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WATER QUALITY of the PEEL-HARVEY ESTUARINE SYSTEM

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Report to the Waterways Commission for the period

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I N D E X

Data listing: Available on request from the Waterways Commission.

1. Introduction

This report is concerned with the data obtained during the period 10.3.81 to 31.8.82 from a monitoring programme carried out in the Peel-Harvey estuarine system. The main purposes of this report are to place the information formally on record so that it is more widely accessible, to interpret the data in relation to previous monitoring projects in the estuary so that long term trends might be established, and to comment on those particular features of the data which appear to be most important in interpreting the water quality of the system during the period under investigation.

Background information about the estuary is available in the report by Hodgkin et al. (1980), the technical reports cited in that work, and a recent review of the system (McComb 1982).

2. Background to the monitoring programme

As part of the Peel-Harvey Estuarine System Study, which was carried out under the auspices of the Estuarine and Marine Advisory Committee of the Environmental Protection Authority, preliminary monitoring was undertaken during 1976. This work was funded by the Department of Conservation and Environment (DCE), and the Botany Department of the University of Western Australia (UWA). With the involvement of the Centre for Resource and Environmental Studies of the Australian National University, and the appointment of Dr P B Birch as assistant to the research co-ordinator (Dr E P Hodgkin), a weekly water sampling programme was commenced in August 1977, and continued for two years until September 1979. An analytical facility was established in the Botany Department, UWA, to process these samples, under the direction of Mr R P Atkins. This facility has continued to process all samples until the present time. Field sampling was initiated by P B Birch, and the work was later shared and then taken over by R J Lukatelich, whose interpretation of the data in relation to estuarine ecology forms the basis of a PhD programme. The analytical facility, which also processed the samples from the Cockburn Sound Study, has been incorporated into the Centre for Water Research at the University of Western Australia, and is now under the direction of F Salleo. R J Lukatelich has remained in charge of the monitoring programme and the interpretation of the monitoring data.

3. Sampling sites

The original sampling sites used in the first year of the study are shown in Fig. 1a. The 6 sites in Peel Inlet were originally chosen to represent sectors of the inlet, and so provide information about transfer of nutrients from one sector to another. At that time the growth of larger algae in Peel Inlet was of primary importance, and Harvey Estuary was treated as an input to Peel Inlet and sampled at only one site. Monitoring continued for those 7 sites during the period 31.8.77 to 25.9.79.

Because of the massive Nodularia bloom in the Harvey in 1978, and the realization that this was likely to be a very serious environmental problem, the number of sites was increased in March 1979 at the suggestion of R J Lukatelich, to those shown in Fig. 1b. Thus the same number of sites were represented in each estuary to allow statistical comparisons.

The sampling programme at these sites was continued until September 1979 when DCE funding of this aspect of the programme was discontinued. Analysis by R J Lukatelich of the available data showed that a reduced sampling programme could be carried out at the sites shown in Fig. 1c, and that these should be used for any on-going programme of monitoring. Sampling at these sites was continued by R J Lukatelich until February 1981, and was partly funded by DCE.

A new programme, the subject of this report, was financed by the Waterways Commission, and sampling commenced in March 1981 at the sites shown in Fig. 1c. This report is concerned with the analysis of the first phase of this programme. However, for convenience the data for the entire sampling period from 1977 is included, and where this is done, mean values for the estuaries are calculated on the basis of the same sampling sites used in the present study (see Fig 1c), extracted from the earlier data set.

The on-going sampling has been a collaborative arrangement, funded by the Waterways Commission, and organized by the Centre for Water Research who have provided technical and other facilities. Field sampling is carried out by representatives from the University, in collaboration with Mr W Hosja of the Waterways Commission, and using a boat belonging to DCE.

4. Techniques

The sampling and analysis techniques for nutrients and chlorophyll 'a' have been well documented for the purpose of the Peel-Harvey programme, and are summarised as a working paper by R P Atkins, and included as an appendix to Chiffings (1979).

The methods have not changed significantly during the entire study and will not be detailed further here.

Sampling techniques for the physical variables are detailed in Lukatelich and McComb (1981), the only significant change being that pH is now measured *in situ* using a Metrohm pH meter.

5. Results

Full data listings of the information are presented as an appendix to this report, available on request to the Waterways Commission.

It is convenient to examine the average figures for the sampled sites in relation to those of preceding years, and the following points can be made concerning the trends in the data.

5.1 Temperature

Temperatures are shown in Fig. 2, and show a seasonal change from 11-12^{o}C in winter, to 26-27^{o}C in summer. The recent year was no exception to these general trends, except for a rather large temperature change over the period from February to March.

5.2 Salinity

Salinity (Fig. 3) typically changes seasonally from about 5 to 45 ^{o}/oo. The most recent set of data differs significantly from the preceding years of the study in that the minimum in winter 1981 was the lowest encountered, and the unseasonal summer weather pattern, which brought rain to the entire southwest of the State, provided a very significant input of fresh water to the rivers feeding the system, which depressed the salinity in January. After that time evaporation from the system was not sufficient to raise the salinity to the high levels encountered in previous summers; the maximum salinity reached was almost 35 ^{o}/oo in the Harvey, and just above 35 ^{o}/oo in the Peel. Riverflow had depressed salinity to a minimum of 4.1 ^{o}/oo in the Harvey, and 6.7 ^{o}/oo in the Peel at the end of the sampling period under consideration.

5.3 Chlorophyll

Chlorophyll levels are shown in Fig. 4. The main peaks are due to massive blooms of the blue-green alga Nodularia spumigena, and where these occur they are preceded by blooms of diatoms. Typically, the blue-greens are at higher levels in the Harvey than in the Peel. The most recent period of monitoring has included the largest Nodularia bloom encountered so far. The bloom was found throughout the Harvey Estuary, and in Peel Inlet, especially in the western half. The eastern half of Peel generally had very low levels. The 1981 Nodularia bloom was preceded by particularly large diatom blooms. At the time of the depressed salinity in winter there was a minor bloom of the blue-green Microcystis, accounting for a small proportion of the chlorophyll, and very large populations of the Cladoceran Crustacean Daphnia, presumably grazing on the diatoms. The diatom species were the same as in previous winters. Following the collapse of the main Nodularia bloom there was a second peak of chlorophyll in the water accounted for by diatoms (mainly Chaetoceros and Asterionella), and also by the blue-green Oscillatoria. It seems possible that the Nodularia bloom had begun to collapse when there was a marked input of fresh water to the system in January 1982, which was followed by the second main peak.

At the end of the sampling period under consideration the diatom bloom appears considerably less than that encountered the previous year.

5.4 Light

Light is presented as attenuation coefficients in Fig. 5, the highest attenuation coefficients indicating maximum reduction of incident light as it passes through the water column. Overall, the graph tends to follow that of chlorophyll (Fig. 4) with marked peaks at the time of Nodularia blooms. Much of the variation not accounted for by chlorophyll is due to wind stirring in the system, which brings sedimented material into the water column. It seems that there would have been less light available at depth in both Harvey and Peel during the year of sampling, as compared with the years before. It might be noted that the diminution of summer light in the last two years, when compared to previous years, may well have reduced the size of the macroalgal populations which might have otherwise developed in the Peel.

5.5 pH

Intermittent records have been kept of pH (Fig. 6) because of the possible insight they may give to interpreting carbon metabolism in the estuary. The range is from 7.4-10.0, the maximum pH being encountered during the *Nodularia* bloom because of the depletion of dissolved inorganic carbon through uptake in photosynthesis by *Nodularia*. At this extreme pH ammonia may be lost from the system.

5.6 Oxygen

Oxygen levels are presented as both absolute concentration (mg l^{-1}) (Fig. 7) and as percentage saturation at the surface (Fig. 8) and bottom (Fig. 9). The data set is interrupted. Oxygen was monitored during the early part of the study, and has recently been included once again in the programme because of its possible importance in interpreting fish kills. These data were collected during the day, and one might expect depletion during darkness, especially at times of high phytoplankton biomass. At the time of sampling, levels were often supersaturated in the surface water (i.e. above 100%, which indicates equilibrium with air), with a peak 220% at the time of the *Nodularia* bloom, resulting from photosynthesis. The bottom water had rather less oxygen, but was not anaerobic, a minimum of approximately 50% being encountered on one occasion during the bloom. The lower waters of the estuary would certainly have been below the photic zone during a bloom, and one might have expected to find severe oxygen depletion. However, the levels are presumably maintained by down-mixing of oxygen-rich surface water. Oxygen levels in the surface water were reduced from April-June when there was little phytoplankton, and when surface and bottom oxygen levels were approximately the same.

5.7 Nutrients

As noted in previous reports, phosphorus is particularly important in controlling algal populations in the system. Phosphate is shown in Fig. 10, and it is instructive to compare this graph with salinity (Fig. 3). Depressions in salinity reflect river flow, and river flow also provides phosphorus to the system. Thus at times of low river flow, salinity is less depressed and phosphate concentration remains relatively low. In the winter of 1981, salinity was markedly depressed, and the concentration of phosphate was very high in both Harvey and Peel. The high phosphate concentration is reflected in the massive *Nodularia* bloom which occurred in the following spring and summer. It is also reflected in the size of the diatom blooms, which would have been responsible for trapping phosphorus in the system. Thus maximum phosphate concentrations were associated with the lowest salinity and the largest Nodularia bloom observed in the system.

Organic phosphorus is shown in Fig. 11. The levels are typically erratic because of effects of wind-stirring; nevertheless, the maximum concentrations coincided with maximum phytoplankton biomass.

Nitrate is shown in Fig 12. Nitrate is derived, in part, from the river systems and there are spikes in nitrate concentration each winter. The highest concentration encountered was in 1978, when there was a large flow from the Murray River. Generally levels tend to be higher in Peel than Harvey at the time of winter freshwater input. There was also a regeneration of nitrate in the system in summer/autumn 1979, in the Harvey, due to the collapse of the Nodularia bloom. This regeneration has been less well seen in subsequent years. The proportion appears to have fallen with the years, and this may in part be due to the fact that secondary diatom blooms now follow the Nodularia blooms. There was no such diatom bloom in the summer/autumn of 1979.

Ammonium (Fig. 13) is present at very low concentrations in river water, and so is largely produced in the system through the decomposition of organic material derived mainly from phytoplankton. As with nitrate, there was a marked regeneration after the first Nodularia bloom observed in the study. There was also a marked peak, though of short duration, following the collapse of the 1980 Nodularia bloom. There was, however, very little regeneration of ammonium after the collapse of the recent Nodularia bloom, presumably because of diatom uptake and growth. Following Nodularia blooms there were subsequent winter increases in ammonium. The relatively high level of ammonium in the Peel in winter 1979, when there was little river flow, and following a summer when there had been little Nodularia in the Peel may have resulted from decomposition of the remains of the large populations of Cladophora.

Organic nitrogen (Fig. 14) moved mainly in sympathy with Nodularia, the peaks being in part due to nitrogen fixation by this organism. The base levels of organic nitrogen in the estuary appear to have slowly increased during the period of the study.

6. General Comments

An analysis of these years suggested that two important parameters in the Harvey reflect the intensity of the *Nodularia* bloom. These are, firstly, the minimum salinity reached in the estuary; and secondly, the maximum concentration of phosphorus reached in the estuary. The relationships are given in Fig. 15 for the different years of the study.

The minimum salinity reached during the winter of a particular year is a reflection of the amount of water which arrives in the Harvey estuary by river flow, the water coming down the river bringing with it phosphorus and other nutrients. This is presumably the reason for the direct relationship between the growth of a *Nodularia* bloom in spring and early summer, and the minimum salinity to which the estuary fell in the previous winter (Fig. 15).

During the present sampling period, the minimum salinity of 4.1 $^{o}/oo$ was reached on 31.8.82 and so one would predict that the maximum *Nodularia* bloom which will be experienced this year may be about 400 $\mu g\ l^{-1}$ chlorophyll 'a'. However, the unseasonal summer rain in January, and consequent riverflow which depressed the salinity in Harvey Estuary (see Fig. 3), resulted in a much lower salinity maximum at the onset of riverflow than in previous years. This means that the phosphorus loading would be less than that predicted by the minimum salinity, and so the estimate of the maximum level of the *Nodularia* bloom on the basis of minimum salinity reached may be an overestimate this year.

The maximum phosphate-phosphorus level reached in the estuary also depends on river flow, but being somewhat transient in the estuary the absolute maximum may be missed in the sampling programme. Nevertheless the maximum level of the *Nodularia* bloom is related to the observed peak of phosphate concentration (Fig. 15). This year peak phosphate was reached on 28.7.82 when the concentration was 109 $\mu g\ l^{-1}$, suggesting that a maximum chlorophyll concentration of 200 $\mu g\ l^{-1}$ will be reached by *Nodularia*.

The monitoring programme therefore suggests, on the basis of this simple model, that the maximum level of the *Nodularia* bloom in the summer 1982 should be in the order of 200-400 $\mu g\ l^{-1}$ chlorophyll 'a'. It should be emphasized that the system is a complex one, and that a considerable time elapses between the input of phosphorus and the peak of a *Nodularia* bloom, so that there is ample time for other complexities to affect the simple relationship. As monitoring continues, however, it will be possible to add the data from this year to the graphs (Fig. 15), and to examine the possible reasons for any departure from the prediction.

7. Summary

1. Data are presented for the period 10.3.81 to 31.8.82, and mean values plotted in comparison to data from August 1977.

2. The parameters monitored are temperature, salinity, chlorophyll, light, pH, oxygen and nutrients.

3. Salinity was lower during the most recent summer, compared with previous years, because of unseasonal summer rain. Winter salinity was markedly depressed in the system, indicating high river flow.

4. As in previous years, diatom blooms followed winter nutrient input from the rivers, and these were followed in spring/summer by the largest *Nodularia* bloom so far recorded.

5. Light penetration was markedly reduced by *Nodularia* blooms and by wind stirring. Summer light penetration has been poorer in the Peel during the last two years, compared to previous data.

6. Mean pH reached 10.0 during the *Nodularia* bloom.

7. Mean oxygen levels during the day often showed supersaturation in the surface water, especially during *Nodularia* blooms. At depth oxygen was reduced, but only as far as 50% saturation.

8. Concentrations of phosphate were particularly high in the most recent winter.

9. For the entire data set there is a close relationship between the magnitude of the *Nodularia* bloom in spring/summer, and both the minimum salinity and the maximum phosphate in the previous winter. The use of this relationship in predicting the size of *Nodularia* blooms is explained, and a prediction made for late 1982.

8. References

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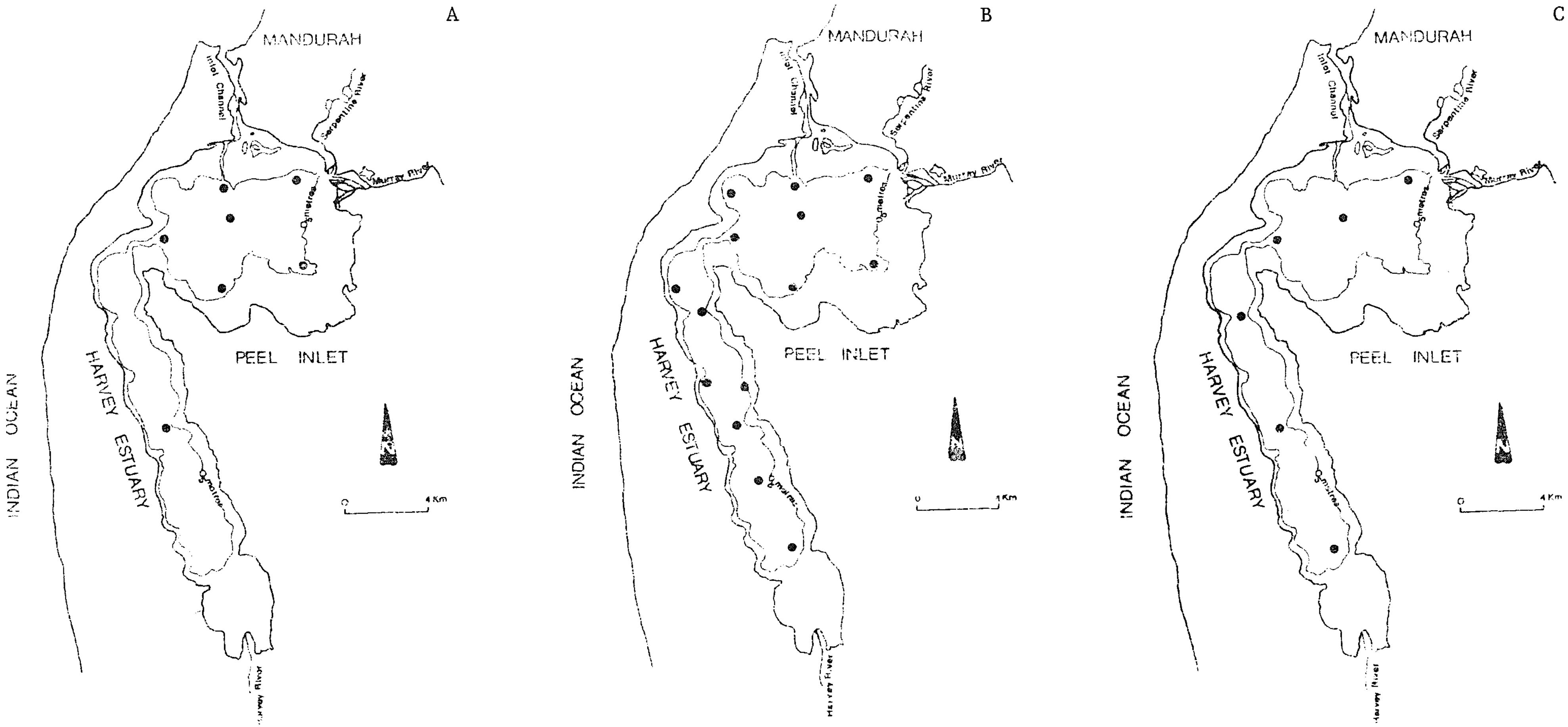

Fig. 1 Sampling sites. A, August 1977 to March 1979; B, March 1979 to September 1979; C, September 1979 to present.

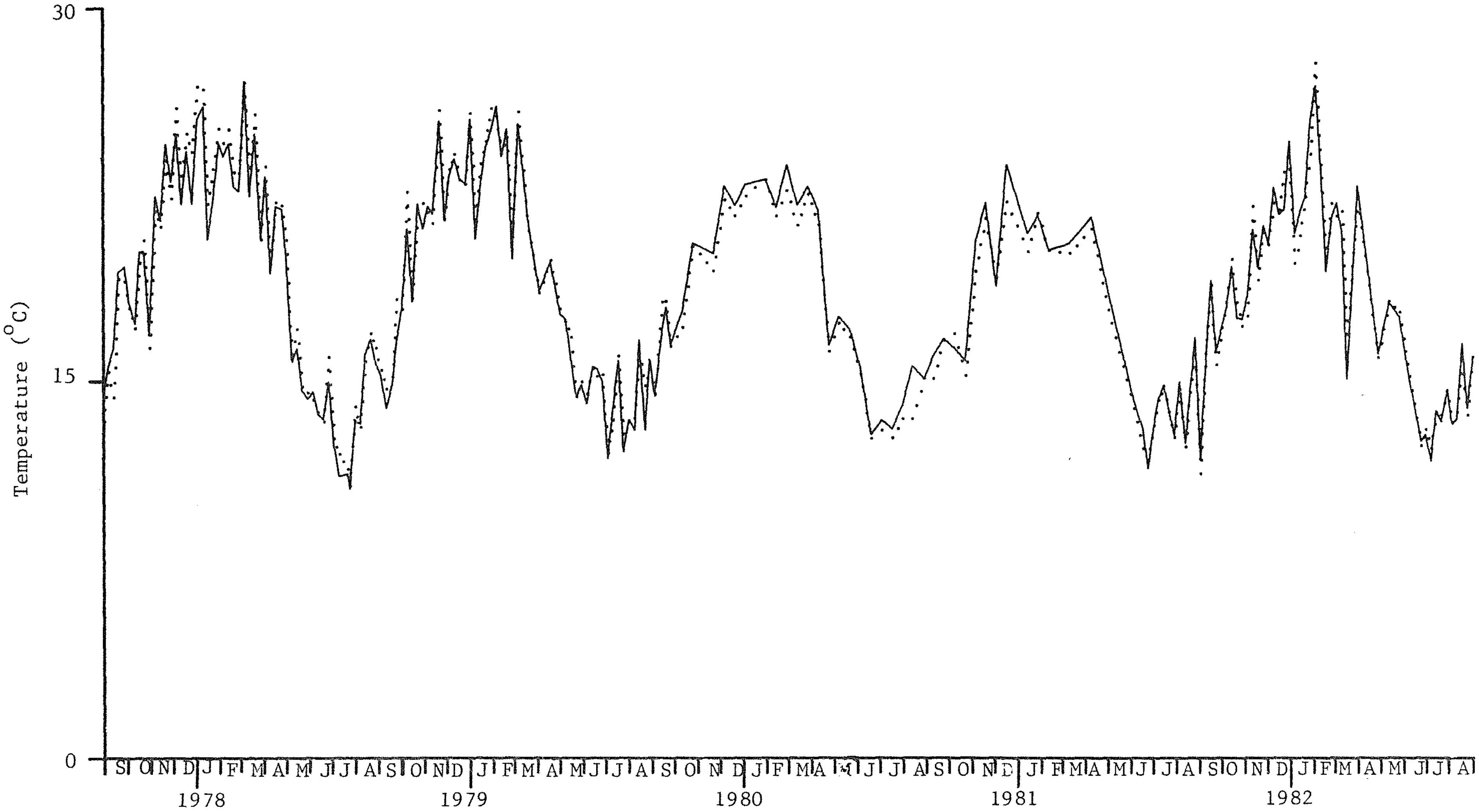

Fig. 2 Surface water temperature. Harvey Estuary = solid line, Peel Inlet = dotted line. These symbols also apply to Figs. 3 -14.

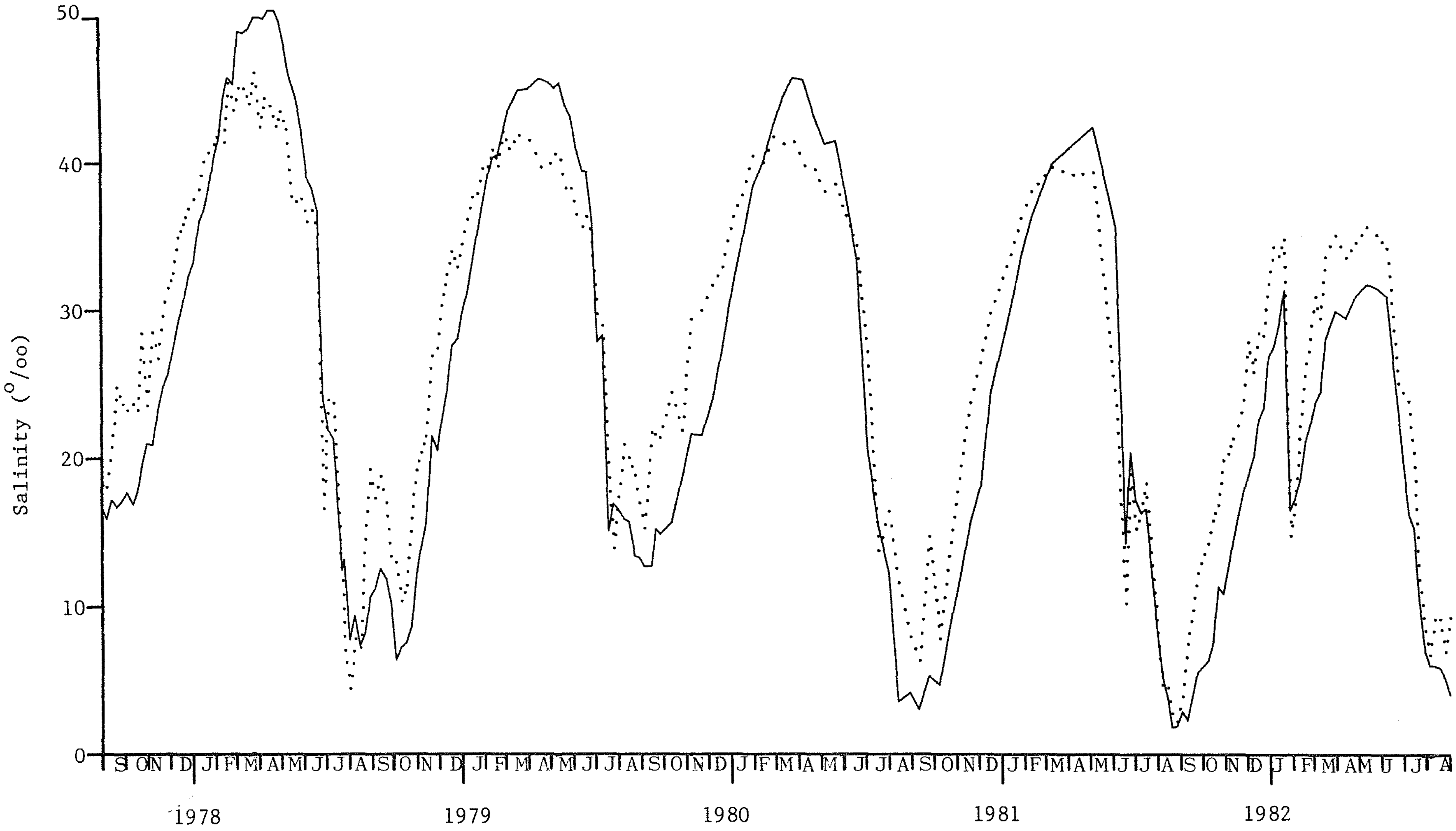

Fig. 3 Surface salinity.

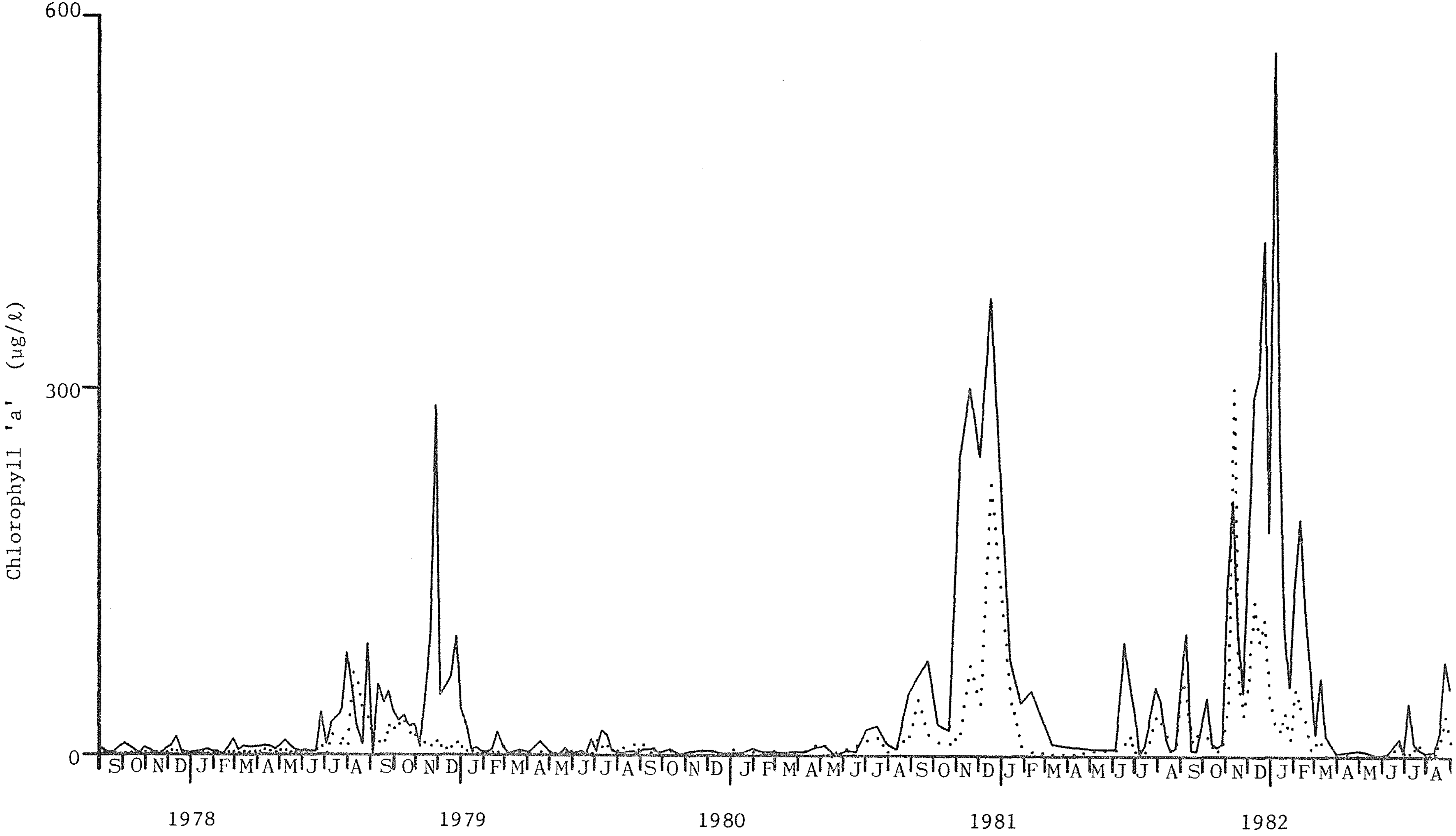

Fig. 4 Surface chlorophyll.

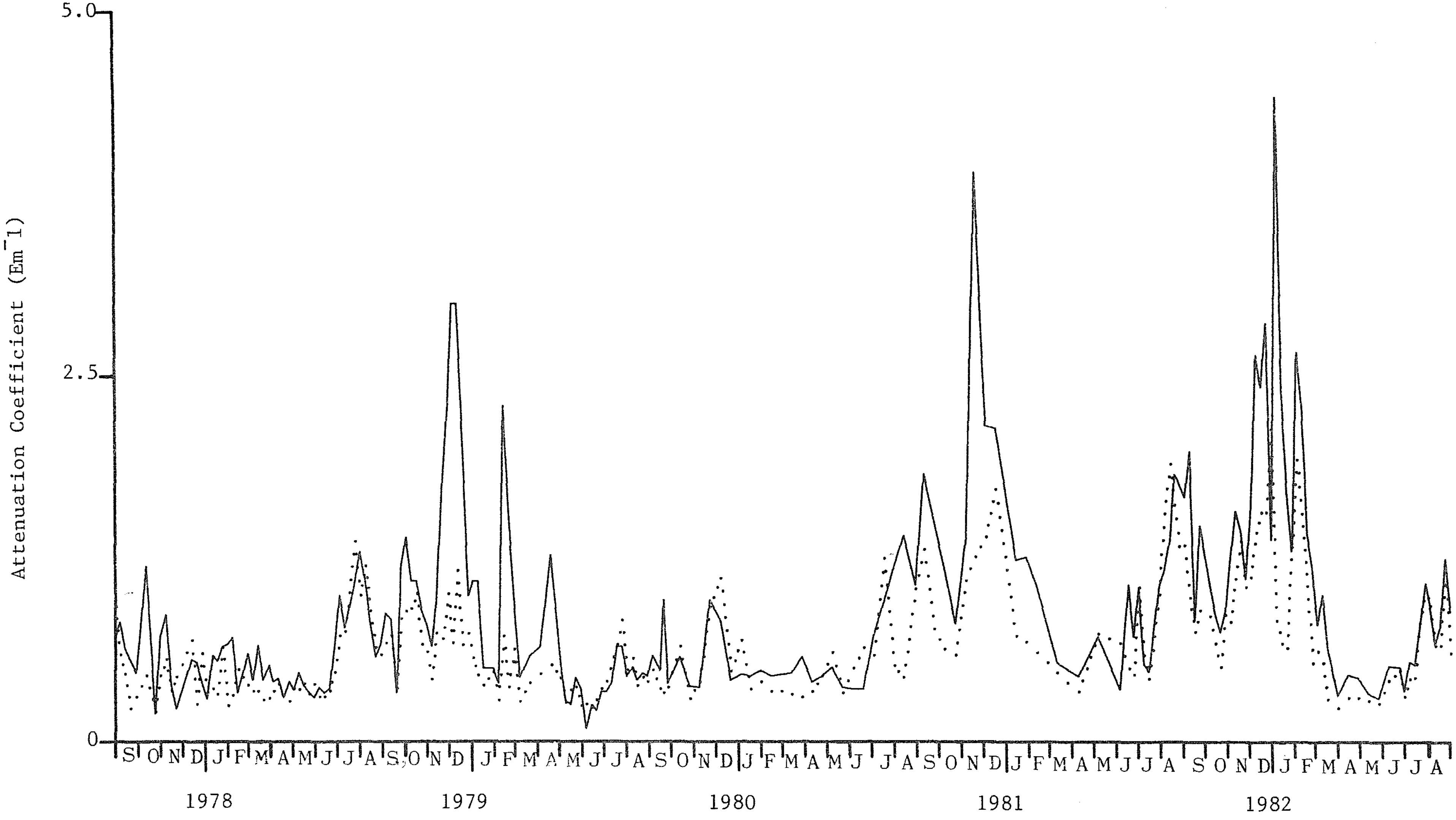

Fig. 5 Attenuation coefficient.

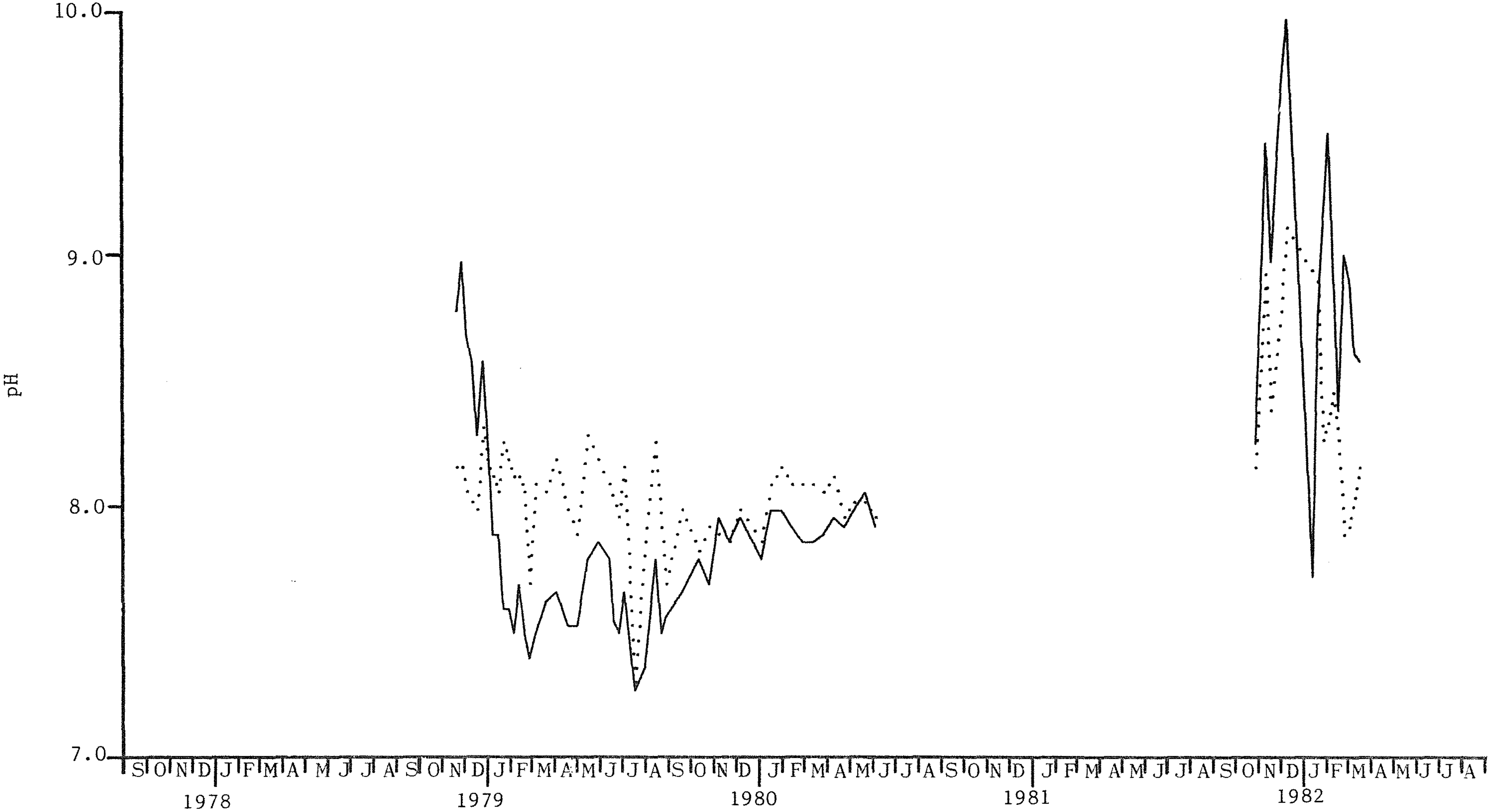

Fig. 6 Surface pH.

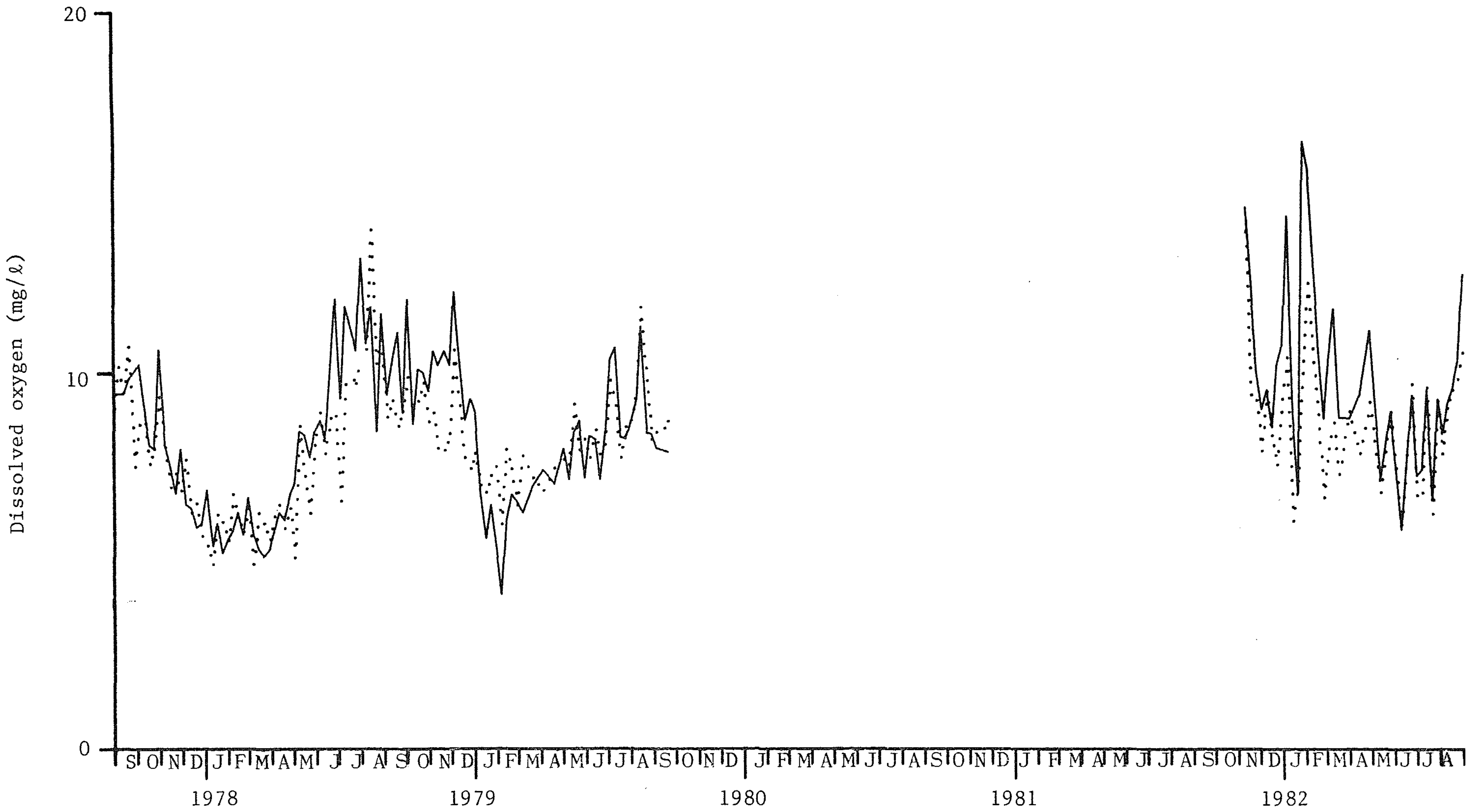

Fig. 7 Surface dissolved oxygen.

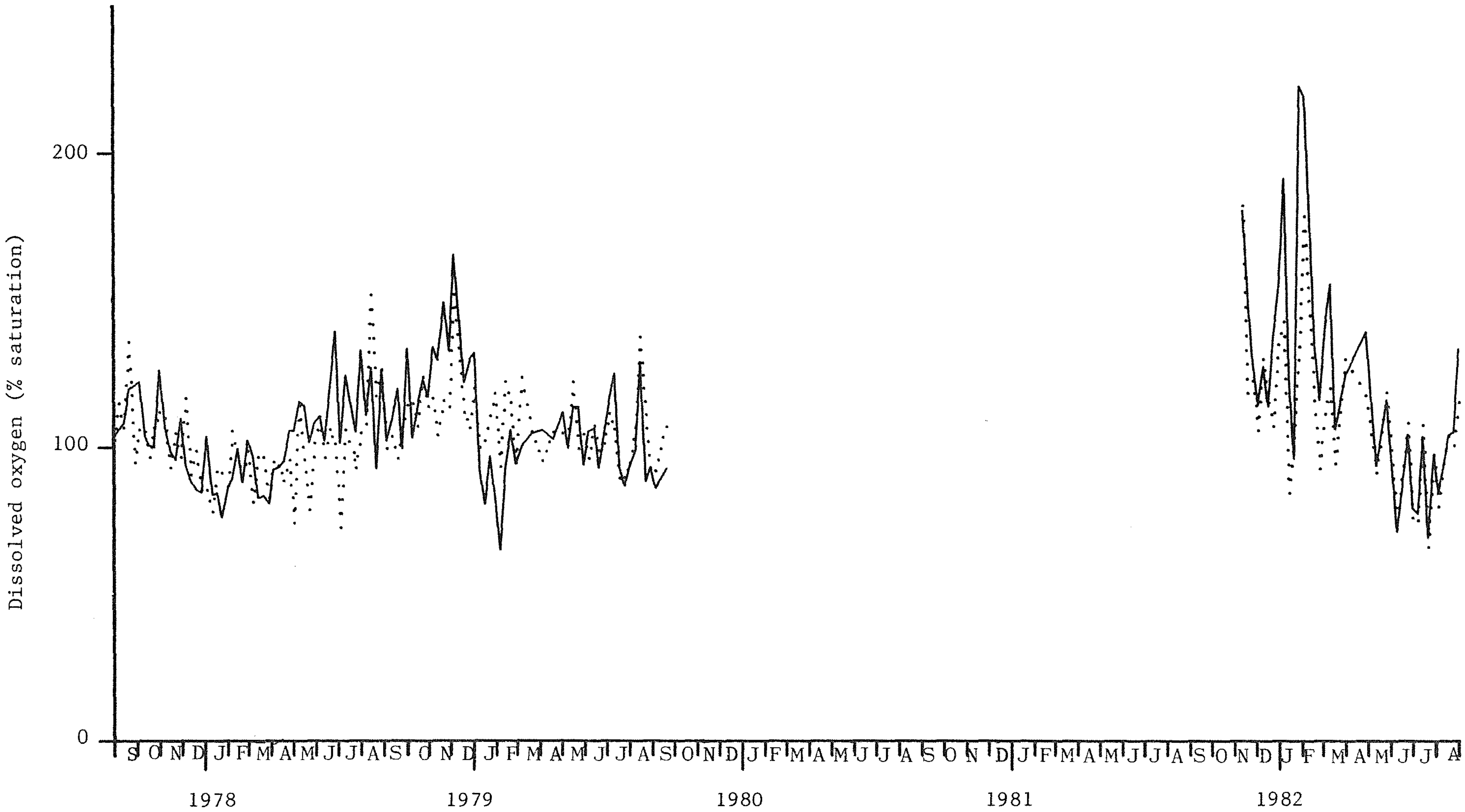

Fig. 8 Surface dissolved oxygen expresses as percent saturation.

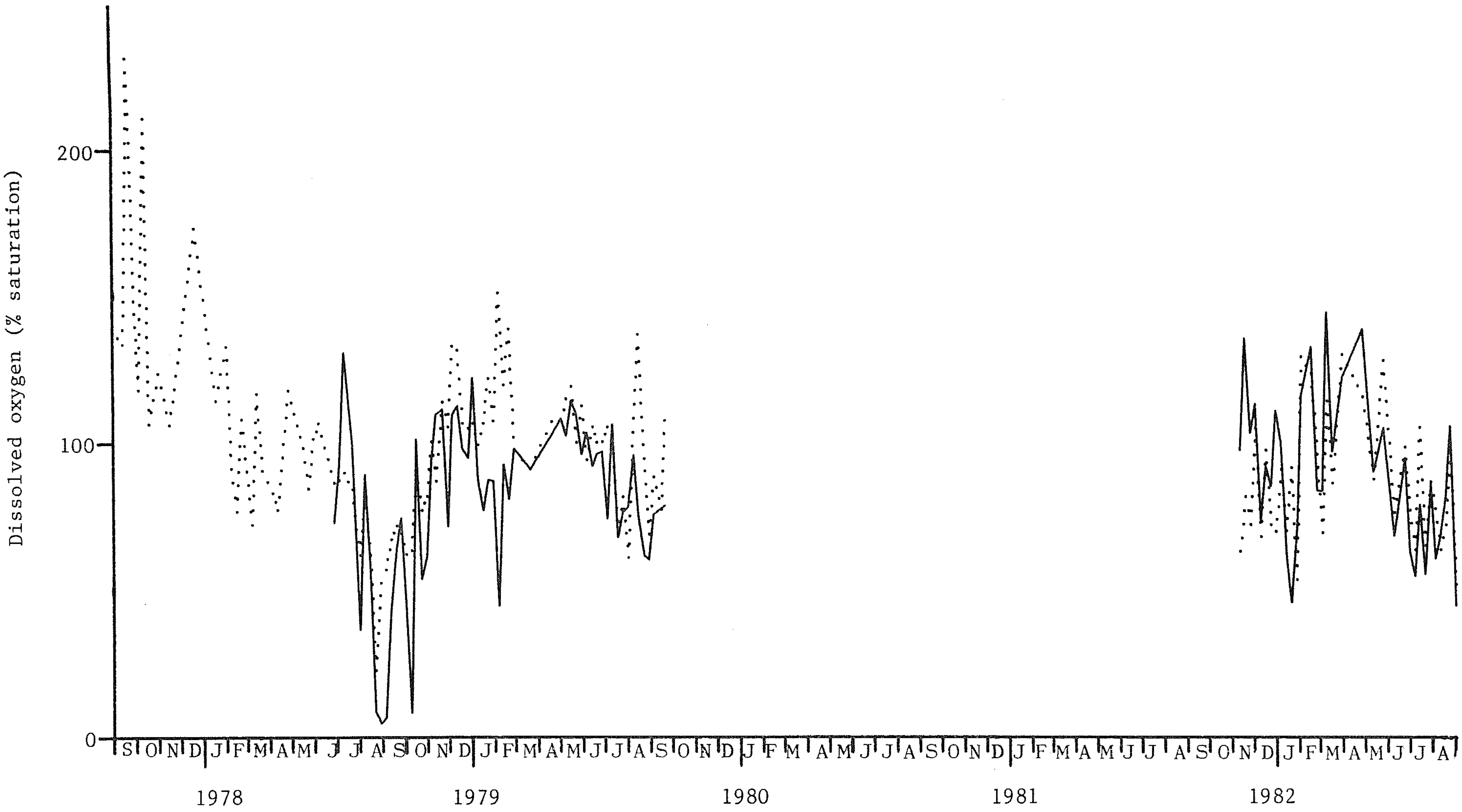

Fig. 9 Bottom dissolved oxygen expressed as percent saturation.

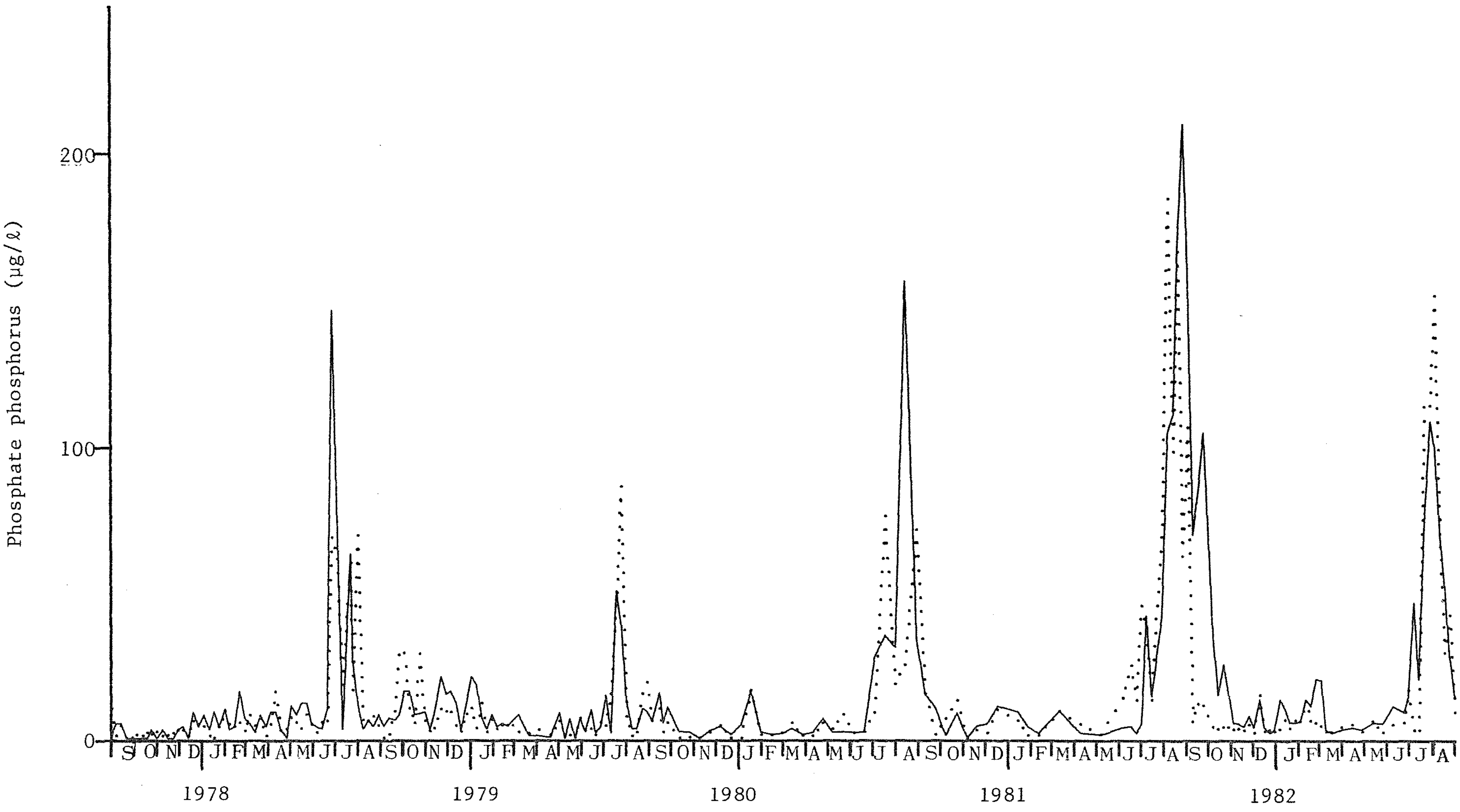

Fig. 10 Surface phosphate phosphorus.

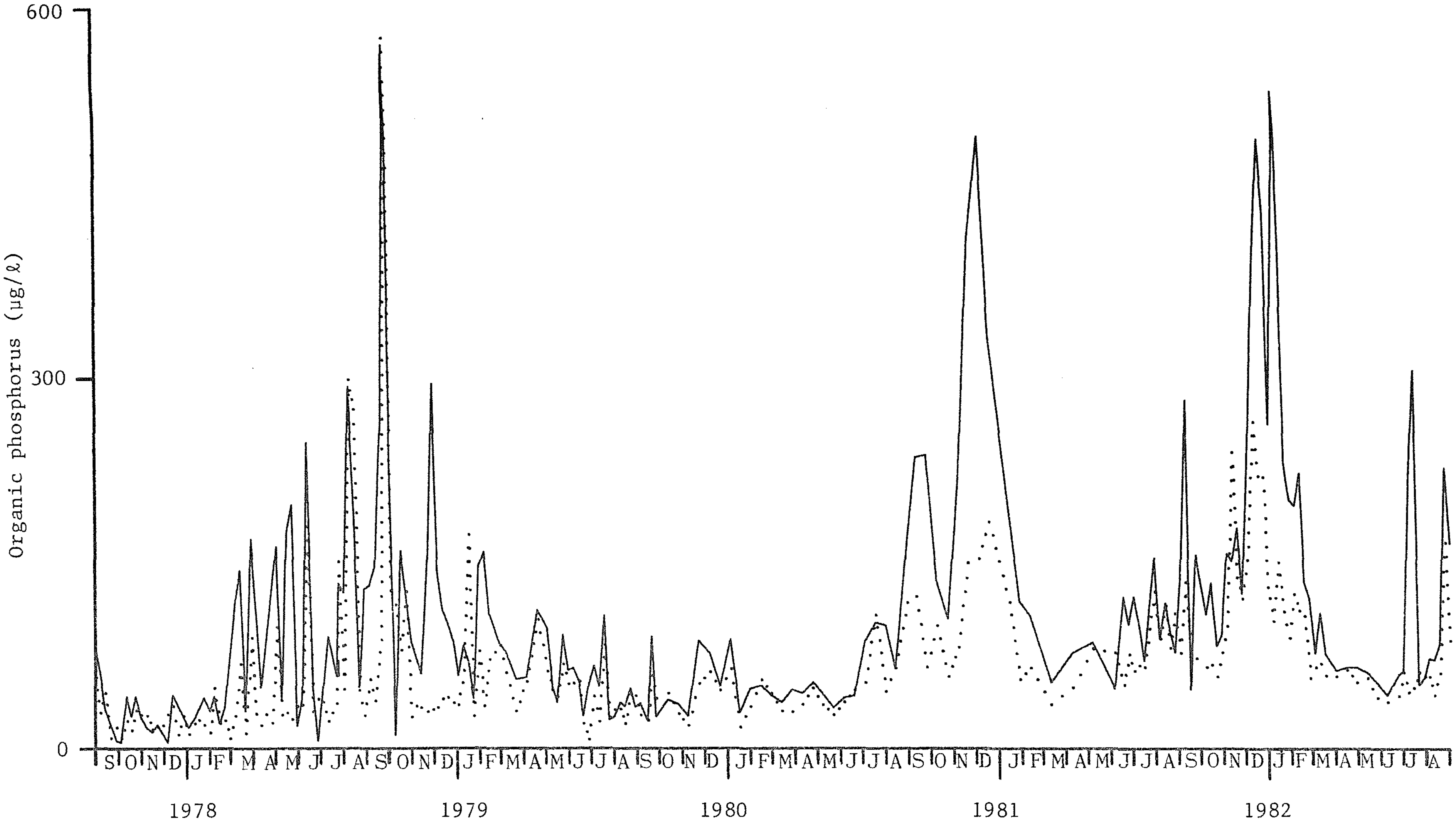

Fig. 11 Surface organic phosphorus.

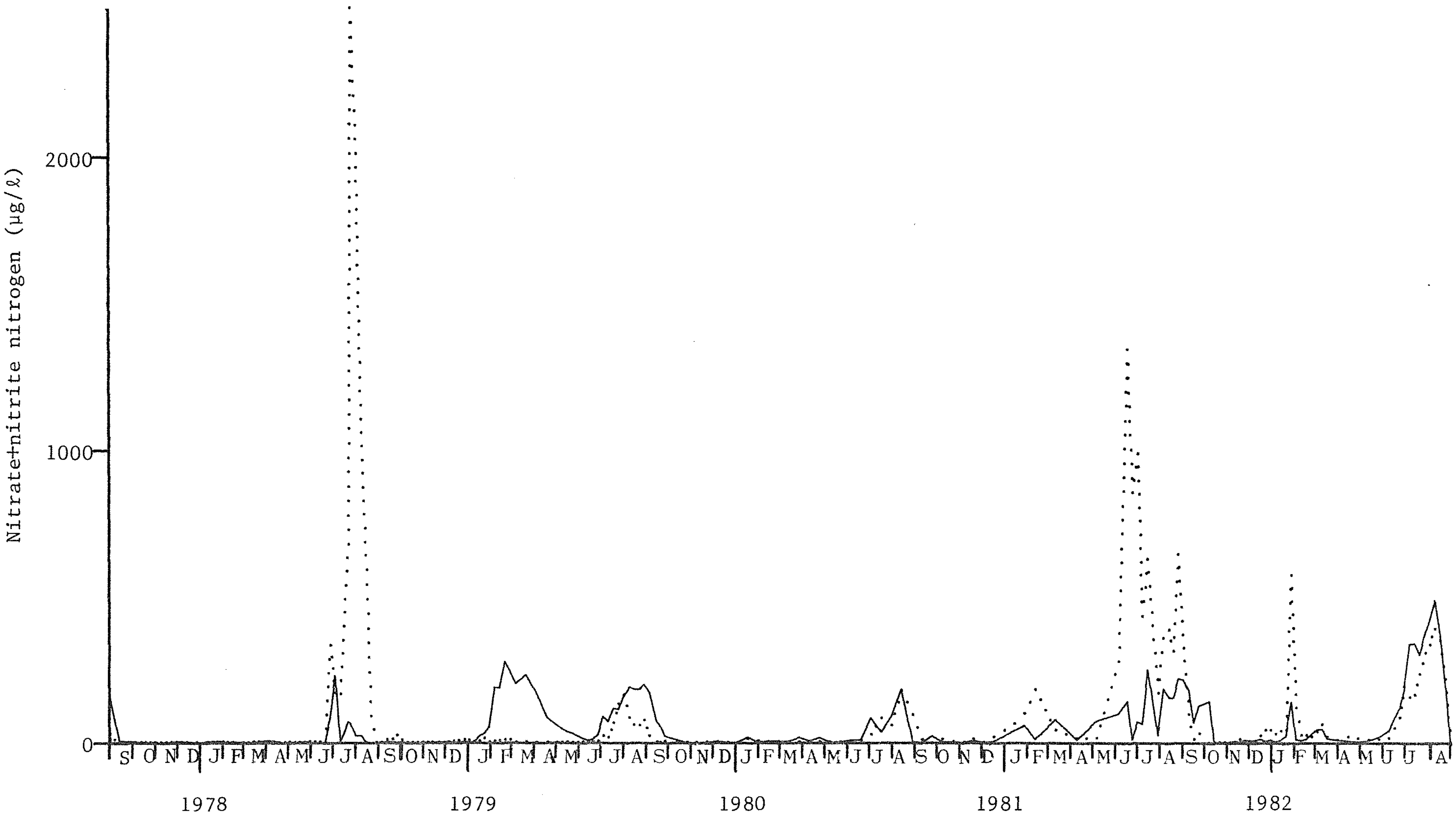

Fig. 12 Surface nitrate+nitrite nitrogen.

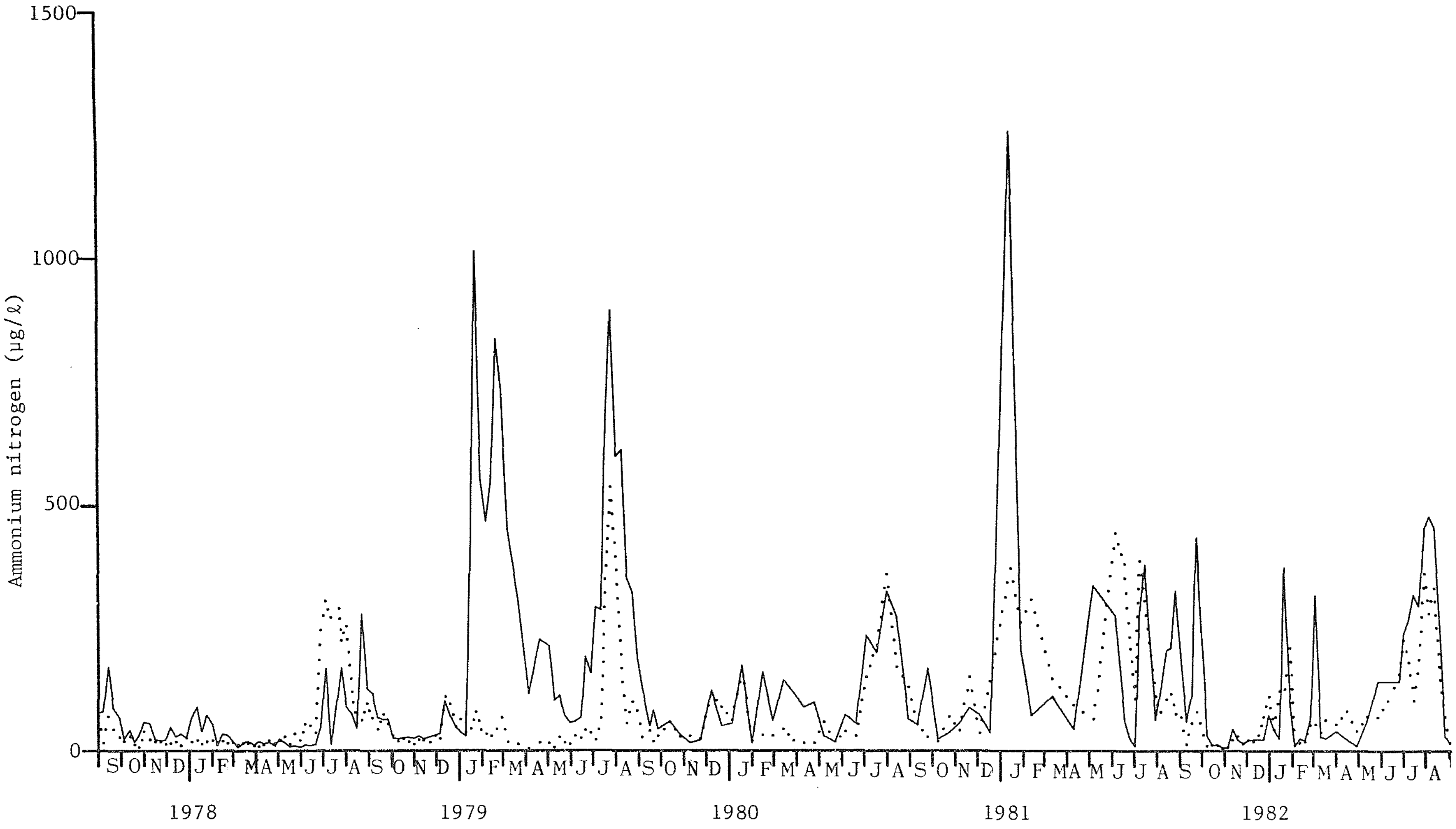

Fig. 13 Surface ammonium nitrogen.

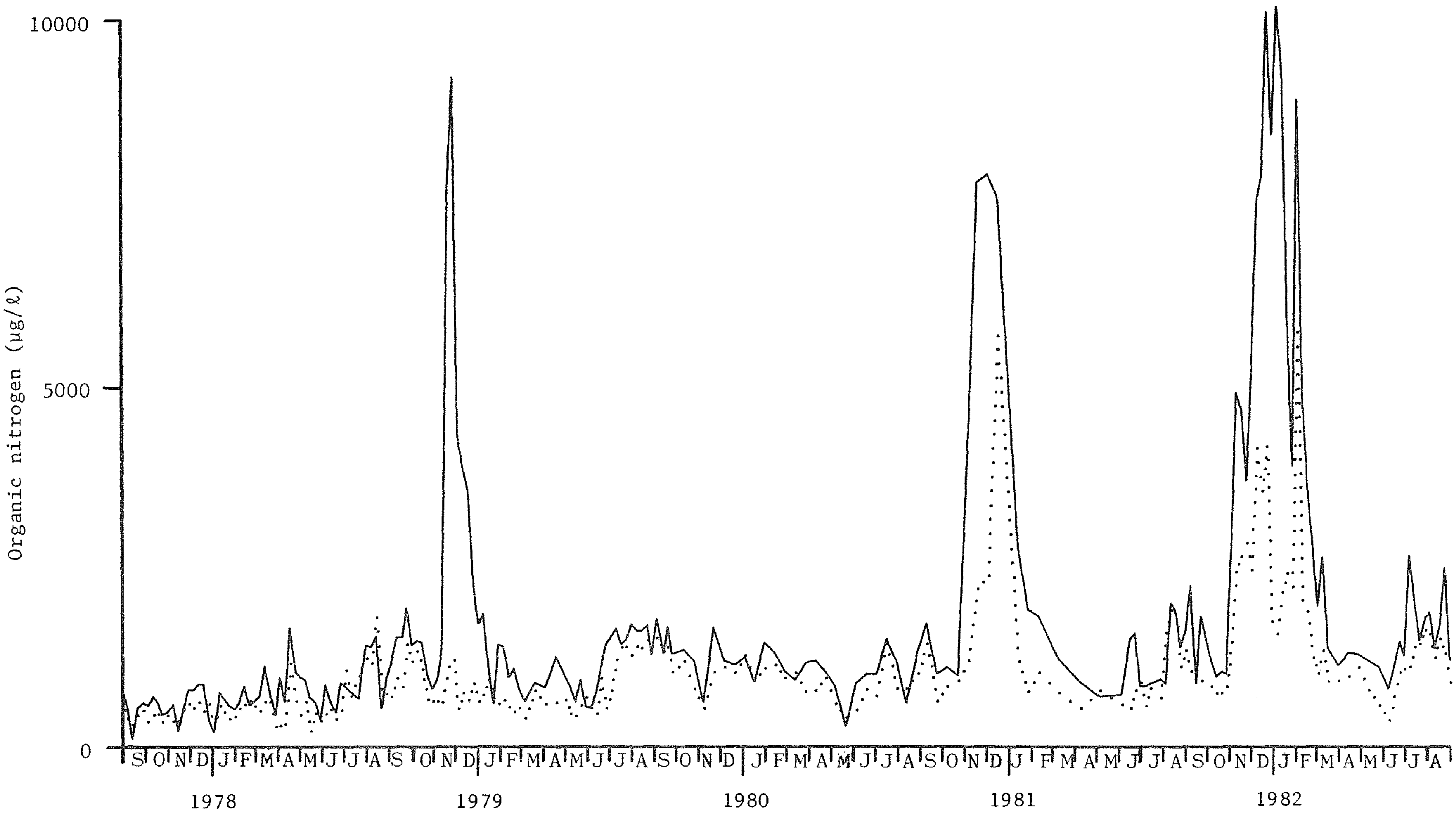

Fig. 14 Surface organic nitrogen.

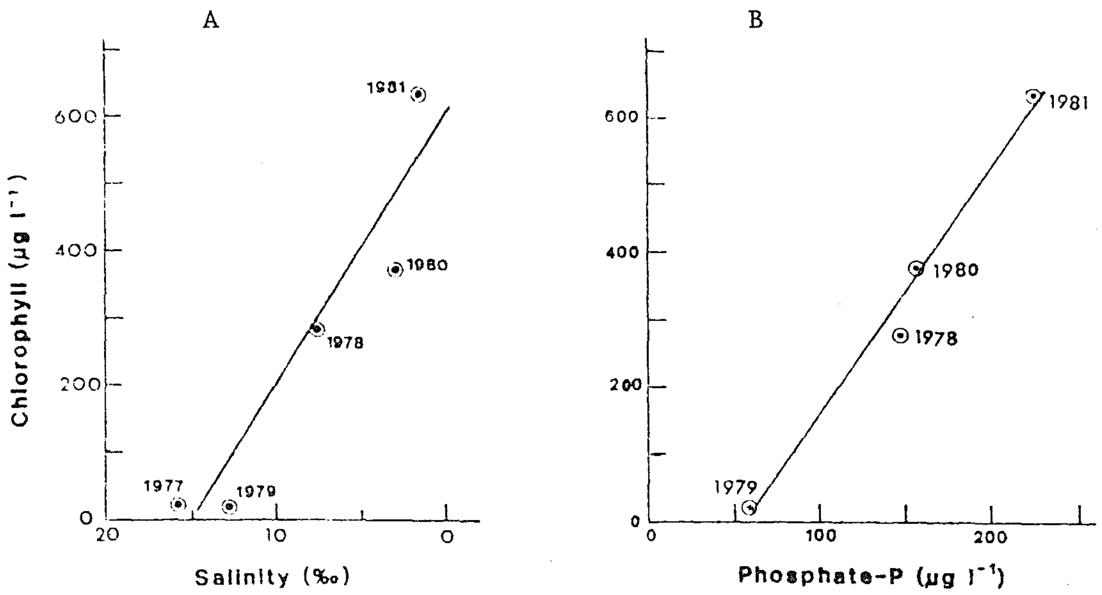

Fig. 15 The maximum concentration of chlorophyll in Harvey Estuary each year, plotted against (A) the minimum salinity, and (B) the maximum phosphate concentration, reached in the preceding winter.