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Studies on the primary phytoplankton production in 1973-1974 in the Baltic

by

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INTRODUCTION

This report deals with the results of the primary phytoplankton production studies carried out in the Baltic proper, the Åland Sea and the Bothnian Sea in 1973 and 1974. The work began in January 1973 and has continued since then. For each of the years 1973 and 1974 the authors have published a comprehensive report (Ackefors & Lindahl, 1975 a,b).

The aim of the investigation is to find adequate values for the primary production in the different offshore areas of the Baltic. Continuous sampling with rather short intervals (12-18 times per year) has been possible to perform far away from the coast. The results are therefore considered to be representative for real offshore conditions in the Baltic.

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METHODS AND MATERIAL

Station net

The measurements are carried out at four stations (fig. 1). The position of the stations has been chosen in such a way that the coastal influence will be little. The experimental water is thus supposed to be "off shore" water.

Data collected

In addition to the primary production the following parameters are measured: water temperature, salinity, qualitative phytoplankton samples down to 20 metres depth, samples for determining the amount of chlorophyll, the C:N:P content of the phytoplankton and the phytoplankton biomass down to 15 metres depth. At station 1, 2 and 3 pH is measured down to 20 metres depth, and at station 1 and 2 microzooplankton and other zooplankton samples are taken from the whole vertical column. At all stations air temperature, wind-direction and secchi-disc value (diam. 20 cm) are observed. Cloudiness, wind-speed and state of sea are also observed.

Radiation measurements

All stations are equipped with a Kipp & Zonen solarimeter integrator type CC 1. Each solarimeter is situated at a fixed point in the outer archipelago, where sufficient electric current is available. A printer is connected to the integrator. The total incoming radiation is measured between 300-2500 nm. The radiation values are presented as a number of "counts" printed every hour on a papertape. These counts are easily transformed to mWh cm^{-2} h^{-1} or cal cm^{-2} h^{-1}.

Primary production measurements

The primary production measurements are carried out with the ^{14}C-technique *in situ*. As production measurements with labelled carbon is a well known method, it will not be described in detail here. The measurements are carried out in nearly all respects according to "Recommendations for measuring primary production in the Baltic" (in press) proposed by W.G. 4 inside the Baltic Marine Biologists.

Fixed incubation depths are used with a single light-bottle at each sampling depth. The depths are 0, 1, 2, 3, 4, 6, 8, 10, 15 and 20 metres. Four dark-bottles are used at 0, 4, 10 and 20 metres depth. The production below 20 m depth is negligible in the Baltic according to our experience.

In the recommendations, it is stated that the incubation should take place from sunrise to true noon or from true noon to sunset. 24 hours incubation time can also be used. Due to practical reasons it has not been possible to follow the recommendations in this respect. In this study, 4 hours incubation time has been used. The incubation is always carried out during the same period of the day (9 am–3 pm). It is then possible to compare different measurements without any transformations. However, it is necessary to transform the 4 hour values (mg C m^{-2} h^{-1}) into daily production (mg C m^{-2} d^{-1}). The factor used for this transformation is called the lightfactor (LF). $LF = \frac{TR}{TR_m}d$, where TR_d is the incoming total radiation during the day and TR_m is the incoming total

radiation during the measurement. Schindler & Holmgren (1971) have tested 4 hours incubation versus longer incubation times and they have found good agreement. However, in some situations as extremely dark days the method seems to fail somewhat.

The ampouls and filters used (Sartorius, pore size 0.2 μ) are bought at The International Agency for ^{14}C-Determination in Copenhagen. The Agency has carried out the measurements of the radio-activity on the filters. The radio-activity has been measured with a GM (Geiger Müller) counting equipment but will probably be replaced by a liquid scintillation counter during 1975.

RESULTS

The winter was comparatively mild in 1973 and the water temperature was in general higher than previous years. No fast ice occurred in the winter. The summer temperature was in the range of 14-20 °C. The salinity was rather homogenous from surface down to 20 m depth and fluctuated at the various stations and seasons between 4.5 and 9.5 ‰.

The results of the primary phytoplankton production measurements in 1973 are reported in fig. 2. The production at the most southern station in the Hanö Bight (station 1) was 105 g C m^{-2} $year^{-1}$, at station 2 east of Gotland 91 g C m^{-2} $year^{-1}$, at station 3 in the Åland Sea 94 g C m^{-2} $year^{-1}$ and at the most northern station (station 4) 71 g C m^{-2} $year^{-1}$ (table 1). The third quarter of the year (July-September) was the most productive or about 50 % of the yearly production.

The chlorophyll values were in the magnitude 10-20 mg m^{-2} at the three southern stations and 20-30 mg m^{-2} at the most northern station. In March, April and May the values were higher at the two most northern stations where maximum values of 50-60 mg m^{-2} appeared.

The phytoplankton biomass was very low at the two southern stations; on most sampling occasions in the range 1-2 g m^{-2} (wwt). At the two northern stations there were a conspicuous spring bloom. The biomass fluctuated between 10 and 17 g m^{-2}. The dominating phytoplankton species were the diatoms (Sceletonema costatum, Chaetoceras spp., Thalassiosira baltica, Achnantes taeniata) at station 4, blue-green algae (Aphanizomenon flos-aquae, Nodularia spumigena) at stations 1-3, dinoflagellates (Dinophysis spp., Gonyaulax catenata, Gyrodinium spirale)at stations 2-4 and monads at stations 1 and 3.

In 1974 sampling were carried out 42 times altogether at the same four stations. The winter 1974 was also comparatively mild with ice at sea only in the very northern part of the Bothnian Sea. The summer water temperature in 1974, how-

ever, was lower than in 1973 and ranged between 14 and 16°C.

The results of the primary phytoplankton production measurements in 1974 are reported in fig. 3. The annual production has been calculated: in the Hanö Bight (station 1) 121 g C m^{-2} $year^{-1}$, east of Gotland (station 2) 116 g C m^{-2} $year^{-1}$ and in the Sydostbrotten area (station 4) 70 g C m^{-2} $year^{-1}$ (table 1). It has not been possible to calculate the annual production for 1974 in the Åland Sea since too few measurements have been carried out. Compared with 1973 the calculated production was about 15 % higher at station 1 and 2, while the calculated production at station 4 was almost the same. At the two southerly stations it was the spring bloom which mostly contributed to the increase. At the northern station the spring bloom was lower in 1974 but this was compensated by a higher summer production. In 1974 the third quarter was still found to be the most productive one. The highest daily production measured in 1974 was 976 mg C m^{-2} d^{-1}. This occurred at station 1 in April.

The chlorophyll a fluctuated almost like in 1973. Unfortunately there have until now been no time for phytoplankton biomass and species analyses of the 1974 samples.

Table 1. Primary production was measured at four stations in the Baltic (see fig. 1) in 1973 and 1974. The figures show the quarterly and yearly production in g C m^{-2}.

	I quarter		II quarter		III quarter		IV quarter		The yearly production	
	1973	1974	1973	1974	1973	1974	1973	1974	1973	1974
Station 1	6	8	34	50	53	54	12	9	105	121
Station 2	4	6	25	37	50	64	12	9	91	116
Station 3	8	7	37	-	41	-	8	-	94	-
Station 4	3	~0 (ice)	29	17	36	47	4	6	71	70

The estimate of the quarterly and yearly production in 1973-1974 is summarized in table 1. The most productive quarter was the third at all stations. The production in July-September was estimated to 44-55 % (1973), 45-67 % (1974) of the yearly production. The contribution of the second quarter was 27-41 % in 1973 and 24-41 % in 1974. By adding the production figures from April-September, those two quarters made 82-92 % in 1973 and 86-91 % in 1974 of the yearly production. The contribution to the production from the months October-March is thus comparatively small.

The vertical distribution of primary phytoplankton production is described by Ackefors & Lindahl (1975 a). The maximum production occurred above 6 m level

with a few exceptions. On cloudy days the maximum production appeared at 1-2 m level and on bright days at 3-6 m level. The main part of the production occurred above the level, where 15 % of the subsurface light was still available; in general above 6-12 m level. Below 20 m level the production was negligible. The maximum production at any level was 10.3 mg C m^{-3} h^{-1} in 1973. The highest daily production was 725 mg C m^{-2} and occurred in August, 1973, at station 3. In 1974 a peak value of 976 mg C m^{-2} d^{-1} occurred in April at station 1.

DISCUSSION

The annual primary production of 105 g C m^{-2} $year^{-1}$ (1973) and 121 g C m^{-2} $year^{-1}$ (1974) at station 1 in the Bornholm Sea is higher than most authors have reported for the southern Baltic proper. The same thing can be stated for the area east of Gotland (station 2). The reported values of 91 resp. 116 g C m^{-2} $year^{-1}$ in the Gotland Sea are higher than the results of previous investigations by other authors. Kaiser & Schulz (1973) compared the annual primary production in 1969 with that of 1970 in different parts of the Baltic proper. They found such great differences between the two years as 94-46.5 g C m^{-2} $year^{-1}$ (Arkona Sea), 138.0-59.0 (Bornholm Sea) and 69.4-35.0 (Gotland Sea). From our point of view it is quite obvious that the reason for such great differences is too few sampling occasions (3-4 per year) and too sparse sampling depths and not different kinds of hydrographical situations during the two years. With continuous sampling during the year Hobro and Nyqvist (1972) reported about an annual primary production of 114 g C m^{-2} $year^{-1}$ in the Landsort area, close to the Askö station (cf. fig. 1).

An investigation in the Baltic proper by Sen Gupta (1972) with even lower values (29.4-30.6 g C m^{-2} $year^{-1}$) was carried out with an incubator on board. The samples were preserved with Hg Cl_2 in order to stop the photosynthesis. This technique is disastrous for certain phytoplankton cells and such measurements give erroneous results. This has been verified by experiments both in the field and laboratory (Edler, pers.comm.). Fonselius (1971) reported about an annual primary production of 78 g C m^{-2} $year^{-1}$ from a lightship in the northern part of the Baltic proper at about the same latitude as station 3 (91 g C m^{-1} $year^{-1}$ in 1973). The Fonselius investigation used an incubation time of 24 hours which tend to give a lower primary production value than the 4 hours method.

Ackefors & Hernroth (1972) calculated the production of pelagic and demersal fish in the Baltic proper. Later Ackefors (1975) drew a rough picture of the different trophic levels and calculated backwards the energy flow in the food chain from fish to primary production. Using an ecological efficiency of 15 % in each link of the food chain, Ackefors stated that the minimum primary pro-

duction in order to keep a fish production at the present level in the Baltic proper must be at least 100 g C m^{-2} $year^{-1}$. The reported values in this paper seem thus to be in the true magnitude.

The third quarter of the year was the most productive and 44-67 % of the yearly production occurred during that period (cf. Renk et. al, 1974). Next to the third quarter in importance is the second quarter. In this investigation the second quarter contributed with 24-41 % of the annual production. In good agreement with this is the investigation by Bagge and Niemi (1971) which stated that one third of the annual primary production is produced during the spring bloom.

The phytoplankton biomass at station 1 in the Hanö Bight and at station 2 east of Gotland did not show any great fluctuations in 1973 and there were no pronounced vernal bloom. The low biomass values are conspicuous when comparing with values from April, 1969, showing a phytoplankton biomass of 24-50 g m^{-2} in the southern Baltic (Hobro, 1972). Such high biomass values seem, however, to be rare since 1970 (Hobro, pers.comm.). Although the phytoplankton biomass values were low, it was still a rather high yearly primary production (105 resp. 91 g C m^{-2}). It is striking that there is no high production value in spring. On the other hand the real spring bloom might have occurred between two sampling occasions.

The authors, however, suppose that the real reason is the mild winter in 1972/73 which favoured the development of zooplankton. This is verified by investigations in the Hanö Bight in March, 1973. All important copepods (Acartia spp., Centropages hamatus, Temora longicornis and Pseudocalanus m. elongatus) were abundant already at that time of the year (Hernroth, pers.comm.). If mild winters promote a higher density of copepods, the grazing effect will be of great importance as early as in March and impede a great accumulation of phytoplankton during spring bloom.

At station 3 in the Åland Sea a high phytoplankton biomass was found on one occasion in April (16.5 g m^{-2}). This is in accordance with the investigations carried out in 1973 in the Askö area (Hobro, pers.comm.), but it is still much lower biomass value than in April 1969, where Hobro (1972) found 40-60 g m^{-2} in April in the Askö area. This might be explained by the fact that the winter 1968/69 was cold and probably the zooplankton density was low and therefore the grazing effect small.

At station 4 in the northern Baltic there was an obvious increase in the phytoplankton biomass during the vernal bloom. The maximum primary production during that time was about 500 mg C m^{-2} d^{-1}. In August the maximum primary production was 600 mg C m^{-2} d^{-1}, when the phytoplankton biomass was 20 times less than during the spring bloom. This is an evidence of the fact that there is no or very little correlation between the density of phytoplankton and the primary production.

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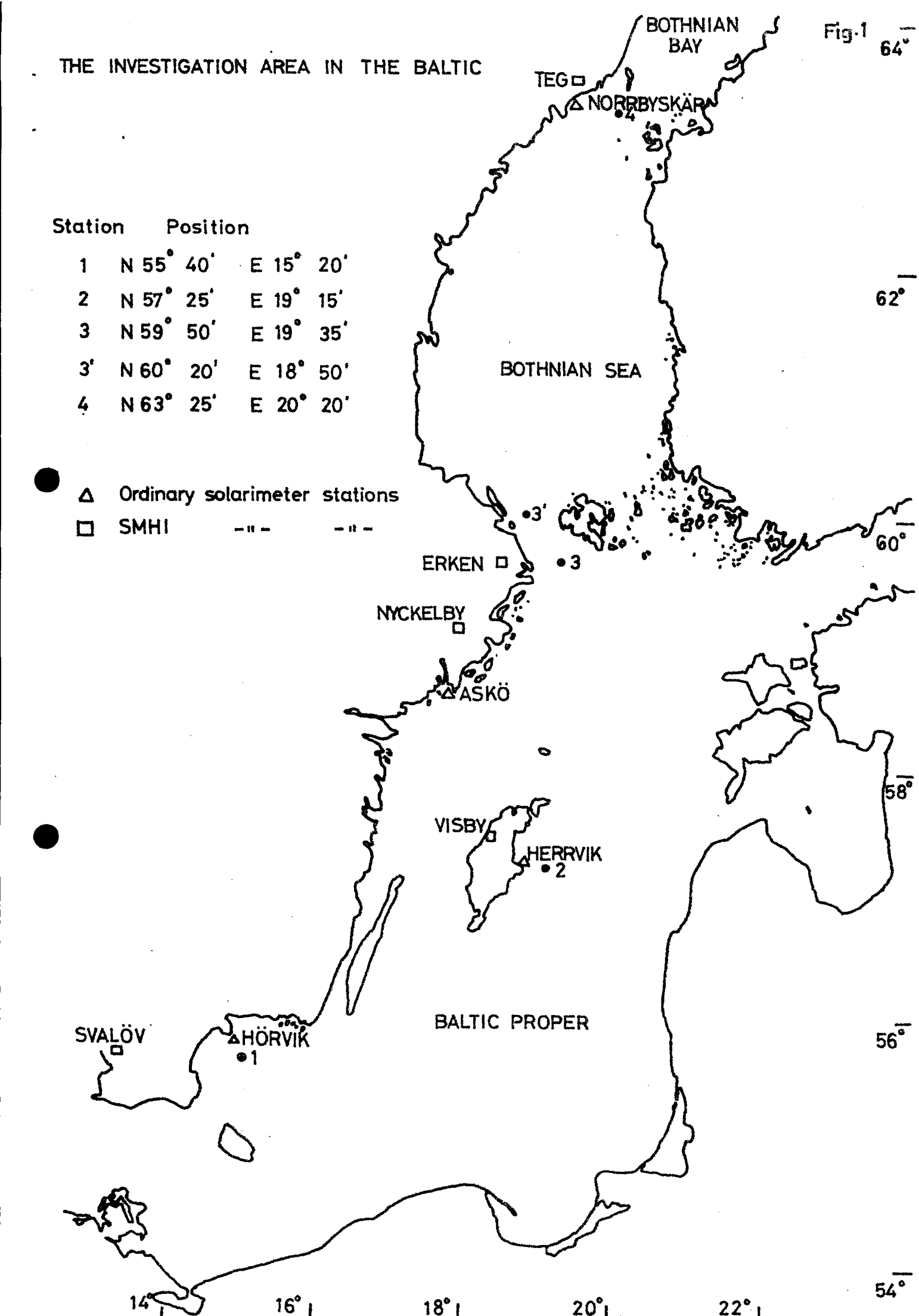
Fig.1

THE INVESTIGATION AREA IN THE BALTIC



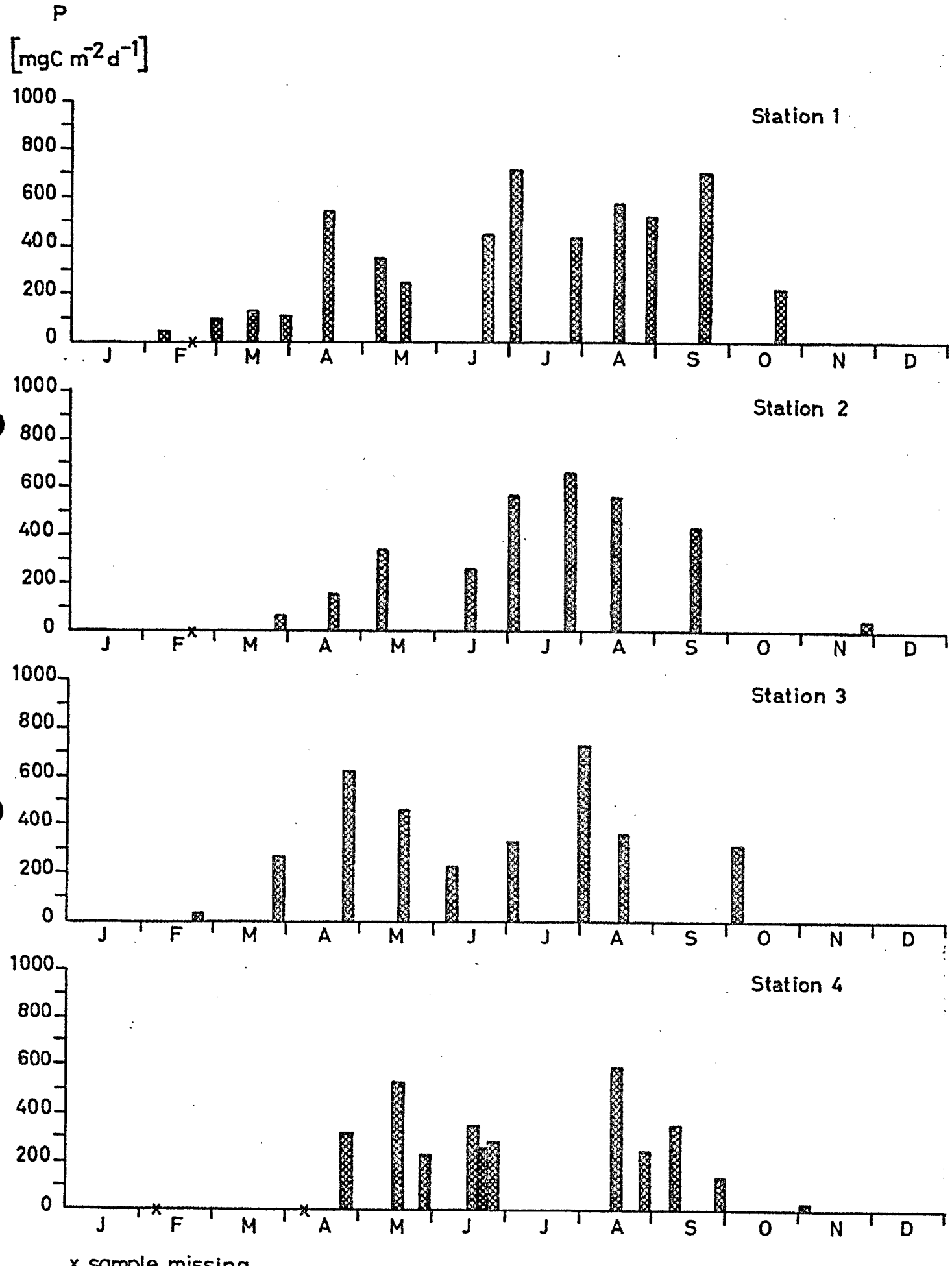
Station	Position		
1	N 55° 40'	E 15°	20'
2	N 57° 25'	E 19°	15'
3	N 59° 50'	E 19°	35'
3'	N 60° 20'	E 18°	50'
4	N 63° 25'	E 20°	20'

△ Ordinary solarimeter stations

□ SMHI -"- -"-

Fig. 2

PRIMARY PRODUCTION 0 - 20 M IN THE BALTIC 1973



PRIMARY PRODUCTION 0-20M IN THE BALTIC

1974

Fig. 3