# THE PEEL-HARVEY ESTUARINE SYSTEM STUDY (1976 - 1980)

## TECHNICAL REPORT



## PHOSPHATASE ACTIVITIES

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# PHOSPHATASE ACTIVITIES IN THE PEEL-HARVEY ESTUARINE SYSTEM

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## SUMMARY

Phosphatase activities in the Peel-Harvey Estuarine system have been studied in order to define the potential of the system to recycle organic phosphorus.

The following observations are made.

1. There are areas of high and low phosphatase activities; these areas change seasonally. Activities were higher in the Harvey Estuary in March 1978 and 1979, but higher in the Peel Inlet in August 1978.

2. There was a decrease in overall activity from March 1978 to March 1979.

3. A diurnal pattern was usually evident, but this varied with location and depth. It was probably related to the response of phosphatase producing organisms ot diurnal changes in nutrients and physical conditions.

4. The variation of phosphatase activities in the water column is likely more related to other characteristics of the system, such as the organisms present, stirring etc., rather than depth.

5. Activity appears to be related to phytoplankton populations and nutrient concentrations, especially of orthophosphate and nitrogen.

6. On the basis of the data collected, and <u>potential</u> release rate of phosphorus for biomass production varied from 0.3 to 1.9 X $10^7$kg/year in the Peel-Harvey Estuary system.

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# 1. INTRODUCTION

Metabolic processes such as photosynthesis and nitrogen fixation, and ultimately growth, require phosphorus.

High phosphorus levels are often implicated in initiating and maintaining nuisance growths of macroalgae and phytoplankton in aquatic systems. The abundance of phosphorus in a system is not necessarily equal to its availability. Many forms of phosphorus cannot be assimilated by plants or microorganisms. Organic phosphorus, which results from the decomposition of non-living tissue, ie. detritus in the case of aquatic systems, is one of these forms. The phosphatase enzyme removes the orthophosphate portion from organic phosphate molecules; this form of phosphorus is readily assimilable by organisms. The process is represented in Figure 1.

It is the phosphatase enzyme, then, that renders the phosphorus in the organic form available, and thus provides a link between detritus and growing organisms.

Extracellular phosphatase production is not restricted to one particular group of organisms. Under conditions of low available inorganic phosphorus and adequate concentrations of other nutrients, it may be secreted by any organism requiring phosphate for active metabolism. In other words, these phosphatase activities reflect an inadequate supply of freely available orthophosphate in the system.

The following report deals with a study of the activities of this enzyme from the Peel-Harvey Estuarine waters and some of the factors governing this.

## 2. METHODS

Phosphatase concentrations were assayed using essentially the method of Reichardt *et al* (1967).

A 2:2:1 mixture of water sample, 1 *M* Tris buffer (at pH 7.5 or 8.6 for neutral or alkaline phosphatase, respectively), and 0.7 M *p* -nitrophenyl-phosphate in a $10^{-2}$ *M* $MgSO_4$ solution was incubated at $25^{0}C$ in the dark for 24 or 48 hours. The release of *p*-nitrophenol was measured spectrophotometrically, at 410 nm. This gave a measure of the potentially available phosphatase activity in the water.

Nutrient analyses were done by the Botany Department, University of Western Australia.

# 3. RESULTS

## 3.1 GRID STUDIES

On three occasions (March, 1978; August, 1978; and March, 1979), concurrent with the large biomass/nutrient surveys conducted by the Botany Department, University of Western Australia, water from 36 sites (Fig. 3.1.1) was assayed for phosphatase activity. Both surface and bottom waters were tested on the latter two occasions. In March, 1979, sediment phosphatase activities were also examined (Gabrielson, 1980). The results of these surveys are shown in Figs. 3.1.2, 3.1.3, 3.1.4 and Table 3.1.1. Table 3.1.2 summarizes the data for the Peel Inlet and Harvey Estuary.

Several points emerge from these data. Firstly, in both March surveys, the phosphatase activity was higher in the Harvey than in the Peel. In 1978 the averages for Harvey and Peel surface waters were 33 and 9 ug phosphorus released/L/hr, respectively. The corresponding 1979 figures were 6 and 1. In August, 1978 however, the average phosphatase activity in the Peel Inlet was 10 ug P released/L/hr compared to 5 in the Harvey Estuary. The phosphatase activity in the Harvey had remained fairly level from August '78 to March '79, but that of the Peel fell considerably. (Table 3.1.2, Fig. 3.2.2a). From March '78 to August '78, it was the level in the Harvey which had dropped, while that in the Peel rose very slightly (9 to 10 ug P released/L/hr).

The Peel Inlet and Harvey Estuary can be treated as two distinct systems. Fig. 3.1.5 is the plots of phosphatase activity versus total nitrogen for the three surveys. The points fall into two distinct clusterings with very little overlap. In the March surveys, the Harvey samples had high total nitrogen levels and often high phosphatase activities. For the August survey, the total nitrogen concentrations were higher in the Peel. The linear regression equations for the Peel and Harvey surface waters are plotted in Fig. 3.1.5. These data also indicate the variability within each system. The ranges of phosphatase activities are given in Table 3.1.2.

In order to gain some appreciation of the role of phosphatase in the estuarine system, it is necessary to treat each system as a unit. The surface water nutrient and phosphatase data in relation to sample volume and chlorophyll _a_ levels for the three surveys are summarized in Table 3.1.3. For both March surveys, chlorophyll _a_ and suspended turbidity were the highest in the Harvey but in August 1978, the concentrations were highest in the Peel.

The Harvey to Peel ratios of chlorophyll a are 2.2, 0.56, and 1.6 for Marach 1978, August 1978 and March 1979, respectively. The corresponding phosphatase activities ratios on a chlorophyll basis are 1.6, 1.0 and 3.0 ug orthophosphate released/ug chlorophyll/hr. In August 1978, therefore, the higher phosphatase activity in Peel surface waters (10 compared to 5 ug P released/L/hr in the Harvey) may be explained by the higher phytoplankton biomass. In both systems, the activity was only 0.2 ug P released/ug chlorophyll/hr. Concentrations of orthophosphate were also very low (Table 3.1.3). This might be expected to have stimulated phosphatase production. However, since cellular nitrogen concentrations also appear to have been low (organic nitrogen to phosphorus ratios were 7.0 and 6.1 for the Peel Inlet and Harvey Estuary, respectively), it may be that nitrogen was the limiting nutrient in August 1978 and high phosphatase activities were not required.

In March 1978, the Harvey to Peel phosphatase (on a chlorophyll basis) ratio was 1.6. Part of the reason for higher phosphatase activity in the Harvey (33 ug P released/L/hr compared to 9 in the Peel) was likely due to higher phytoplankton concentrations (Harvey, 6 ug chlorophyll a/L; Peel, 3 ug/L) (Table 3.1.3). In this case, organic nitrogen per ug chlorophyll concentrations were high and therefore were not likely to be limiting. Organic phosphorus levels are also high; an analysis of the weekly data shows that phosphatase activity had been high preceding this survey and therefore, phosphate uptake rates would also have been high. The concentration of orthophosphate in the Peel was higher than in the Harvey (1 and 0.5 ug ortho-P released/L respectively) and therefore phosphatase production may have been product inhibited in Peel surface waters.

In March 1979, the specific activity of phosphatase on a chlorophyll basis was three times greater in the Harvey than in the Peel. At least some of this difference in phosphatase activity can be explained in terms of phytoplankton biomass. The Harvey to Peel chlorophyll a ratio is 1.5; the phosphatase activity (per litre) ratio is 3.1. Again, the organic nitrogen concentrations are very high, particularly in the Harvey Estuary, and not likely growth limiting. Nitrate plus nitrate and ammonia nitrogen concentrations (which have been shown to stimulate phosphatase, Taft et al. 1977) were very high in the Harvey. In the Peel Inlet, the orthophosphate level was high, and might have inhibited phosphatase production. These factors likely contributed to the greater phosphatase activity in the Harvey Estuary.

Though the Peel Inlet and Harvey Estuary have been treated as units, within each there are areas of high or low phosphatase activity. In the Peel, in the March surveys, the eastern third had the greatest activities (Figs. 3.1.2, 3.1.4). In August, the highest concentrations occurred in

the south-east corner and on the western side, around the Harvey entrance (Fig. 3.1.3).

The area in the Harvey having the highest phosphatase activities was the northern third, especially the western side in 1978 (Figs. 3.1.2, 3.1.4). The 1979 March survey indicated high activities in the southern end as well (Fig. 3.1.4). In August 1978, apart from an increased phosphatase activity around its entrance, as already discussed, the levels are uniformly low.

Bottom waters were also assayed for neutral phosphatase activity in March 1978 and August 1979; the data are shown in Tables 3.3.1 and 3.1.2. The mean bottom phosphatase activity was generally slightly higher than that of the surface waters. The exception to this was the Peel surface water in the August survey. This great surface activity was likely due to high phytoplankton levels as indicated by chlorophyll a concentrations. The effect of depth will be discussed later. In March 1978, sediment phosphatase activities were determined (Gabrielson, 1980). These are listed in Table 3.2.1 and summarized in Table 3.2.2. The mean activity is slightly greater in the Harvey. There is a very wide range in both the Peel and in the Harvey (Table 3.2.2); high activities correspond to areas of high organic matter while sediments with low activities had low organic matter concentrations (see Gabrielson, 1980).

## 3.2 REGULAR MONITORING PROGRAM

Stations 1 to 7 (Fig. 3.1.1) were sampled on a weekly basis. The phosphatase activities at seven sites are shown in Figure 3.2.1. Though these activities were variable over time, they were generally higher at Stations 1 and 5, and consistently low at Station 2. Neutral and alkaline phosphatase activities in surface waters are listed in Tables 3.2.1.1 and 3.2.1.2. These data, along with those of the three large surveys are plotted in Fig. 3.2.2. It should be noted that the Harvey data, except for the large surveys, is derived from only one site, Station 1.

Several points should be noted. Firstly, the neutral phosphatase activities were high in February and March, 1978. This was especially the case for the Harvey surface waters. These high activities corresponded to low levels of phosphorus in the system. Activities expressed per unit chlorophyll are shown in Tables 3.2.1.1-2. For both neutral and alkaline phosphatase, the phosphatase to chlorophyll concentration ratios were high in February and March. The decline in phosphatase activities was concomitant with an

increase in phosphorus in the estuary waters (see Humphries, Young and Beer, 1980). Also, neutral phosphatase activities were much greater than alkaline (pH 8.6) phosphatase activities in the Harvey. Peel alkaline phosphatase activities, however, were not only greater than neutral activities there but also higher than Harvey alkaline phosphatase activities (See Fig. 3.2.2).

Nutrient and phosphatase data over time for each of the stations are summarized in Table 3.2.2. Correlation coefficients for nutrients with phosphatase are also listed. Neutral phosphatase correlates most highly with total nitrogen. It may be, as previously discussed, that in the Peel-Harvey Estuarine system, the level of neutral phosphatase activity strongly depends on both the biomass and the available nitrogen. Both factors are combined in total nitrogen. Generally, Stations 1 and 5 have the highest activities; Station 2 has the lowest. However, on a per unit chlorophyll a basis, Stations 3 and 5 have the highest relative activities. The overall greater biomass at Station 1 can likely account for its higher average phosphatase concentration.

## 3.3 DIURNAL STUDIES

Three sets of diurnal measurements were done: February 7-8, 1978; February 16-19, 1978; May 8-9, 1978.

### 3.3.1 February 7-8, 1978.

For the first diurnal study, surface, bottom and interstitial (ie. within the Cladophora bed) waters from Station 4 were sampled every two hours by automatic samplers. Neutral phosphatase activities in these waters are plotted in Fig. 3.3.1. Orthophosphate, nitrate plus nitrite and ammonia nitrogen were also determined (Gordon, 1980). The orthophosphate data are also plotted in Fig. 3.3.1.

At each of the three depths there were times of high activities. These peaks did not, however, occur at the same time for all depths. The surface water showed the most distinct diurnal pattern. Phosphatase increased at about 0245 hours and gradually dropped to a minimum at 1445. This increase in activity occurred after the orthophosphate concentration had dropped. The surface phosphatase would be due to phytoplankton.

It is likely that cellular phosphorus was utilized in dark respiration and, after any soluble inorganic orthophosphate

had been taken up, phosphatase production increased to supplement the cell phosphorus supply. A single, sharp peak in activity occurred at 2045 hours in the bottom water samples; the phosphate concentration showed a corresponding increase. Similarly, for interstitial waters, there were two peaks in phosphatase activity at 1845 and 0645 hours. Orthophosphate levels increased after each of the phosphatase activity peaks indicating a release of orthophosphate.

The difference in timing of the phosphatase activities was probably due to the type of organisms producing the phosphatases and their metabolic response to physical and nutrient diurnal changes. Since it is not known which organisms were responsible, further speculations will not be made.

3.3.2 February 16-19, 1978.

The second summer diurnal was carried out over three days. Samples were taken every two hours by automatic samplers. The results are plotted in Figure 3.3.2. Activities were quite high throughout the survey; generally, between 40 and 80 ug orthophosphate released/L/hr. For days 1 and 3, peaks in activity occurred between 1400 and 1700 hours. On day 2 there was an increase at 2100 and 0300 hours. In general however, activities increased in the early afternoon and were otherwise quite stable. The high activities may have been due to high rates of photosynthesis and metabolism in general.

3.3.3 May 8-9, 1978.

An autumn diurnal study was conducted on May 8-9, 1978. Surface and bottom samples from two stations (4 and 5) were taken every three hours. Light, temperature, pH and salinities and orthophosphate concentrations were measured. The data for Stations 4 and 5 are plotted in Figs. 3.3.3.1 and 3.3.3.2, respectively. There are several points to note. At Station 4 particularly, the bottom waters have higher phosphatase activities than surface waters. Next, the phosphatase levels in general are very low: between 5 and 10, and 5 and 20 ug orthophosphate released/L/hr at Stations 5 and 4, respectively. There is a good correlation between phosphatase activity and orthophosphate concentrations, especially at Station 4. For both surface and bottom waters, the increase in phosphatase activity began at about 0230 hours and gradually decreased to 1130 hours. This is very similar to the surface waters in the February 8-9 diurnal study. However, in that survey, high phosphatase activities in surface waters corresponded to low levels of orthophosphate; the May diurnal shown an increase in orthophosphate activity. This is more similar to the bottom waters in the February survey.

The pattern of activities in Station 5 waters was very different. Surface and bottom activities were about the same (Station 5 is shallow) and, further, were similar to Station 4 surface waters. A very slight increase in activity occurred at about 0230 hours. Orthophosphate concentrations appeared variable over the entire 24 hour sampling period. The rates of change in phosphatase and phosphate concentrations are plotted in Fig. 3.3.3.3. These were closely correlated for both Stations 4 and 5.

In general phosphatase activity does show some diurnal variation but it is related to other factors, the most important of which is likely to be the particular organism(s) producing the phosphate and their response to

## 3.4 DEPTH STUDIES

To assess where in the water column phosphatase activity was likely to be most significant, phosphatase concentrations were measured at Stations 3, 4, and 5. The Results for the neutral phosphatase activities are shown in Fig 3.4.1. In this survey, activities were highest in the bottom waters for Stations 3 and 5. The activities at Station 4 were variiable. Two surveys of the alkaline phosphatase activities (not shown) also gave a variable response to depth. In these cases, activity was greater in the bottom samples at Station 4 but not always at Stations 5 and 3.

From the May 1978 diurnal study, activities in bottom water at Station 4 were higher than surface waters at the peak activities. At Station 5 they were similar. The February 8-9 diurnal study indicated that the relative phosphatase actiivity depended on the time of sampling. It was greatest during the night in surface waters, but during the evening in bottom water.

The lack of relatedness between top and bottom activities is best shown by the August 1978 and March 1979 surveys (Tables 3.1.1 and 3.1.2). Though the mean activities in the bottom samples are generally higher than surface activities, examination of data from individual sites reveals that this relationship is by no means consistent. Again the likely cause for this is the relative concentration and type of biomass.

## 3.5 OTHER STUDIES

Analytical factors affecting the determination of phosphatase actiivities were also examined. These included pH, sample filtering (available versus soluble phosphatase), incubation time and temperature, sample storage time and temperature, sample preservation, and magnesium requirement in the assay. These data will not be discussed in the present report, but will be published elsewhere.

## 4. CALCULATION OF POTENTIAL PHOSPHORUS RELEASE

In order to assess the significance of phosphatase activity in the estuarine system, it is necessary to examine the potential input in terms of released phosphorus. Since the extracellular enzyme may be presumed to be produced only when required for growth, as is suggested in the diurnal surveys, this phosphoruss will result in an increase in biomass as well.

A calculation of potential phosphorus release per year, using the average phosphatase activity determined in the March 1978 survey, is shown in Figure 4.1. Gross phosphorus release, over a year, would be 1.9 x 107 kg. In terms of biomass production on an area basis, that would be sufficient for1.6 x $10^2$ kg biomass/$m^2$/year.

Results from the August 1978 and March 1979 surveys and the weekly monitoring program indicate that the phosphatase activity is not always as high as it was during February and March 1978. The potential phosphorus release and equivalent biomass production for the two remaining surveys and the averaged weekly monitoring are shown in Table 4.1. The potential release of organic phosphorus for biomass production varies from 0.3x $10^7$ to 1.9 x $10^7$ kg/year.

## 5. CONCLUSIONS

The most important points to note seem to be the following. From the large surveys, the Peel Inlet and Harvey Estuary act as two distinct systems. In the March 1978 and 1979 surveys, activities were higher in the Harvey than in the Peel; the case was reversed in August 1978. Within each system, there are areas of high and low activities. The overall phosphatase activity was highest in the March 1978 survey and lowest in March 1979. Activities are probably related to a combination of biomass, available nitrogen, and low levels of orthophosphate.

The weekly monitoriing showed the variability in the system. Activities in the water at a particular station, on a given day depend on the population, nutrient concentraton and availability, and physical conditions (wind, tide and river-induced turbulence and currents).

There is a diurnal pattern of phosphatase activity which varies with depth, sampling site, and time. These variations may reflect the responses of different organisms to physical (light, temperature) and nutrient conditions (supply of nitrogen and availability of phosphorus). The phosphatase activity in this system does appear to be related to orthophosphate concentrations. Phosphatase synthesis may increase in response to low orthophosphate levels; the resulting release of phosphorus may then repress synthesis.

The relation of phosphatase to depth is variable; it will depend on the types and numbers of organisms and their immediate requirement for orthophosphate.

The present study has defined the capacity of the Peel-Harvey Estuarine System to recycle phosphorus from organic sources, in terms of the enzyme activty which is responsible for this essential part of the phosphorus cycle.

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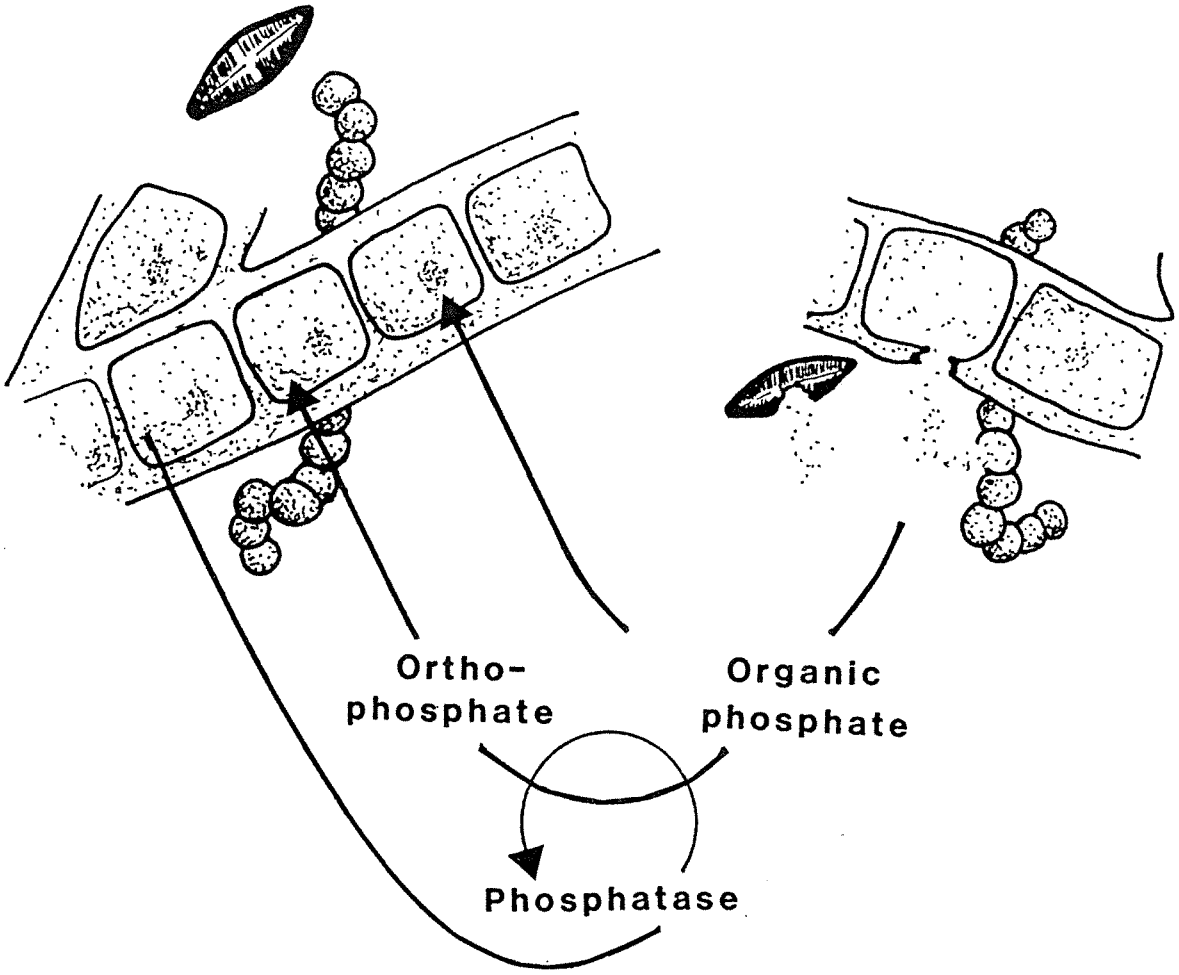


FIGURE 1 The role of extracellular phosphatase in the aqautic environment.

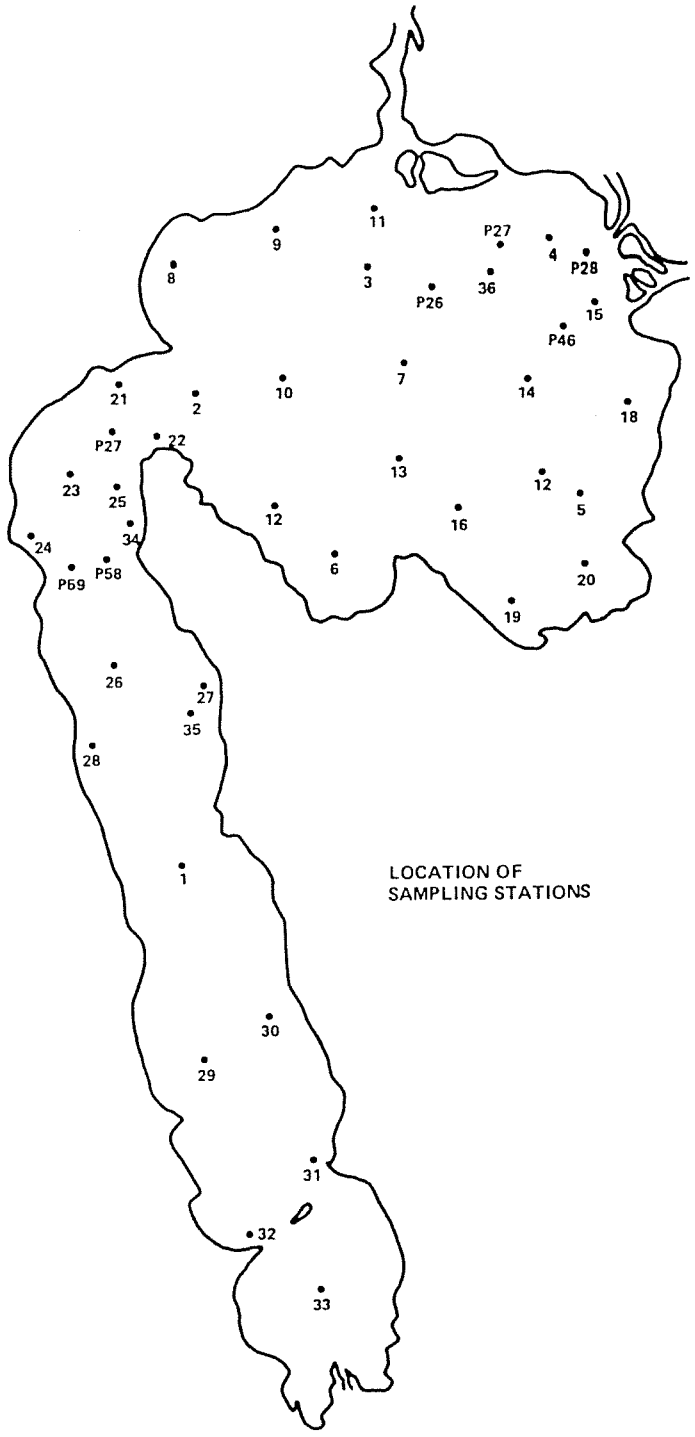


FIGURE 3.1.1 Location of sampling sites.

# PHOSPHATASE ACTIVITY

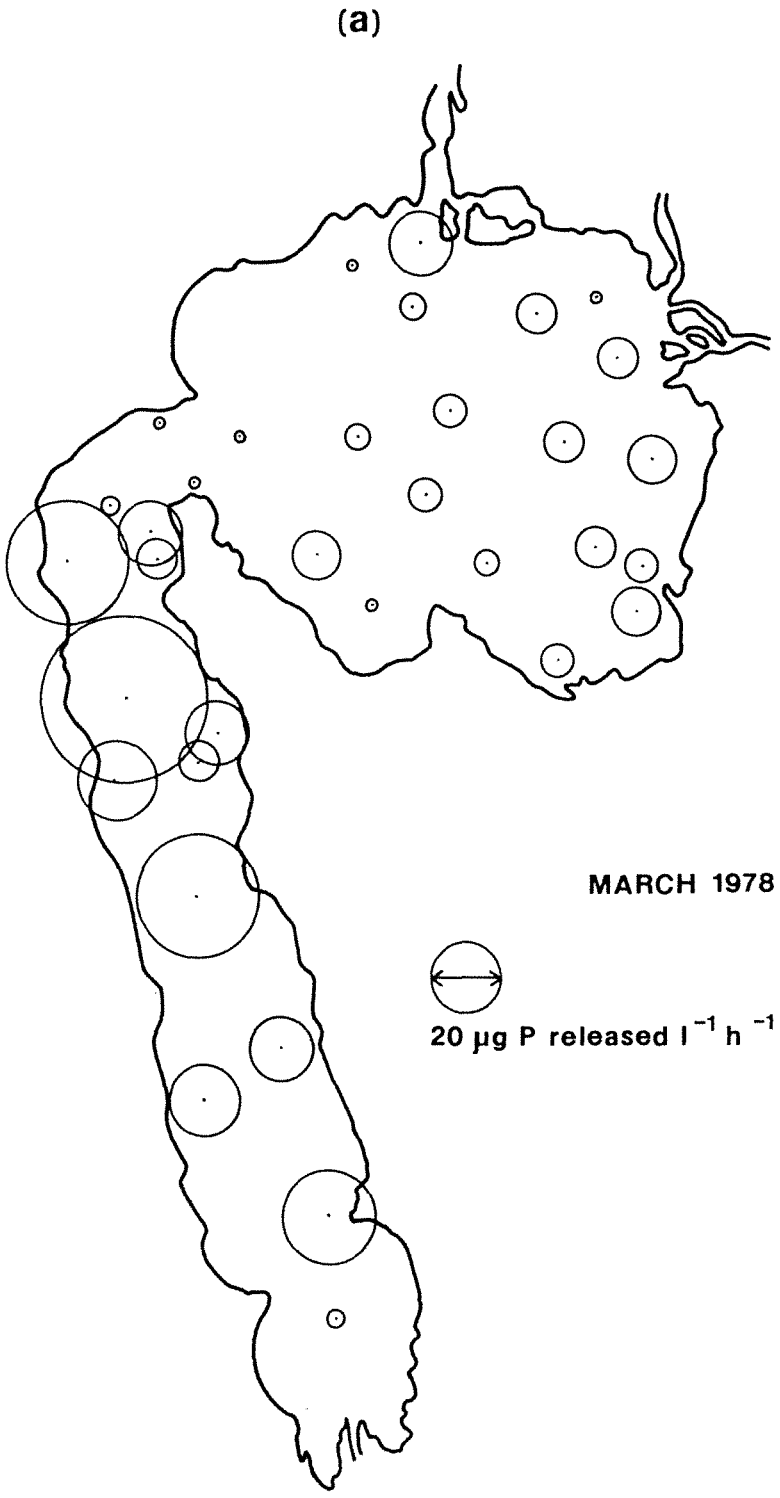


FIGURE 3.1.2 Phosphatase activities; March 1978 survey.

# PHOSPHATASE ACTIVITY

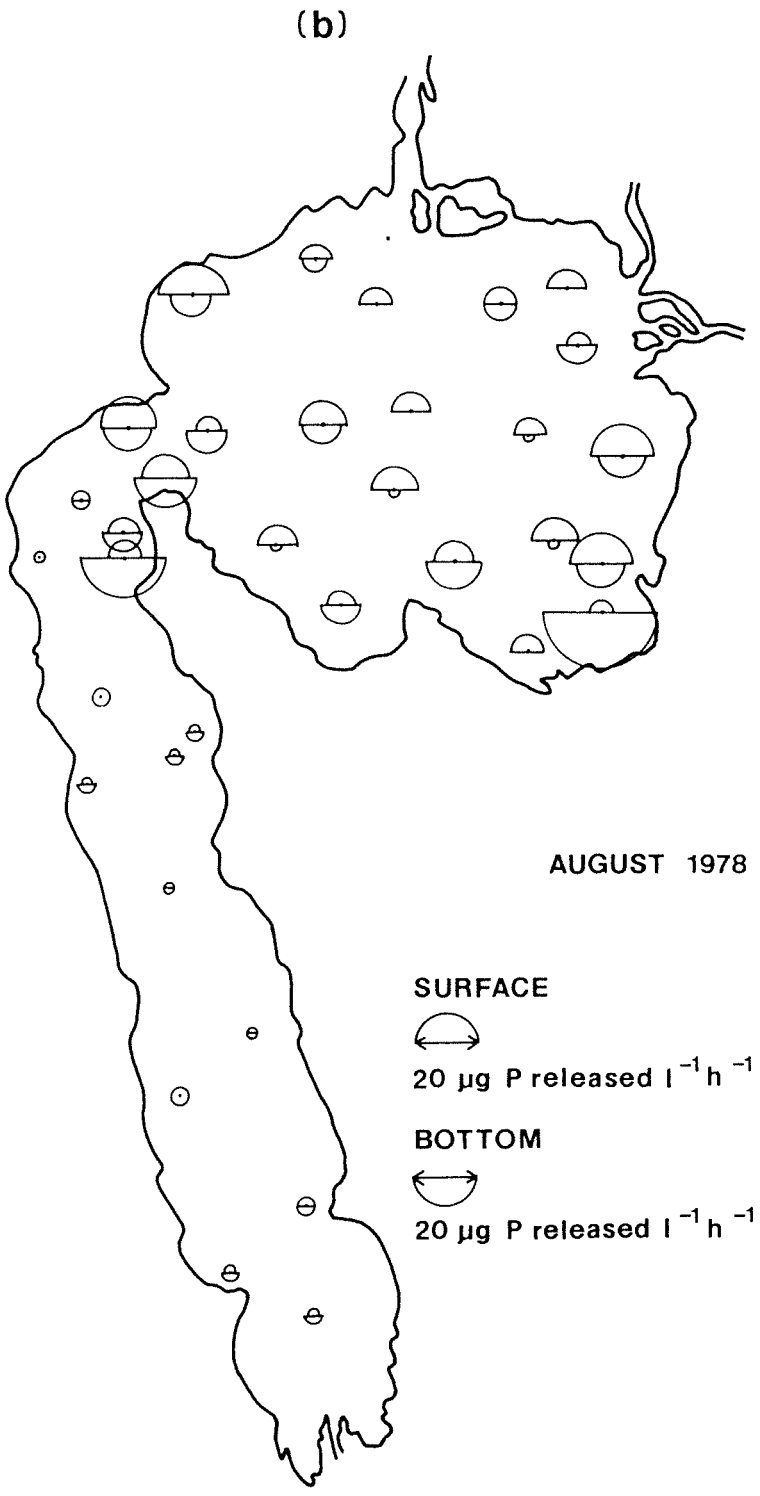


FIGURE 3.1.3 Phosphatase activities; August 1978.

# PHOSPHATASE ACTIVITY

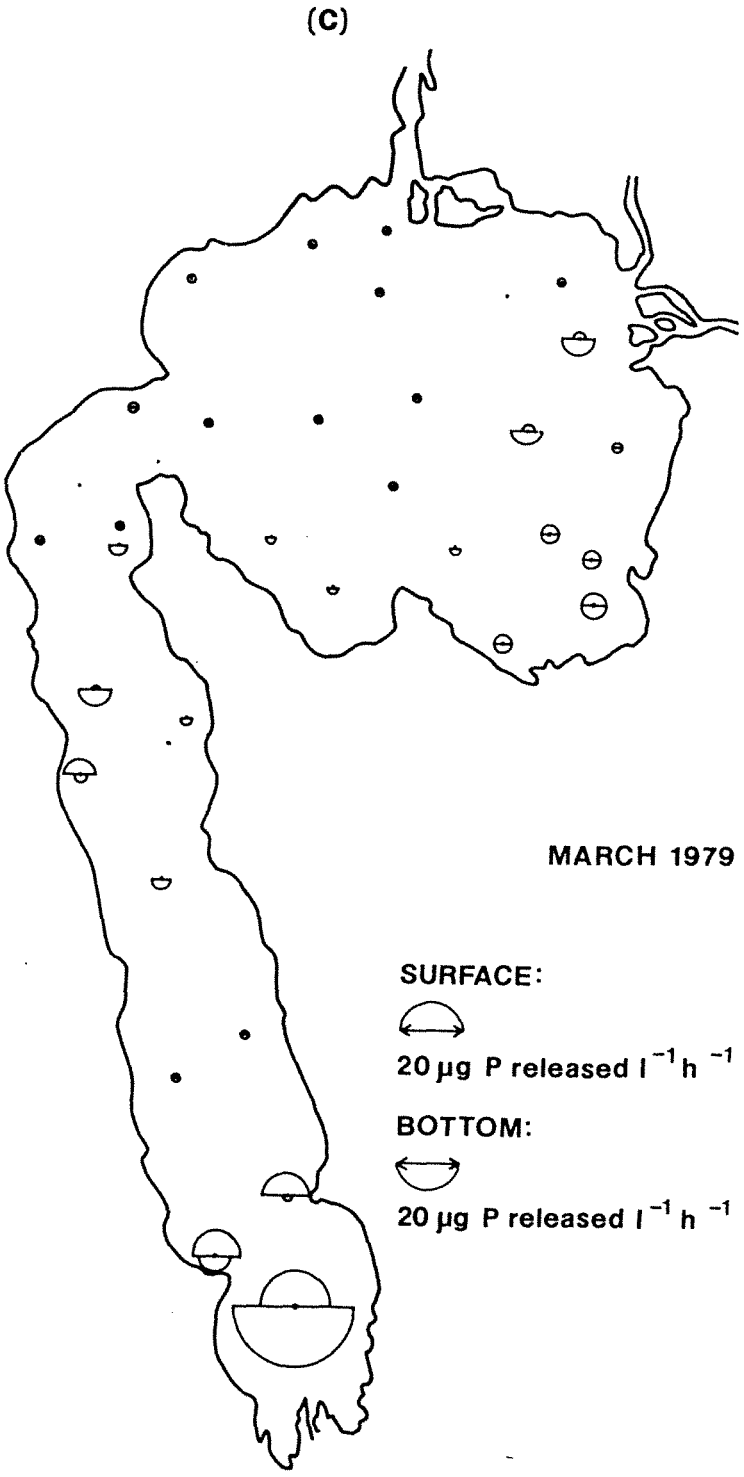


FIGURE 3.1.4 Phosphatase activities; March 1979 survey.

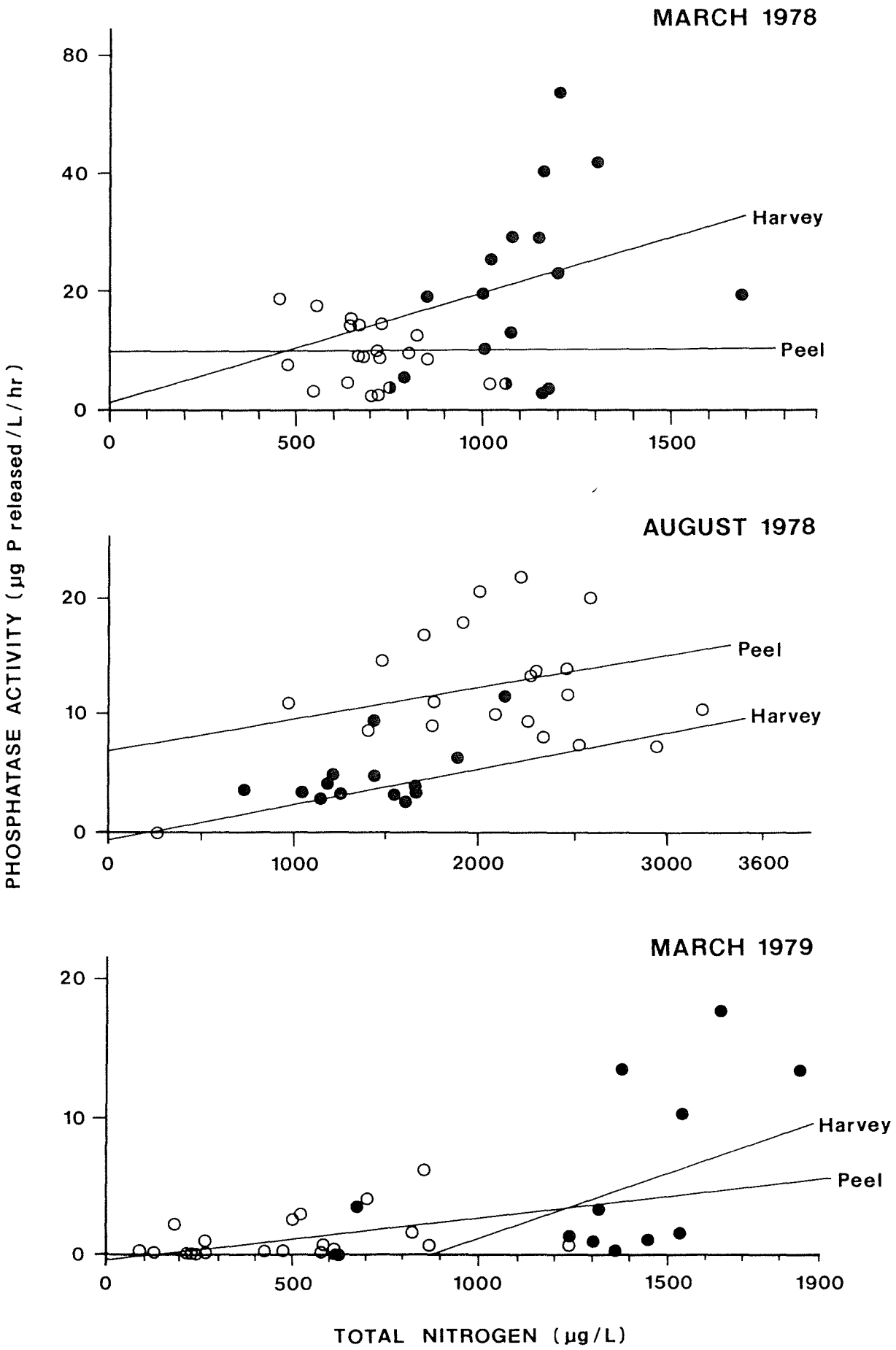


FIGURE 3.1.5 Phosphatase activities related to total nitrogen concentrations in the Peel Inlet and Harvey Estuary; March 1978, August 1978, and March 1979.

# PHOSPHATASE ACTIVITIES

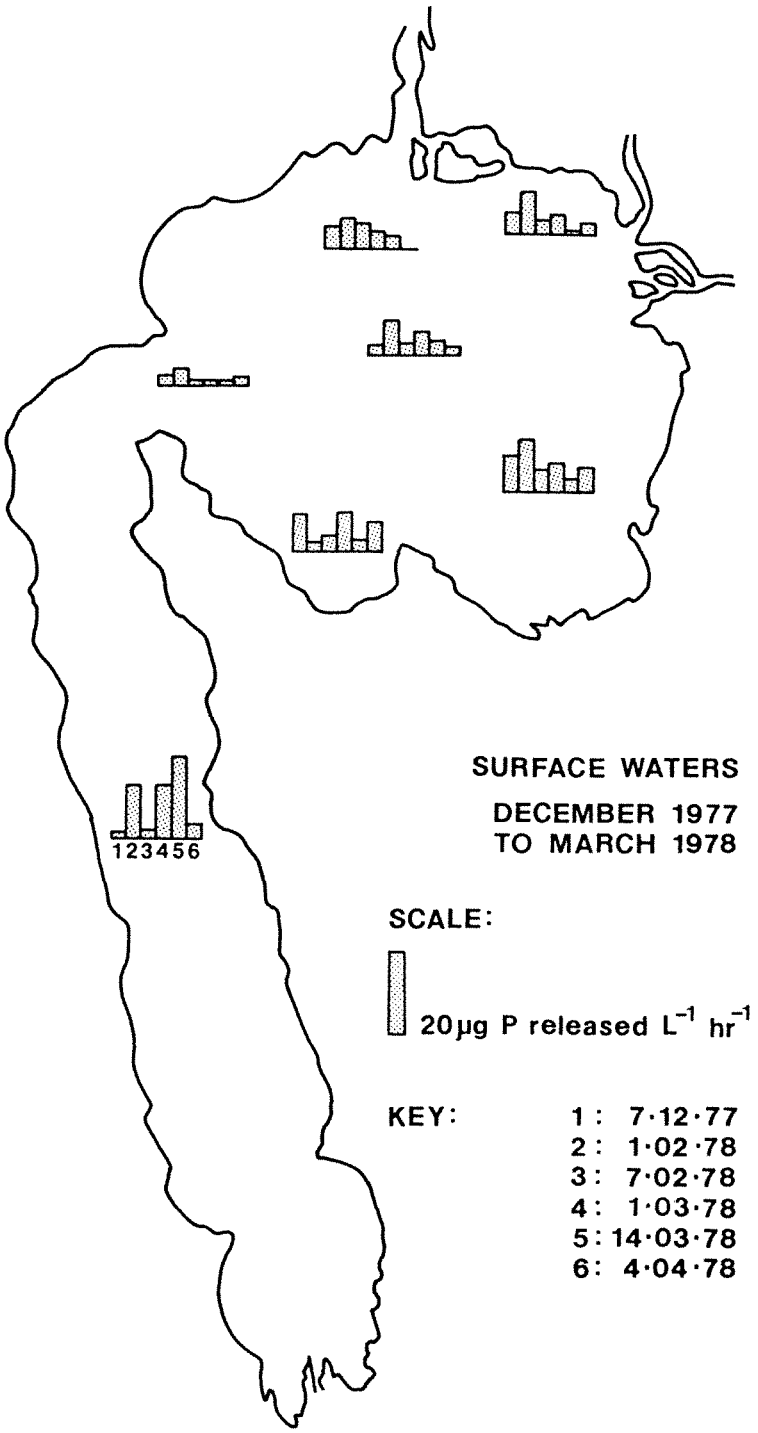


FIGURE 3.2.1 Surface water phosphatase activities; regular monitoring program, December 1977 to April 1978.

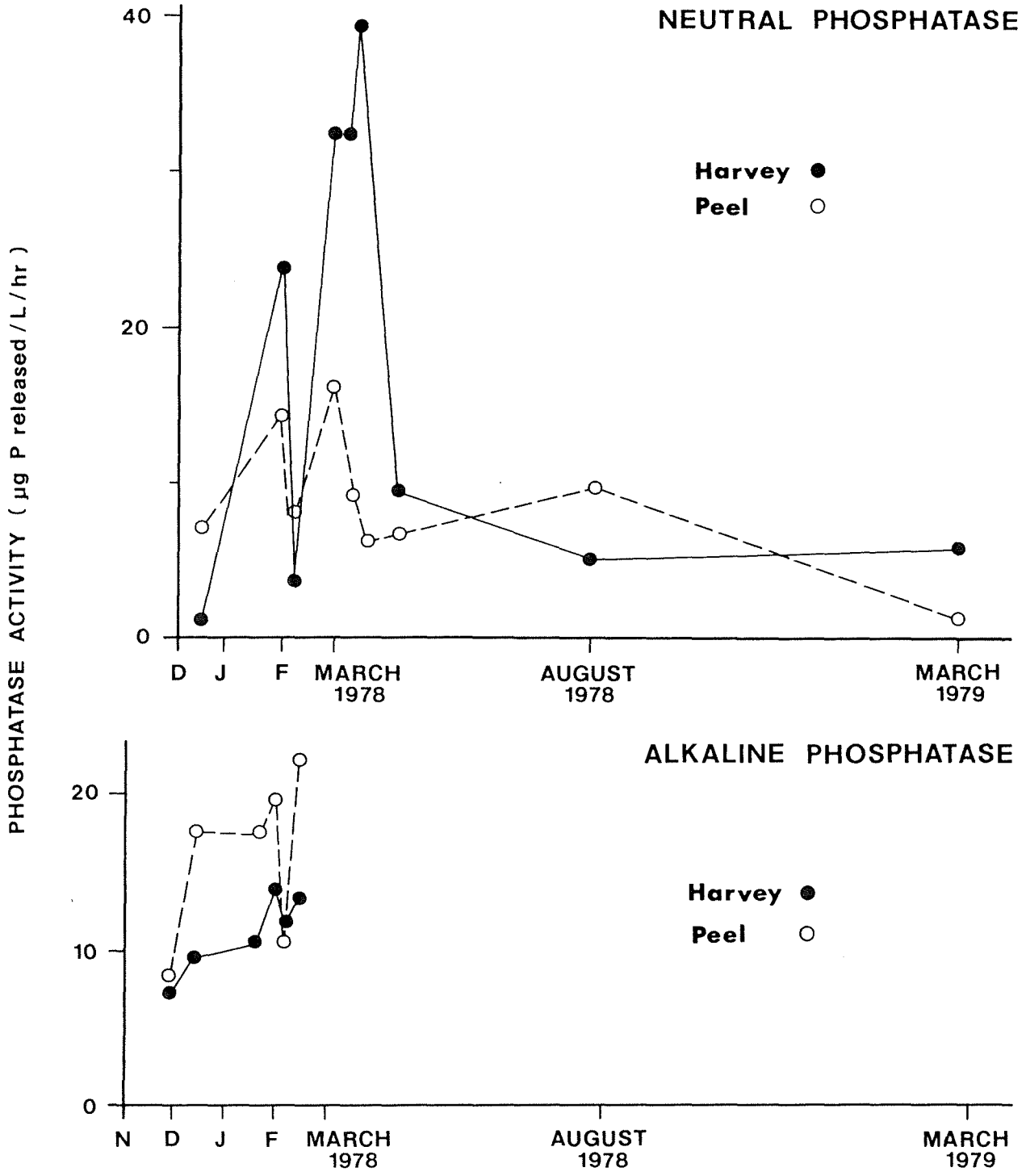


FIGURE 3.2.2 Mean surface water, neutral and alkaline phosphatase activities in the Peel Inlet and the Harvey Estuary, November 1977 to March 1979.

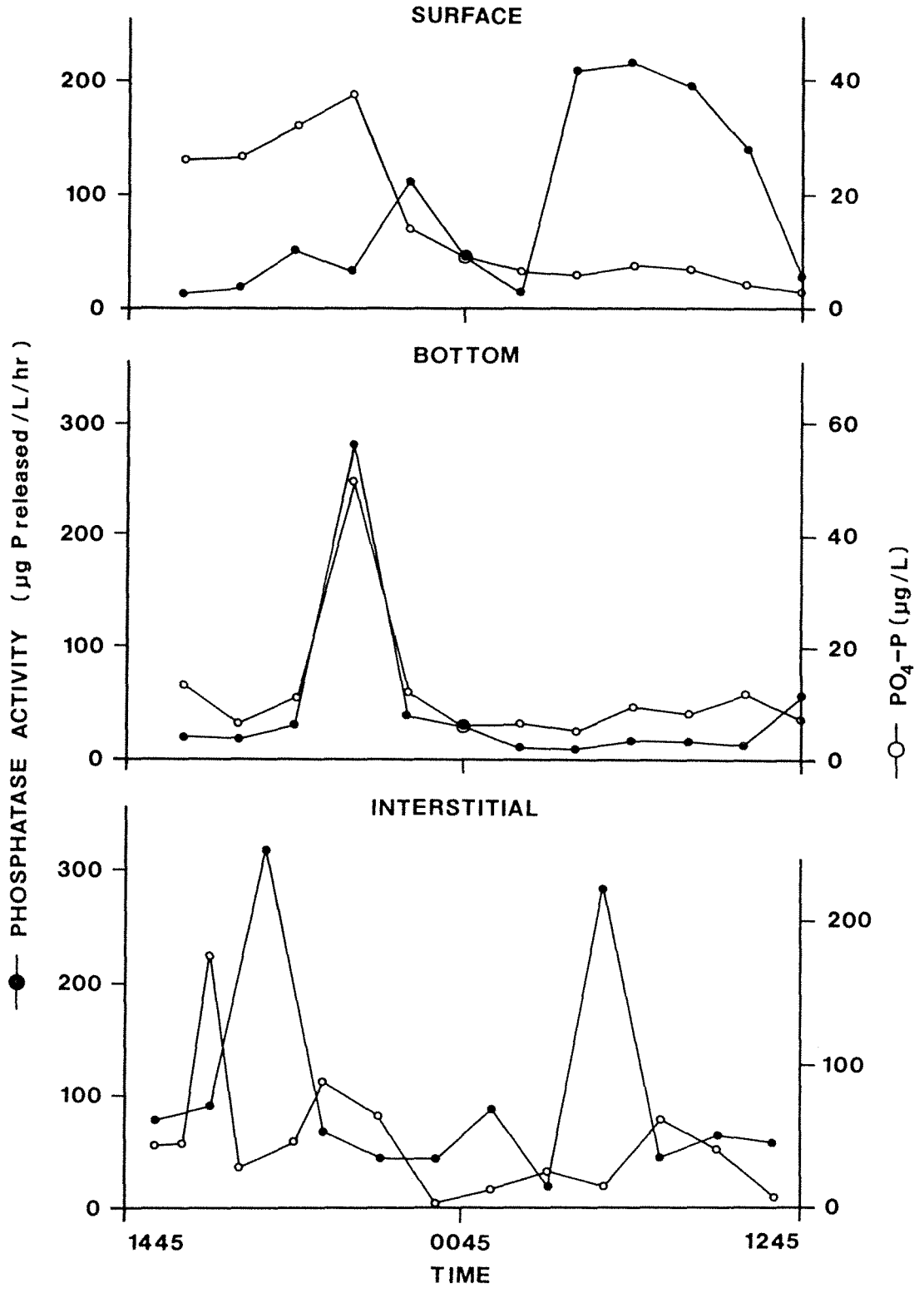


FIGURE 3.3.1 Surface, bottom and interstitial water phosphatase activities and orthophosphate concentrations; diurnal study, February 7-8, 1978.

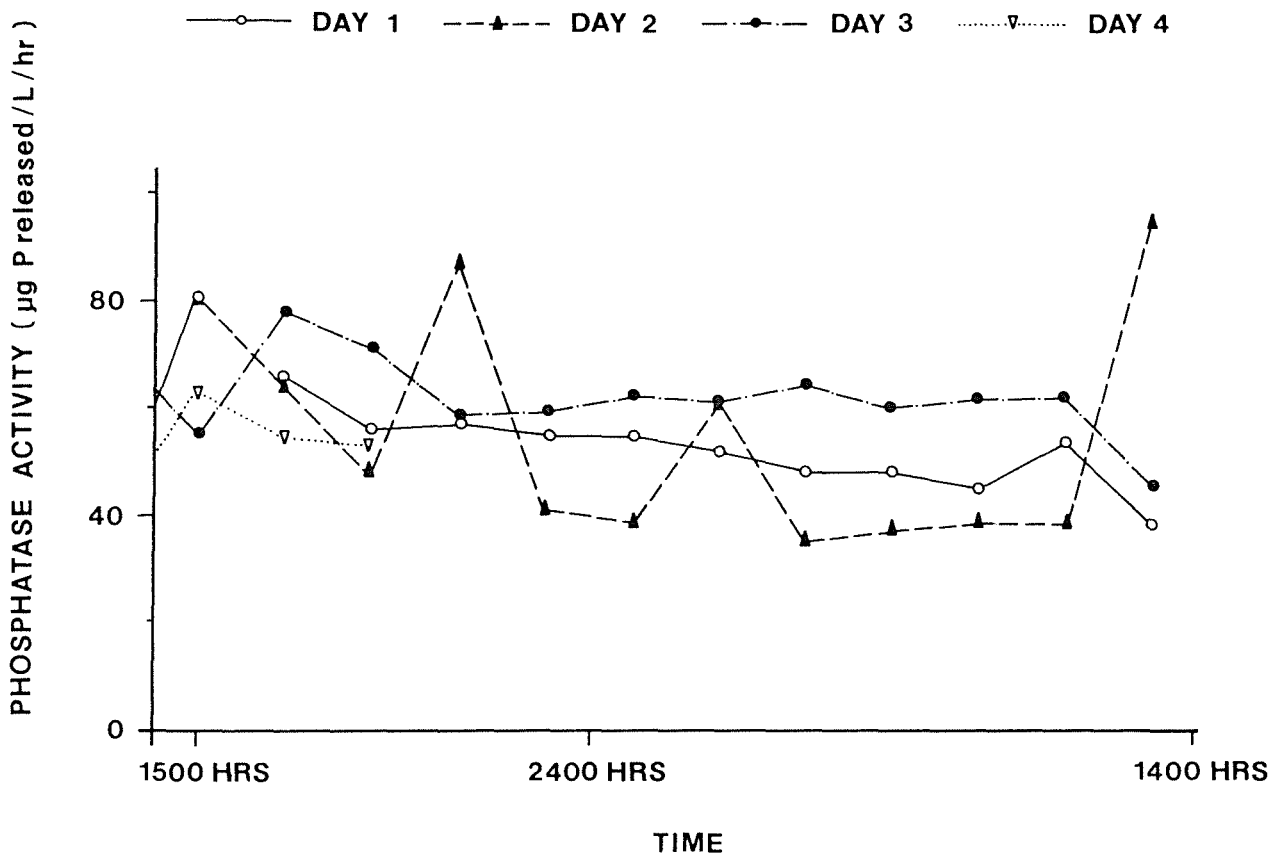


FIGURE 3.3.2 Surface water phosphatase activities; diurnal study, February 16-19, 1978.

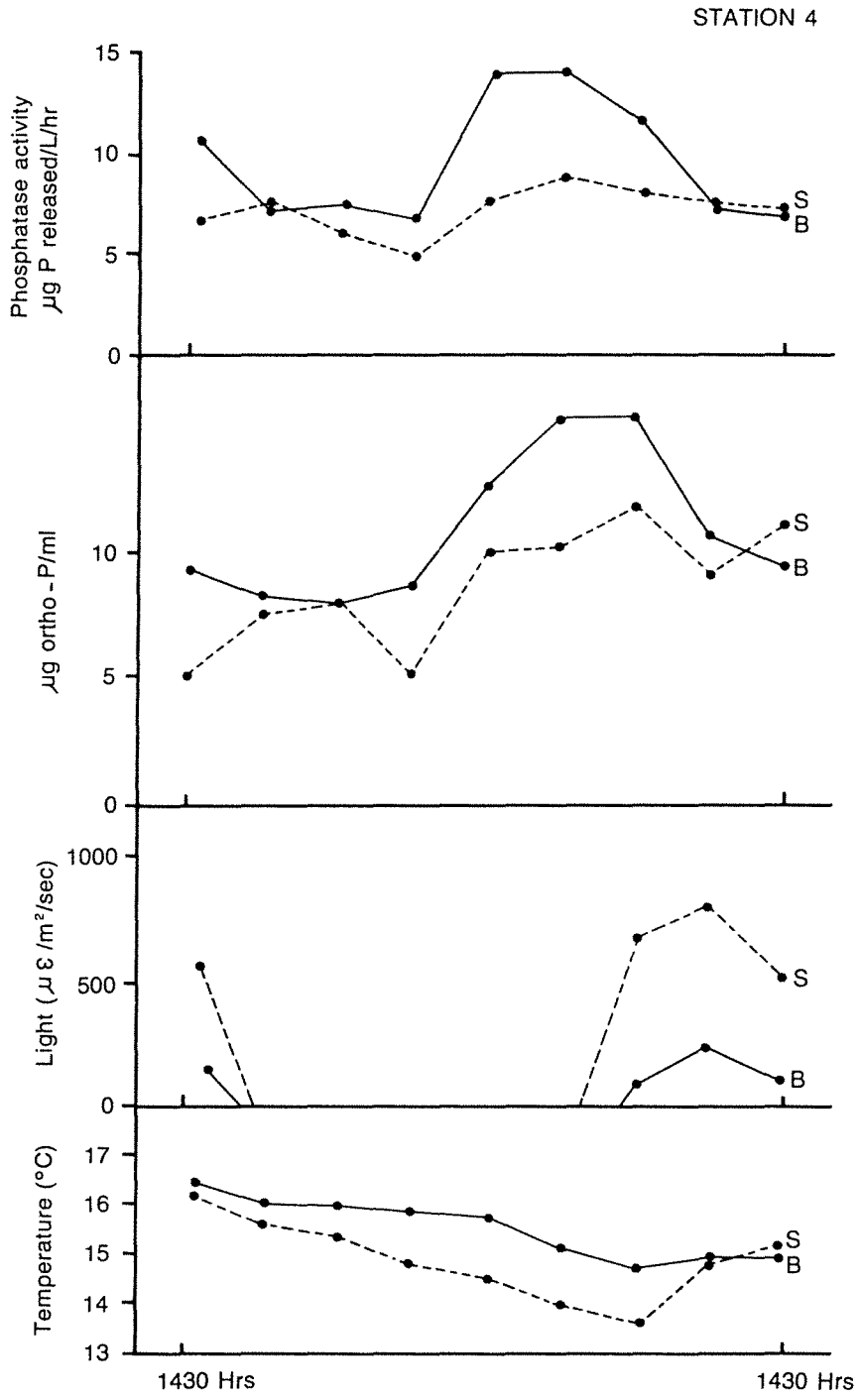


FIGURE 3.3.3.1 Phosphatase activities, orthophosphate concentrations, light and temperature at Station 4; diurnal study, May 8-9, 1978.

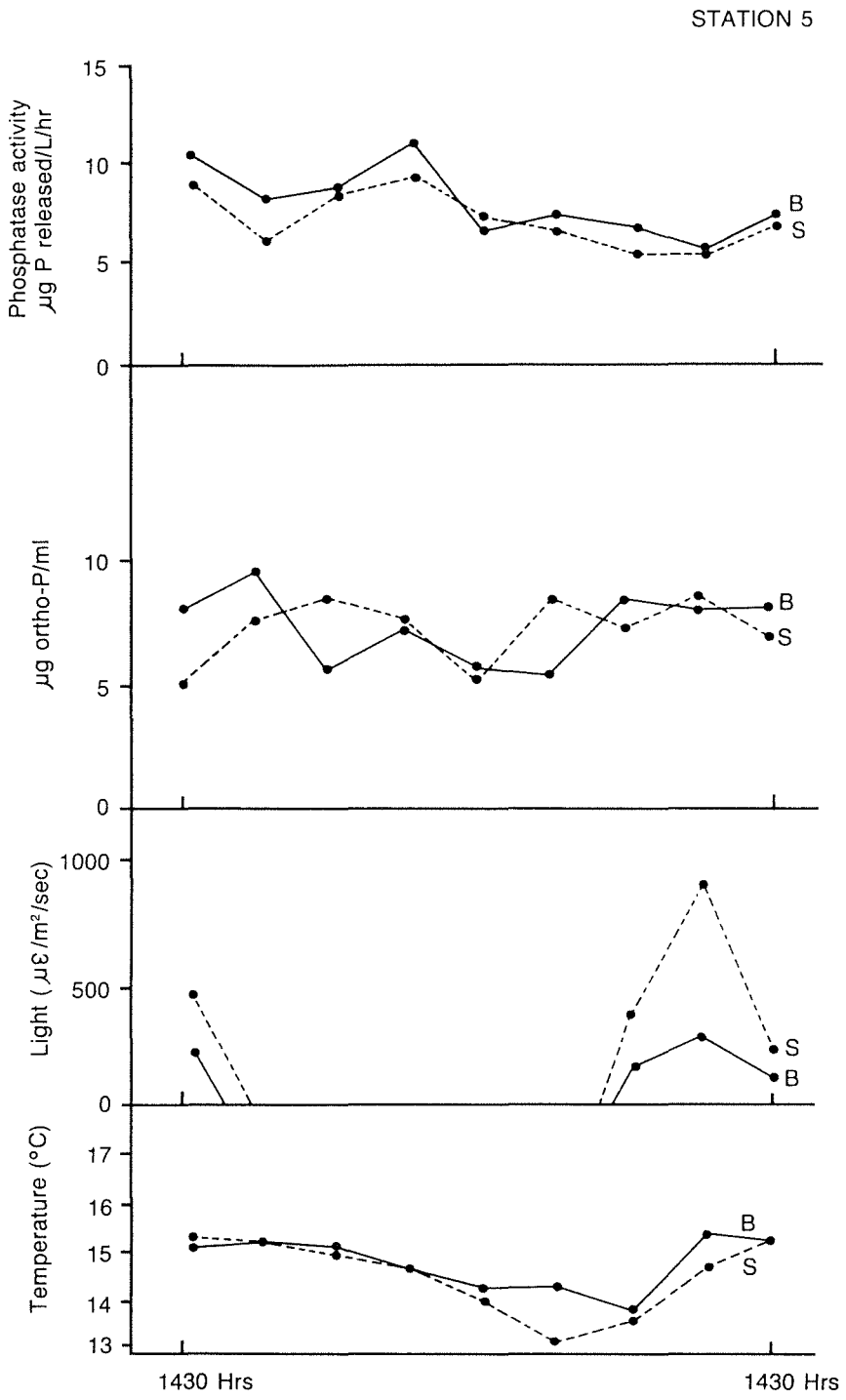


FIGURE 3.3.3.2 Phosphatase activities, orthophosphate concentrations, light and temperature at Station 5; diurnal study, May 8-9, 1978.

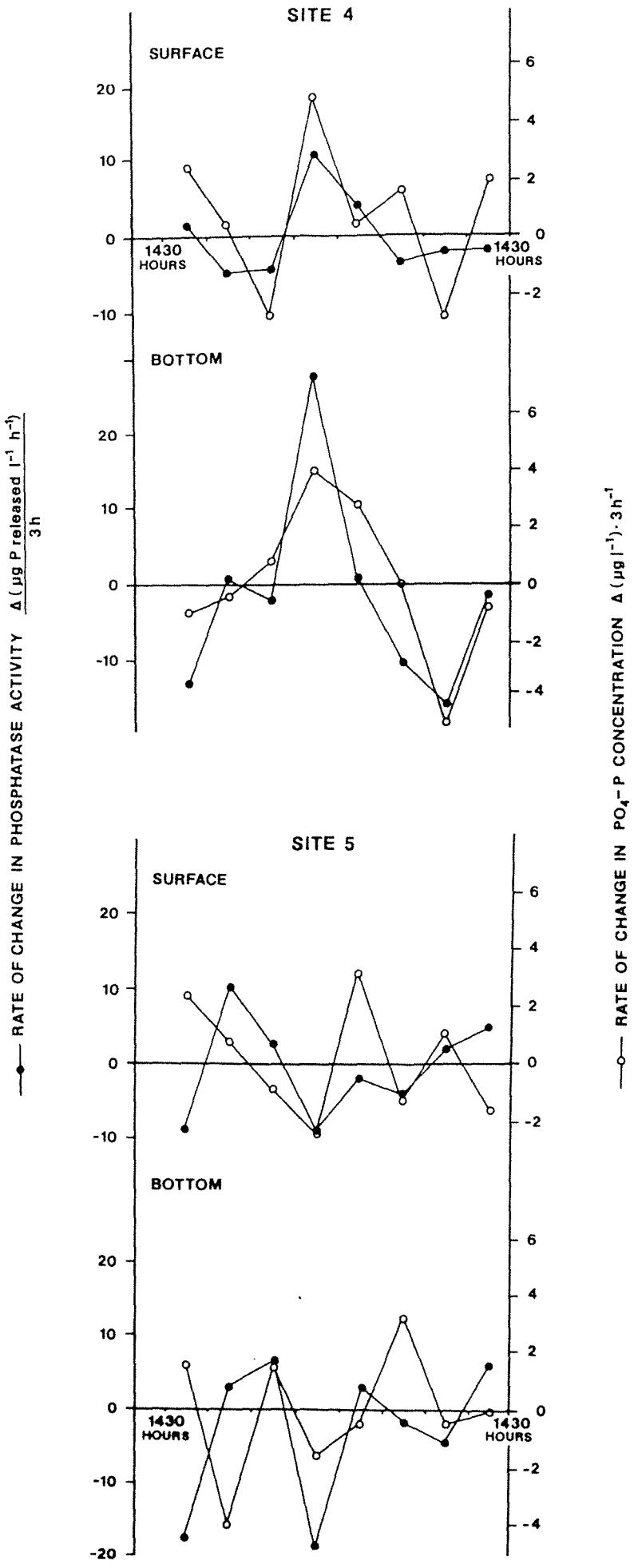


FIGURE 3.3.3.3 Phosphatase activity in the water column; 14.12.78.

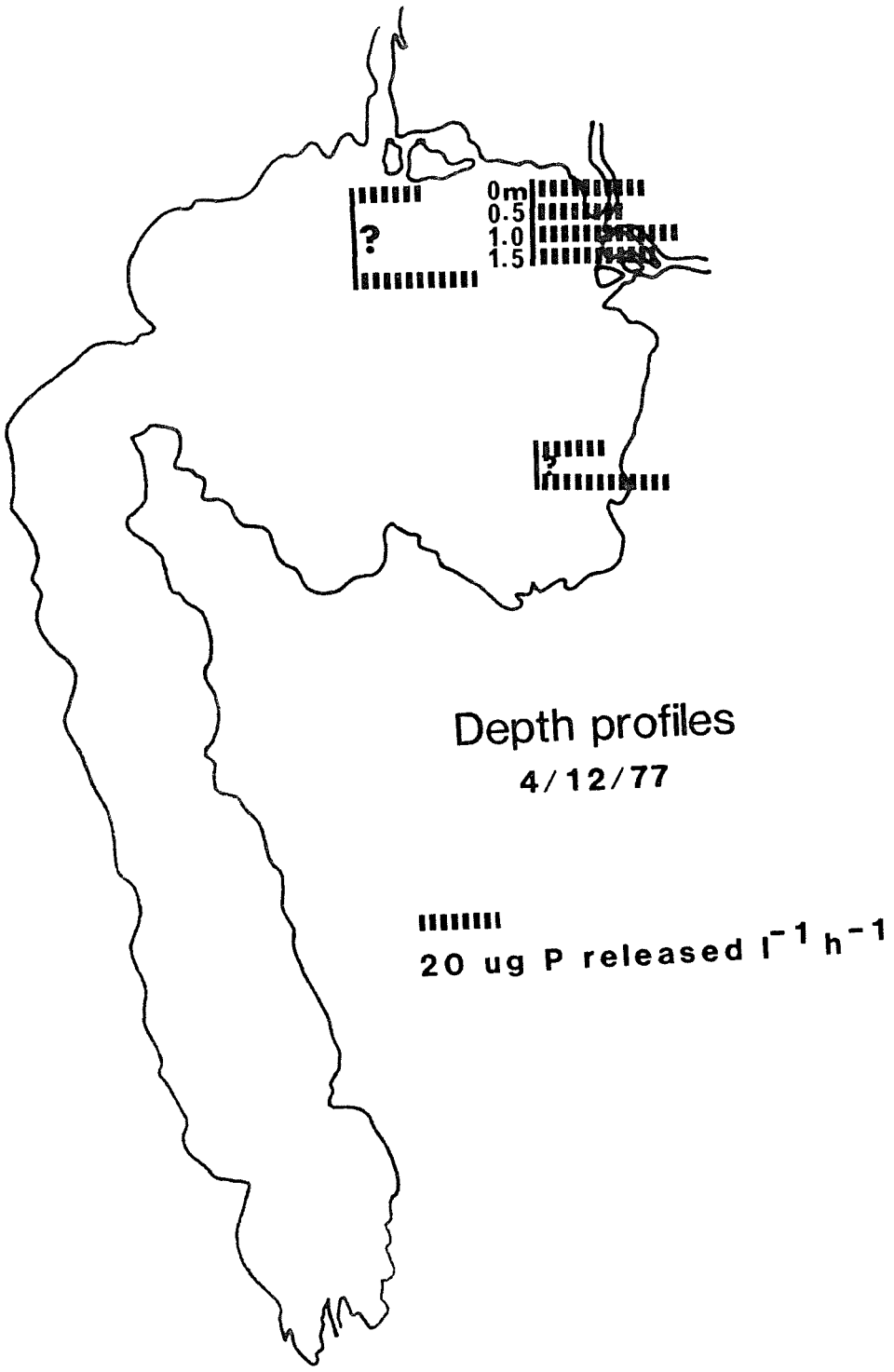


FIGURE 3.4.1 Phosphatase activity in the water column; 14.12.78.

Using the average phosphatase activity from the March, 1978 survey:

Average rate of orthophosphorus = 18.28 ug/L/hr

Peel-Harvey Estuarine system = $11.7 \times 10^{7}$ $m^3$

$= 11.7 \times 10^{10}$ L

the total phosphate released = $21.4 \times 10^{2}$

$= 1.9 \times 10^{7}$ kg/yr.

Assuming a C:P ratio of 100:1, this would support $1.9 \times 10^{9}$ kg biomass/yr (dry weight)

or about $1.9 \times 10^{10}$ kg biomass/yr (wet weight)

In terms of area, using an average of 1 metre depth, that would be $1.6 \times 10^{2}$ kg biomass/$m^2$/yr.

FIGURE 4.1 Calculation of the potential of phosphatase to release organic phosphate for the production of biomass.

Table 3.1.1

Phosphatase activity data from surface and bottom waters and sediments in the Peel Inlet and Harvey Estuary; March 1978, August 1978 and March 1979.

| Station Number | Phosphatase Activity[a] | | | | | |
|---|---|---|---|---|---|---|
| | March 1978 | August 1978 | | March 1979 | | |
| | Surface | Surface | Bottom | Surface | Bottom | Sediment |
| 1 | 39.0 | 3.3 | 3.0 | 0.35 | 5.7 | 46.8 |
| 2 | 2.2 | 7.8 | 14.5 | 0 | 0 | 12.9 |
| 3 | 9.5 | 10.2 | 0 | 0 | 0 | 17.3 |
| 4 | 3.4 | 11.0 | 1.0 | 0 | 0 | 12.2 |
| | | | | | | 6.1 |
| 5 | 8.7 | 17.9 | 16.3 | 2.8 | 2.5 | 19.4 |
| 6 | 4.6 | 9.5 | 11.0 | 0.6 | - | 15.1 |
| 7 | 8.7 | 11.2 | 0 | 0 | 0 | 20.7 |
| 8 | - | 21.8 | 14.3 | 0 | 0 | 53.8 |
| | | | | | | 10.9 |
| 9 | 2.0 | 11.0 | 8.1 | 0 | 0 | 8.4 |
| 10 | 8.5 | 15.1 | 12.1 | 0 | 0 | 10.5 |
| 11 | 18.6 | 0 | 0 | 0 | 0 | 12.1 |
| 12 | 14.7 | 13.8 | 4.8 | 0.5 | 1.6 | 41.0 |
| | | | | | | 15.2 |
| 13 | 12.5 | 14.3 | 1.4 | 0 | 0 | 21.3 |
| 14 | 13.7 | 10.2 | 1.3 | 1.3 | 0.5 | 17.3 |
| 15 | 14.1 | 7.6 | 14.0 | 3.0 | 9.4 | 24.2 |
| 16 | 7.7 | 13.1 | 18.6 | - | 1.8 | 25.1 |
| 17 | 13.5 | 16.6 | 4.5 | 3.5 | 9.4 | 10.1 |
| 18 | 17.2 | 20.0 | 16.7 | 2.0 | 1.6 | 16.6 |
| 19 | 10.1 | 8.8 | - | 4.6 | 4.9 | 133.5 |
| | | | | | | 45.9 |
| 20 | 15.1 | 7.5 | 34.7 | 7.1 | 6.9 | 29.9 |
| 21 | 3.5 | 20.5 | 16.1 | 0.8 | 0.8 | 36.5 |
| | | | | | | 15.0 |
| 22 | 4.2 | 15.9 | 20.7 | 0 | 0 | 16.2 |
| 23 | 5.5 | 3.6 | 3.0 | 0 | 0 | 22.0 |
| | | | | | | 11.7 |
| 24 | 40.8 | 3.9 | 4.2 | 0.9 | 1.4 | 86.7 |
| | | | | | | 25.6 |
| 25 | 19.4 | 9.5 | 13.4 | 4.3 | 1.3 | 9.3 |
| 26 | 52.7 | 3.3 | 4.2 | 2.0 | 9.6 | 13.4 |
| 27 | 18.4 | 3.7 | 5.2 | - | 2.9 | 12.7 |
| 28 | 28.4 | 5.0 | 6.2 | 12.0 | 3.4 | 27.0 |
| 29 | 24.8 | 5.0 | 6.8 | 1.1 | 0.7 | 40.5 |
| 30 | 22.8 | 3.7 | 2.5 | 2.0 | - | 13.9 |
| 31 | 29.0 | 6.5 | 2.7 | 15.6 | 14.0 | 29.0 |
| 32 | 2.4 | 3.7 | 5.5 | 15.6 | 10.0 | 36.6 |
| 33 | 3.8 | 4.3 | 5.3 | 21.8 | 38.2 | 34.7 |
| | | | | | | 23.2 |
| 34 | - | 11.4 | 27.4 | 0.15 | 5.1 | 18.5 |
| | | | | | | 8.0 |
| 35 | 13.5 | 2.9 | 6.6 | 2.7 | 8.0 | 13.7 |
| 36 | 12.2 | 9.6 | 9.7 | 0 | 0 | 15.5 |
| | | | | | | 6.0 |

a Surface and bottom water phosphatase activity is expressed as µgP released/L/hr.

Sediment phosphatase activity is expressed as µgP released/g dry weight/hr.

b Where two values are listed the first refers to the activity in the enriched surface layer of "black ooze" material, while the second refers to the underlying sediment.

Table 3.1.2 Summary of phosphatase activity data from surface and bottom waters and sediments in the Peel Inlet and Harvey Estuary; March 1978, August 1978 and March 1979 surveys.

| Date | March 1978 | August 1978 | | March 1979 | | |
|---|---|---|---|---|---|---|
| Sample Location | Surface | Surface | Bottom | Surface | Bottom | Sediment |
| Peel[1]: mean activity[3] | 9.1 | 9.8 | 8.7 | 1.2 | 1.8 | 25.9 |
| range of activities | 2.0-18.6 | 0-21.8 | 0-34.7 | 0-7.1 | 0-9.4 | 8.4-133.5 |
| Harvey[2]: mean activity | 32.6 | 5.0 | 6.9 | 5.7 | 6.7 | 28.9 |
| range of activities | 2.4-52.7 | 2.9-11.4 | 2.5-27.4 | 0.2-21.8 | 0.7-38.2 | 9.3-86.7 |

[1] Peel Inlet stations are 2 to 22, 36.

[2] Harvey Estuary Stations are 1, 23 to 35.

[3] Surface and bottom water phosphatase activity is expressed in µg orthophosphate-P released/l/hr.

Sediment phosphatase activity is expressed as µg orthophosphate-P released/g dry weight/hr.

The mean has been calculated using the surface, black ooze value where two activities have been listed (see Table 1.1).

TABLE 3.1.3 Mean values of nutrient concentrations and ratios, and phosphatase activities in surface waters of the Peel Inlet and Harvey Estuary in March 1978, August 1978 and March 1979.

| Survey | | Chloro-phyll$_a$ (µg/L) | Suspended turbidity | Phosphorus (µg/L) | | Nitrogen (µg/L) | | | | Phosphatase Activity µgP released /L/hr | Organic N : P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Ortho-P | Organic P | $NO_3$+$NO_2$ | $NH_4^+$ | Organic N | Total N | | |
| March 1978 | | | | | | | | | | | |
| Peel | nutrient/L | 2.7 | 16.9 | 3.1 | 49.0 | 7.6 | 17.0 | 652.9 | 676.5 | 9.1 | 13.3 |
| | nutr/µgChl$_a$ | - | 6.3 | 1.1 | 18.1 | 2.8 | 6.3 | 241.8 | 250.6 | 3.4 | - |
| Harvey | nutrient/L | 5.9 | 37.1 | 3.1 | 117.4 | 5.9 | 21.4 | 1011.2 | 1123.6 | 32.6 | 8.6 |
| | nutr/µgChl$_a$ | - | 6.3 | 0.5 | 19.9 | 1.0 | 3.6 | 171.4 | 190.4 | 5.5 | - |
| August 1978 | | | | | dis.[a] susp.[a] | | | dis. susp. | | | |
| Peel | nutrient/L | 54.5 | 32.6 | 4.0 | 68.1 141.7 | 594.3 | 62.0 | 888.3 568.5 | 2116.2 | 9.8 | 7.0 |
| | nutr/µgChl$_a$ | - | 0.6 | 0.07 | 1.2 2.6 | 10.9 | 1.1 | 16.3 10.4 | 38.8 | 0.2 | - |
| Harvey | nutrient/L | 30.0 | 30.1 | 4.1 | 14.4 200.4 | 51.6 | 95.2 | 859.3 469.5 | 1432.4 | 5.0 | 6.1 |
| | nutr/µgChl$_a$ | - | 1.0 | 0.1 | 0.5 6.7 | 1.7 | 3.2 | 28.6 15.7 | 47.7 | 0.2 | - |
| March 1979 | | | | | | | | | | | |
| Peel | nutrient/L | 2.1 | - | 4.7 | 27.7 | 4.3 | 18.0 | 431.0 | 467.8 | 1.2 | 15.6 |
| | nutr/µgChl$_a$ | - | - | 2.2 | 13.2 | 2.0 | 8.6 | 205.2 | 222.8 | 0.6 | - |
| Harvey | nutrient/L | 3.2 | - | 1.8 | 48.5 | 109.6 | 135.1 | 1011.3 | 1256.0 | 5.7 | 25.9 |
| | nutr/µgChl$_a$ | - | - | 0.6 | 15.2 | 34.3 | 42.2 | 316.0 | 392.5 | 1.8 | - |

a. dissolved or suspended.

Table 3.2.1.1 Summary of neutral (pH 7.5) phosphatase activities[a] in surface waters; Dec. 1977 to April 1978 and March 1978, August 1978 and March 1979.

| Date | 1 | 2 | 3 | 4 | 5 | 6 | 7 | Mean of Peel Waters | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | µgP/L/hr | µgP/ugChl/hr |
| 7.12.77 | 1.6 | 4.4 | 6.4 | 9.2 | 12.4 | 11.4 | 3.2 | 7.8 | 2.8 |
| 1.02.78 | 24.1 | 6.8 | 11.2 | 19.5 | 28.9 | 4.4 | 15.6 | 14.4 | 16.0 |
| 7.02.78 | 3.8 | 4.8 | 5.6 | 7.2 | 14.0 | 8.6 | 5.2 | 7.6 | 5.1 |
| 8.03.78 | 27.3 | 15.0 | 12.0 | 12.0 | 19.1 | 21.7 | 14.8 | 15.8 | 8.3 |
| 14.03.78 | 39.3 | 2.0 | 9.6 | 3.4 | 8.8 | 4.6 | 8.8 | 6.2 | 2.0 |
| 4.04.78 | 9.6 | 4.8 | 0 | 5.8 | 15.2 | 12.6 | 2.2 | 6.8 | 1.2 |
| Average | 17.6 | 6.3 | 7.5 | 9.6 | 16.8 | 10.6 | 8.3 | 9.8 | |
| March 78 | 32.6 | | | | | | | 9.1 | |
| August 78 | 5.0 | | | | | | | 9.8 | |
| March 79 | 5.7 | | | | | | | 1.2 | |

a. µg orthophosphate-P released/L/hr.

Table 3.2.1.2 Summary of alkaline (pH 8.6) phosphatase activities[a] in surface waters November 1977 to February 1978.

| Date | Sampling Station | | | | | | | Mean of Peel Waters | |
|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | ug P/L/hr | ug /ug $Chl_a$/hr |
| 24.11.77 | 11.6 | 14.2 | 2.6 | 9.0 | 30.1 | 15.2 | 10.4 | 13.6 | 10.5 |
| 7.12.77 | 24.3 | 21.9 | 9.0 | 14.4 | 42.5 | 31.7 | 11.6 | 21.9 | 8.1 |
| 15.12.77 | 9.2 | 13.8 | 21.5 | 13.2 | 21.9 | 14.8 | 20.2 | 17.6 | 11.7 |
| 17.01.78 | 11.0 | 13.8 | 25.5 | 14.8 | 20.1 | 15.6 | 15.6 | 17.6 | 8.0 |
| 25.01.78 | 14.6 | 16.9 | 17.3 | 16.1 | 27.3 | 22.1 | 16.7 | 19.4 | - |
| 1.02.78 | 11.4 | 7.8 | 6.4 | 7.4 | 14.2 | 16.1 | 13.6 | 10.9 | 18.2 |
| 7.02.78 | 13.0 | 13.0 | 11.0 | - | 43.7 | 29.9 | 15.2 | 22.6 | 17.4 |
| Average | 15.9 | 16.9 | 15.6 | 15.0 | 33.3 | 24.2 | 17.2 | 20.4 | |

a. µg orthophosphate-P released/L/hr.

Table 3.2.2. Summary of nutrient concentrations and neutral phosphatase activity data for surface waters from December, 1977 to April 1978.

| Station No. | Chl *a* (µg/L) | NITROGEN (µg/L) | | | | PHOSPHATE (µg/L) | | | PHOSPHATASE | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $NO_3^-$ $NO_2^-$ | $NH_4^+$ | Organic | Total | Ortho-P | Organic | Total | Preleased /L/hr | Preleased /µgChl/hr |
| 1 | 5.2 | 6.5 | 24.0 | 787 | 818 | 6.5 | 67.6 | 74.1 | 17.6 | 3.4 |
| 2 | 1.9 | 3.3 | 11.2 | 496 | 508 | 8.2 | 25.4 | 33.6 | 6.3 | 3.3 |
| 3 | 1.2 | 3.8 | 13.8 | 405 | 469 | 10.2 | 29.0 | 39.2 | 7.5 | 6.3 |
| 4 | 2.4 | 3.0 | 15.2 | 465 | 484 | 7.7 | 46.2 | 53.9 | 9.6 | 4.0 |
| 5 | 2.6 | 3.8 | 16.8 | 607 | 627 | 7.8 | 21.0 | 28.8 | 16.8 | 6.5 |
| 6 | 4.1 | 4.2 | 15.2 | 573 | 596 | 12.2 | 20.0 | 32.2 | 10.6 | 2.6 |
| 7 | 1.8 | 4.0 | 17.8 | 474 | 495 | 9.5 | 16.8 | 26.3 | 8.3 | 4.6 |
| Correlation with phosphatase activity | | | | | | | | | | |
| $r^2$ | $0.7^3$ | 0.67 | $0.78^2$ | $0.86^2$ | $0.87^1$ | -0.48 | 0.48 | 0.46 | | |

1. significant at .001
2. significant at .01
3. significant at .02

Table 4.1 Potential phosphorus release and equivalent biomass production from neutral phosphatase activities in surface waters in March 1978, August 1978, March 1979, and December 1977 to April 1978.

| Survey | Mean Phosphatase Activity ($\mu g$ P /L/hr) | Potential Phosphorus released in the system (kg/yr) | Equivalent Biomass Production ($kg/m^2$) x $10^2$ |
|---|---|---|---|
| March 1978 | 18.2 | $1.9 \times 10^7$ | 1.6 |
| August 1978 | 7.9 | $0.8 \times 10^7$ | 0.7 |
| March 1979 | 3.0 | $0.3 \times 10^7$ | 0.3 |
| Dec 77 - Apr 78 | 10.9 | $1.1 \times 10^7$ | 1.0 |