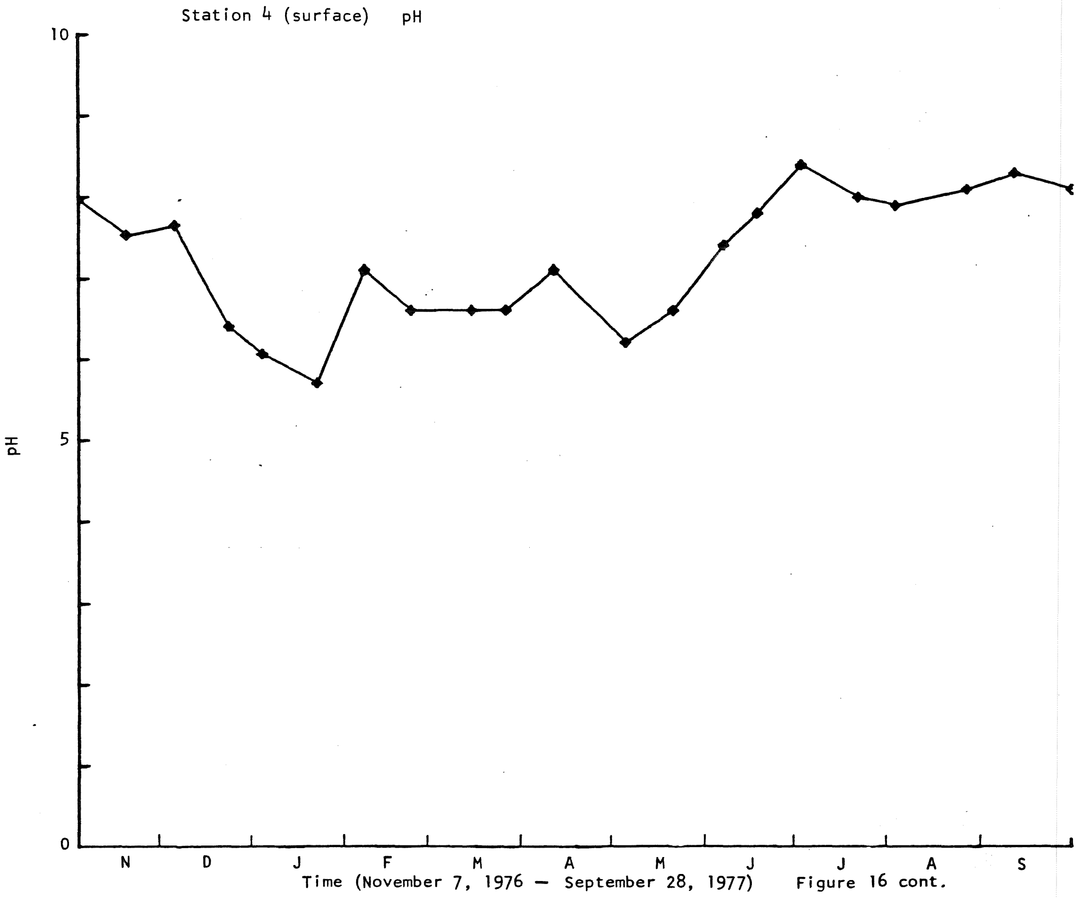


Figure 16 cont.



Station 4 (surface) pH

Figure 16 cont.

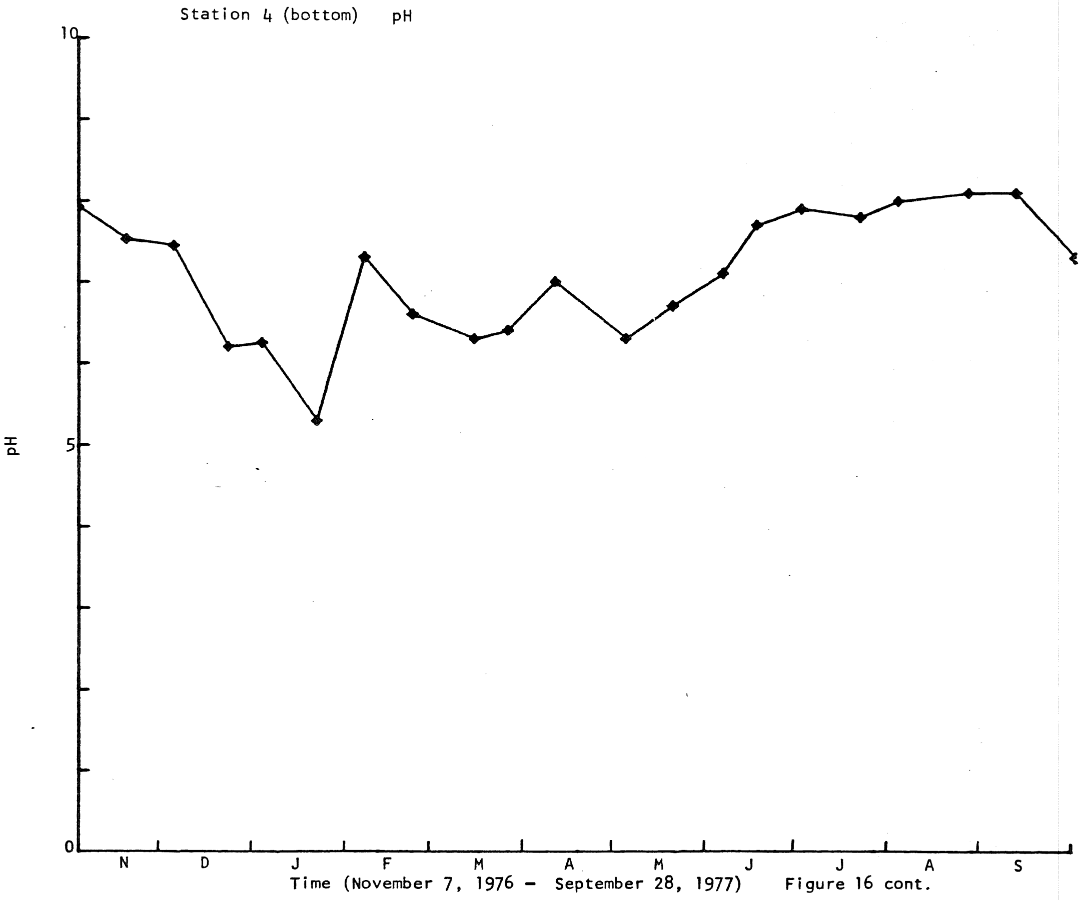
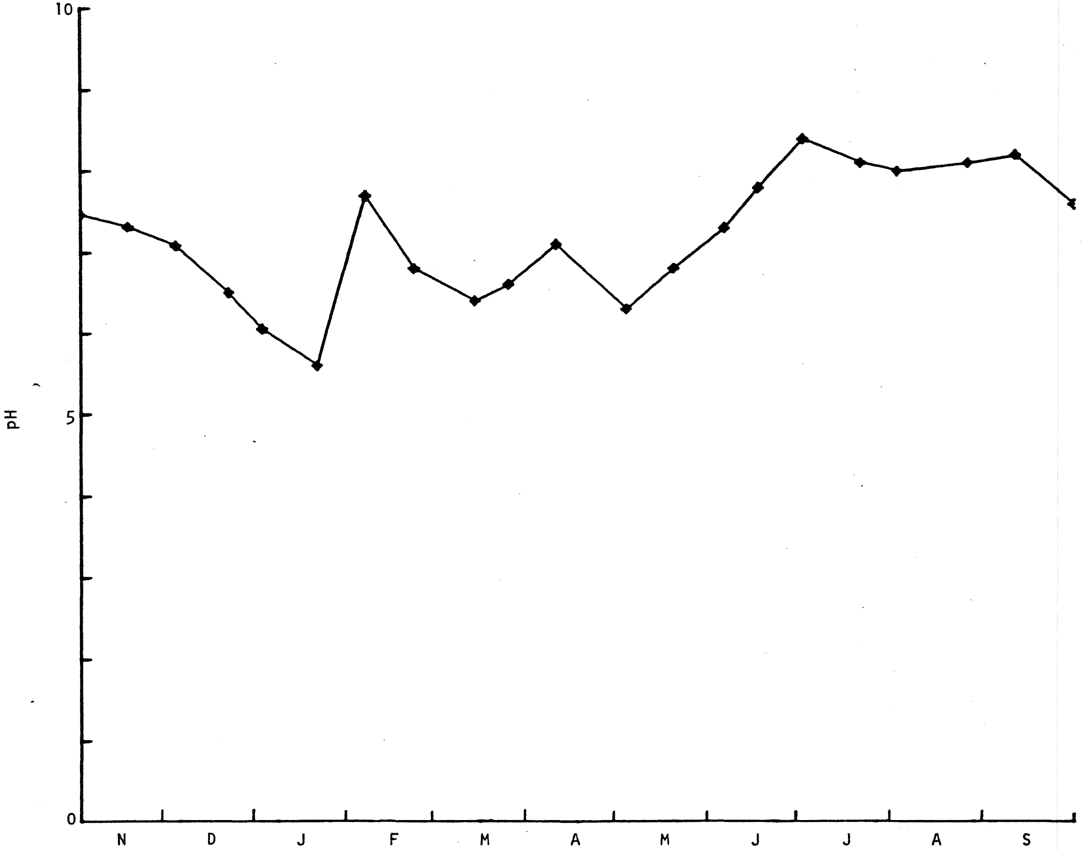
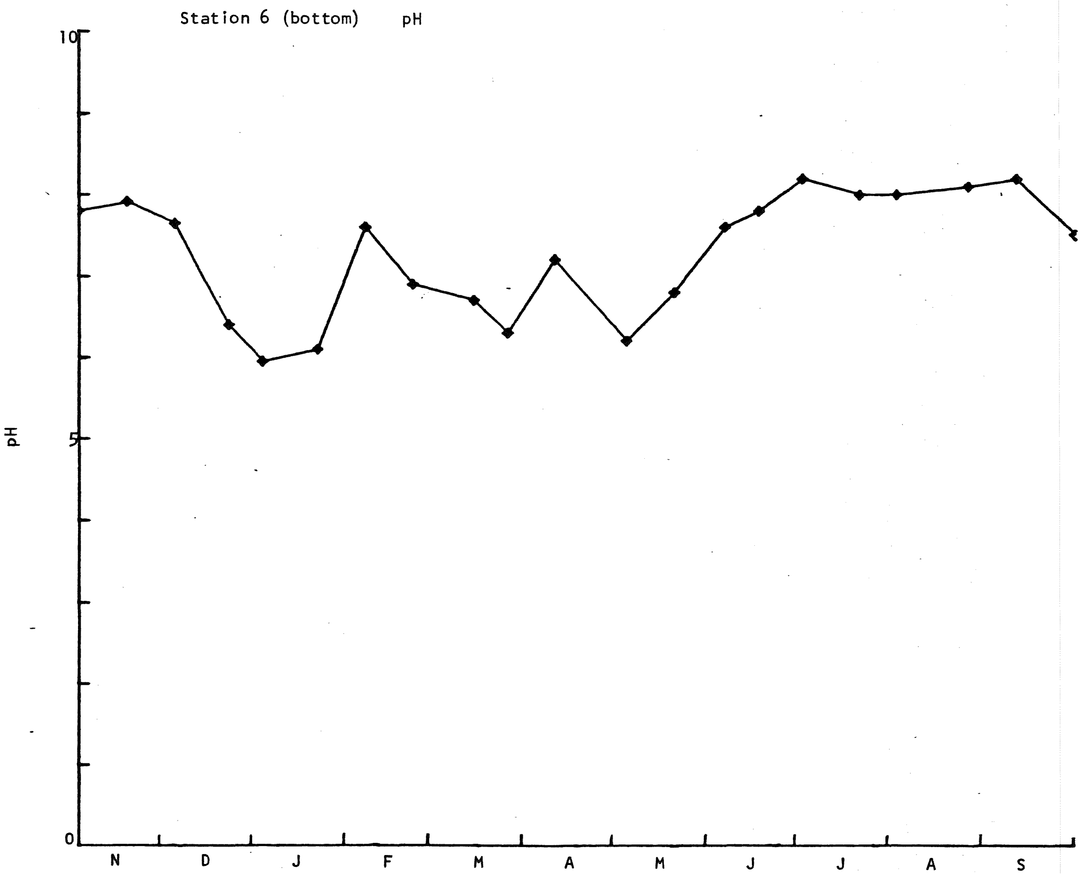


Figure 16 cont.

Station 6 (surface) pH



Time (November 7,1976 — September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

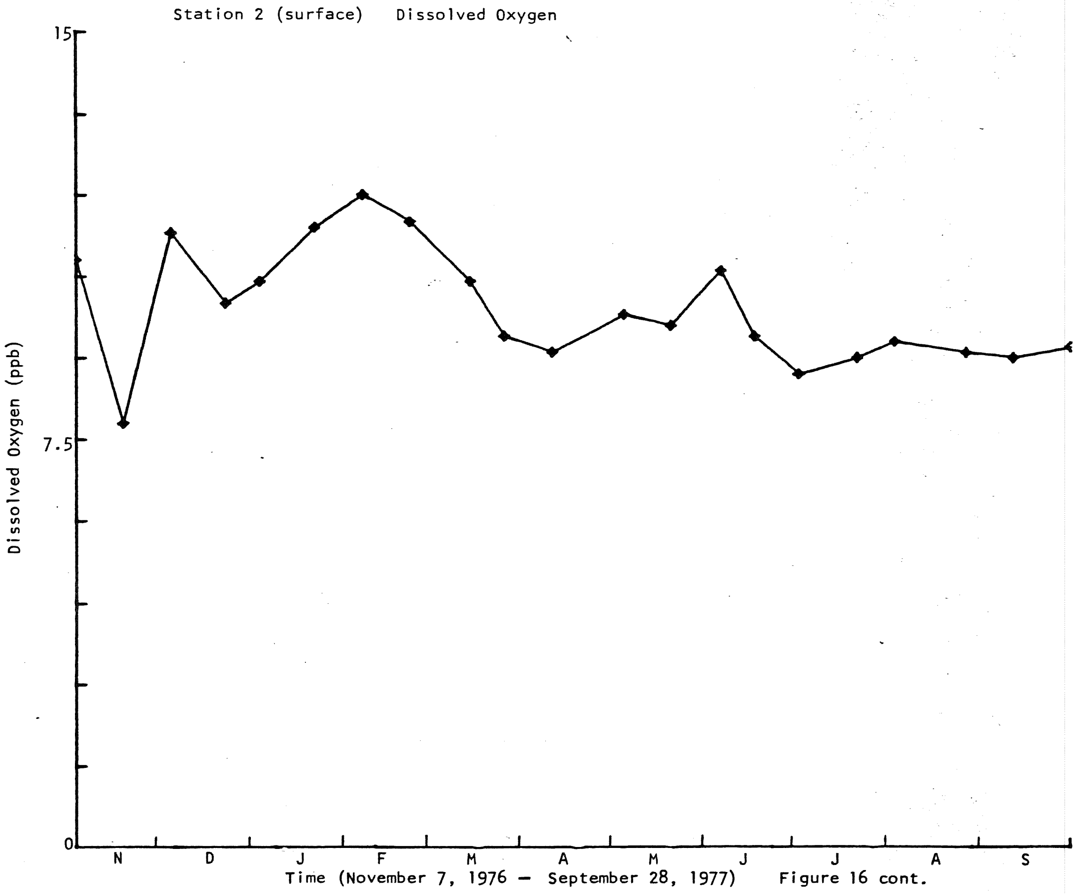
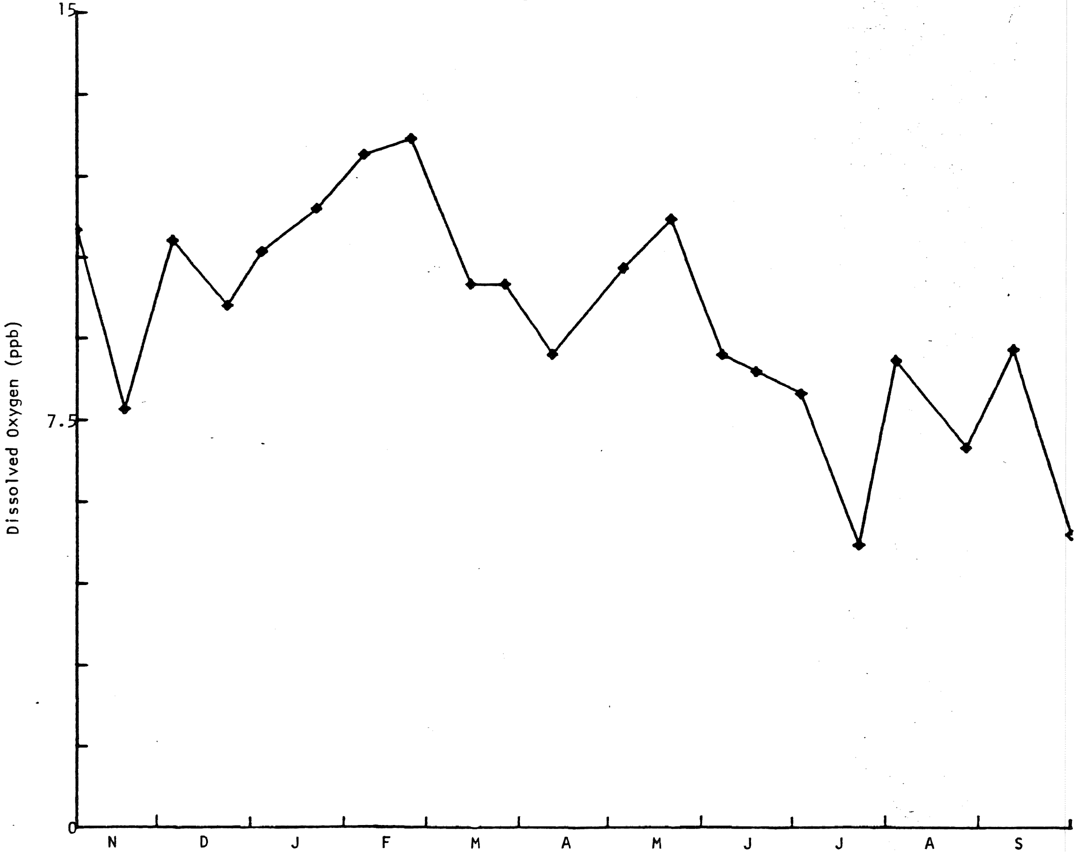

Station 2 (surface) Dissolved Oxygen

Figure 16 cont.

Station 2 (bottom) Dissolved Oxygen



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

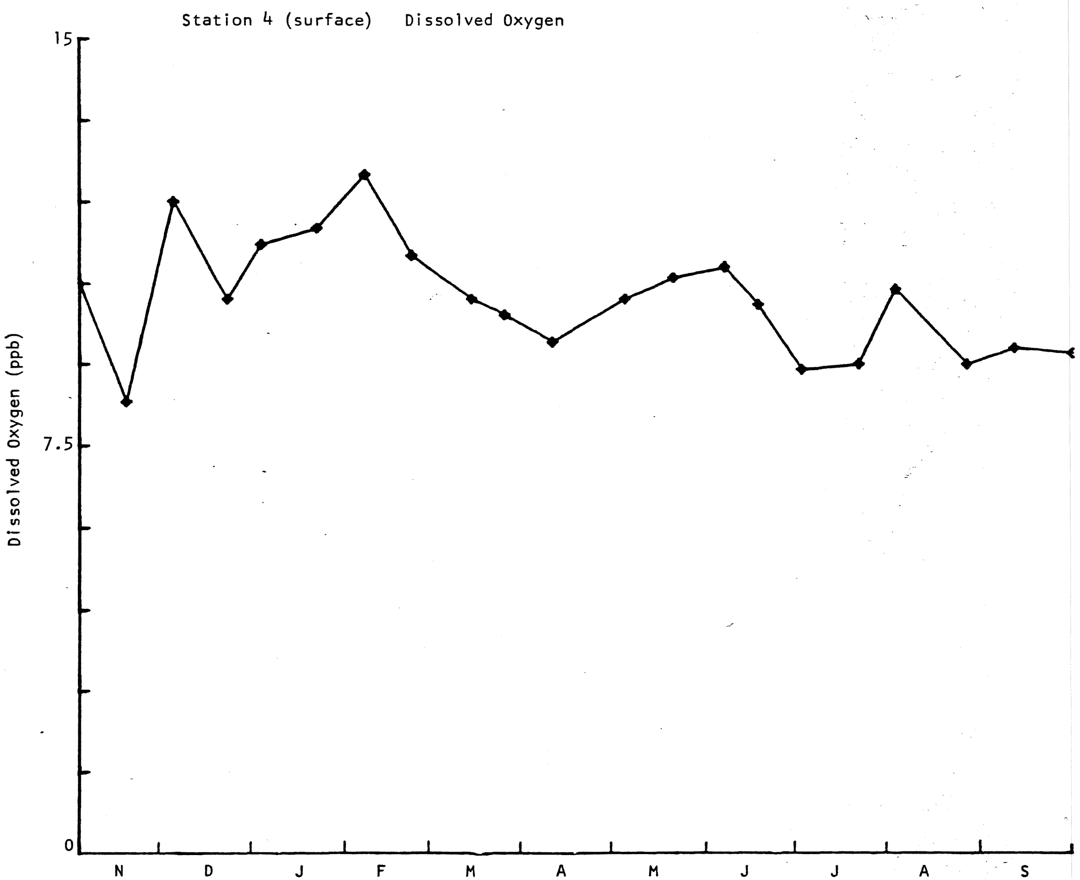


Figure 16 cont.

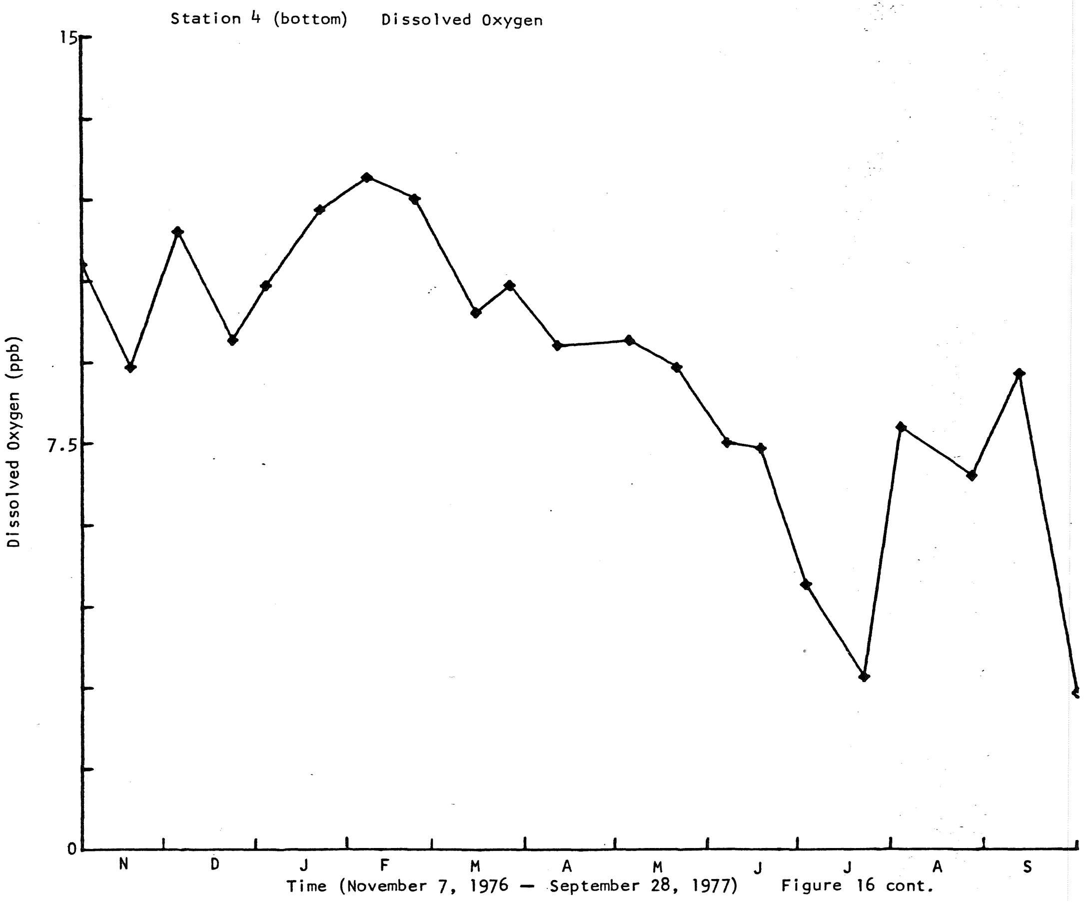
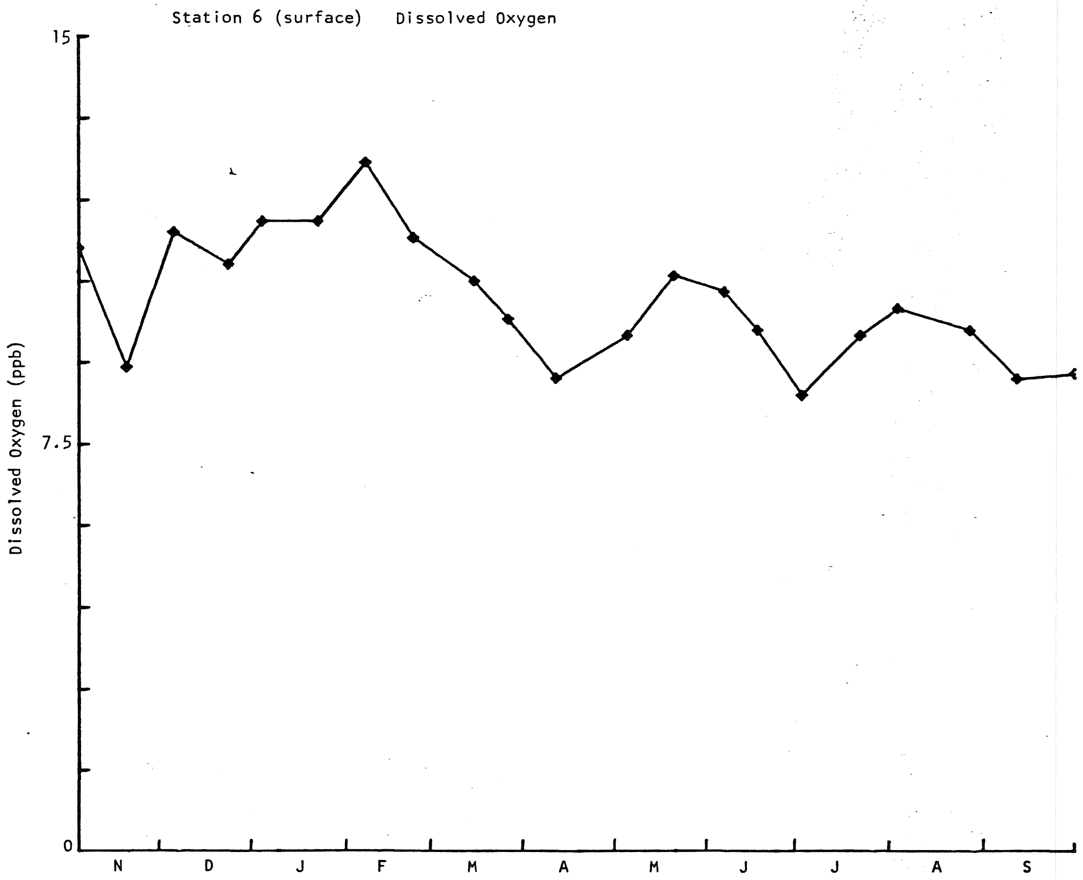


Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

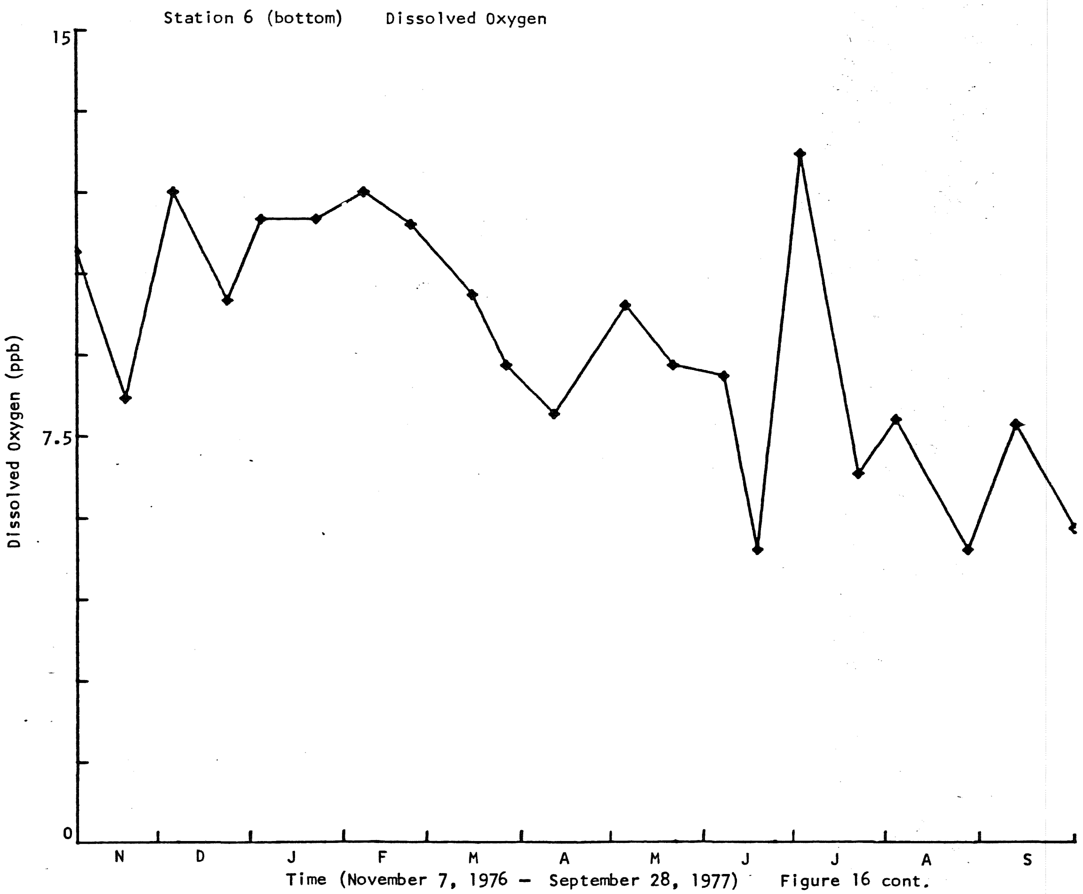


Figure 16 cont.

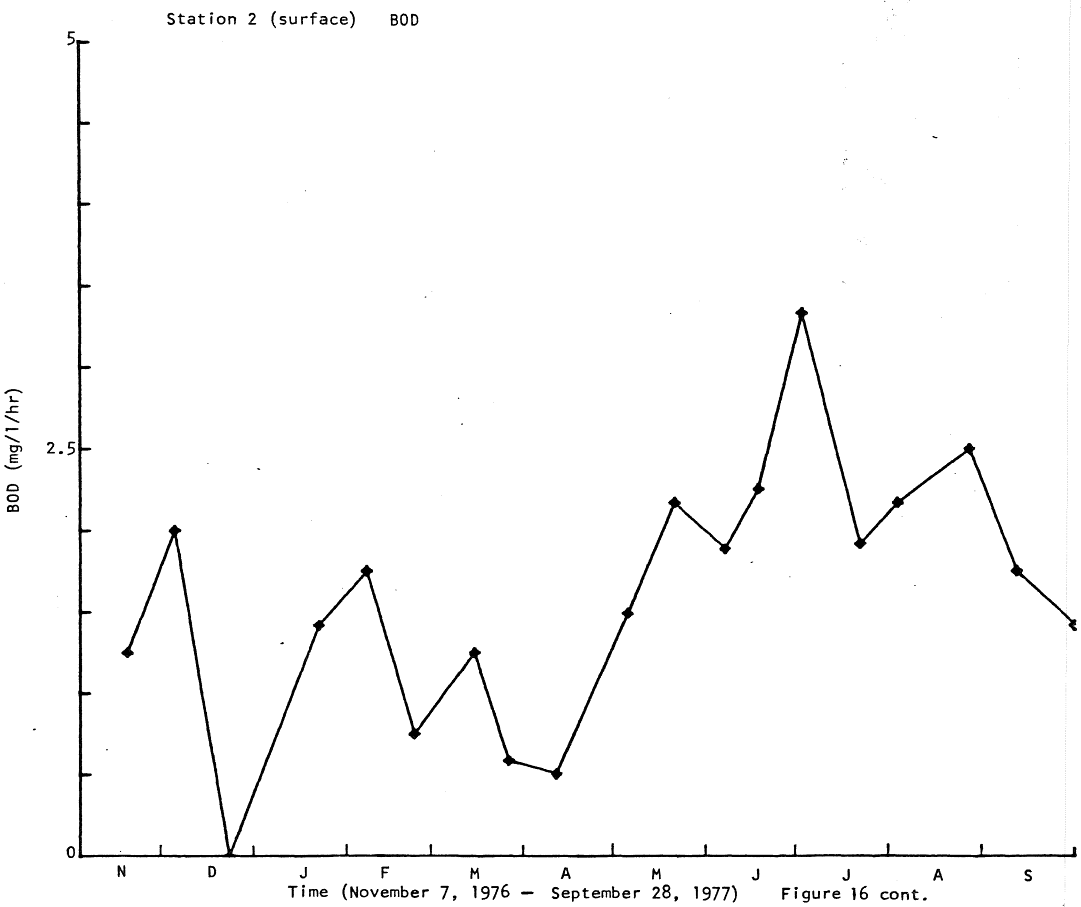


Figure 16 cont.

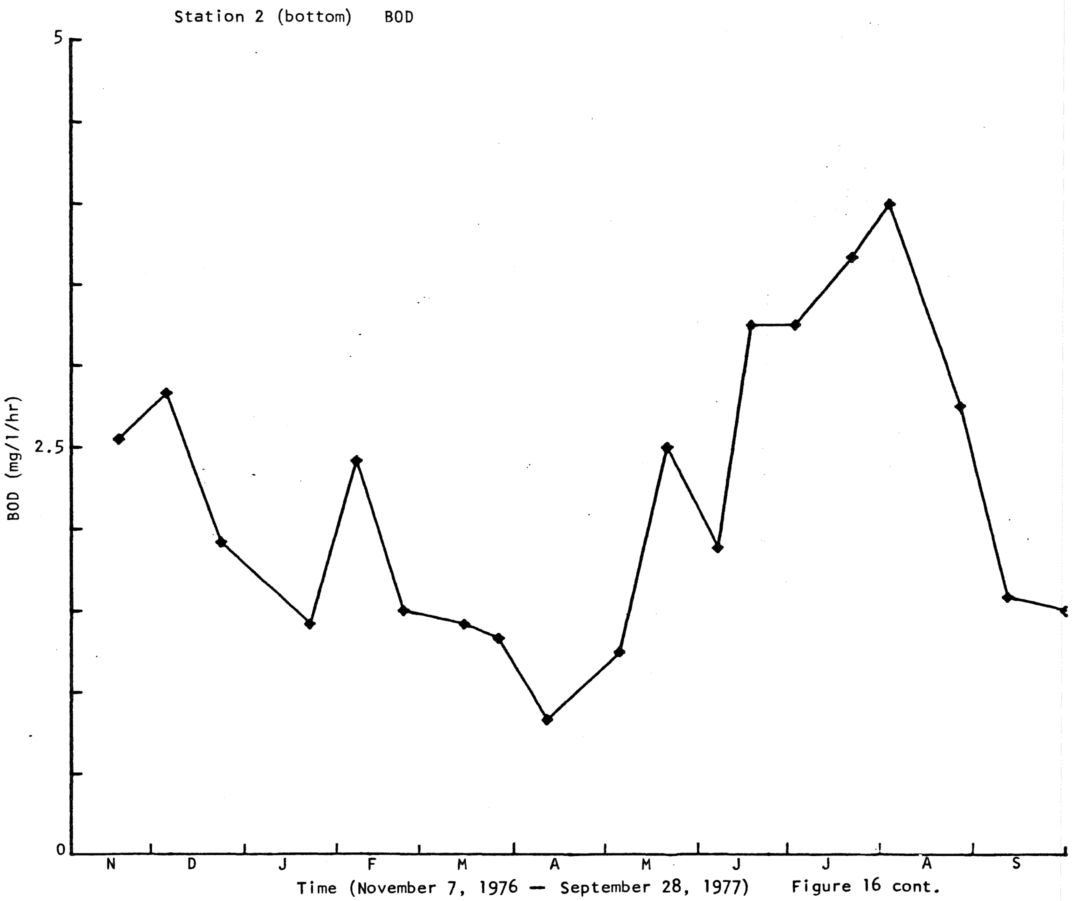
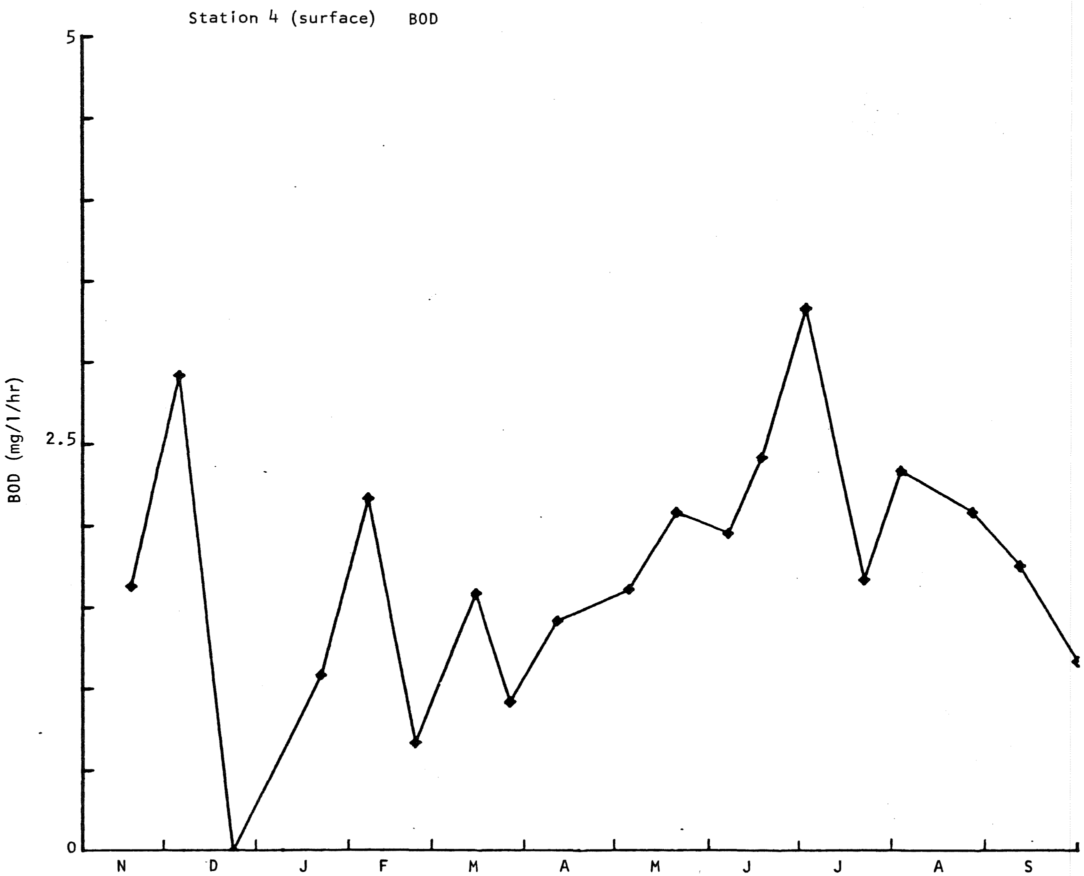


Figure 16 cont.



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.

Station 4 (bottom) BOD

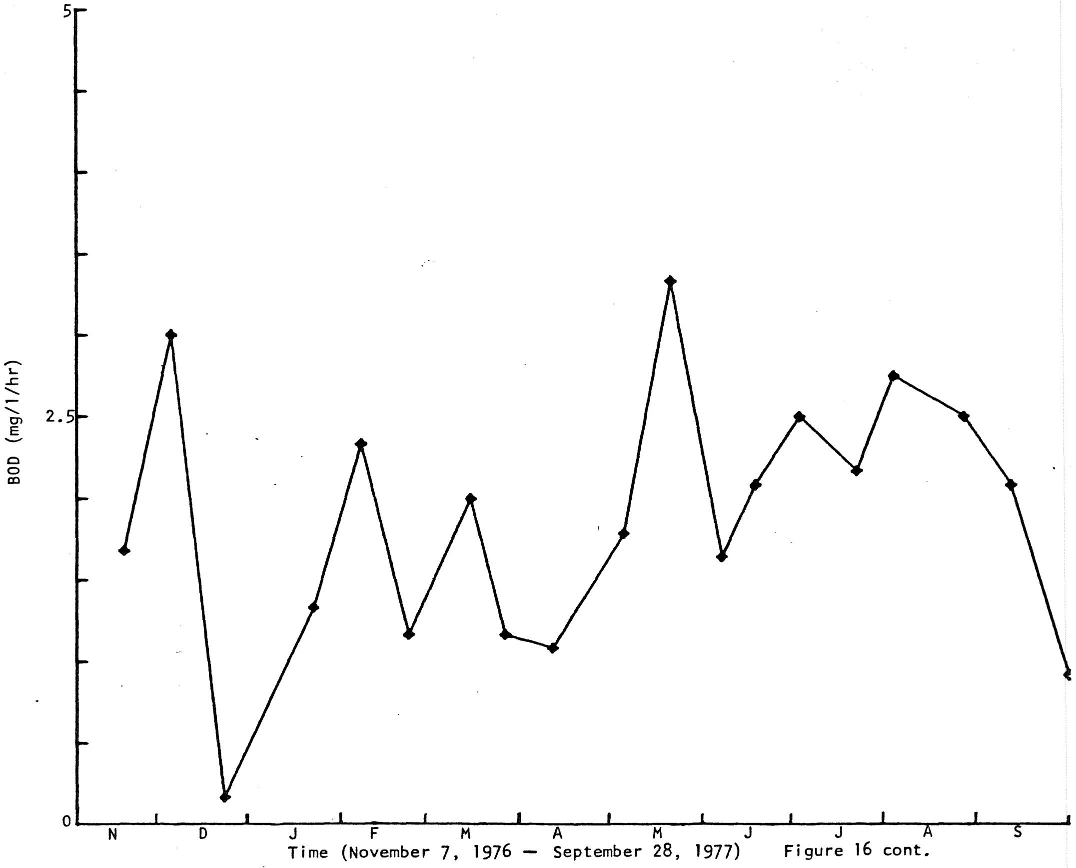
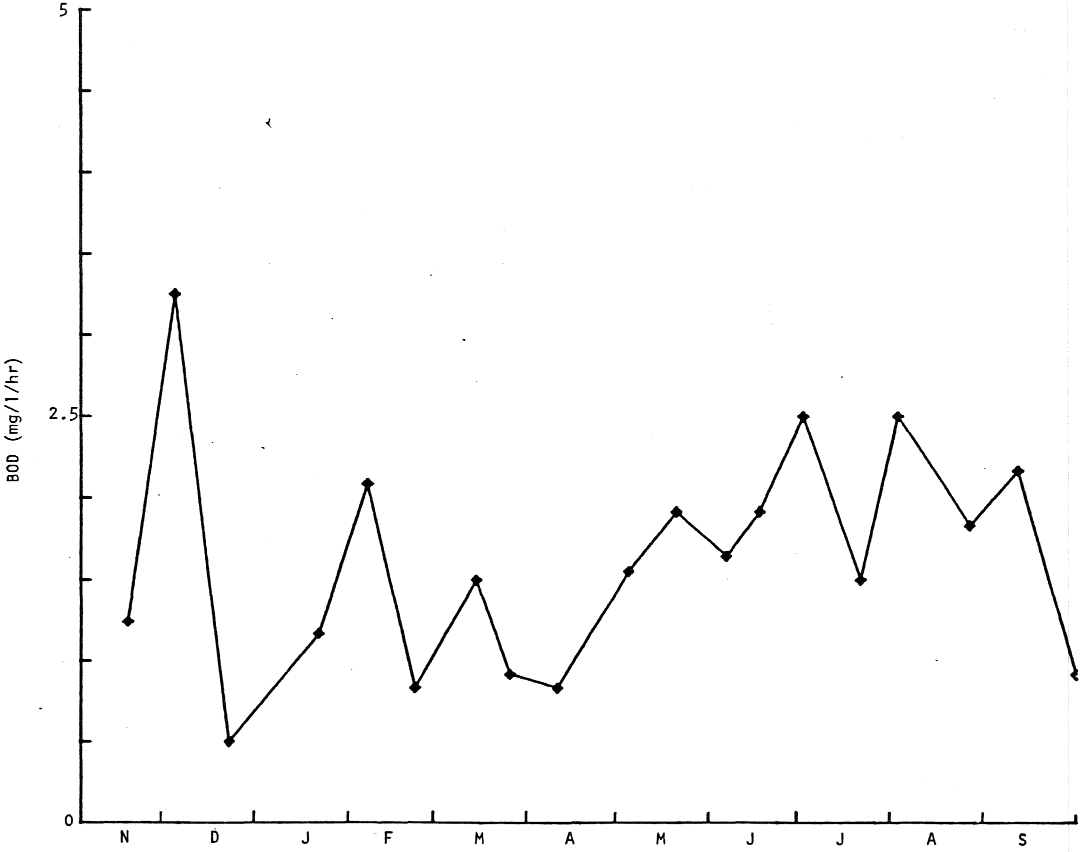


Figure 16 cont.

Station 6 (surface) BOD



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.

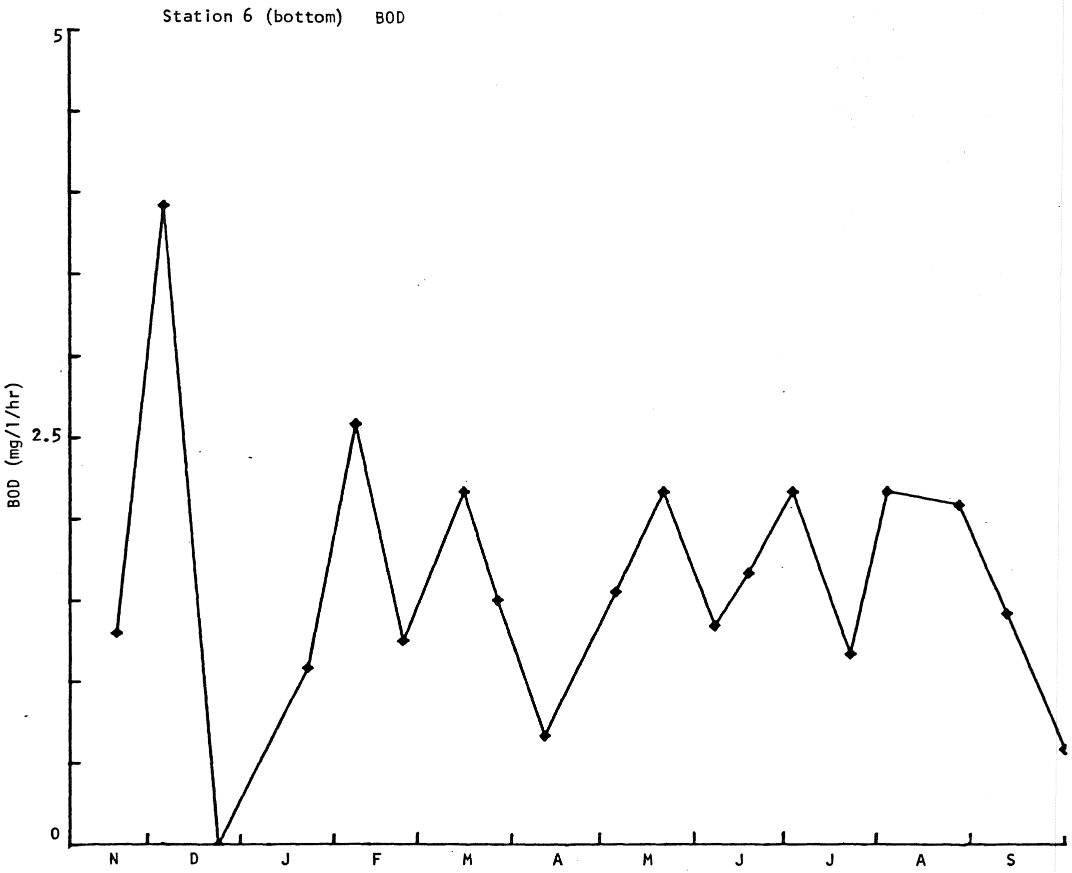


Figure 16 cont.

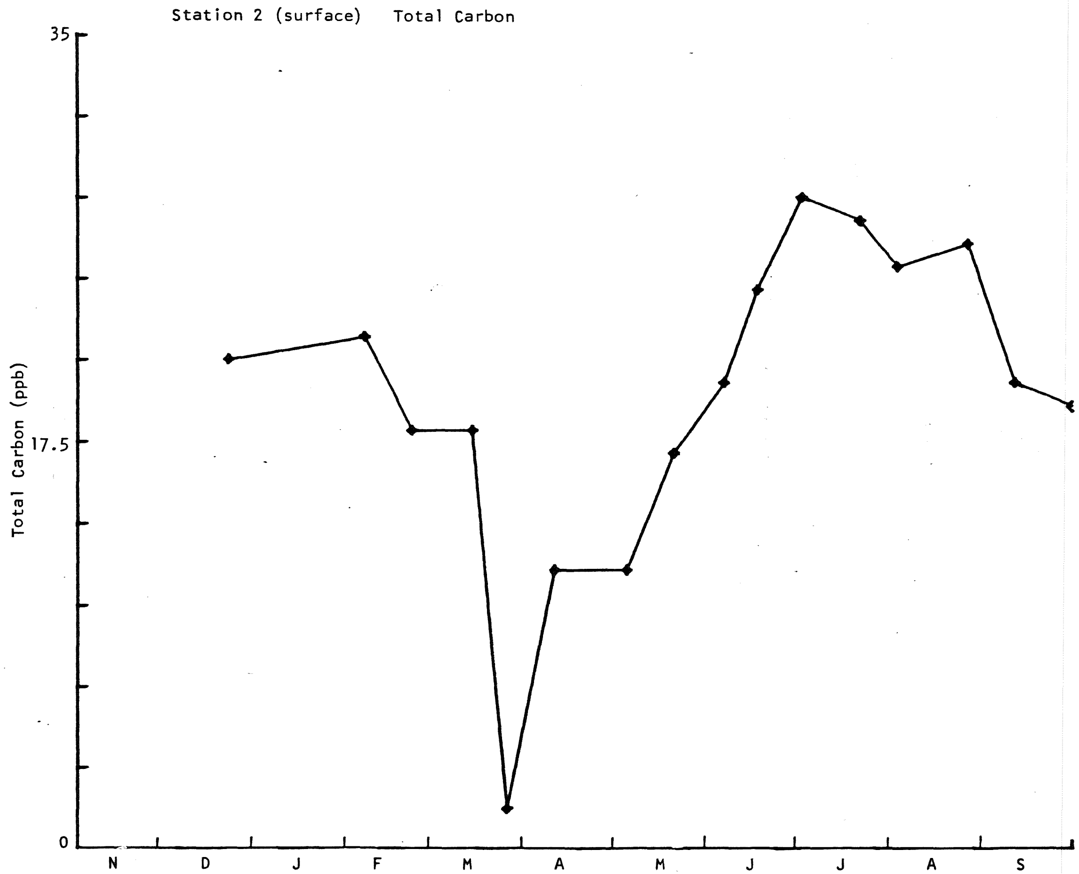
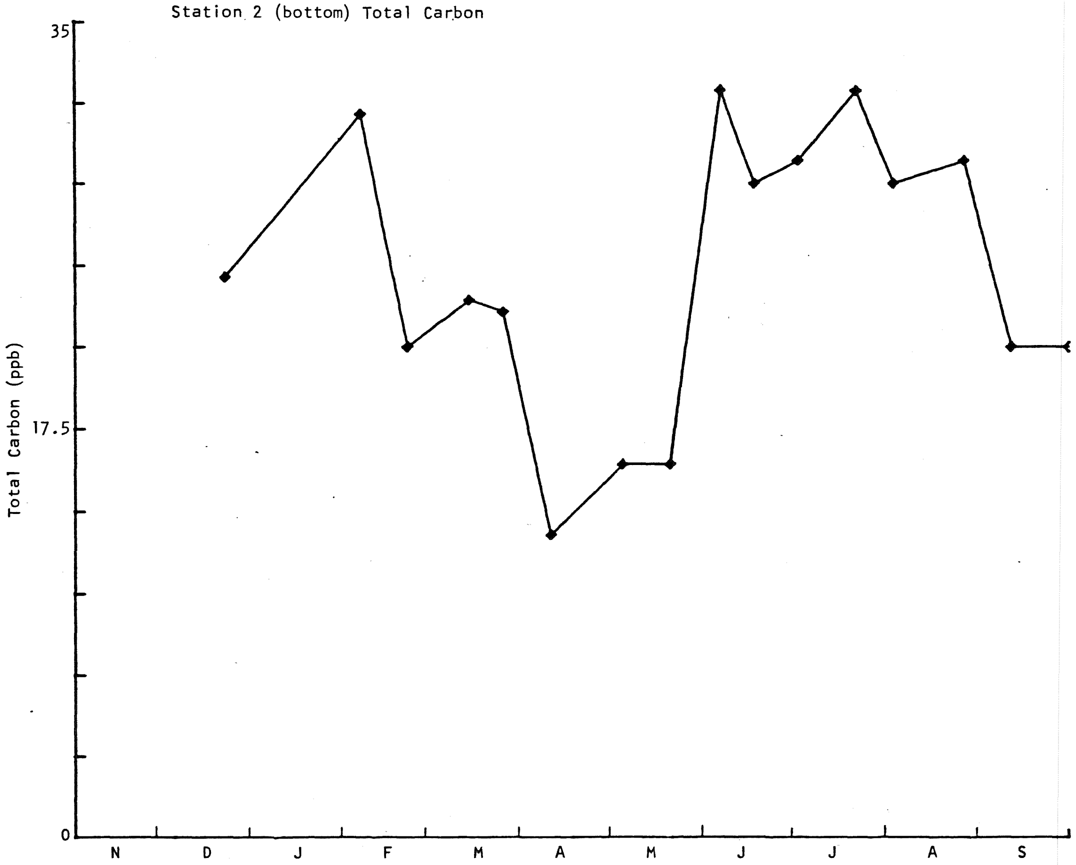


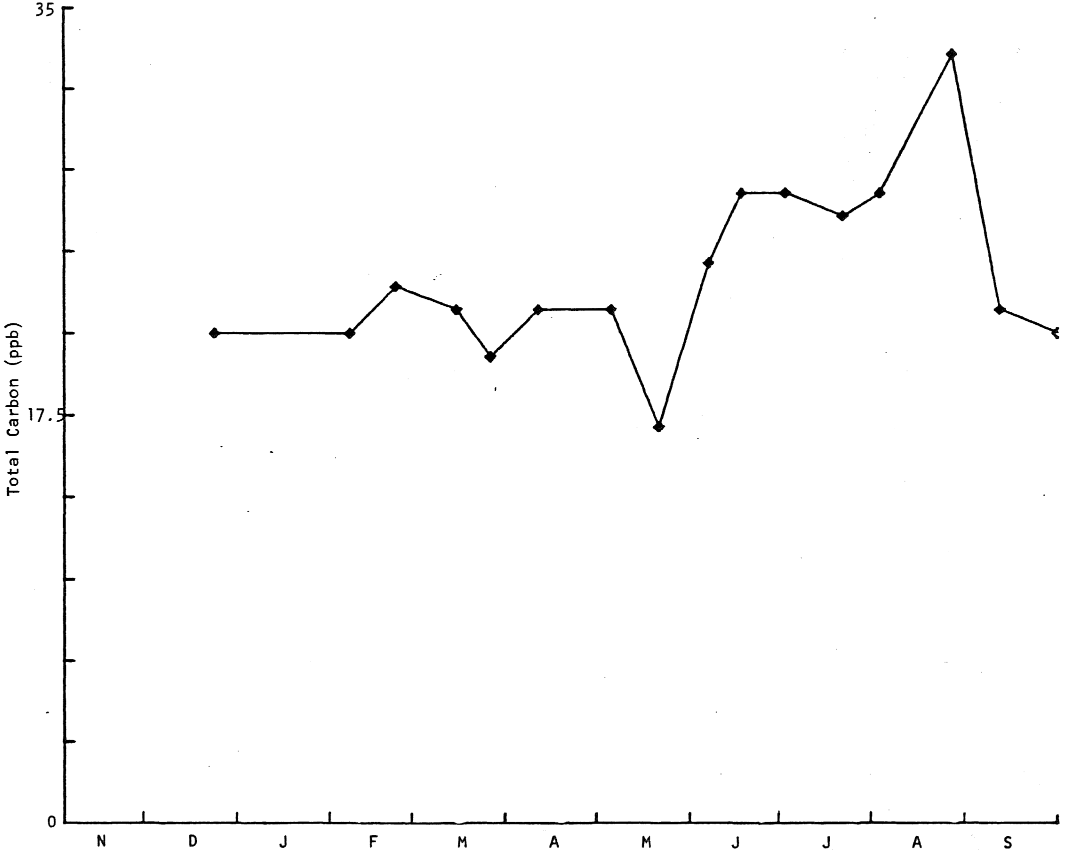
Figure 16 cont.



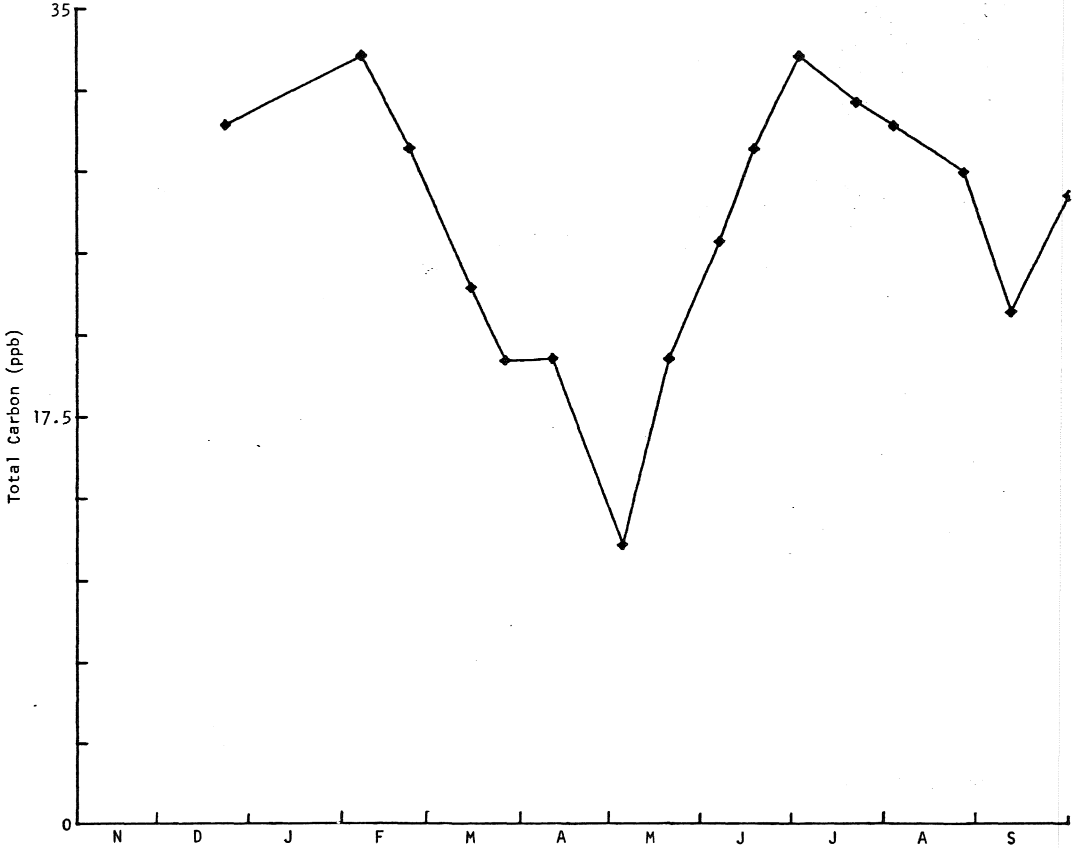
Station 2 (bottom) Total Carbon

Figure 16 cont.

Station 4 (surface) Total Carbon

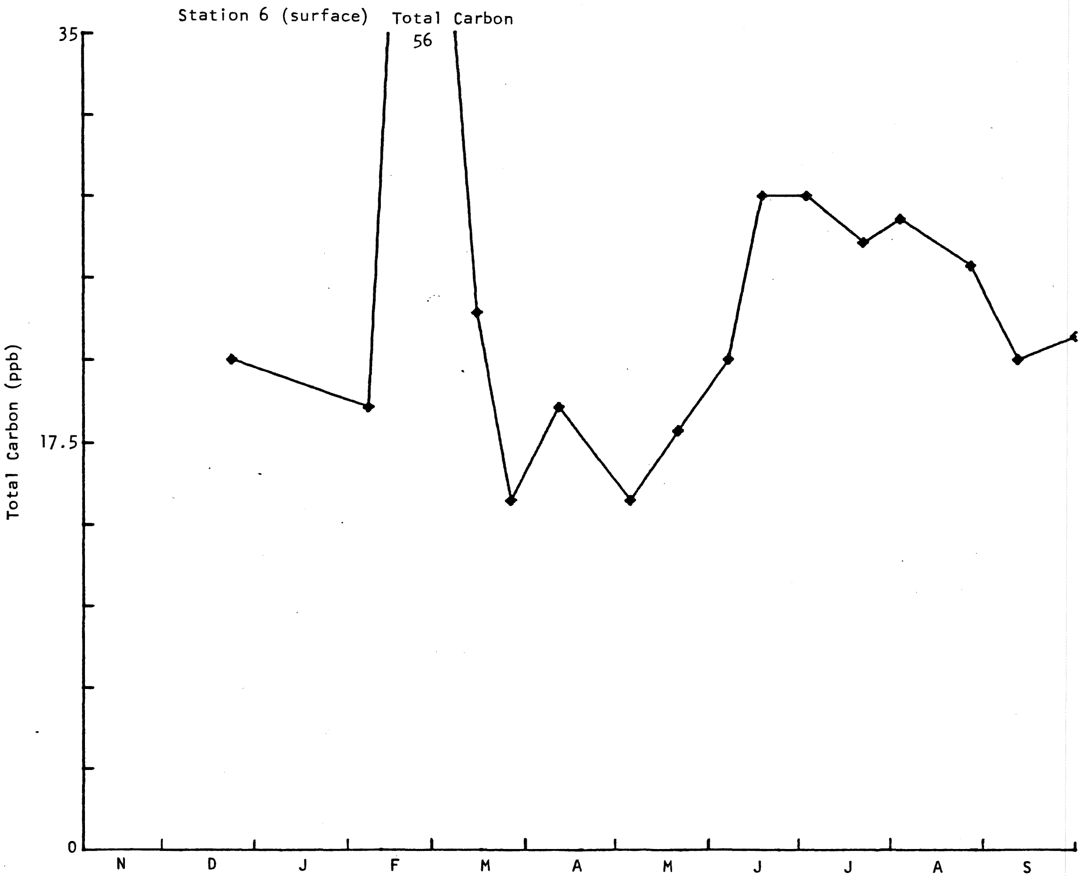


Time (November 7, 1976 — September 28, 1977) Figure 16 cont.



Station 4 (bottom) Total Carbon

Time (November 7, 1976 — September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

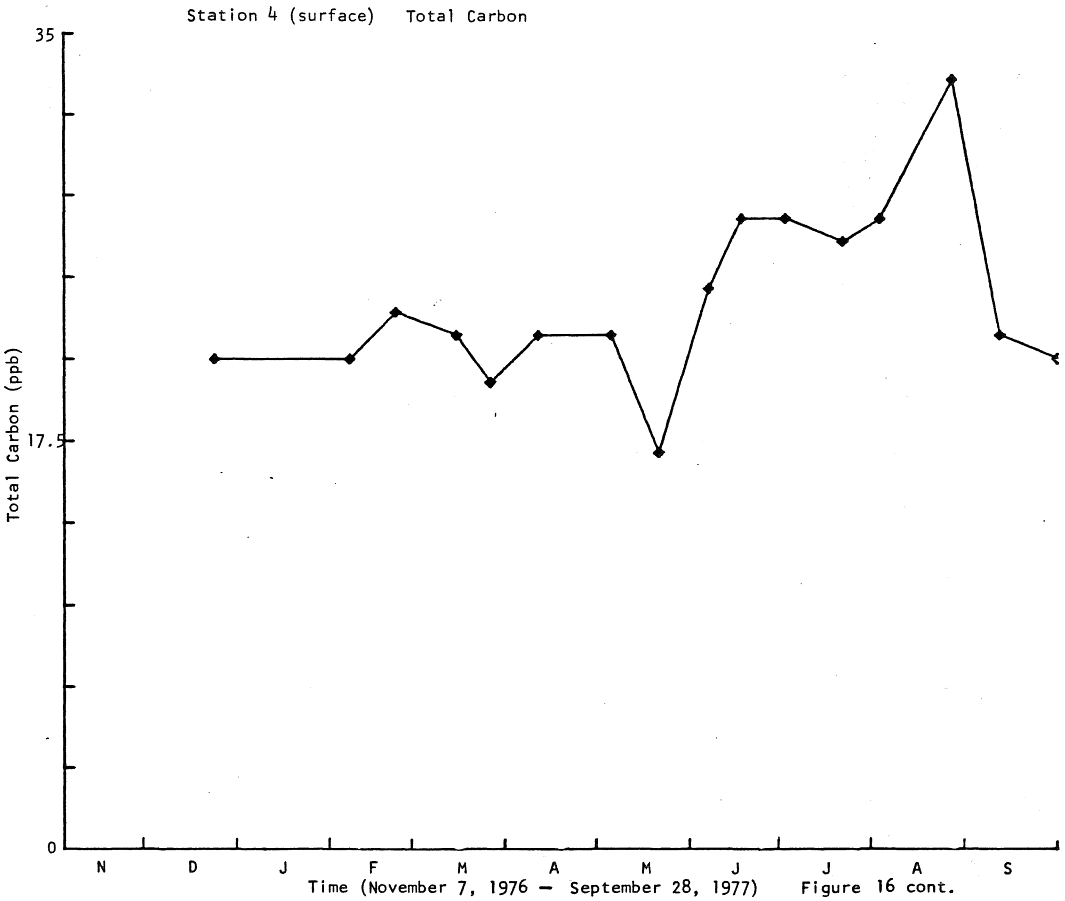
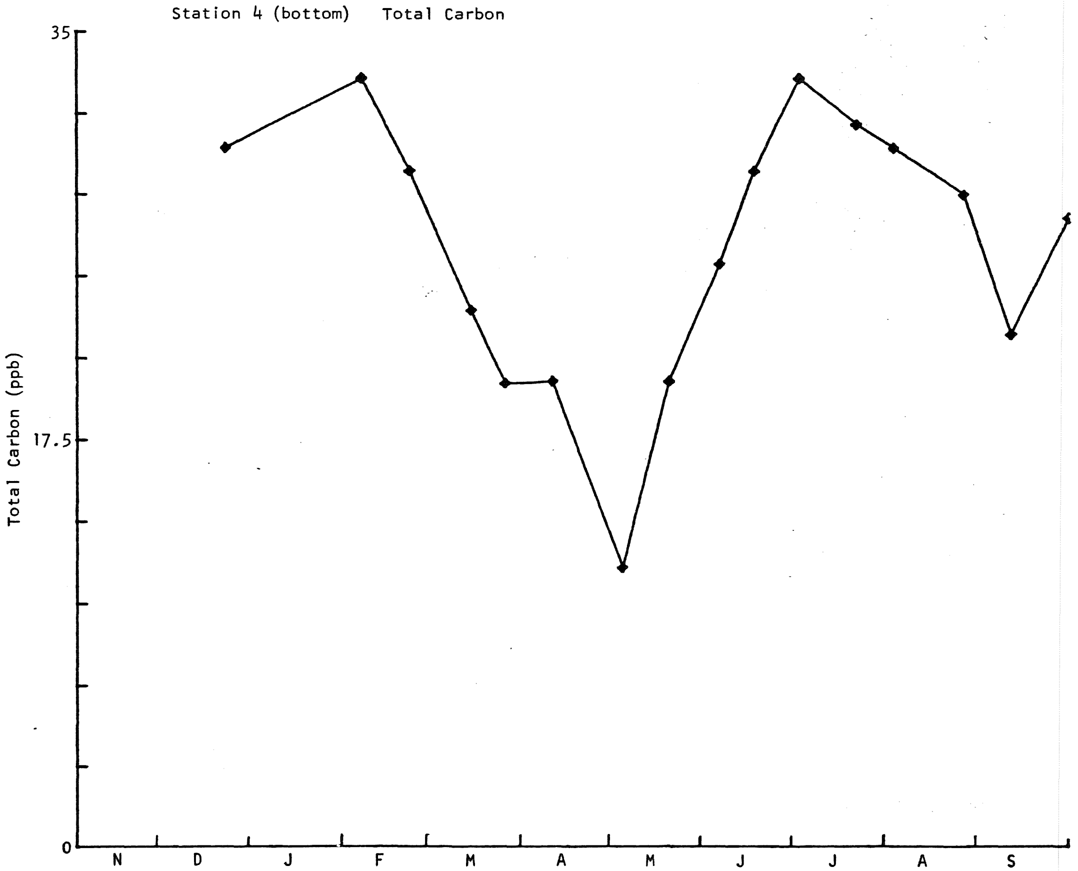


Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

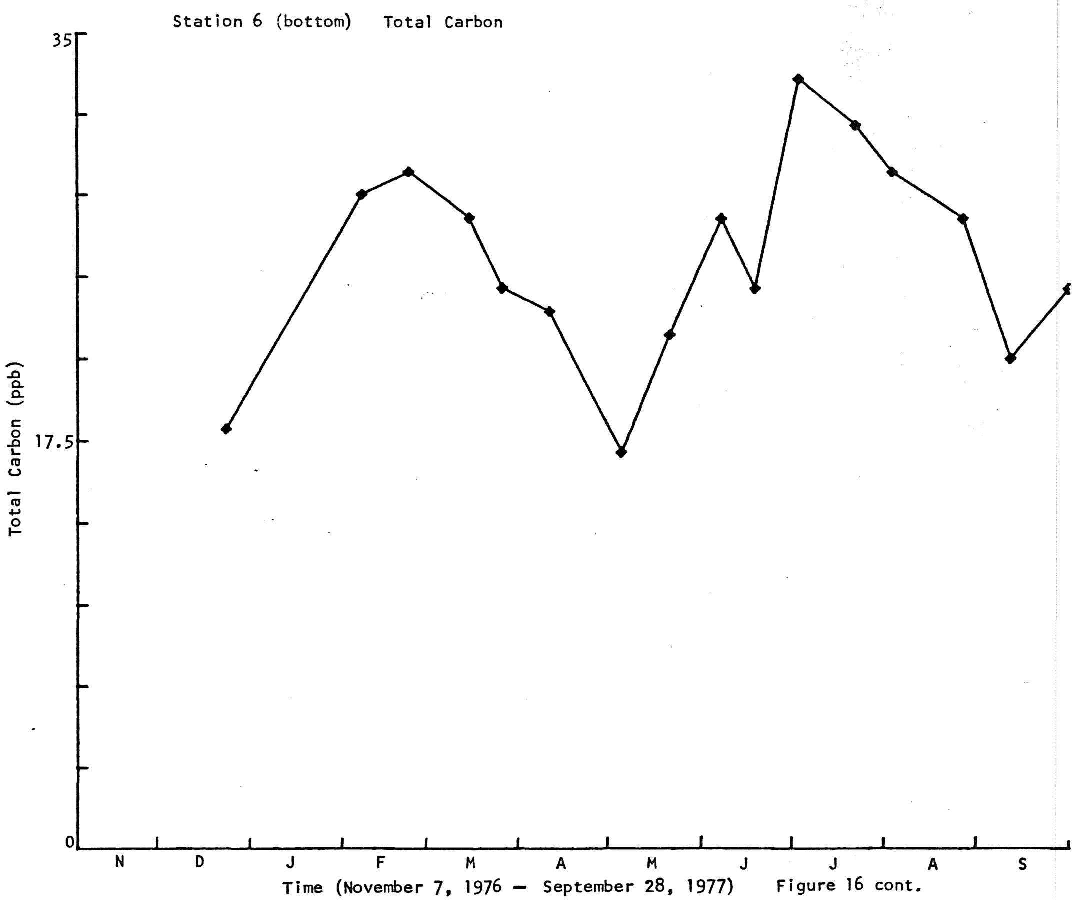


Figure 16 cont.

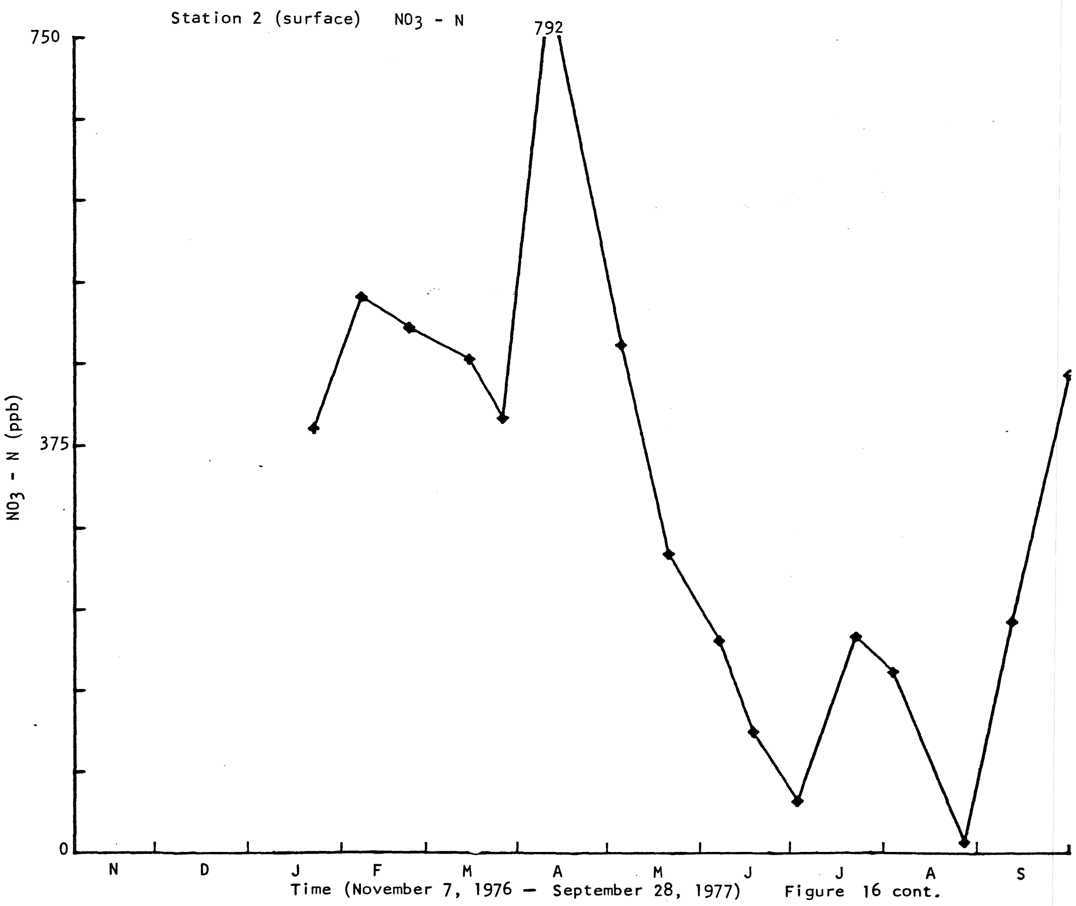


Figure 16 cont.

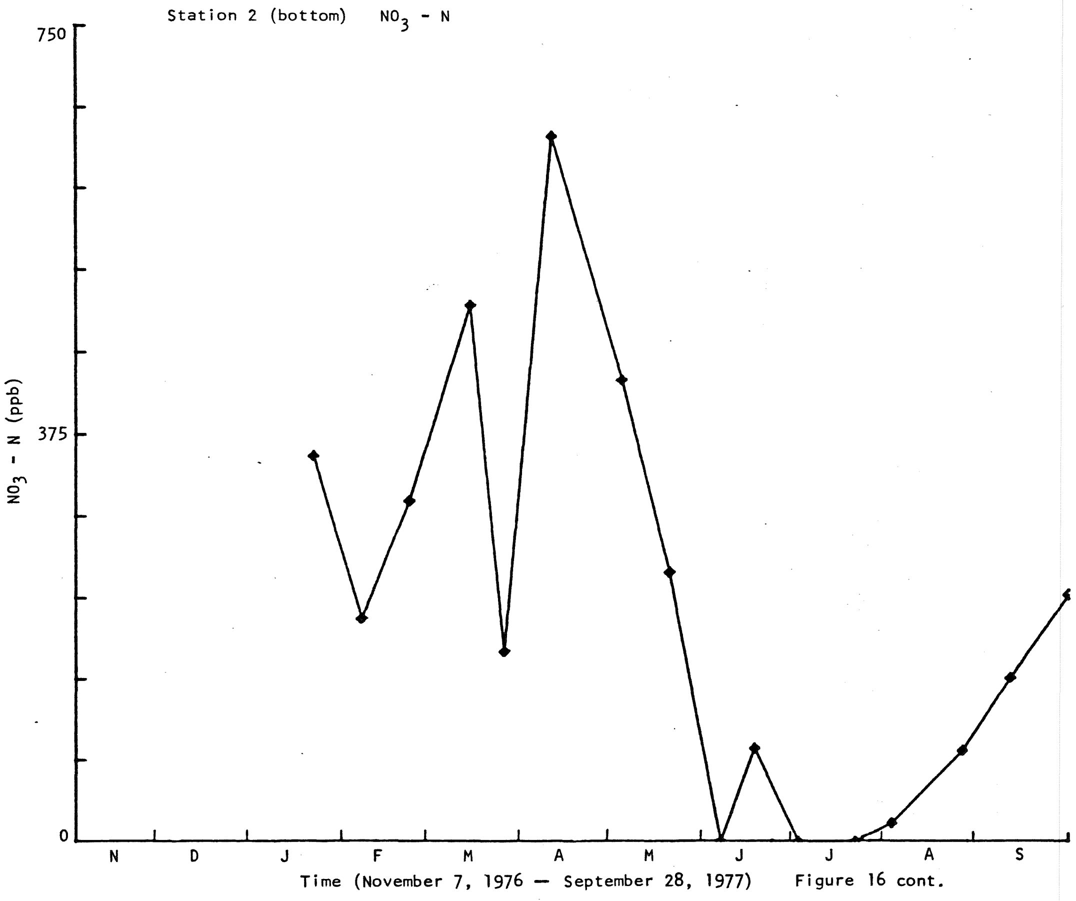


Figure 16 cont.

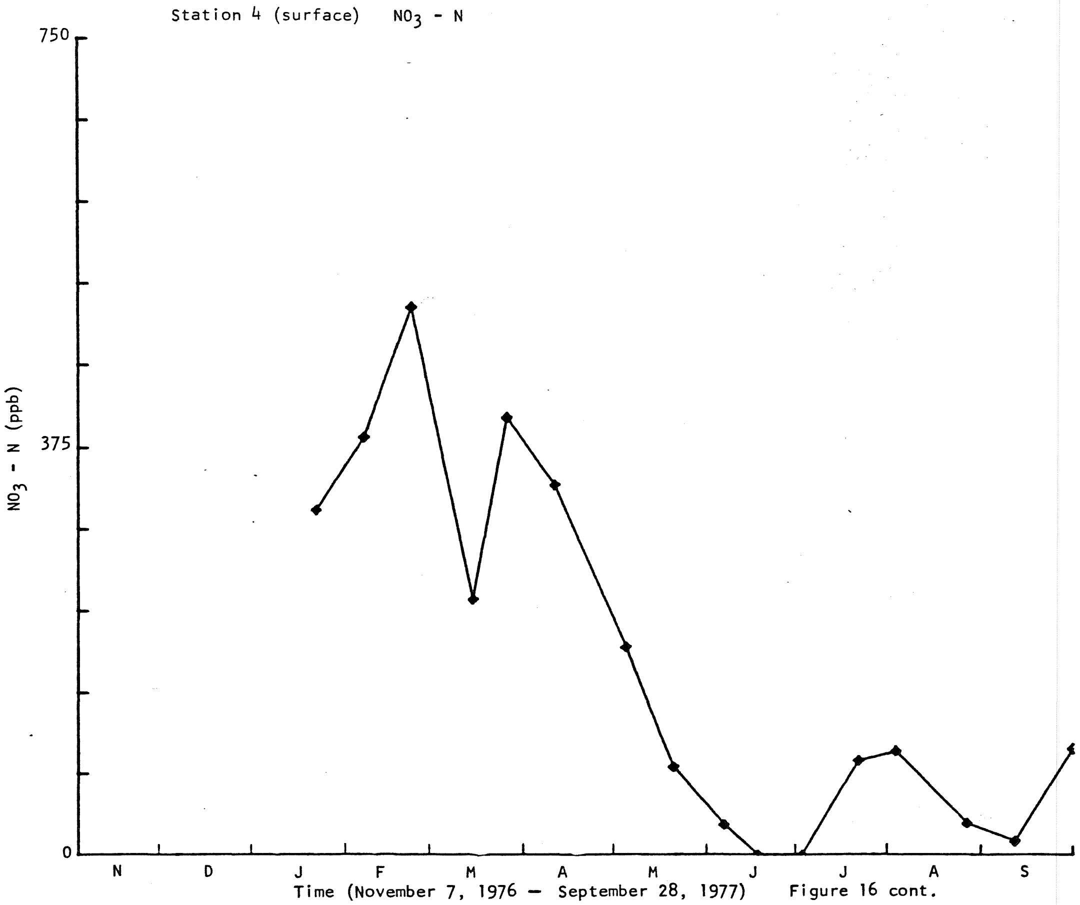


Figure 16 cont.

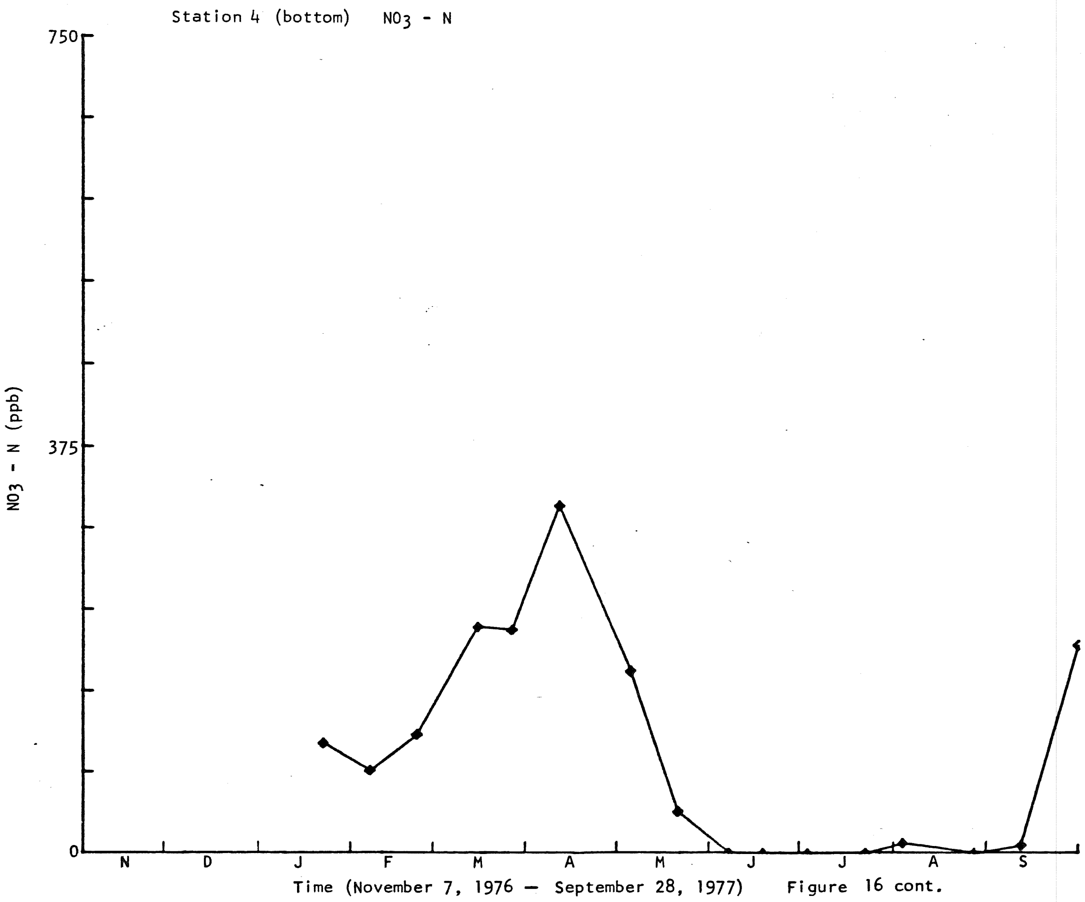
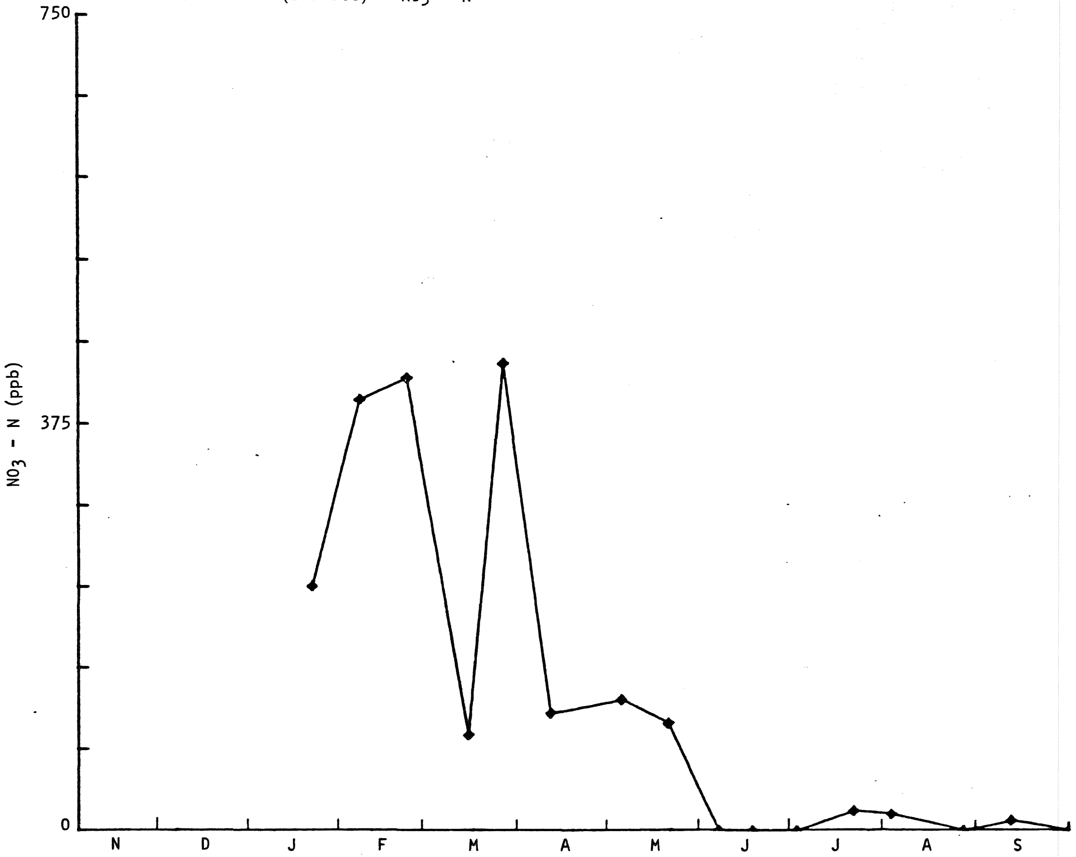


Figure 16 cont.



Station 6 (surface) NO_3 - N

Figure 16 cont.

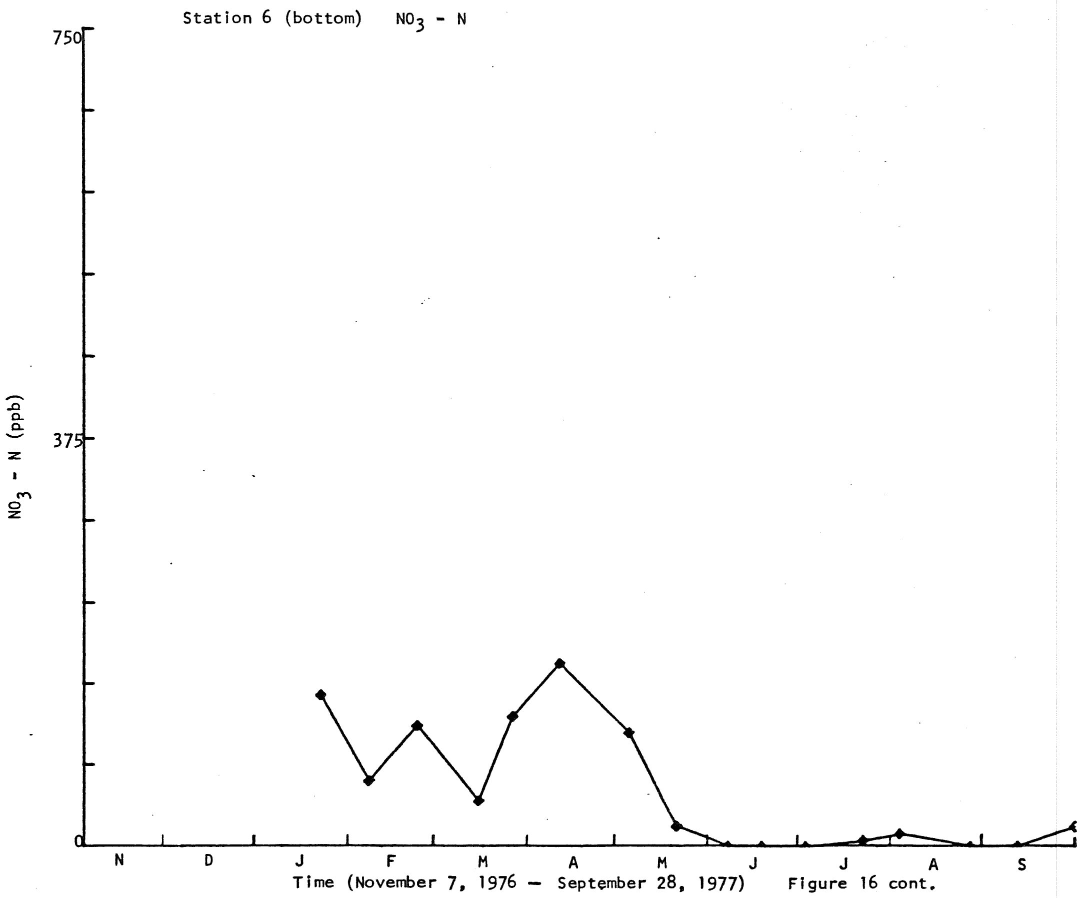
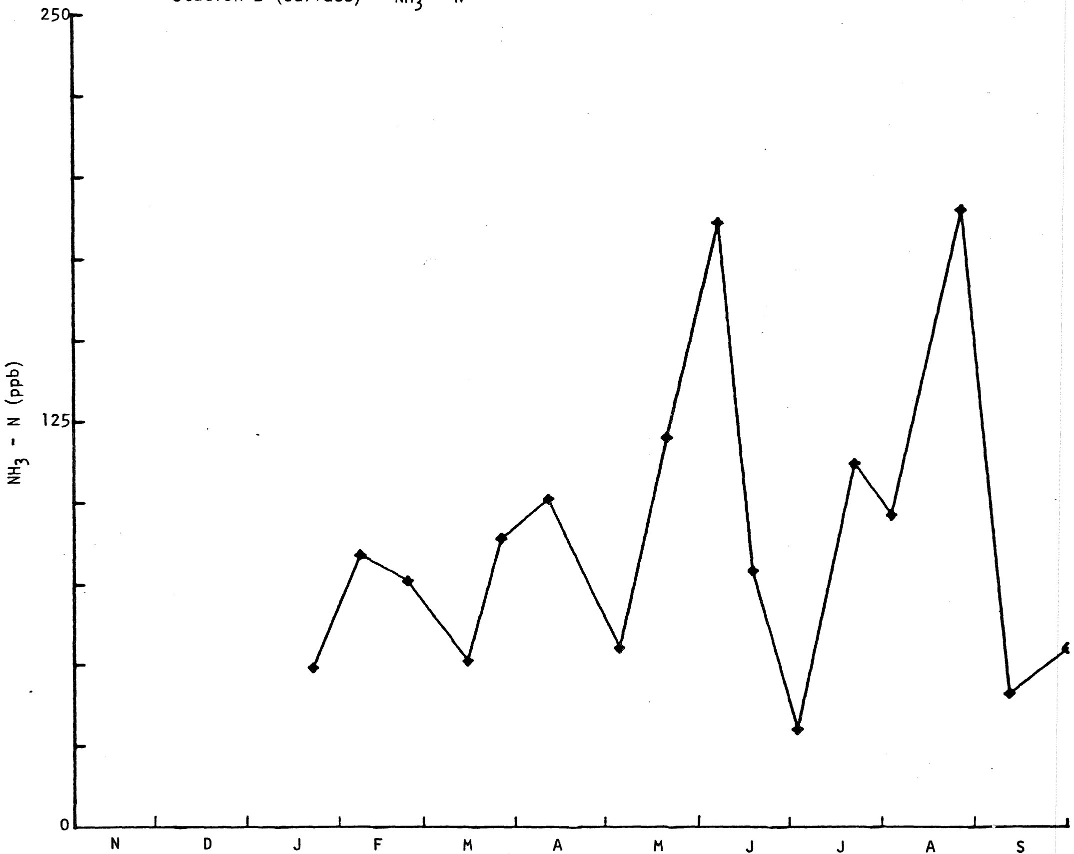


Figure 16 cont.

Station 2 (surface) NH_3 - N



Time (November 7, 1976 – September 28, 1977) Figure 16 cont.

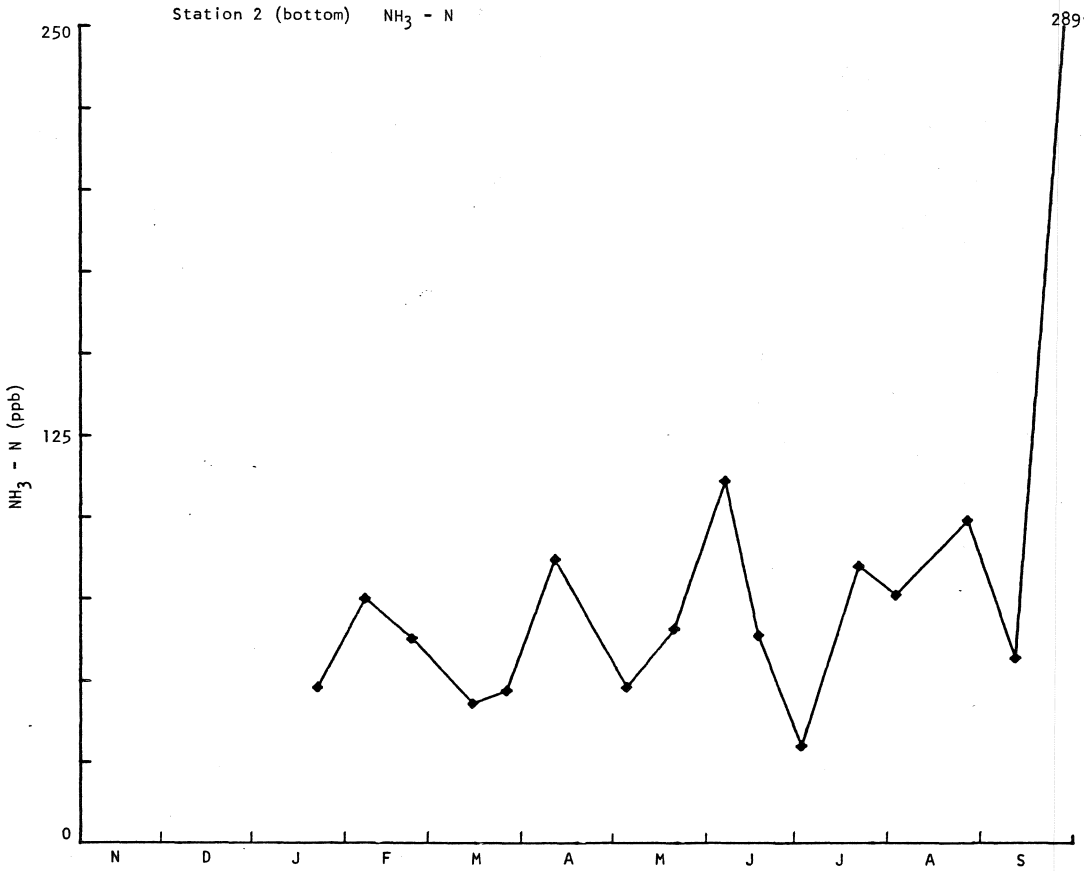


Figure 16 cont.

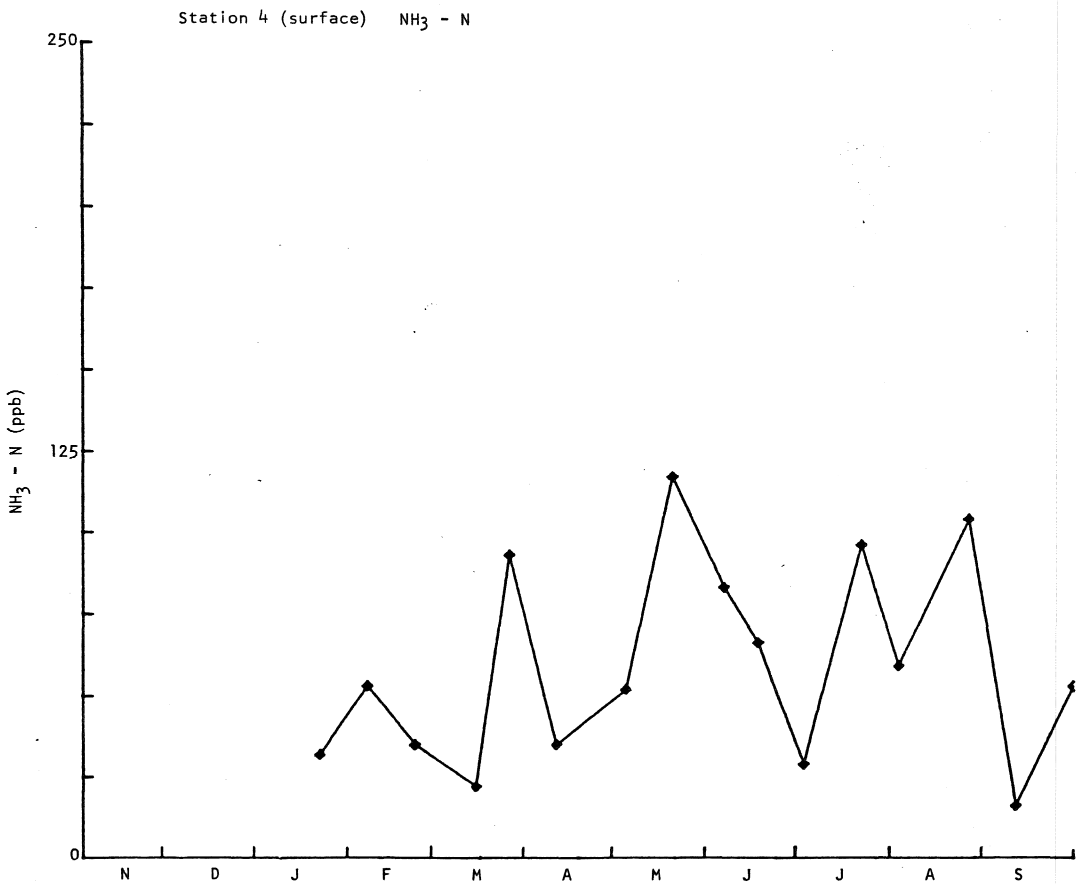
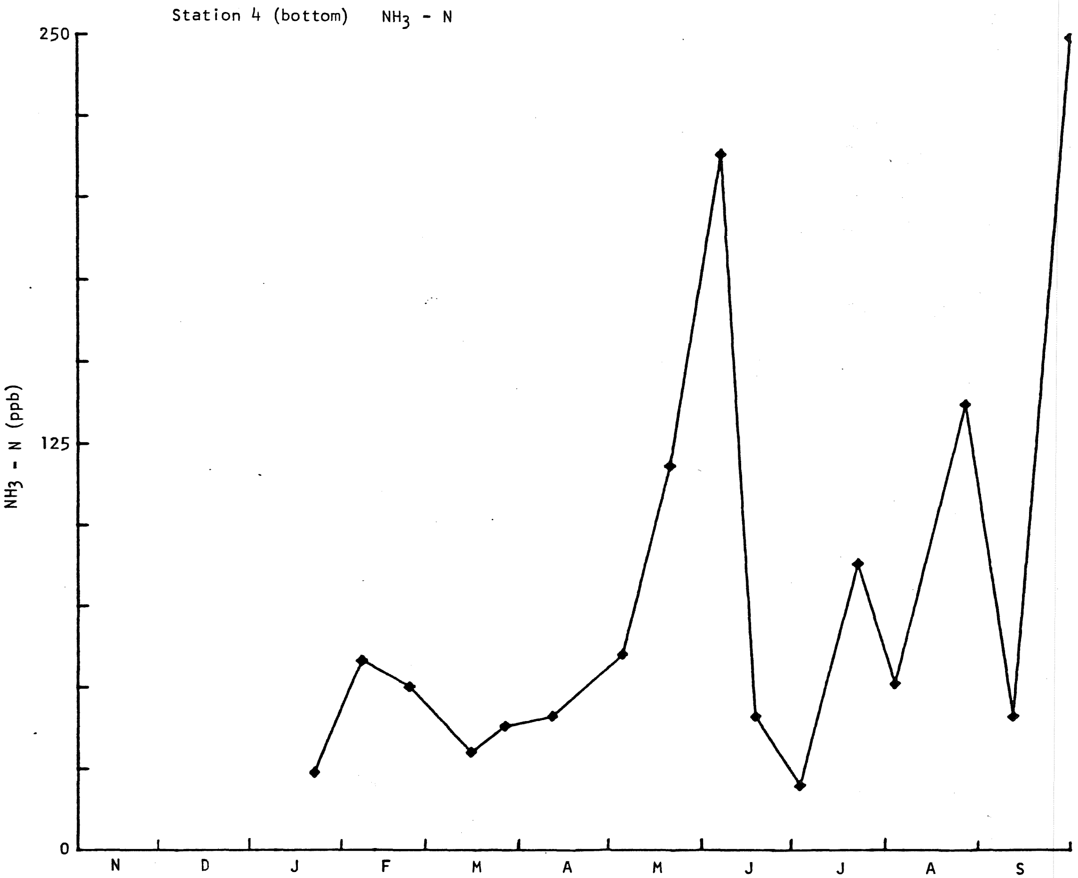
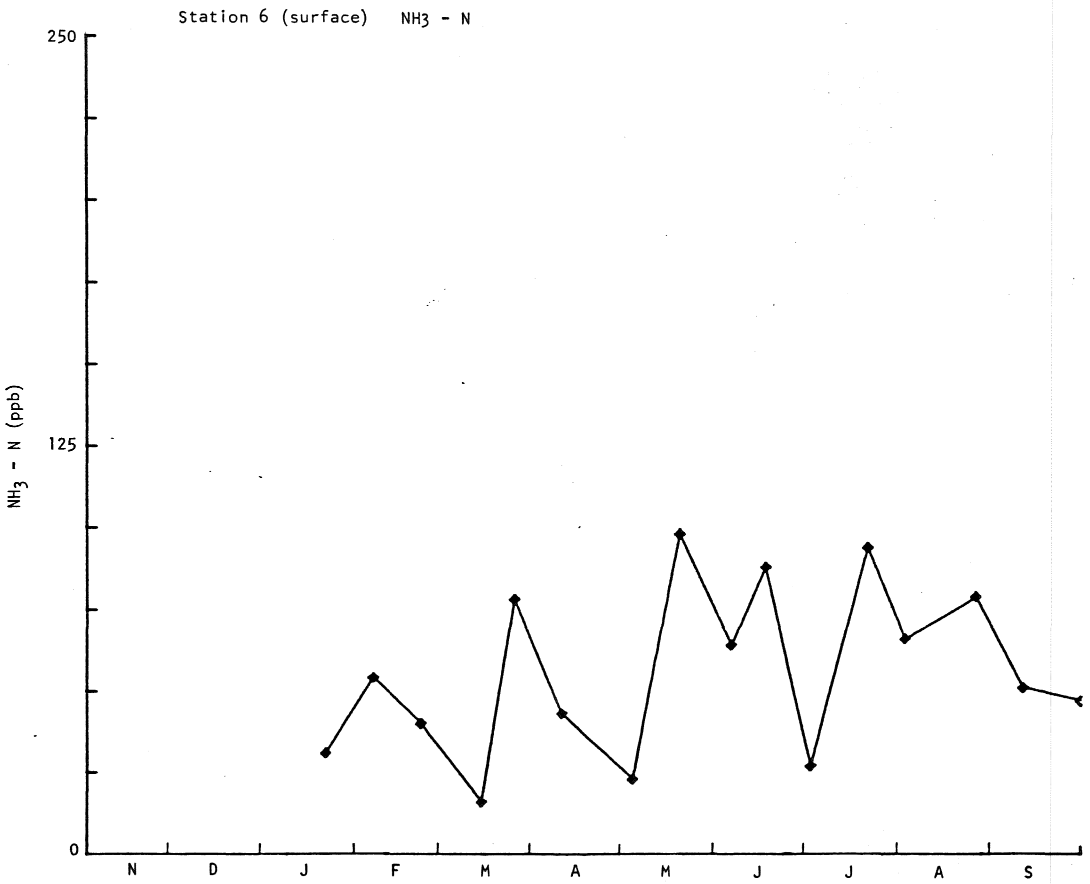


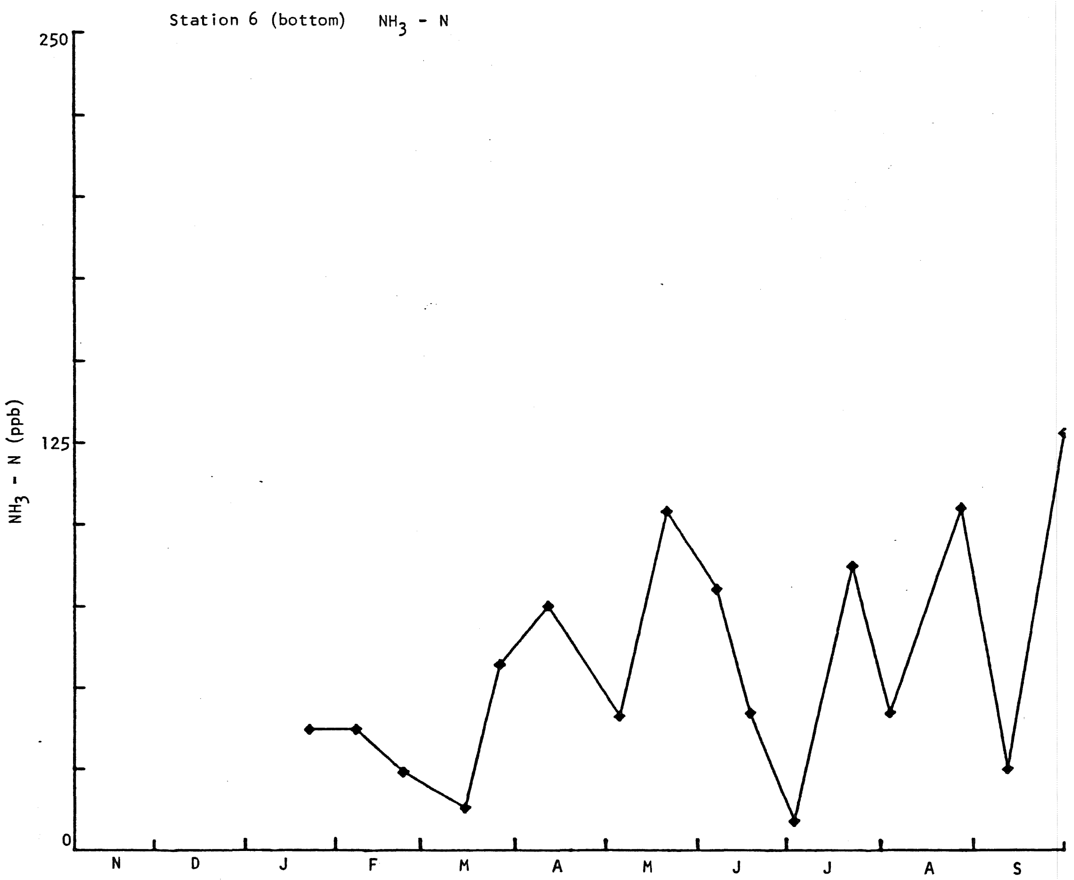
Figure 16 cont.



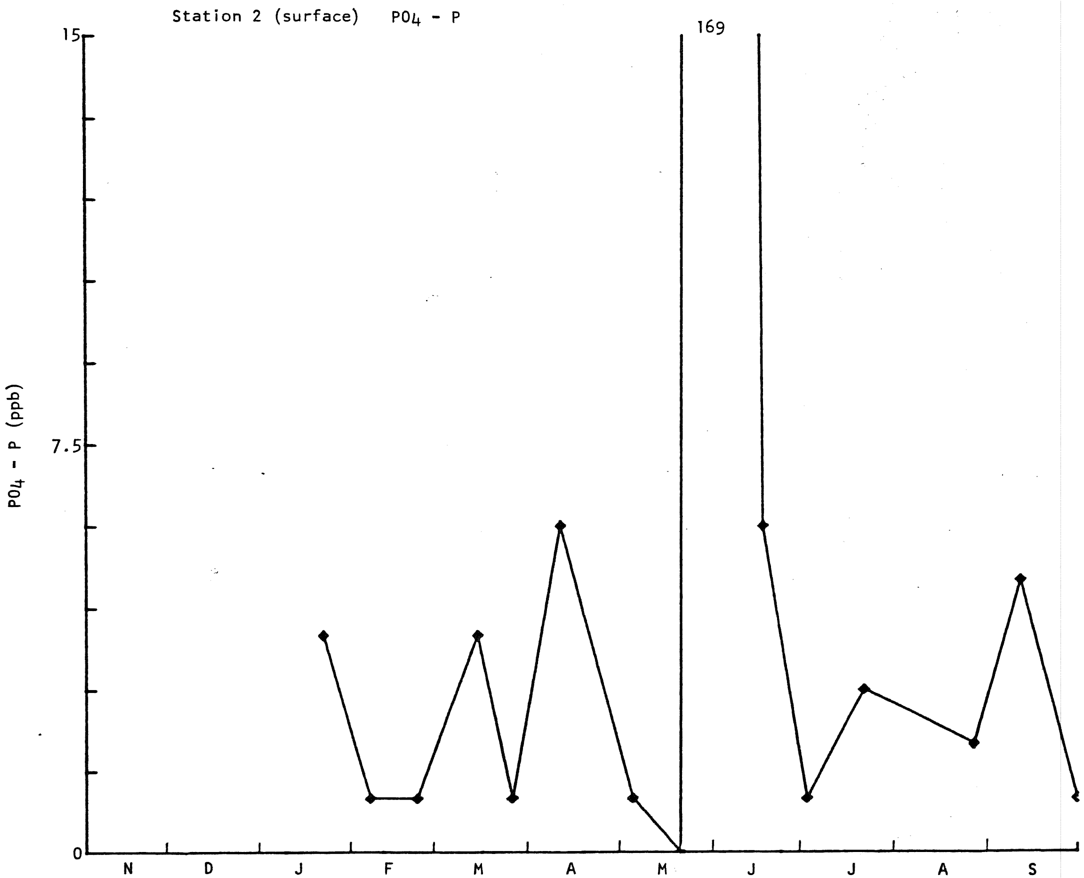
Time (November 7, 1976 - September 28, 1977) Figure 16 cont.



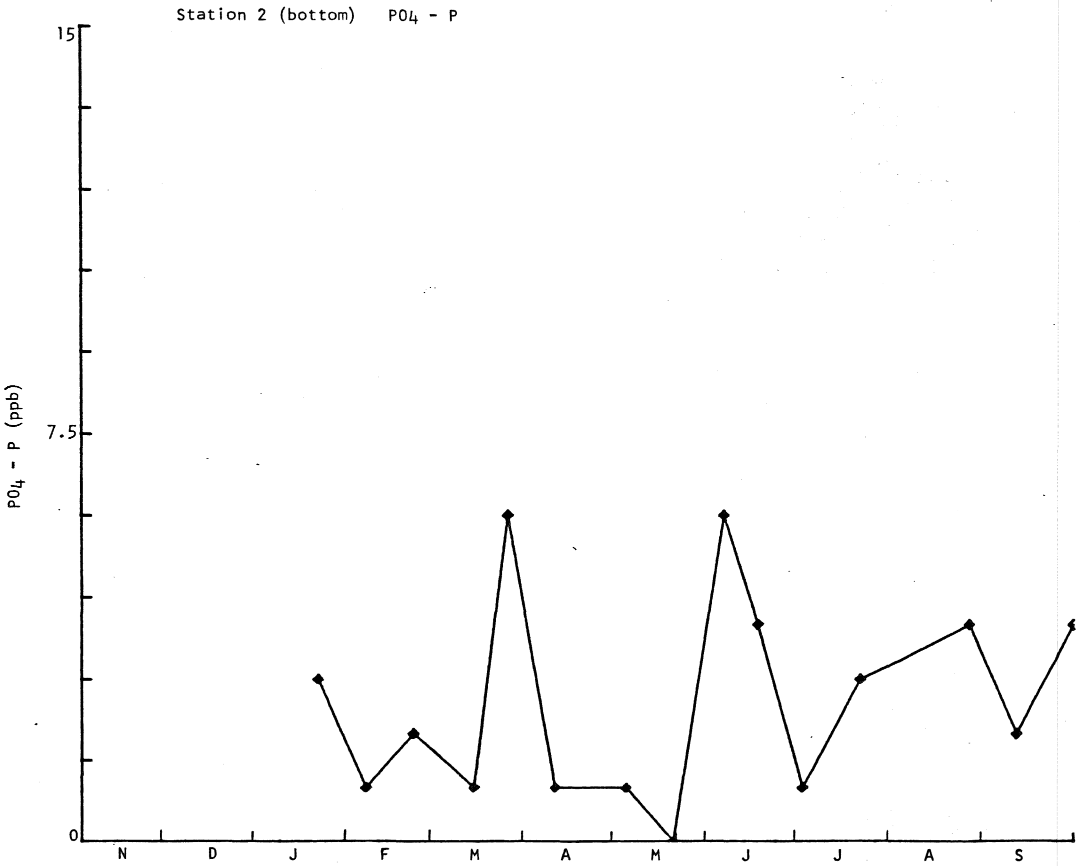
Time (November 7, 1976 — September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

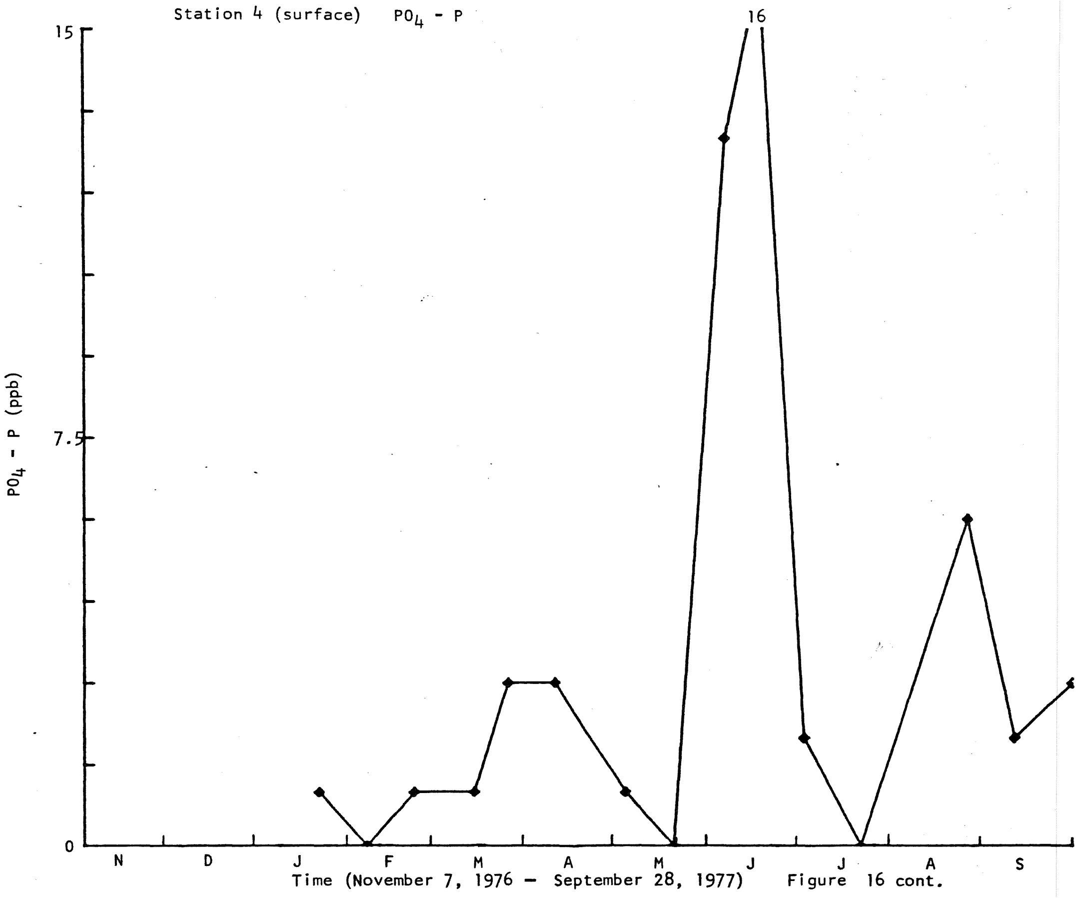


Figure 16 cont.

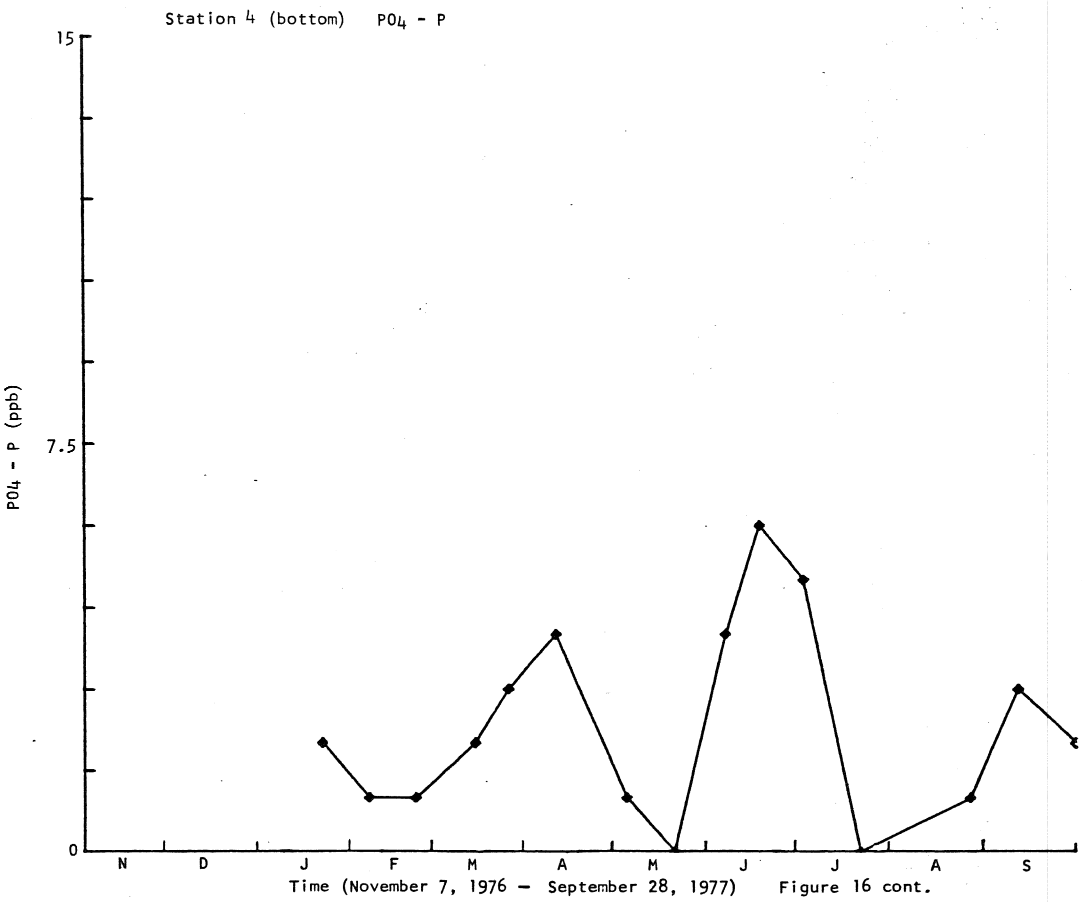


Figure 16 cont.

Station 6 (surface) PO_4 - P

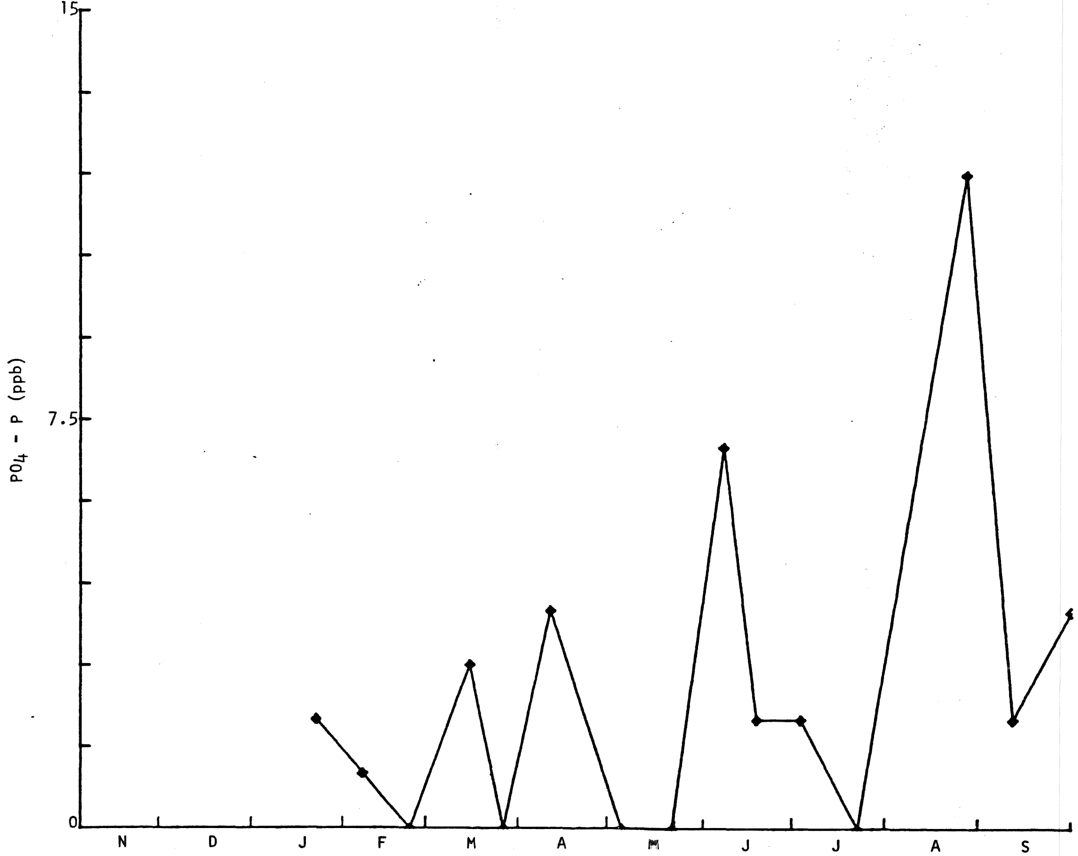
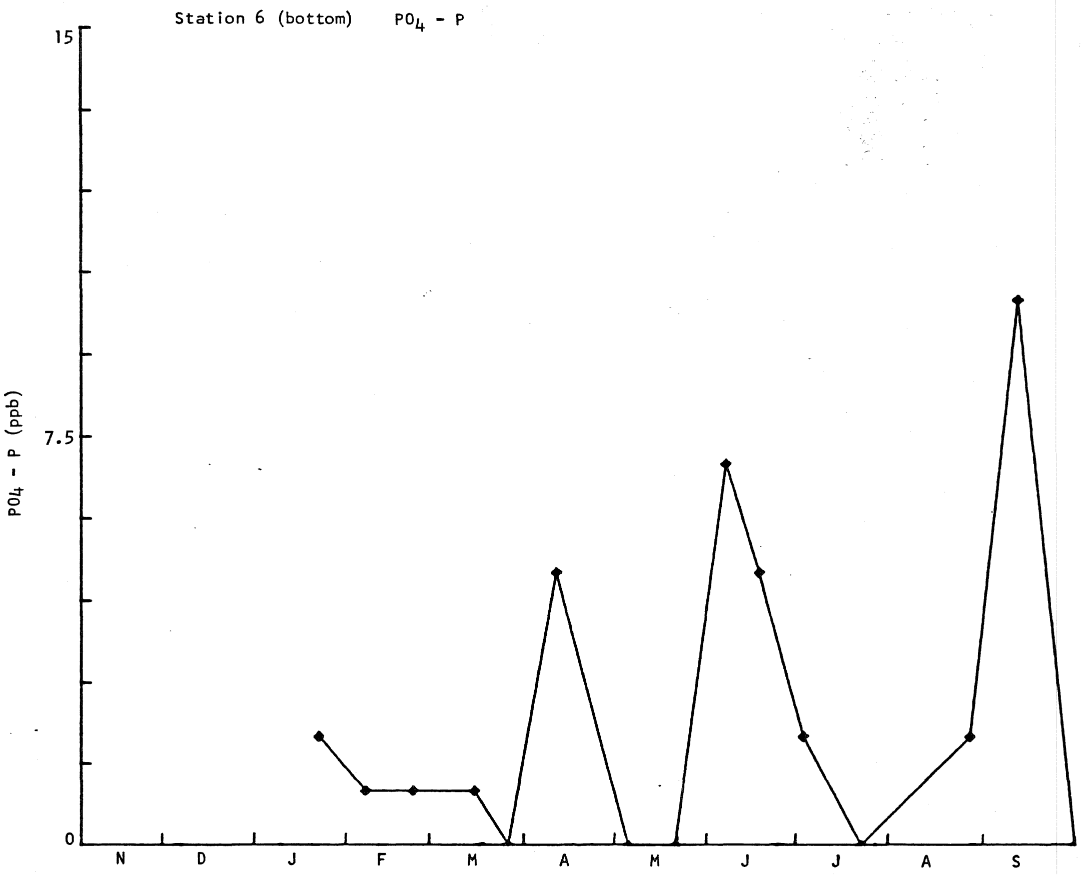


Figure 16 cont.



Time (November 7, 1976 — September 28, 1977) Figure 16 cont.

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