FINAL REPORT TO THE HUDSON RIVER FOUNDATION FOR GRANT NO. 001/87A/002, "MICROBIAL BREAKDOWN OF ORGANIC PHOSPHATES IN THE HUDSON RIVER", 8/1/87 - 7/31/88, $41,291

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DECEMBER 21, 1989

Note: In addition to this manuscript and the accompanying figures, a series of summary data tables is included at the end.

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INTRODUCTION

This project was undertaken for the following reasons:

1) Phosphorus (P) is an essential nutrient which often limits primary production in freshwater ecosystems.

2) Soluble reactive phosphate (SRP) may currently limit primary production in the mid-Hudson region north of river mile (RM) 76 (J. Cole, pers. comm.).

3) Dissolved SRP concentrations in the lower Hudson Estuary are currently far in excess of demands of phytoplankton and bacteria. However, as sewage treatment improves, phosphorus loading in this area has declined, perhaps as much as 25%. Thus, organic phosphates, both dissolved and particulate, may assume increasing importance as P sources as measured concentrations of SRP in the River decline.

4) My own preliminary results showed that bacterial breakdown of dissolved 5'-nucleotides (5'-nucleotidase activity) in the lower Hudson is very rapid, with summer hydrolysis rates up to 67%/h. Moreover, about one-third of the P released by the enzyme 5'-nucleotidase was taken up by bacteria, despite the fact that background SRP concentrations were 3-5 uM. Thus, dissolved organic phosphate (DOP) may be an important P source for bacteria even in the presence of a high SRP concentration.

OBJECTIVES

The objectives of this project were:

1) To measure concentrations of dissolved and particulate phosphorus, both organic and inorganic, in the estuarine portion of the Hudson.

2) To determine mechanisms and rates of microbial breakdown of some of the readily-decomposed organic phosphorus compounds.

Our sampling program contrasted the spring high-flow season with the summer low-flow season, and covered the length of the salinity gradient in the Hudson Estuary.

SAMPLING PLAN

Stations were taken approximately every 5 miles in the main channel of the Hudson River from West Point to the Narrows (mile points 53 to -7.5) in April 1988 and from Newburgh to 5 miles south of the Narrows (mile points 60 to -12.5) in August 1988. Other upstream samples were collected for us by B. Peierls and D. Lints of the Institute of Ecosystems Studies in Millbrook, N.Y. These samples were collected as part of other Hudson River Foundation sponsored projects directed by J. Cole, S. Findlay, and M. Pace. Surface samples were collected from a depth of 1 meter and deep samples from 10 - 15 m, when the bottom depth was sufficient.

Samples were analyzed for the following :

1) Physical-chemical measurements:
   a) Temperature (°C)
   b) Salinity (conductivity)

c) Turbidity (secchi depth)

2) Particulate measurements:
   a) Total suspended solids
   b) Particulate phosphorus (PP) - assumed to be largely organic
   c) Particulate carbon and nitrogen - assumed to be largely organic

3) Dissolved phosphorus measurements:
   a) Soluble reactive phosphate (SRP) - largely orthophosphate (Pi) but probably includes other acid-labile P
   b) Dissolved organic phosphorus (DOP)

4) Plankton biomass measurements:
   a) Chlorophyll *a* and phaeopigments
   b) Abundance of bacteria
   c) Abundances of autotrophic and heterotrophic nanoplankton (2-10 um)

5) Phosphorus cycling measurements:
   a) Turnover of soluble reactive phosphate
   b) Alkaline phosphatase (AP) enzyme activity
   c) 5'-nucleotidase (5PN) enzyme activity

DETAILED METHODOLOGY

All water samples were collected with an acid-washed Niskin (or Go-Flo) bottle which was rinsed several times with ambient water before sampling. Water temperatures were measured by inserting a hand-held digital thermometer into the samples immediately after pouring from the sampling bottle to the storage bottle. Water turbidity was measured with a Secchi disk that was lowered over the side of the boat opposite the sun to avoid glare interference. One-liter water samples were taken from depths of one meter and 10 - 15 m (or as deep as possible) below the surface, and stored in an insulated cooler, in the dark until our return to the laboratory. In the laboratory, water samples were carefully inverted several times, to ensure homogeneous distribution of the contents before subsampling for the assays described below.

Salinities were measured with an AGE Minisal salinometer. Total suspended solids were measured by drawing 250 ml water samples through pre-weighed GFF filters (47 mm diameter) using a vacuum less than 200 mm Hg. Filters were rinsed with 30 ml distilled water to remove soluble salts, dried at 90°C for 5 days and then weighed using a digital microbalance.

Particulate carbon and nitrogen were determined by drawing 100-ml water samples through pre-combusted GFF filters (25 mm diameter). These samples were dried overnight in a 60°C oven and stored at -20°C prior to analysis with a Carlo Erba carbon and nitrogen elemental analyzer.

Soluble reactive phosphate (SRP) was determined by absorbance of the phosphomolybdate complex (Strickland and Parsons 1972). Spectrophotometric measurements in this and in the other phosphate assays were done in a 10 cm cuvette at a wavelength of 855 nm, the absorbance maximum of the colored reaction mixture with our spectrophotometer. Particulate phosphorus (PP) was determined by the high temperature combustion method (Solorzano and Sharp 1980). Dissolved organic phosphorus (DOP) was determined by subtracting SRP from total dissolved phosphorus

(TDP). Total dissolved phosphorus was determined by the high temperature combustion method (Solorzano and Sharp 1980).

Chlorophyll *a* and phaeopigments were determined by drawing 30 - 100 ml samples through GFF filters (25 mm diameter), using a vacuum of <200 mm Hg. Filters were stored at -80°C for one to three weeks prior to analysis. Pigments were extracted from the samples by homogenizing the filters in a glass tissue grinder half-filled with absolute methanol (Holm-Hansen and Riemann 1978), and further extraction was achieved by storing the homogenates in the dark for 5 hours at -20°C. Dissolved pigments were then separated from the homogenates by centrifugation and the chlorophyll *a* and phaeopigment concentrations determined with a Turner Designs fluorometer (Strickland and Parsons 1972).

Bacterial abundance in the water samples were determined by staining 5-ml aliquots with diamidinophenyl indole (DAPI) (Porter and Feig 1980). Bacteria on the DAPI-stained slides were counted using a Leitz epifluorescent microscope equipped with a 50 watt Hg lamp and UV filters.

Abundances of autotrophic and heterotrophic nanoplankters (2-10 um) were determined by scanning the DAPI-stained slides. Generally 3 to 5 scans were done for each slide in order to count a total of 30 or more of these small eukaryotic cells.

Uptake of SRP was determined by incubating water samples with ^{32}Pi, followed by filtration and rinsing of the filter with particle-free sample water. To calculate the actual SRP flux, the uptake rate determined above was multiplied by the measured SRP concentration.

Alkaline phosphatase (AP) was measured according to the established method (Hoppe 1983), using 100 nM of substrate. Incubations were performed in phosphate-free disposable tubes. We used a Turner Designs Model 10 fluorometer with an F4T5 near UV lamp and a Corning 7-60 excitation filter and Corning 5-60 and Kodak 2A emission filters. A piece of soft glass was used as a reference filter to attenuate the UV light from the lamp. Samples were maintained in a temperature-controlled water bath and each one periodically subsampled for fluorometry so several could be run at the same time. To maximize fluorescence, we added 1 ml of 50 mM borate buffer (pH 10.8) to 3 ml of sample before measurement, giving a final pH above 10. The fluorescent breakdown product of the AP reaction, 4-methylumbelliferone, is most fluorescent at pH values of 10 or higher (Chrost and Krambeck 1986).

5'-Nucleotidase activity was assayed by a method developed in my own lab (Ammerman and Azam 1985). The substrate for this assay was [g-^{32}P]ATP, ICN Radiochemicals (Irvine, CA). We used substrate with a specific activity of about 700 Ci mmol^{-1} without background problems from ^{32}P-orthophosphate (^{32}Pi). These high-specific-activity substrates have the advantage that they can be added at true tracer levels (50 pM final concentration at 700 Ci mmol^{-1}). We used this tracer approach, as opposed to a saturation assay, for both 5PN and AP assays so that true turnover rates and Pi fluxes could be determined. The ^{32}Pi background in [g-^{32}P]ATP stock increased with time unless it was stored at -20°C or below.

Samples for 5PN activity measurement were incubated at near *in situ* temperatures (all the samples from an individual cruise or experiment were usually incubated at one average temperature) in a covered water bath in the laboratory. The incubation time used for 5PN assays in this study ranged from 15 to 60 min??.

Following incubation, excess [g-^{32}P]ATP was bound by adding ca. 20 mg activated charcoal and 10% v/v 0.03 N H_2SO_4. In estuarine waters, addition of the above was usually sufficient for complete binding of the remaining [g-^{32}P]ATP, though we have found that estuarine waters occasionally interfere with ATP binding by charcoal. In this study we used blanks which were water samples boiled for 10-15 min. Boiled blanks are essential in eutrophic environments where activity is high and zero-time "blanks" would show significant activity. Blanks were automatically subtracted and 5PN activity and uptake of released Pi were calculated by computer. Most values shown are means of two replicates.

RESULTS and DISCUSSION

There is a nearly linear relationship between salinity and mile point (MP), from the New York Bight up to MP 40 (Figure 1). At a given mile point, salinity was generally greater in August than in April. To emphasize the influence of the salinity gradient, most of the parameters we measured have been plotted against salinity (see below).

There was a temperature difference of 10 to 20 degrees between spring and summer (Figure 2). Whereas temperatures were fairly uniform (about 10°C) at all of the stations sampled in April, there was a notable temperature gradient (decreasing downstream) in the lower Hudson in August. Water temperature was generally only 1 to 4°C lower at depth than at the surface. The combined effect of winds and strong tidal action in this relatively shallow estuary prevent the formation of a major thermocline.

Although there was some inter-seasonal variability in suspended solids loading at specific mile points, the mean and range of total suspended solids was quite similar in April and August (Figures 3a and 3b). During the low-flow season (August), there was a marked decrease in the concentration of suspended solids with increasing salinity.

Concentrations of SRP were strongly correlated with salinity during both spring and summer and were highest at salinities of 15 to 25 ppt (see Figures 4a and 5a). The SRP concentrations were two-fold greater in August than in April, probably as a result of the reduced flow rate during August.

Dissolved organic phosphate (DOP) concentrations were much lower than the SRP levels (see Figures 4a and 5a); generally less than 0.5 uM in April and less than 0.7 uM in August. Concentrations of DOP increased with salinity in both seasons.

Particulate phosphate (PP) was generally the most abundant form of phosphorus (see Figures 4b and 5b). Concentrations of PP were higher in August than in April, but aside from a decrease seaward of New York City in August, there was no clear relationship between PP and salinity or mile point.

Particulate carbon was ten-times more abundant than particulate nitrogen in all of the stations, in both spring and summer samples (Figures 6a, 6b). The mean concentration of particulate carbon was 1000 ug/l and particulate nitrogen fluctuated around 100 ug/l. There was more variability in concentrations of these elements in the August samples than in the April samples.

Except for a few high values in freshwater, chlorophyll *a* concentrations increased with salinity in April (Figure 7). Chlorophyll concentrations were much

higher in August and peaked in Haverstraw Bay (Figure 8), due to a phytoplankton bloom observed throughout the lower-salinity portions of the estuary,

Bacterial abundance increased with salinity in April (Figure 9). Bacterial numbers were almost two-fold greater in August (Figure 10) and peaked in Haverstraw Bay, at low salinities. There was a strong correlation between the concentration of chlorophyll and bacterial numbers in most of the samples.

Nanoplankton abundance showed an increase with salinity in April (Figure 11a), possibly corresponding to a similar bacterial distribution pattern (bacteria are an important food source for heterotrophic nanoflagellates). Some of the increase may also be due to an increase in autotrophic nanoplankton abundance with increased Secchi depth or light transparency. In August (Figure 11b), there was a peak in nanoplankton abundance at both the freshwater and the marine end-members of the estuary. The lowest numbers were found in those parts of the estuary with the highest chlorophyll concentrations, i.e. Haverstraw Bay, showing that this bloom was due to larger organisms.

SRP turnover rates were low (generally less than 1%/h) in both April and August (Figure 12). The highest values were found in August toward the freshwater portions of the estuary.

Alkaline phosphatase activity was lower in April than in August (Figure 13), however, the turnover rate for this enzyme never exceeded 10%/h (the mean turnover rate was 2%/h), because it is largely inhibited by the high concentrations of SRP found in the Hudson estuary. Activity of 5' nucleotidase was much higher than alkaline phosphatase (see Figure 14). The turnover rate of this enzyme ranged between 20 and 40%/h in April and 50 to 250%/h in August, as a result of the higher temperatures and the relative insensitivity of this enzyme to SRP.

The ratio of SRP uptake to SRP regeneration by alkaline phosphatase (Figure 15) was generally greater than 20:1, showing that alkaline phosphatase activity played a minor role in phosphorus cycling. The ratio of SRP uptake to SRP regeneration by 5' nucleotidase, in contrast (Figure 16), was about 2:1, underscoring the potentially important role this enzyme played in the microbial regeneration of Pi in the Hudson.

SUMMARY and CONCLUSIONS

1) Due to high SRP concentrations, SRP turnover was slow (usually less than 1%/h), though total SRP uptake was appreciable (mean = 5 nmol/l/h, range = 0-22).

2) SRP release by alkaline phosphatase (AP) was low (mean = 0.2 nmol/l/h, range = 0.01-0.9), probably because the enzyme was repressed by the high ambient SRP concentrations. The ratio of SRP uptake to SRP release by AP was high, showing the contribution of AP to replenishing the SRP pool was negligible. This would change only if our assumed concentration of AP substrate (10 nM) was about 10X or more too low.

3) In contrast with AP, the activity of 5'- nucleotidase (5PN) was high (mean = 4 nmol/l/h, range = 0.5-12). This enzyme was apparently unaffected by the high ambient SRP concentrations. The ratio of SRP uptake to SRP release by 5PN was slightly above 1, suggesting that 5PN itself could replenish much of the SRP taken up by organisms.

4) Related studies (not shown) suggest that much of SRP released by 5PN may be taken up directly by microbes without mixing with the high concentrations of ambient SRP. This suggests that much of this ambient SRP may not be "biologically available".

5) Though sewage-derived SRP dominates the cycling of dissolved phosphorus in the Hudson Estuary, components of the DOP are being actively decomposed and may be an important source of phosphorus for microorganisms.

ACKNOWLEDGEMENTS

I wish to acknowledge the support of the Hudson River Foundation which made this study possible. I would also like to acknowledge the help and cooperation of J. Simpson, R. Bopp, and D. Robinson at Lamont and B. Peierls, D. Lints, J. Cole, S. Findlay, and M. Pace of the Institute of Ecosystems Studies in Millbrook, N.Y. Finally I wish to acknowledge the able assistance of D. Angel in nearly all phases of this project, including the writing of this report.

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Strickland, J. D. H., and T. R. Parsons. 1972. A practical handbook of seawater analysis. 2nd. ed. Ottawa, Canada: Fisheries Research Board of Canada.

Figure 1. Salinity vs Mile Point

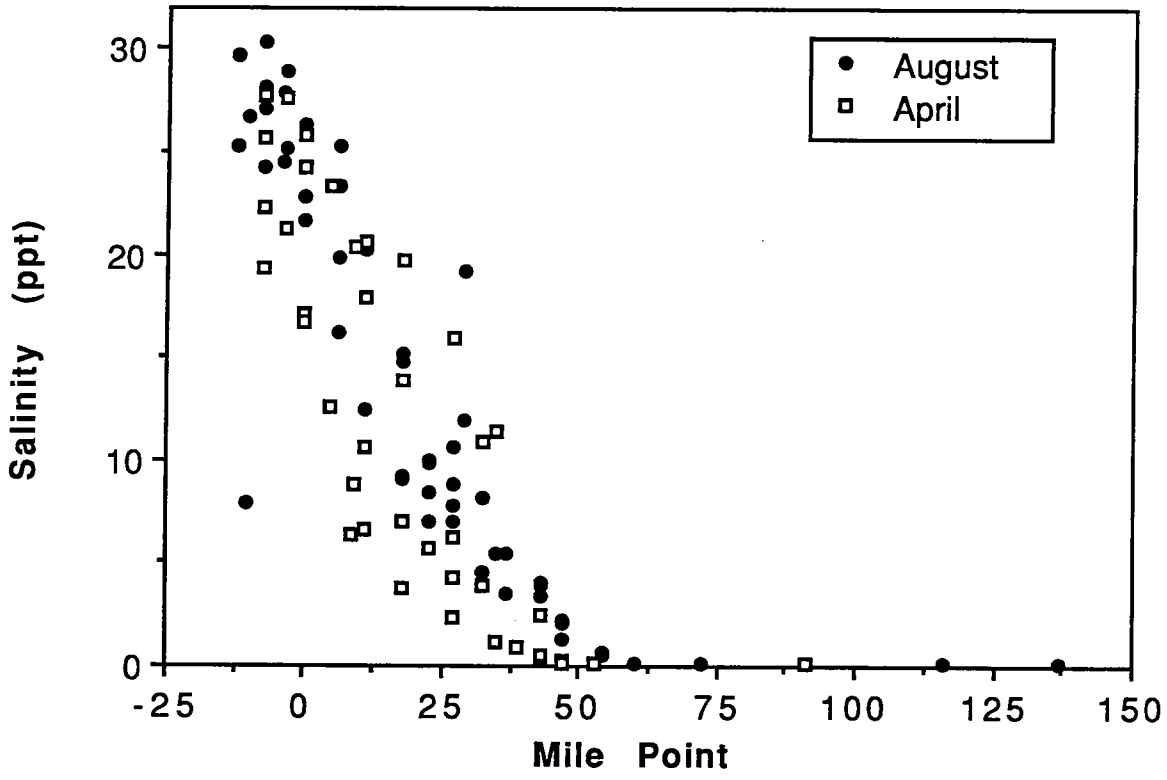


Figure 2. Temperature vs Mile Point

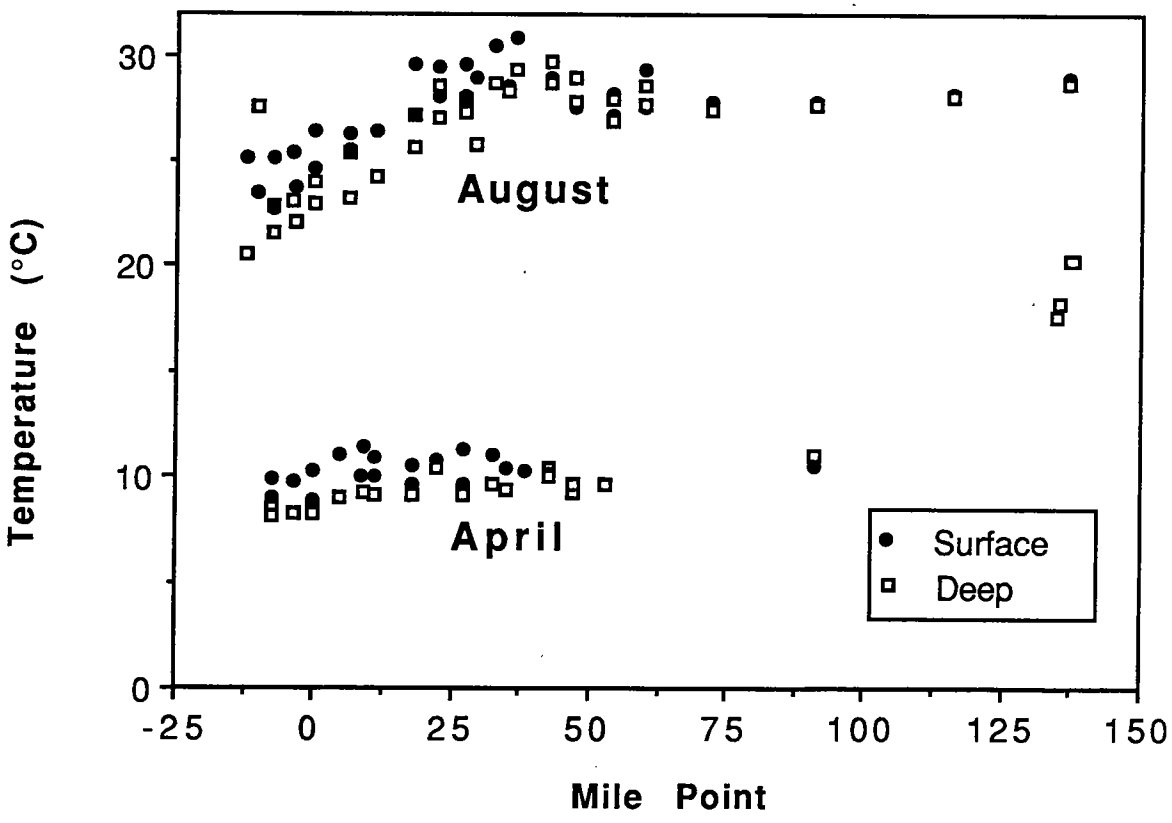


Figure 3a. Suspended Solids, Surface vs Deep in April

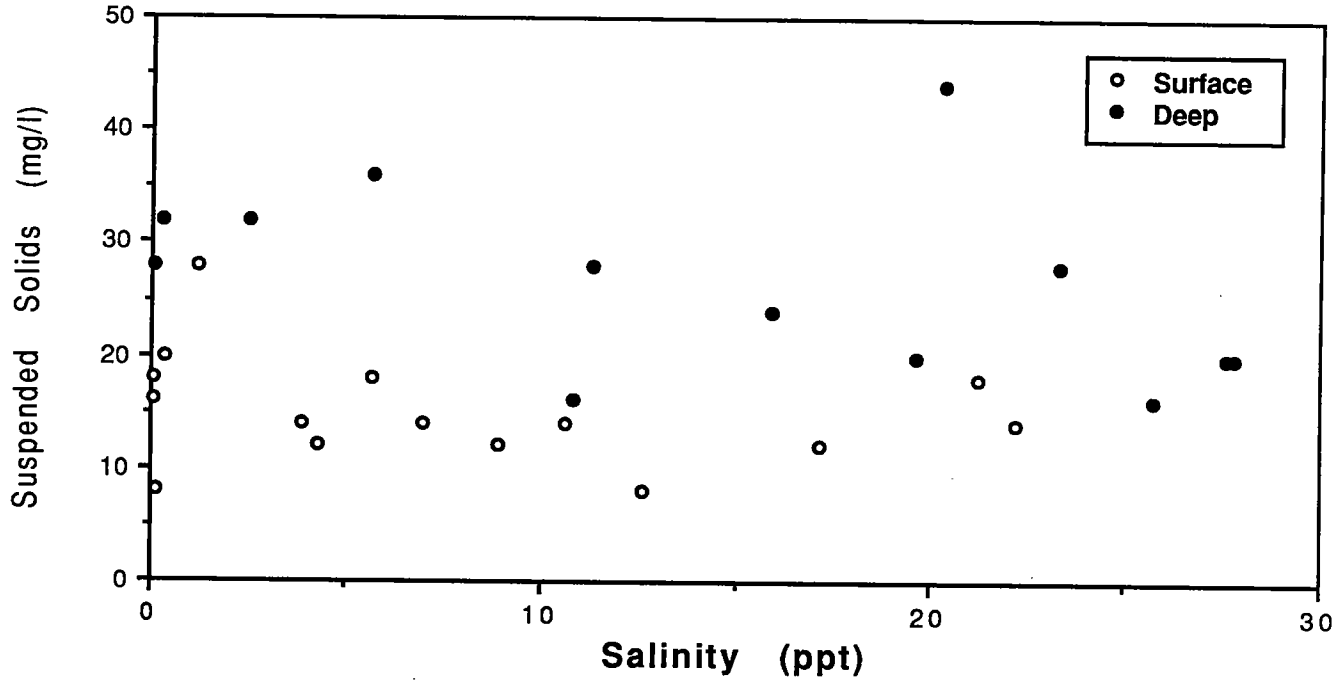


Figure 3b. Suspended Solids, Surface vs Deep in August

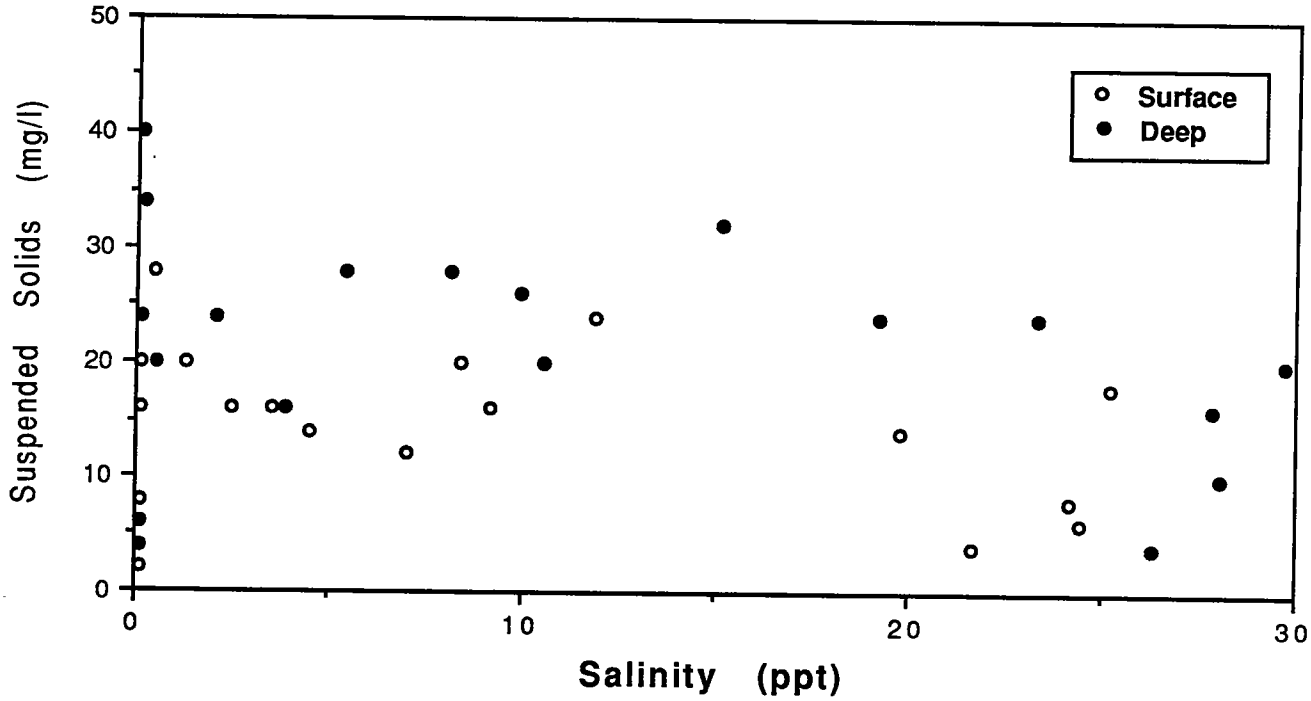


Figure 4a. SRP and DOP vs Salinity - April 1988

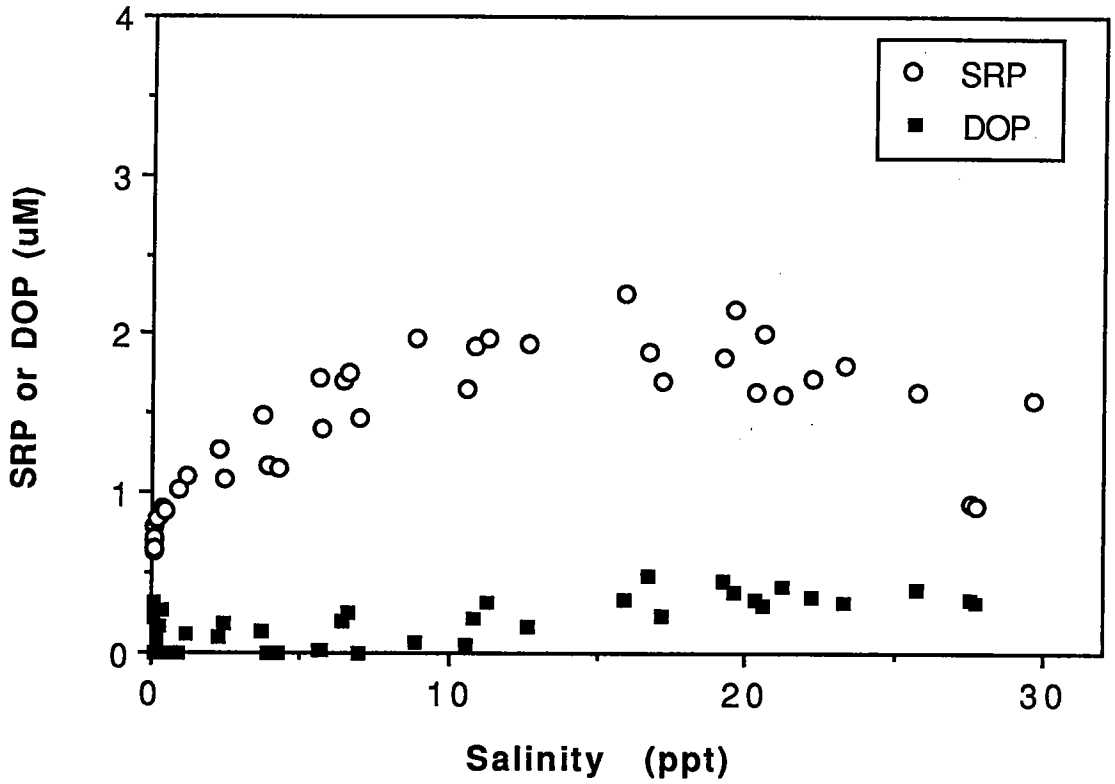


Figure 4b. Particulate Phosphate (PP) - April 1988

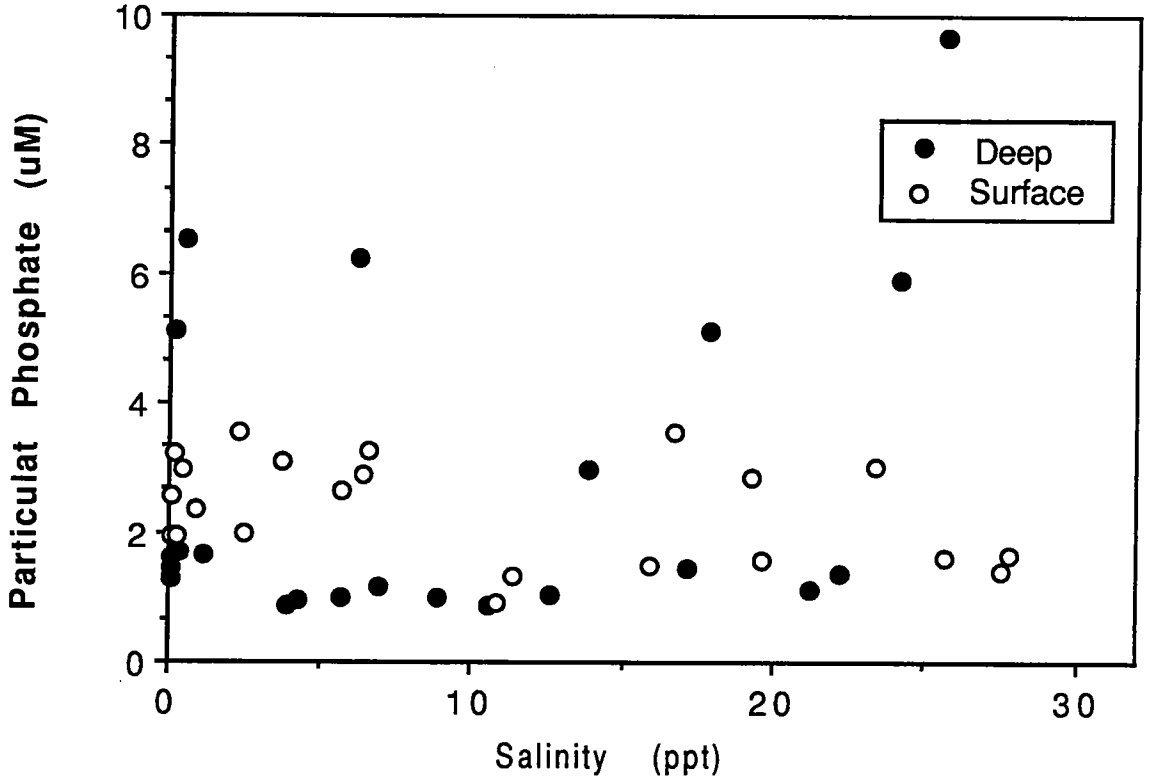


Figure 5a. SRP and DOP vs Salinity - August 1988

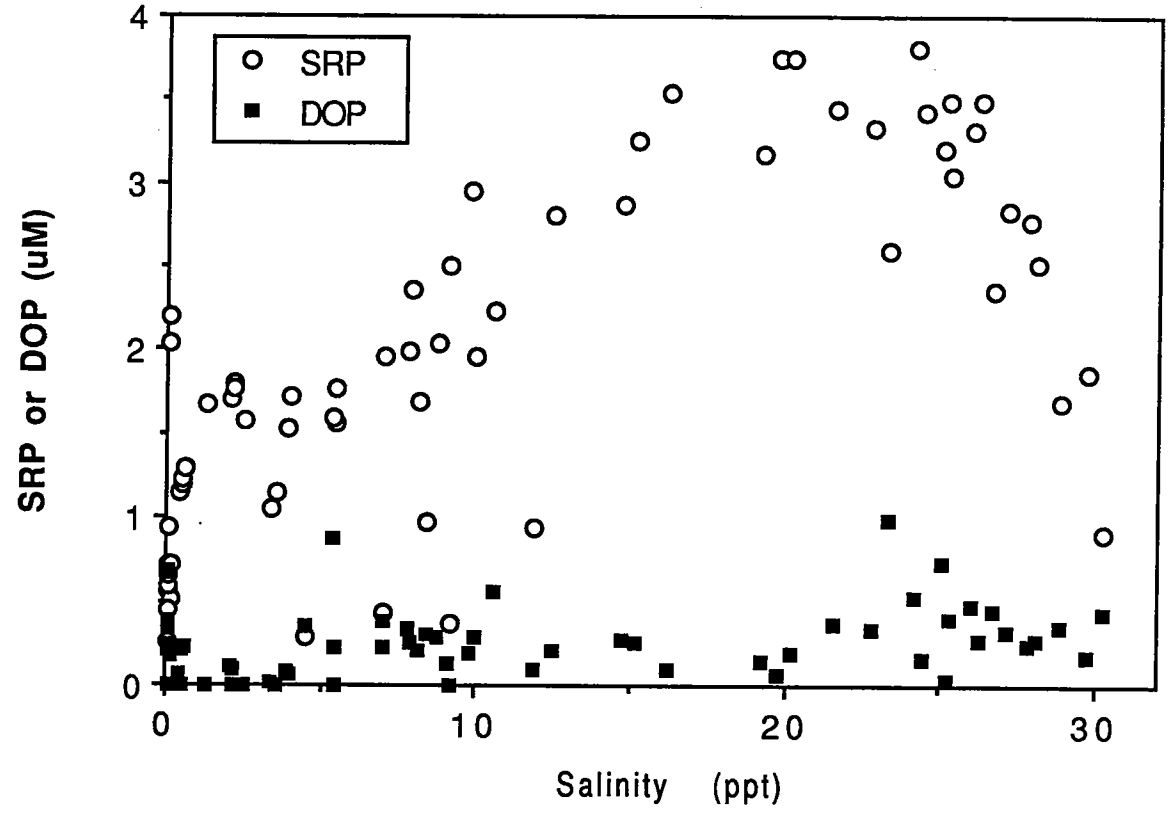


Figure 5b. Particulate Phosphate (PP) - August 1988

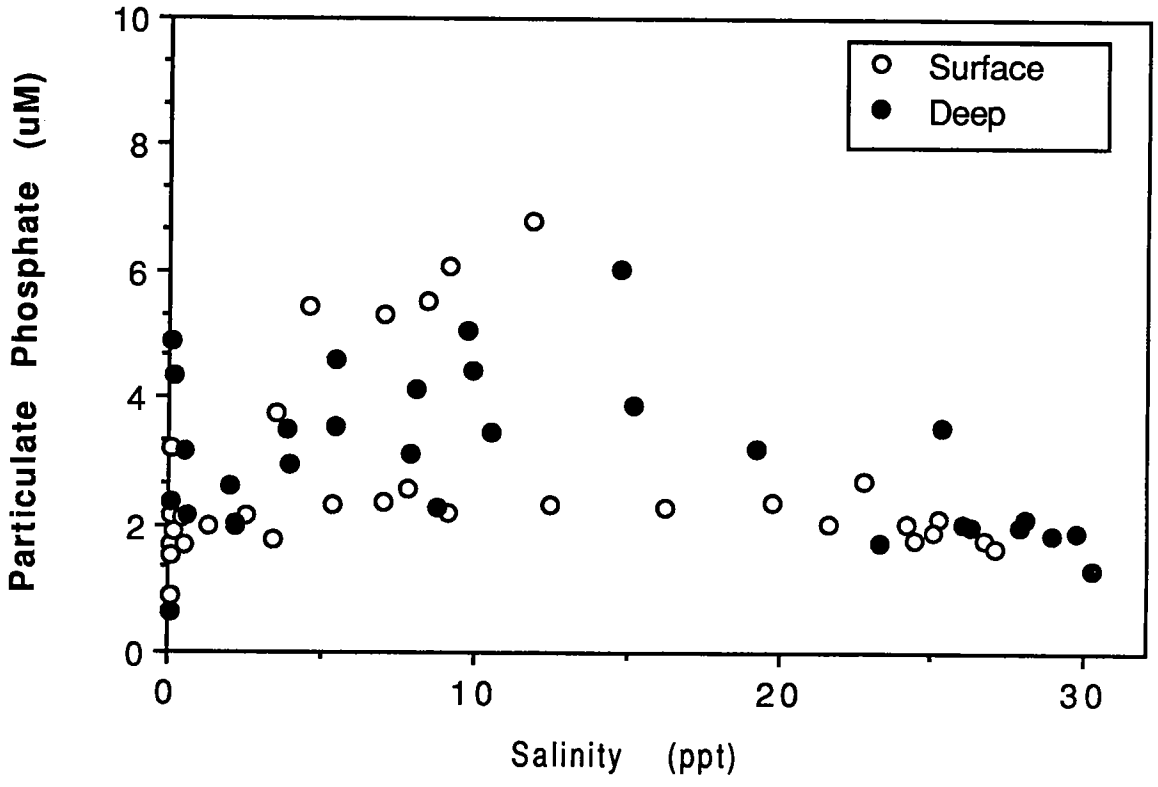


Figure 6a. Particulate Carbon and Nitrogen vs Salinity - April 1988

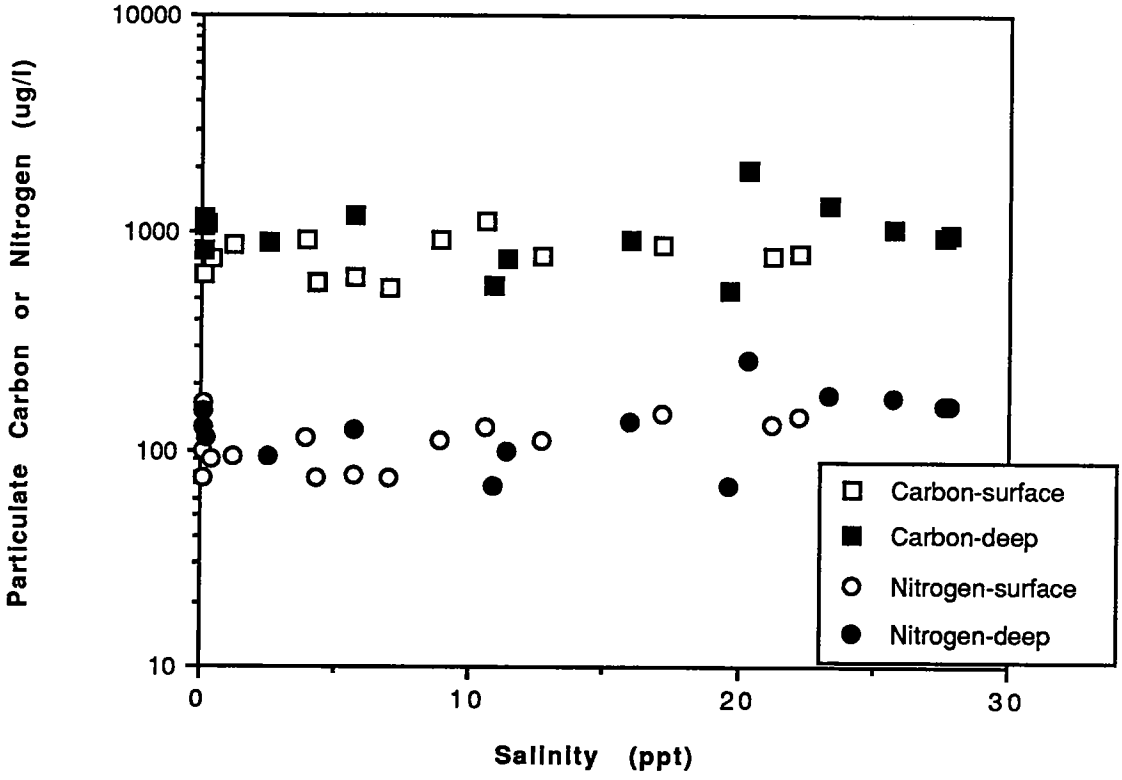


Figure 6b. Particulate Carbon and Nitrogen vs Salinity - August 1988

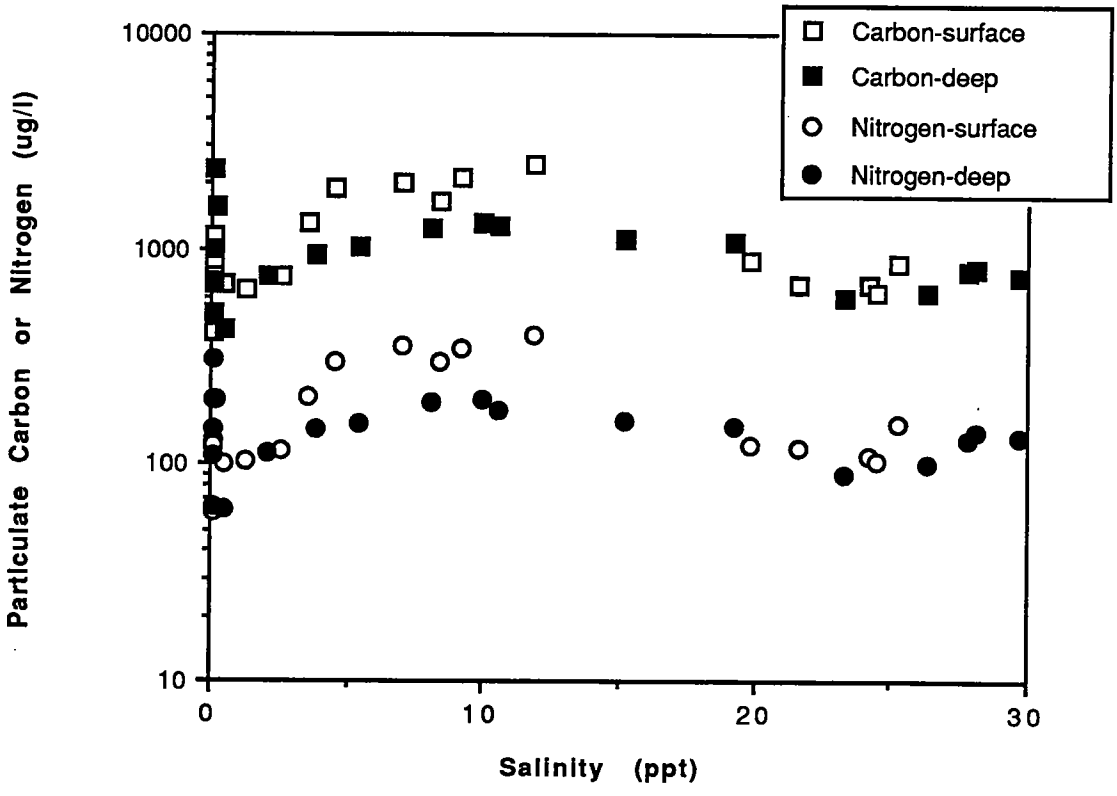


Figure 7. Chlorophyll a vs Salinity - April 1988

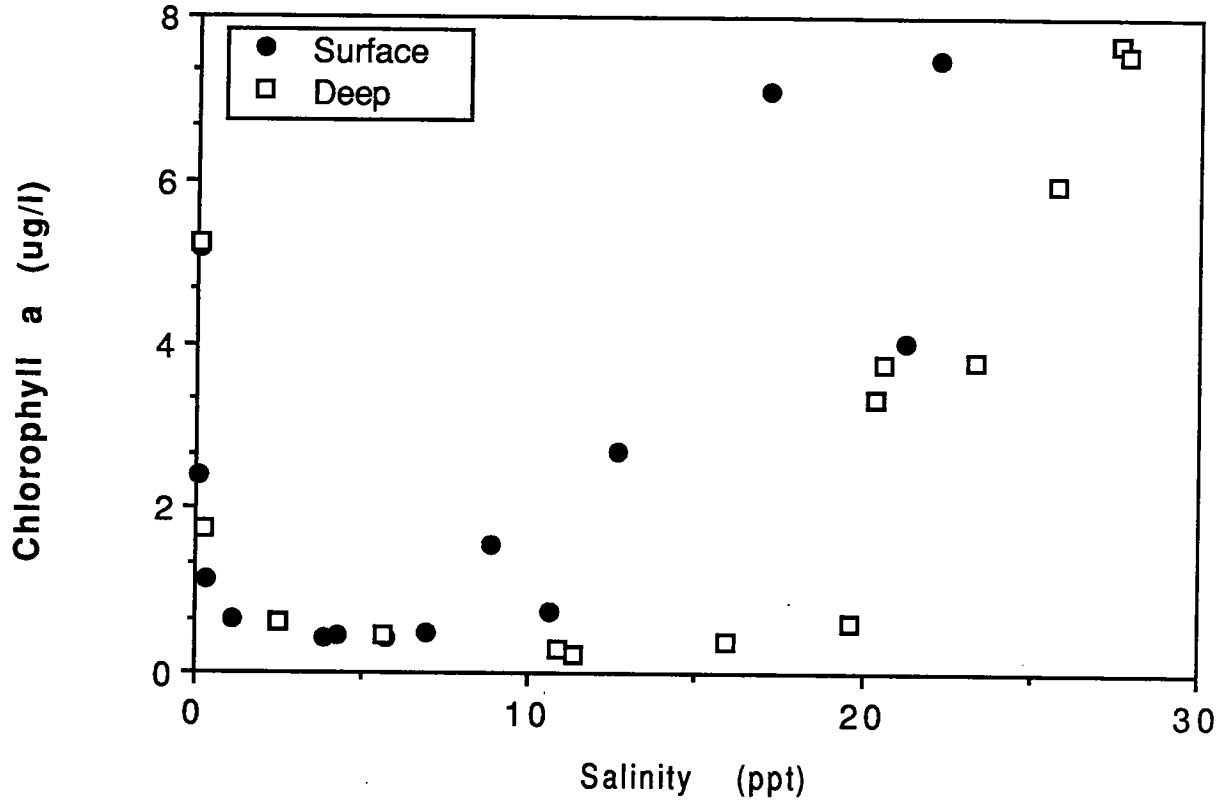


Figure 8. Chlorophyll a vs Salinity - August 1988

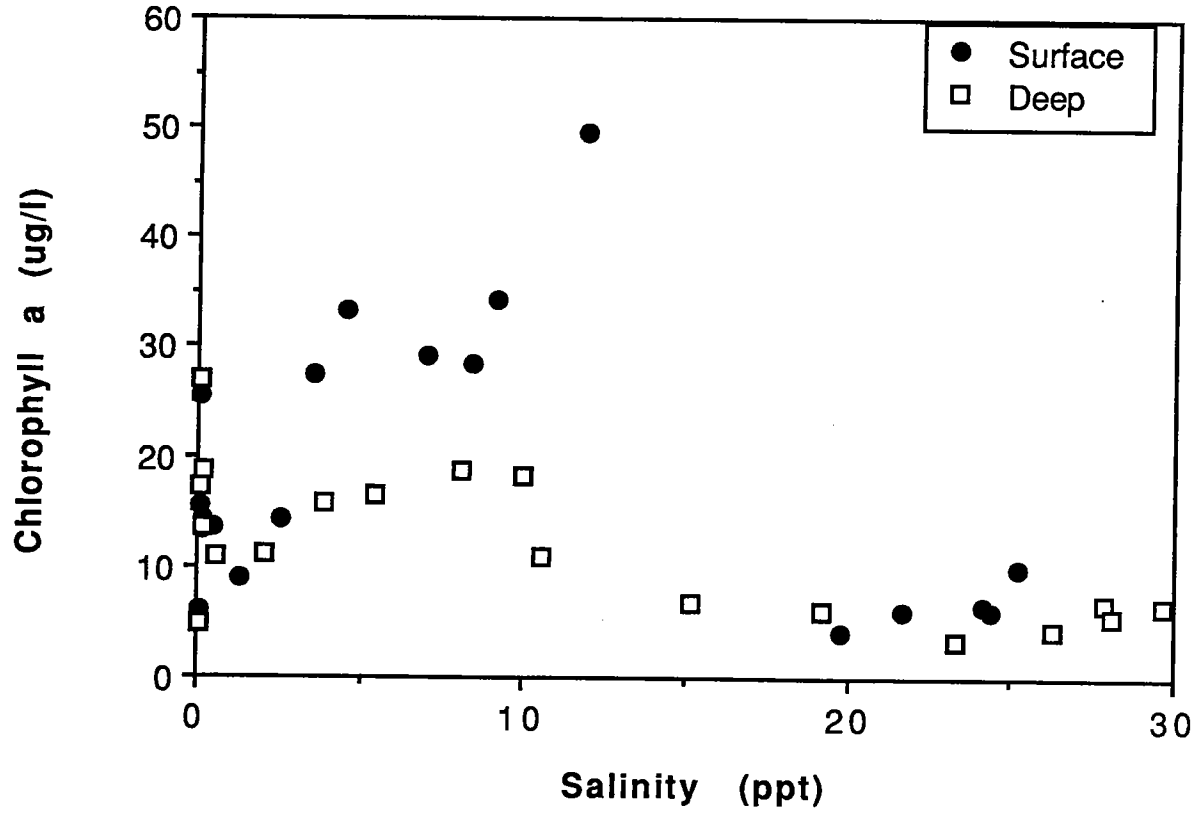


Figure 9. Bacteria vs Salinity - April 1988

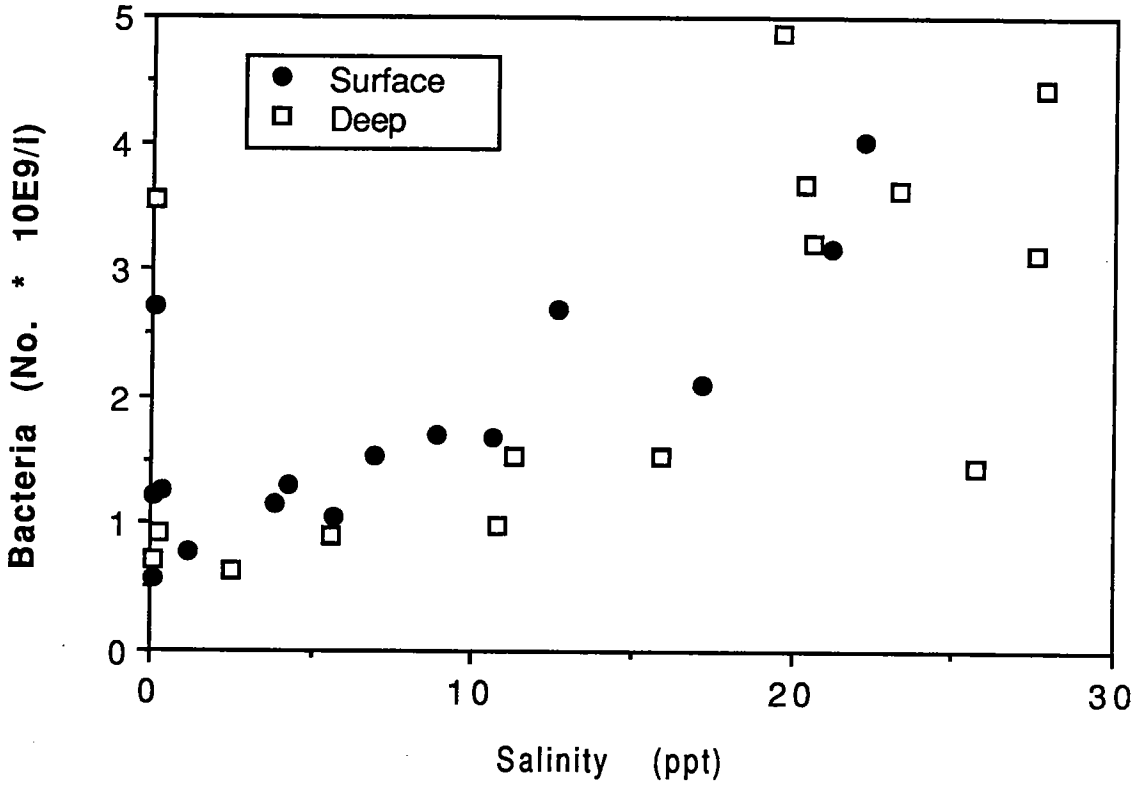


Figure 10. Bacteria vs Salinity-August 1988

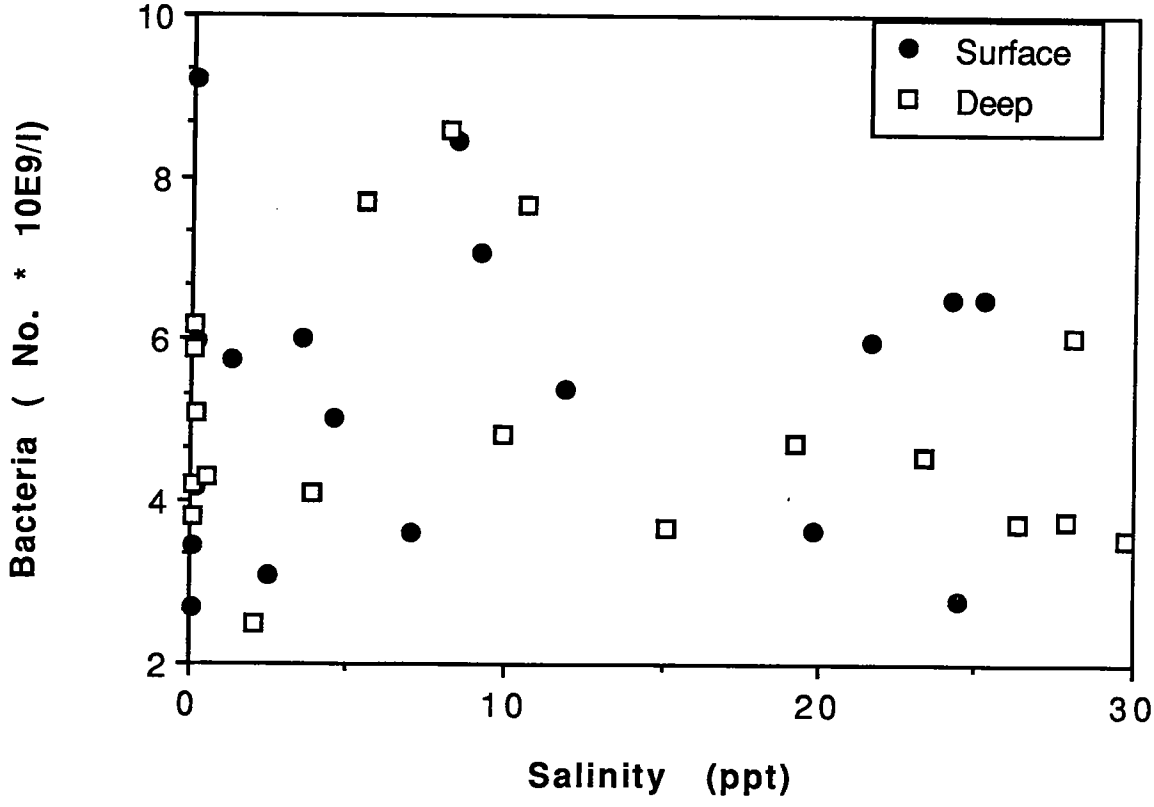


Figure 11a. Autotrophic and Heterotrophic Nano-plankters vs Salinity - April 1988

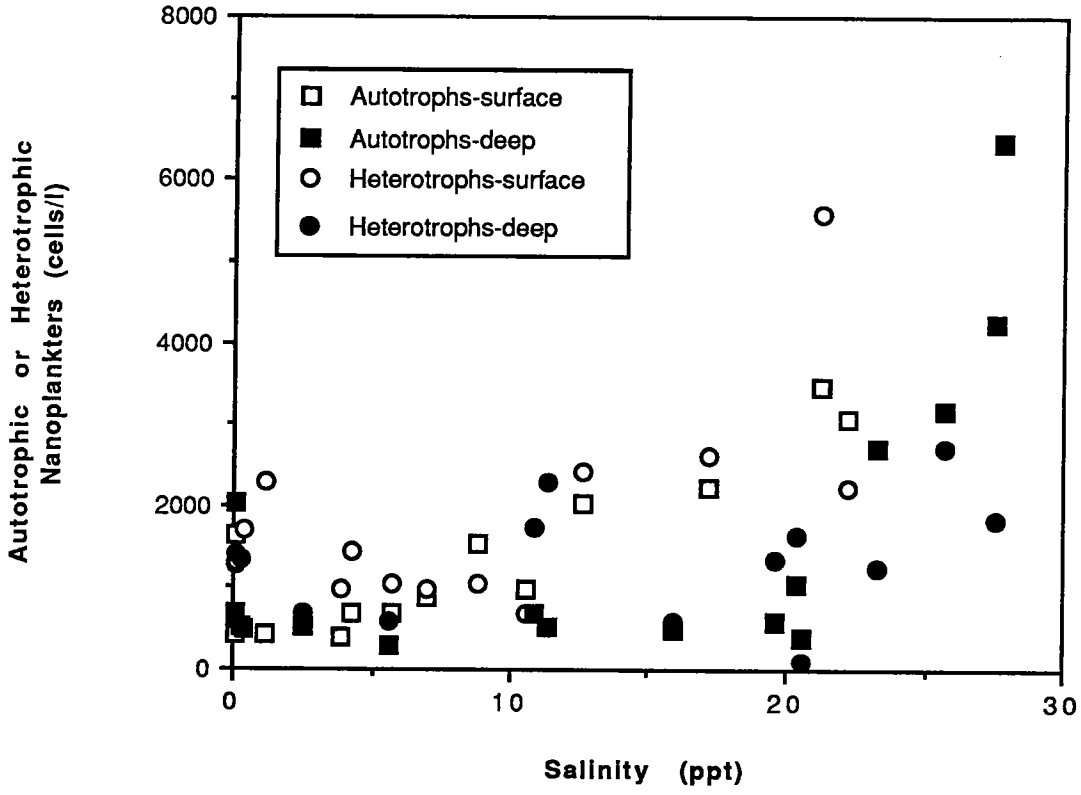


Figure 11b. Autotrophic and Heterotrophic Nano-plankters vs Salinity - August 1988

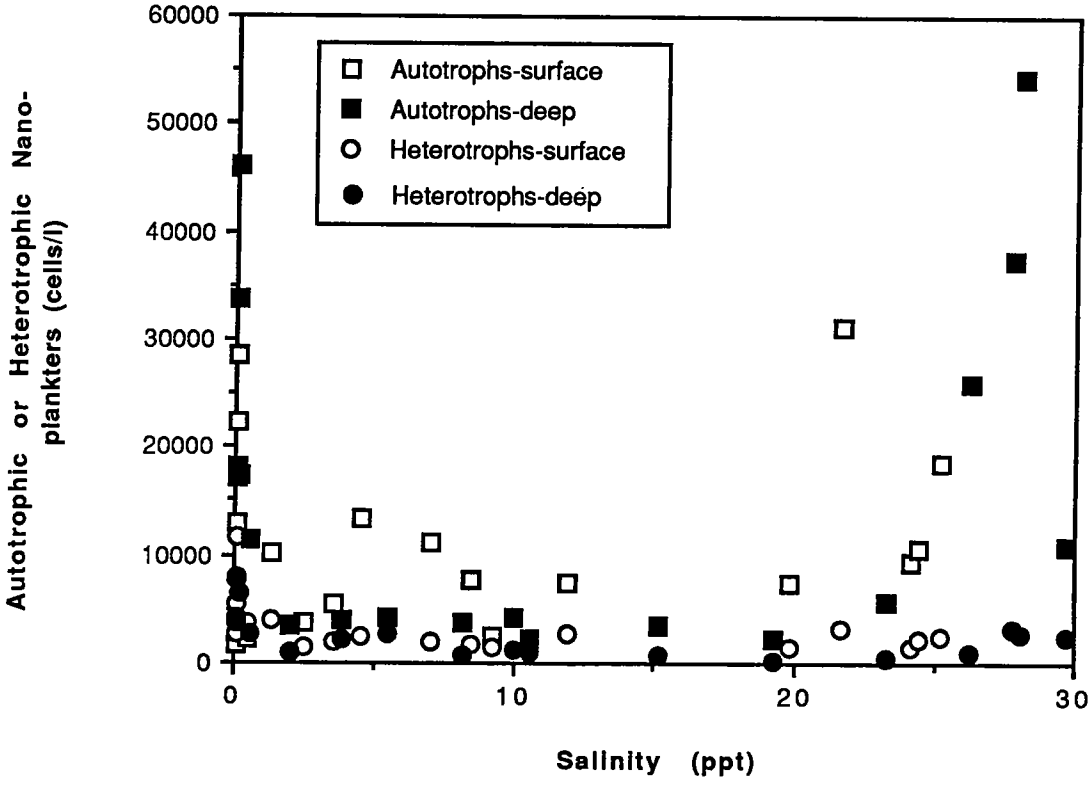


Figure 12. SRP Turnover - April and August 1988

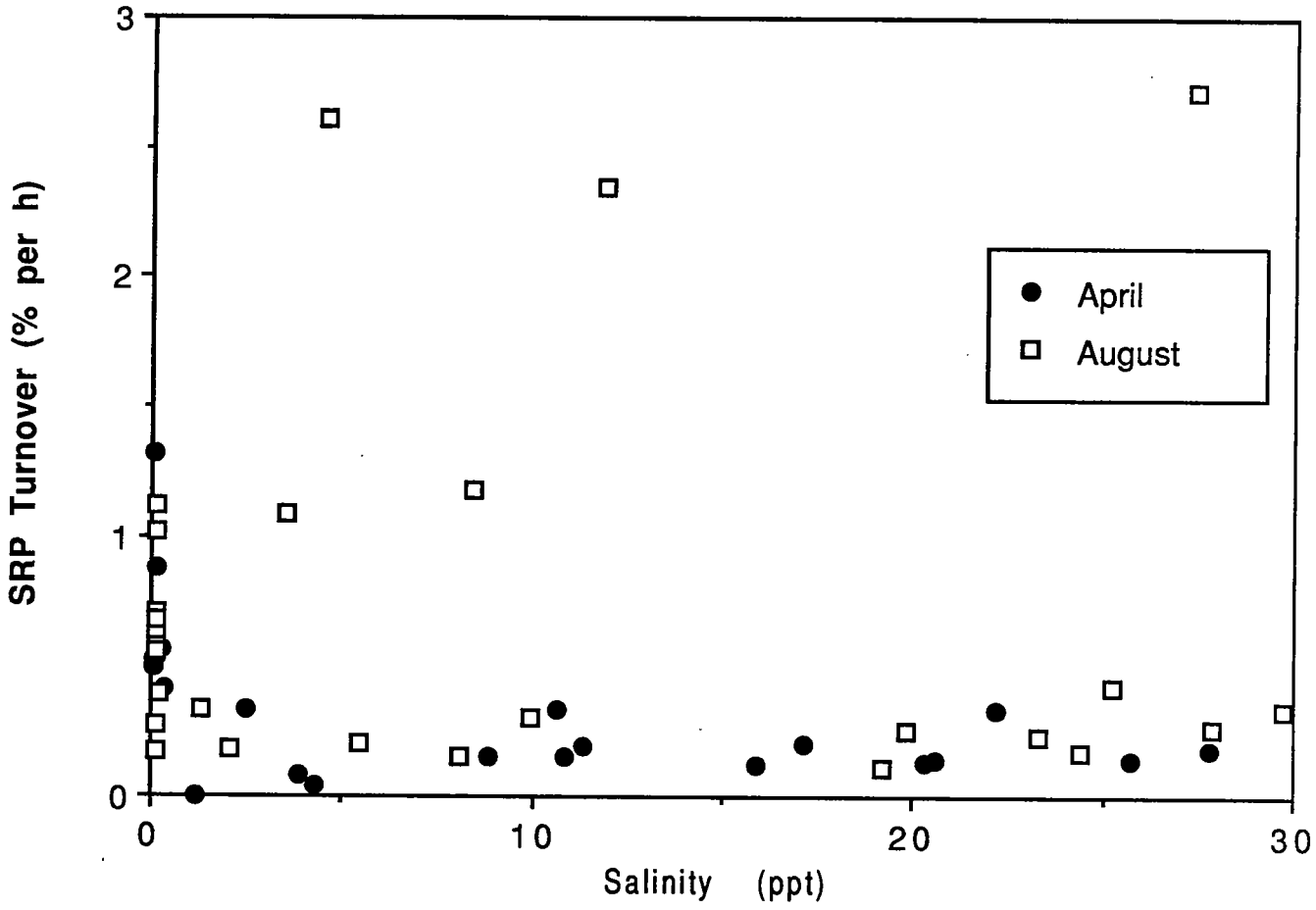


Figure 13. AP vs Salinity - April and August 1988

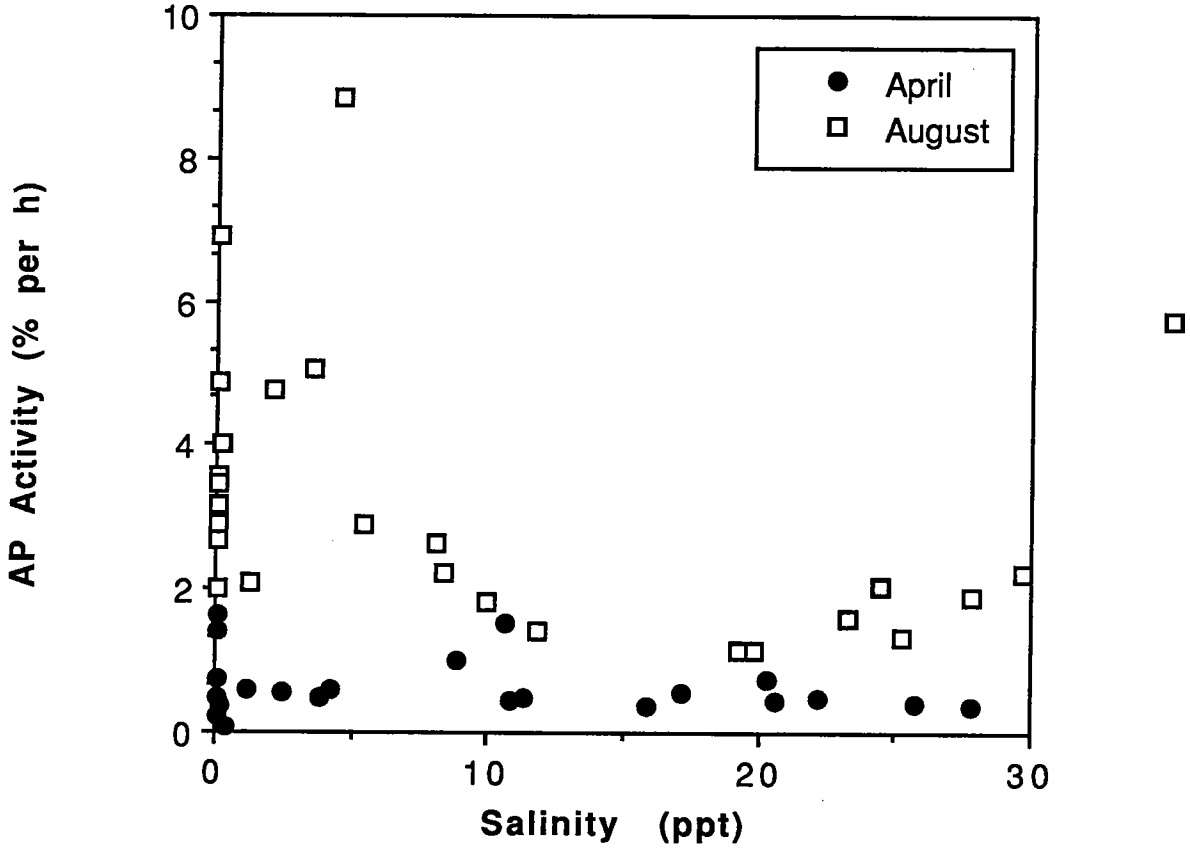


Figure 14. 5PN vs Salinity - April and August 1988

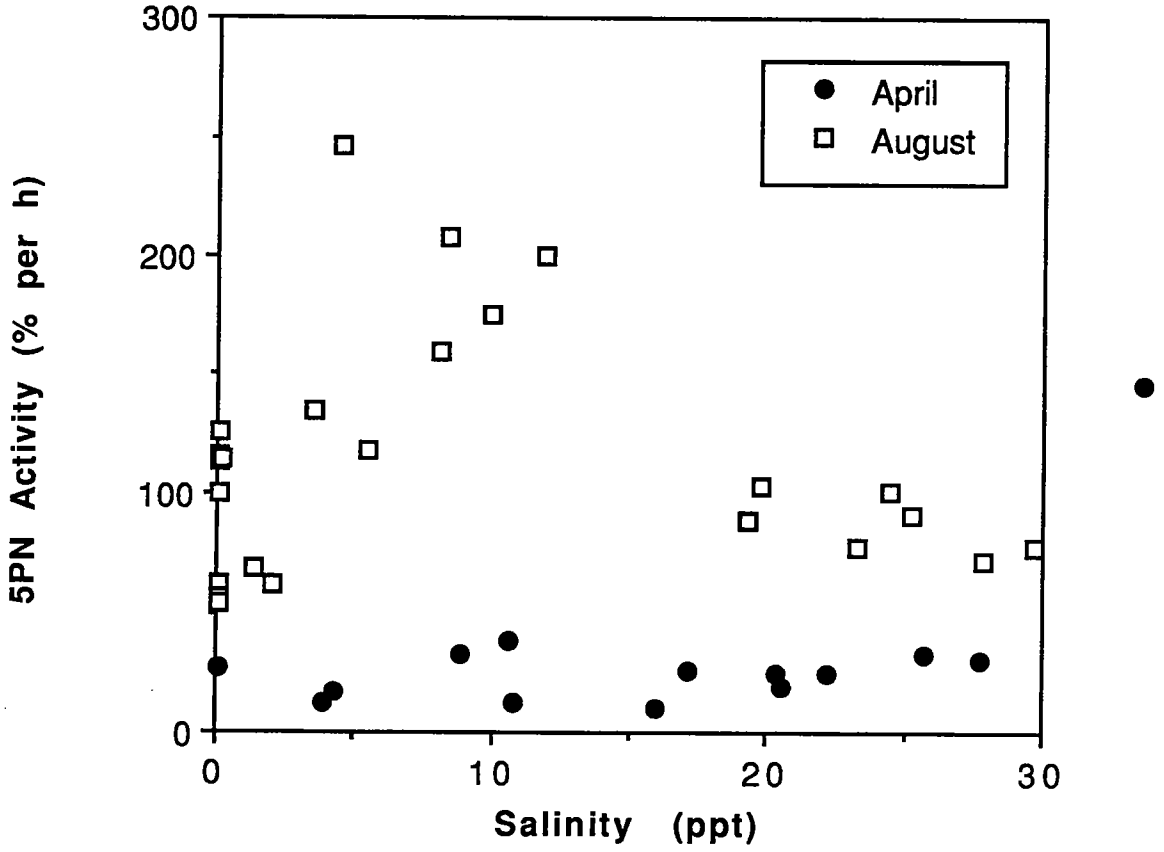


Figure 15. SRP Uptake/SRP Regeneration by AP vs Salinity

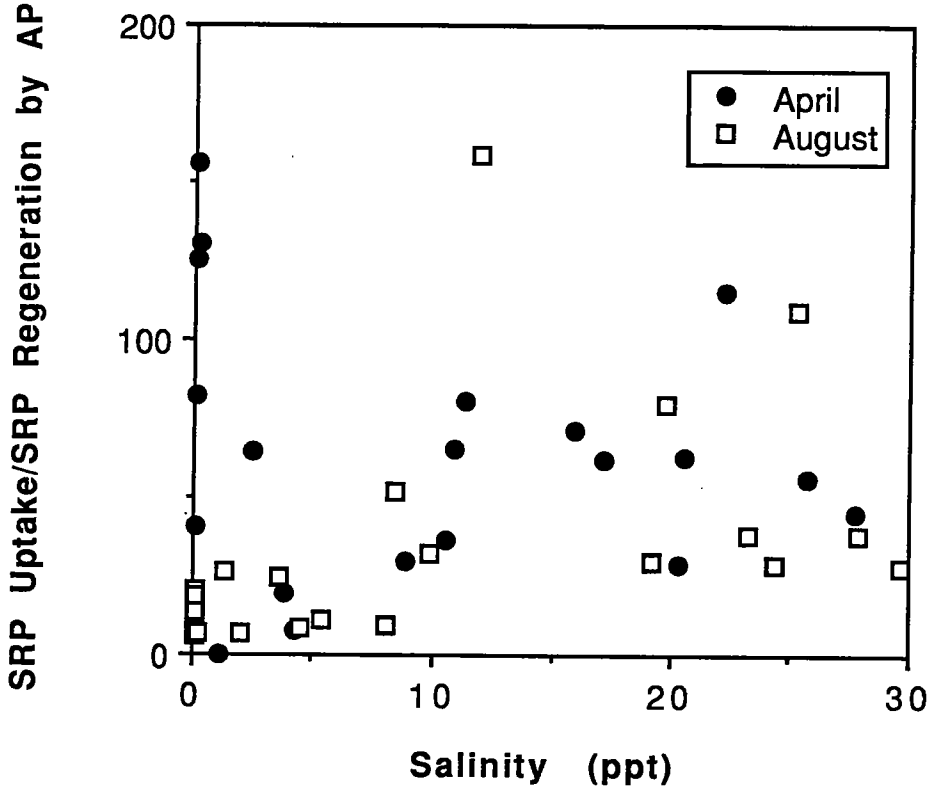
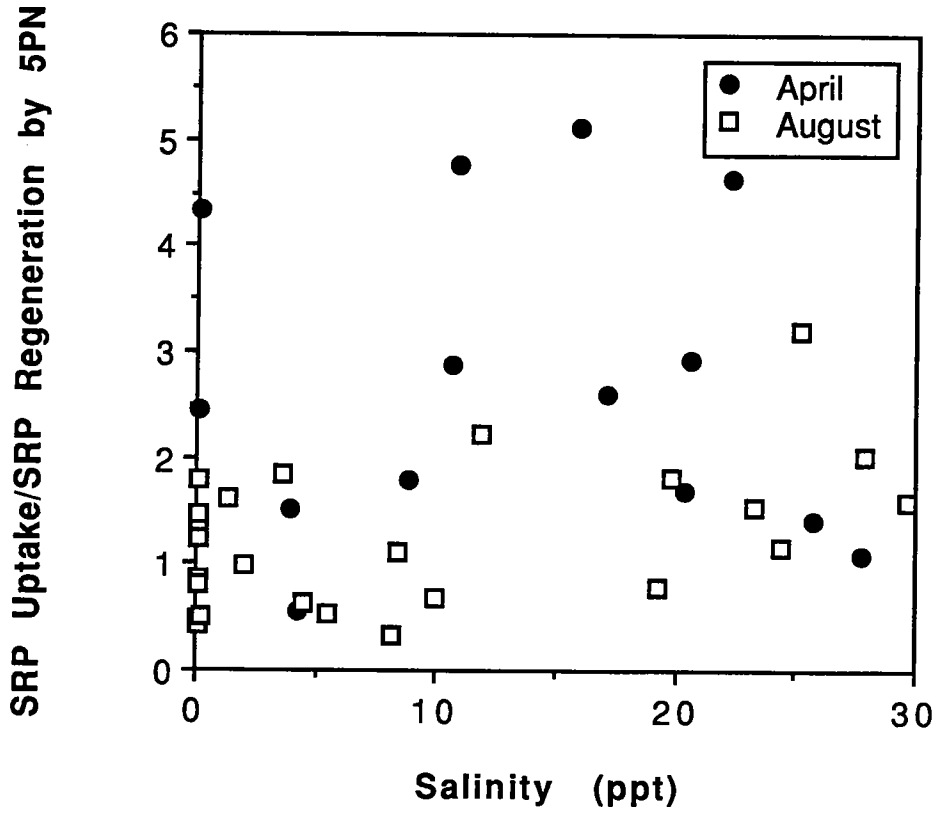


Figure 16. SRP Uptake/SRP Regeneration by 5PN vs Salinity



APRIL SURFACE DATA

Date	Sample Code	Mile Point	Kilometer Point	Sample Depth (m)	Water Temp. (°C)	Salinity (ppt)	Suspended Solids(mg/l)	Secchi Depth (cm)
4/25/88	R	35	56	1	10.4	1.1646	28	40
4/25/88	T	43	69	1	10.1	0.3532	20	60
4/25/88	V	47	76	1	9.4	0.0992	16	70
4/25/88	X	53	85	1	9.6	0.0885	18	90
4/26/88	Z	11	18	1	10.9	10.612	14	100
4/26/88	AB	18	29	1	10.5	6.955	14	80
4/26/88	AD	22.5	36	1	10.8	5.687	18	75
4/26/88	AF	27	43	1	11.3	4.279	12	70
4/26/88	AH	32.5	52	1	11	3.871	14	70
4/28/88	AJ	-7.5	-12	1	9.9	22.222	14	270
4/28/88	AL	-3.5	-6	1	9.8	21.221	18	180
4/28/88	AN	0	0	1	10.3	17.144	12	130
4/28/88	AP	4.5	7	1	11	12.612	8	120
4/28/88	AR	9	14	1	11.4	8.873	12	100
5/4/88	AS	91	147	0.5	10.5	0.1039	8	

APRIL SURFACE DATA

Particulate Carbon (ug/l)	Particulate Nitrogen (ug/l)	SRP (uM)	TDP (uM)	DOP (uM)	PP (uM)	Chlorophyll a (ug/l)	Phaeopigment (ug/l)	Bacteria (*10E6/ml)
870.9	92.8	1.104	1.221	0.117	1.665	0.658	1.752	0.787
760.1	91.2	0.905	1.174	0.269	1.701	1.141	1.614	1.27
650.1	75.2	0.787	1.107	0.32	1.27	2.415	1.981	0.558
825.3	99.1	0.711	0.973	0.262	1.444	5.179	1.883	1.21
1145.73	127.33	1.659	1.707	0.048	0.857	0.764	0.476	1.68
556.67	74	1.472	1.426	0	1.163	0.503	0.489	1.53
622.93	77.2	1.403	1.417	0.014	0.984	0.424	0.56	1.06
590.8	75.33	1.153	1.119	0	0.943	0.451	0.527	1.31
921.47	115.2	1.177	1.134	0	0.883	0.433	0.597	1.16
795.8	144.6	1.716	2.064	0.348	1.382	7.486	0.954	4.02
772.7	131.5	1.617	2.034	0.417	1.1	4.023	0.977	3.18
874.9	148.5	1.704	1.935	0.231	1.457	7.085	1.457	2.11
778.2	111.8	1.947	2.107	0.16	1.037	2.697	1.038	2.68
918.2	109.8	1.974	2.046	0.072	0.989	1.556	0.941	1.71
1059.3	163.3	0.629	0.517	0	1.615		1.564	2.7

APRIL SURFACE DATA

% Attached Bacteria	Autotrophic Nanoplankton (#/ml)	Heterotrophic Nanoplankton (#/ml)	Pi Uptake (%/h)	AP Activity (%/h)	5PN Activity (%/h)	% Pi Uptake (%/h)
83.12	4.39E+02	2.29E+03	0	0.61		
91.06	4.87E+02	1.71E+03	0.41	0.09		
36.45	4.39E+02	1.32E+03	0.49	0.47		
34.97	5.36E+02	1.27E+03	1.32	0.75		
24.53	9.64E+02	6.75E+02	0.33	1.51	38.05	12.54
22.02	8.68E+02	9.64E+02				
21.62	6.75E+02	1.06E+03				
31.44	6.75E+02	1.45E+03	0.04	0.59	16.46	11.73
30.08	3.86E+02	9.75E+02	0.08	0.48	12.51	15.99
2.38	3.08E+03	2.22E+03	0.33	0.49	24.46	19.3
8.52	3.47E+03	5.59E+03				
9.86	2.22E+03	2.60E+03	0.2	0.55	26.28	16.21
33.28	2.02E+03	2.41E+03				
18.34	1.54E+03	1.06E+03	0.15	1.01	33.05	12.31
15.76	1.64E+03	5.78E+02	0.53	1.65	27.37	33.18

APRIL DEEP DATA

Date	Sample Code	Mile Point	Kilometer Point	Sample Depth (m)	Water Temp. (°C)	Salinity (ppt)	Suspended Solids(mg/l)	Particulate Carbon (ug/l)
4/25/88	Q	35	56	10	9.4	11.343	28	753.7
4/25/88	S	43	69	15	10.4	2.477	32	902.9
4/25/88	U	47	76	15	9.3	0.2437	32	1086.2
4/25/88	W	53	85	15	9.7	0.0885	28	1164.2
4/26/88	Y	11	18	10	9.1	20.588		6430.75
4/26/88	AA	18	29	10	9.1	19.635	20	543.6
4/26/88	AC	22.5	36	5.5	10.4	5.645	36	1194.44
4/26/88	AE	27	43	11	9.3	15.928	24	914.4
4/26/88	AG	32.5	52	6	9.7	10.851	16	571.73
4/28/88	AI	-7.5	-12	15	8.5	27.789	20	994.6
4/28/88	AK	-3.5	-6	14	8.3	27.592	20	962.9
4/28/88	AM	0	0	15	8.6	25.723	16	1032.2
4/28/88	AO	4.5	7	15	9	23.334	28	1328.2
4/28/88	AQ	9	14	12	9.3	20.349	44	1923.8
5/4/88	AT	91	147	5	11	0.1078		835.4

APRIL DEEP DATA

Particulate Nitrogen (ug/l)	SRP (uM)	TDP (uM)	DOP (uM)	PP (uM)	Chlorophyll a (ug/l)	Phaeopigment (ug/l)	Bacteria (*10E6/ml)	% Attached Bacteria
99.9	1.983	2.304	0.321	1.335	0.229	0.38	1.54	31.99
94.1	1.09	1.275	0.185	1.969	0.606	1.373	0.62	48.97
114.1	0.861	1.032	0.171	1.934	1.745	2.236	0.922	29.33
128.9	0.72	0.935	0.215	1.94	5.232	2.487	0.712	55.65
705	2.011	2.318	0.307		3.761	6.933	3.21	3.59
69.07	2.152	2.531	0.379	1.589	0.629	1.164	4.88	12.34
124.11	1.716	1.736	0.02	2.645	0.453	0.889	0.908	33.05
136.53	2.267	2.601	0.334	1.483	0.401	1.028	1.53	29.57
68.13	1.92	2.132	0.212	0.923	0.284	0.686	0.979	27.59
162.5	0.923	1.234	0.311	1.659	7.553	2.616	4.44	3.9
158.6	0.935	1.277	0.342	1.409	7.686	2.788	3.13	4.93
176.8	1.644	2.043	0.399	1.611	5.948	2.085	1.46	4.1
181.4	1.812	2.125	0.313	2.996	3.81	2.19	3.63	12.64
262.2	1.641	1.968	0.327		3.348	2.437	3.68	11.76
149.6	0.656	0.594	0	2.542		3.011	3.56	8.34

APRIL DEEP DATA

Autotrophic Nanoplankton (#/ml)	Heterotrophic Nanoplankton (#/ml)	Pi Uptake (%/h)	AP Activity (%/h)	5PN Activity (%/h)	% Pi Uptake (%/h)
5.36E+02	2.29E+03	0.19	0.47		
5.25E+02	7.00E+02	0.33	0.56		
5.25E+02	1.34E+03	0.56	0.37		
7.00E+02	1.40E+03	0.52	0.24		
3.86E+02	9.60E+01	0.14	0.45	19.22	19.3
5.78E+02	1.35E+03				
2.89E+02	5.78E+02				
4.82E+02	5.78E+02	0.12	0.38	10.65	47.23
6.75E+02	1.74E+03	0.15	0.44	12.11	45.91
6.46E+03	6.46E+03	0.18	0.37	30.35	12.85
4.24E+03	1.83E+03				
3.18E+03	2.70E+03	0.14	0.41	32.75	11.63
2.70E+03	1.25E+03				
1.06E+03	1.64E+03	0.13	0.75	25.22	16.42
2.02E+03	5.78E+02	0.88	1.41	26.62	52.29

AUGUST SURFACE DATA

Date	Sample Code	Mile Point	Kilometer Point	Sample Depth (m)	Water Temp. (°C)	Salinity (ppt)	Suspended Solids(mg/l)	Secchi Depth (cm)	Particulate Carbon (ug/l)
8/8/88	29	116	188	0.5	28.2	0.13	8	160	837
8/8/88	31	137	222	0.5	28.9	0.12	2	235	410
8/9/88	33	91	147	0.5	27.8	0.12	20	125	1149
8/9/88	35	72	117	0.5	27.8	0.12	8	140	833
8/10/88	38	60	97	1.0	29.3	0.14	16	100	876
8/10/88	40	54	87	1.0	28.2	0.47	28	90	688
8/10/88	42	47	76	1.0	28.9	1.32	20	100	647
8/10/88	44	43	70	1.0	29.7	2.52	16	90	752
8/10/88	46	36.5	59	1.0	30.9	3.54	16	75	1315
8/11/88	48	32.5	52.5	1.0	30.5	4.53	14	80	1898
8/11/88	50	27	44	1.0	29.6	7.00	12	75	2043
8/11/88	52	22.5	36.5	1.0	29.4	8.40	20	70	1636
8/11/88	54	18	29	1.0	29.6	9.17	16	75	2144
8/11/88	56	11	18	1.0	29	11.88	24	75	2436
8/12/88	58	6	10	1.0	26.3	19.81	14	80	890
8/12/88	60	0	0	1.0	26.4	21.64	4	120	689
8/12/88	62	-4	-6.5	1.0	25.4	24.43	6	180	626
8/12/88	64	-7.5	-12	1.0	25.2	24.18	8	180	677
8/12/88	66	-12.5	-20	1.0	25.2	25.24	18	180	854

AUGUST SURFACE DATA

Particulate Nitrogen (ug/l)	SRP (uM)	TDP (uM)	DOP (uM)	PP (uM)	Chlorophyll a (ug/l)	Phaeopigment (ug/l)	Bacteria (*10E6/ml)	% Attached Bacteria	Autotrophic Nanoplankton (#/ml)
130	0.551	0.753	0.202	1.674	14.249	10.928	4.16	1.15	2.86E+04
60	2.033	1.955	0.000	0.872	6.035	4.392	2.70	4.52	1.70E+04
198	0.249	0.662	0.413	3.201	25.593	13.458	9.20	13.90	1.80E+03
120	0.716	1.364	0.648	2.134	15.537	7.915	3.46	14.00	2.22E+04
123	0.509	0.688	0.179	1.878	13.412	8.275	5.99	7.52	1.30E+04
100	1.150	1.208	0.058	2.104	13.575	7.085	4.31	19.10	2.20E+03
103	1.674	1.676	0.002	1.997	9.055	6.213	5.74	6.22	1.01E+04
115	1.572	1.532	0.000	2.148	14.371	10.471	3.07	8.88	3.73E+03
209	1.141	0.756	0.000	3.767	27.424	23.681	6.03	8.50	5.33E+03
298	0.294	0.651	0.357	5.448	33.267	27.958	5.04	13.71	1.33E+04
352	0.425	0.800	0.375	5.334	29.099	25.377	3.62	20.12	1.12E+04
299	0.970	1.268	0.298	5.529	28.493	20.164	8.45	20.45	7.80E+03
345	0.371	0.243	0.000	6.066	34.219	21.764	7.07	18.50	2.40E+03
397	0.943	1.034	0.091	6.797	49.489	27.709	5.38	16.47	7.40E+03
125	3.747	3.810	0.063	2.345	4.059	5.092	3.65	9.27	7.40E+03
120	3.441	3.813	0.372	2.026	5.967	5.778	5.99	13.84	3.12E+04
105	3.432	3.590	0.158	1.779	5.975	6.119	2.80	6.46	1.06E+04
109	3.804	4.336	0.532	2.014	6.518	6.893	6.50	12.31	9.40E+03
155	3.483	3.513	0.030	2.124	9.870	9.193	6.52	4.88	1.86E+04

AUGUST SURFACE DATA

Heterotrophic Nanoplankton (#/ml)	Pi Uptake (%/h)	AP Activity (%/h)	5PN Activity (%/h)	% Uptake (%/h)	PEP Activity (%/h)
4.20E+03	2.89	3.32	0.70	62.07	26.25
1.17E+04	2.66	2.53	0.27	61.02	14.64
5.40E+03	4.87	6.44	1.12	115.33	29.44
2.80E+03	2.67	3.64	0.59	99.70	33.59
8.00E+03	3.57	2.76	0.55	126.19	25.38
3.80E+03					
4.00E+03	2.08	7.07	0.33	68.74	27.08
1.60E+03					
1.87E+03	5.06	12.29	1.09	135.31	46.26
2.40E+03	8.86	14.98	2.61	245.70	46.33
2.00E+03					
1.80E+03	2.22	14.35	1.18	208.26	49.56
1.60E+03					
2.80E+03	1.40	18.23	2.35	199.82	61.04
1.60E+03	1.17	5.21	0.25	103.12	32.45
3.20E+03					
2.20E+03	2.04	4.47	0.17	101.38	34.59
1.60E+03					
2.40E+03	1.34	6.99	0.42	91.27	39.73

AUGUST DEEP DATA

Date	Sample Code	Mile Point	Kilometer Point	Sample Depth (m)	Water Temp. (°C)	Salinity (ppt)	Suspended Solids(mg/l)	Particulate Carbon (ug/l)
8/8/88	30	116	188	5	28.1	0.13	4	691
8/8/88	32	137	222	5	28.7	0.12	6	493
8/9/88	34	91	147	5	27.7	0.12	40	2306
8/9/88	36	72	117	10	27.4	0.12	24	994
8/10/88	37	60	97	13	28.6	0.18	34	1551
8/10/88	39	54	87	17	28.0	0.54	20	422
8/10/88	41	47	76	17	29.0	2.05	24	749
8/10/88	43	43	70	17	29.7	3.86	16	930
8/10/88	45	36.5	59	9	29.3	5.45	28	1016
8/11/88	47	32.5	52.5	12	28.7	8.12	28	1235
8/11/88	49	27	44	12	28.0	10.59	20	1270
8/11/88	51	22.5	36.5	12	28.6	9.94	26	1314
8/11/88	53	18	29	12	27.2	15.17	32	1120
8/11/88	55	11	18	17	25.8	19.24	24	1072
8/12/88	57	6	10	13	25.4	23.31	24	591
8/12/88	59	0	0	15	24.0	26.30	4	619
8/12/88	61	-4	-6.5	17	23.1	27.83	16	786
8/12/88	63	-7.5	-12	17	22.9	28.08	10	818
8/12/88	65	-12.5	-20	15	20.6	29.70	20	750

AUGUST DEEP DATA

Particulate Nitrogen (ug/l)	SRP (uM)	TDP (uM)	DOP (uM)	PP (uM)	Chlorophyll a (ug/l)	Phaeopigment (ug/l)	Bacteria (*10E6/ml)	% Attached Bacteria
110	0.583	0.959	0.376	1.506	13.715	10.972	5.88	4.50
64	2.193	1.943	0.000	1.538	4.894	3.686	6.19	5.37
303	0.452	0.794	0.342	4.895	27.007	17.234	4.2	6.88
147	0.684	1.364	0.680	2.372	17.222	8.953	3.82	6.46
199	0.725	0.588	0.000	4.345	18.627	11.654	5.11	20.54
63	1.195	1.173	0.000	3.149	10.994	7.241	4.31	25.23
114	1.704	1.814	0.110	2.621	11.096	8.787	2.48	5.26
147	1.527	1.602	0.075	3.509	15.782	13.806	4.12	5.37
156	1.569	1.494	0.000	3.552	16.556	15.266	7.68	37.35
196	1.689	1.897	0.208	4.136	18.633	18.186	8.57	73.67
178	2.237	2.796	0.559	3.465	10.837	13.148	7.66	26.31
202	1.953	2.236	0.283	4.420	18.134	13.775	4.84	37.10
161	3.253	3.510	0.257	3.866	6.802	10.060	3.68	36.23
152	3.166	3.316	0.150	3.227	5.959	6.833	4.72	17.20
89	2.597	3.579	0.982	1.721	3.291	4.558	4.58	18.62
101	3.483	3.756	0.273	1.994	4.352	5.085	3.76	4.52
130	2.767	3.010	0.243	1.979	6.870	8.695	3.78	9.74
142	2.510	2.779	0.269	2.098	5.630	7.800	6.05	3.85
134	1.863	2.039	0.176	1.907	6.618	9.440	3.54	0.90

AUGUST DEEP DATA

Autotrophic Nanoplankton (#/ml)	Heterotrophic Nanoplankton (#/ml)	Pi Uptake (%/h)	AP Activity (%/h)	5PN Activity (%/h)	% Pi Uptake (%/h)	PEP (%/h)
4.60E+04	7.60E+03	0.67	3.44	53.50	27.72	3.04
3.37E+04	4.00E+03	0.17	2.01	55.64	17.36	1.79
1.80E+04	4.20E+03	1.02	6.90	113.63	28.36	5.01
1.82E+04	3.80E+03	0.63	3.15	100.07	32.48	3.10
1.73E+04	6.33E+03	0.39	4.01	114.17	27.87	3.54
1.13E+04	2.67E+03					
3.47E+03	1.07E+03	0.18	4.77	62.02	27.87	3.28
4.00E+03	2.33E+03					
4.27E+03	2.67E+03	0.20	2.89	117.42	45.22	7.23
3.73E+03	6.67E+02	0.15	2.65	159.97	40.43	7.80
2.13E+03	1.07E+03					
4.27E+03	1.33E+03	0.30	1.81	175.84	42.22	8.21
3.40E+03	8.00E+02					
2.20E+03	2.00E+02	0.11	1.17	89.20	42.58	4.85
5.60E+03	4.00E+02	0.23	1.58	77.05	38.09	4.96
2.60E+04	1.00E+03					
3.74E+04	3.20E+03	0.26	1.90	71.53	40.62	4.02
5.42E+04	2.80E+03					
1.08E+04	2.40E+03	0.33	2.23	78.01	46.23	4.02