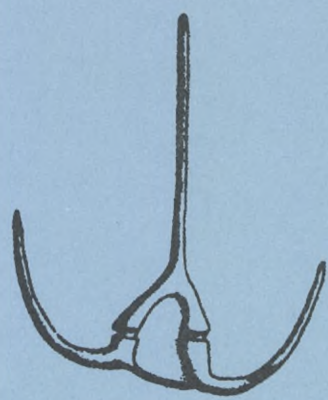
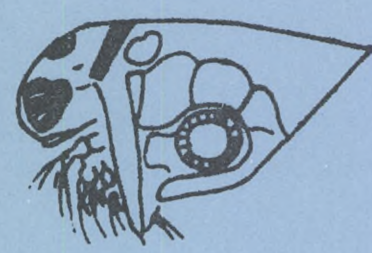
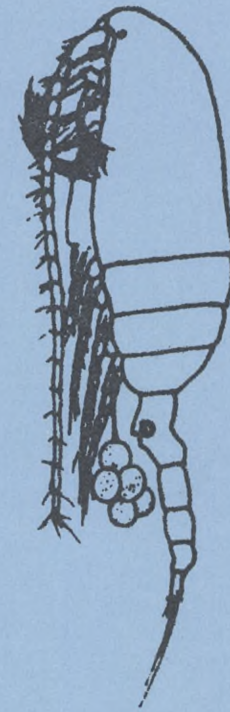
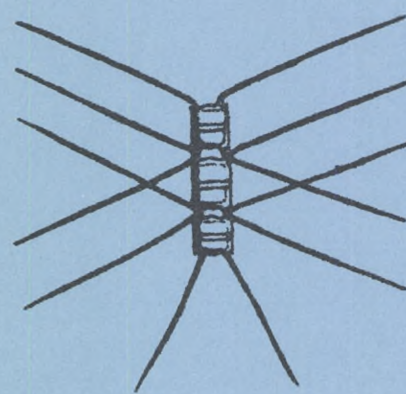
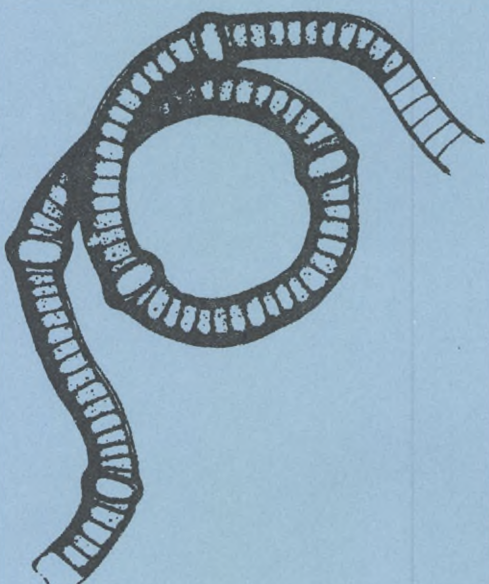
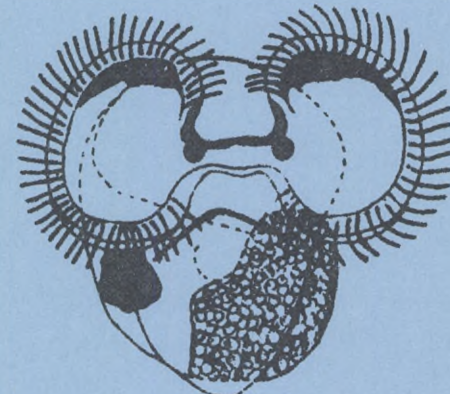

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Studies on the production of phytoplankton and zooplankton in the Baltic in 1976, and a summary of results from 1973 - 1976

by

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Studies on the production of phytoplankton and zooplankton in the Baltic in 1976, and a summary of results from 1973 - 76

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ABSTRACT

Primary production, phytoplankton, chlorophyll a and zooplankton studies were carried out at three off-shore stations in the Baltic in 1976. This is the continuation of an investigation which started in 1973. However, the field work for the programme was finished by the end of 1976. The stations were situated in the Hanö Bight, east of Gotland and in the Åland Sea. The sampling was carried out on 63 occasions.

The primary production was measured in situ with the ^{14}C-technique, using an incubation time of four hours. The measurements were made at ten depths and always around noon. The calculated annual primary production at the most southern station (the Hanö Bight) was 132 gC m^{-2}. East of Gotland the annual production was calculated to be 87 gC m^{-2}, and in the Åland Sea (the most northern station) the annual primary production was found to be 65 gC m^{-2}.

The chlorophyll a values varied mainly between 10 and 30 mg m^{-2}, with slightly higher values in the north than in the south. However, during the vernal bloom, considerably larger amounts of chlorophyll a were recorded.

The phytoplankton biomass values at the Hanö Bight station ranged mainly between 1 and 5 g m^{-2} (wwt). East of Gotland and in the Åland Sea the biomass was in general larger. However, at all stations during the vernal bloom and east of Gotland during the summer, some much larger biomasses were found. The composition of the phytoplankton flora was also investigated.

Zooplankton were sampled with a UNESCO WP 2-net (90 µm). The zooplankton biomass values were in general lower than those usually found in the off-shore areas of the Baltic, due to the shallowness at the stations. The largest biomass was found during the third quarter. The values then fluctuated around 15 to 20 g m^{-2} (wwt) east of Gotland and in the Åland Sea. However, some much higher values were also recorded. The composition of the zooplankton fauna and the developmental stages of the copepods were also investigated.

The zooplankton production was calculated. The annual production east of Gotland and in the Åland Sea was estimated to be 14 gC m^{-2}. No calculations could be made for the Hanö Bight station.

A summary of the results found in 1973-76 is given at the end of the paper. The summary contains mainly a survey of the primary production results and a discussion of the methods and material used for measuring the primary production.

INTRODUCTION AND ACKNOWLEDGEMENTS

Since January 1973 the Institute of Marine Research in Lysekil, Sweden, has carried out a research programme for primary production studies in the Baltic proper and the Bothnian Sea. The field work for the programme was completed by the end of 1976. The aim of this investigation has been from the beginning to find adequate values for the primary production in four different off-shore areas in the Baltic. Later, zooplankton studies were also included. In 1976 the measurements were made at three stations 10 - 20 nautical miles off the coast (fig. 1), representing three different areas. The fourth station was closed at the end of 1975 (see page 6).

The author would like to thank the crews of the rescue cruisers GRÄNGESBERG, ÖSTERGARN and K. A. WALLENBERG for their cooperative help on the many sampling occasions. I would also like to thank Mr Lars Edler, Mr Bo Eriksson and Mrs Brita Gornitzka for carrying out all the expeditions. Further, I would like to thank the following persons, who have implemented different parts of the programme:
Dr Hans Ackefors, Lysekil, for being responsible for the whole investigation. He has also taken part in many valuable discussions, and has given useful criticism regarding the concept of this paper. I am specially thankful to Dr Ackefors, who has spared no pains in the effort to obtain financial support for the programme.
Mr Lars Edler, Lund, for performing the phytoplankton analyses and compiling the results. He has likewise taken part in valuable discussions, and has commented on the concept of this paper.

Mr Lars Hernroth, Lysekil, for compiling the zooplankton results. He has also given much good advice, and has taken part in several fruitful discussions.

Mrs Cornelia Sellei, Uppsala, for performing the zooplankton analyses.

Miss Ann-Christin Rudolphi, Lysekil, for drawing the figures.

Miss Birgitta Bengtsson, Lysekil, for typing the manuscript.

Three separate papers giving the results of 1973, 1974 and 1975 have been published (Ackefors & Lindahl 1975 a, 1975 b, Lindahl 1977).

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METHODS AND MATERIAL

Station network and frequency of measurement

In table 1 the position of the stations and the number of measurements carried out at each station are listed.

Table 1. Station network and frequency of measurement.

Station	Position		Distance from shore	Number of measurements				
No	N	E	Nautical miles	1973	1974	1975	1976	
1	55°40'	15°20'	20	18	15	14	14	61
2	57°25'	19°15'	10	10	9	17	27	63
3	59°50'	19°35'	15	9	7	-	-	16
3'	60°20'	18°50'	10	-	-	14	22	36
4	63°25'	20°20'	15	12	11	4	-	27
				49	42	49	63	203

Data collected

The following parameters were investigated using different sampling methods:

1. Primary production was measured *in situ* at ten depths.

2. Samples for determining the amount of chlorophyll a and the phytoplankton biomass were collected from 15 m to the surface.
3. Net samples for qualitative phytoplankton analysis were taken from 20 m to the surface.
4. Zooplankton (size fraction between 0.2 and appr. 1.0 mm) was sampled from the whole vertical column.
5. Water temperature, salinity and pH (only at station 1 and 2) were measured.
6. Air temperature, cloud, cover, wind direction and speed and secchi-disc values were recorded on different sampling occasions.
7. Irradiation was measured from a land based station close to each sampling area.

The author is well aware of the absence of nutrient data in this investigation. However, it was impossible to solve the practical arrangements in order to obtain accurate chemical results, due to the widespread investigation area.

Primary production

The primary production measurements were carried out *in situ* with the ^{14}C-technique, in nearly all respects according to Dybern *et al*. (1976). However, some of the methods were slightly modified due to practical reasons. Fixed incubation depths were used, with a single bottle at each sampling depth. The depths were 0, 1, 2, 3, 4, 6, 8, 10, 15 and 20 m. Four dark bottles were used at 0, 4, 10 and 20 m depth. Primary production below 20 m was negligible.

Due to practical reasons, it was impossible to use an incubation time of half a lightday. Instead, an incubation time of four hours was used. The incubations were always carried out at the same time of day (9 am - 3 pm). It was then possible to compare different measurements without any transformations. However, it was necessary to transform the four hour values (mgC m^{-2} h^{-1}) into daily production values (mgC m^{-2} d^{-1}). The factor used for this transformation was called the lightfactor (LF). $LF = \frac{I_d}{I_m}$ where I_d was the irradiation during the day and I_m the irradiation during the measurement (see page 25).

The ampoules and filters used (Sartorius, pore size 0.2 µm) were bought at the Carbon 14 Central in Copenhagen. The Central has measured the radioactivity on the filters with Geiger-Müller counting equipment. The author was aware of the fact that the GM-technique may be less accurate than the liquid scintillation technique, but decided not to change method during this investigation (see page 26).

Chlorophyll

The water-samples were taken with a hose (15 m long) as an integral sample. The SCOR/UNESCO method was used when storing the samples and measuring the amount of chlorophyll (Carlberg 1972).

Phytoplankton biomass

The water-samples were taken as described above and were preserved in Keefe's solution. The phytoplankton was analysed according to the Utermöhl technique and the cell volume for each species was calculated (Utermöhl 1958). The density of the biomass was assumed to be 1 g cm^{-3}.

Phytoplankton flora

The samples were collected using a net with a mesh-size of 25 µm. Vertical hauls were taken down to a depth of 20 m. The samples were preserved in Keefe's solution.

Zooplankton

In 1976, almost all zooplankton samples were collected with a UNESCO WP 2-net (90 µm). When the WP 2-net was not used, a Nansen-net (90 µm) was used instead. The hauls were vertical and were taken from the bottom to the surface. The towing speed was 0.5 m s^{-1}. At station 1 the sampling was carried out from 30 m to the surface, at station 2 from 55 m to the surface and at station 3' from 40 m to the surface.

The samples were preserved in 4 % formalin. Before analysis the samples were subsampled in a whirling apparatus (Kott 1953). In the subsamples all specimens were analysed to species and the copepods were, in addition, determined to developmental stages. The biomass was calculated by adding all individual volumes (Ackefors 1972), assuming a density of 1 g cm^{-3}.

In order to make the results from the WP 2-net and the Nansen-net comparable, a correction factor for each net was used. The WP 2-net was considered to have a filtering efficiency of 96 % (UNESCO 1968), and the Nansen-net 50 % (Hernroth, unpubl.).

An attempt to measure the zooplankton production has been made using the technique described by Winberg (1971). The P/B-coefficients used derive from Ciszewski (in print), Hernroth (unpubl.), Zawislak (1972) and Winberg (1971).

Irradiation

The irradiation was measured between 300 - 2 500 nm by a Kipp & Zonen solarimeter of type CM 6 connected to a Kipp & Zonen integrator of type CC 1. A printer connected to the integrator gave the irradiation values hourly on papertape. When irradiation values were missing for one reason or another, values from the nearest irradiation station belonging to the Swedish Meteorological and Hydrological Institute (SMHI) were used. These stations were situated at Svalöv, Visby and Erken for stations 1 - 3' respectively (fig. 1).

RESULTS AND DISCUSSIONS

On 63 occasions different parameters were investigated at three off-shore stations: in the Hanö Bight, east of Gotland and in the Åland Sea (fig 1.). In 1973-74, measurements were made in the Sydostbrotten area between the Bothnian Sea and the Bothnian Bay. This was also planned for 1975-76, but due to practical problems only four measurements were made in 1975. The station was therefore closed at the end of 1975.

The frequency of the separate measurements is evident from fig. 2. The figure also shows the frequency of measurements made in 1973, 1974-75.

Temperature and salinity

The winter of 1976 was colder than the winters of 1973-75. However, the winter of 1976 can be assumed to have been "normal". The isopleths of the water-temperature at the various stations are reproduced in figure 3. At stations 1 and 2 the water-temperature oscillated around 2 °C until the middle of April. At station 3' the temperature was below 2 °C until the beginning of May. Ice at sea was found only in the Åland Sea area.

At stations 1 and 2, the temperature of the surface water was above 16 °C in August. A maximum water-temperature of 18 °C was found at station 2 on one measuring occasion at the end of August. At station 3' the temperature at the surface was above 14 °C from the end of July until the middle of September. The temperature might have been higher in August, but no measurements were made during this month.

On most occasions the salinity was homogeneous from the surface to the 20 m level. There were, however, small differences between the sampling areas. The lowest and highest salinities found at station 1 were 7.5 ‰ and 8.2 ‰. The mean value for the salinity was 7.8 ‰. At station 2 no salinity measurements were made in August, as the slinometer broke down. During the rest of the year the salinity fluctuated between 7.0 ‰ and 8.2 ‰, with a mean value of 7.7 ‰. In the Åland Sea, the salinity was in the range of 5.5 - 6.3 ‰ with a mean value of 5.9 ‰. The salinity conditions at stations 1 - 3' were almost the same as in 1973-75.

Irradiation

In 1976, irradiation measurements were carried out at stations 1 - 3', i.e. at Hörvik, Herrvik and Öregrund. Some small gaps in the registration of the irradiation have been filled by data from the nearest SMHI solarimeter station.

The monthly, quarterly and annual values, as well as the annual mean for the irradiation in the three areas, are shown in table 2 and figure 4. The differences between the annual means for the period 1961-75 (SMHI, pers. comm.) and the 1976 values from this investigation are +1, -4 and ±0 %, for the different areas in a progression from south to north. SMHI states that an annual difference from the annual mean of ±10 % is reasonable (SMHI, pers. comm.).

Primary production

Station 1, the Hanö Bight: 14 measurements were made in 1976 (table 3 and fig. 5). On the first measuring occasion of the year, at the beginning of February (Feb. 4), a daily primary production of 23 mgC $m^{-2}d^{-1}$ was found. This was, compared with earlier investigations, a typical winter-month value. Two measurements were made in March (March 16 and 23), with a mean production of 105 mgC $m^{-2}d^{-1}$. In the first half of April two measurements were made, and a mean production of 284 mgC $m^{-2}d^{-1}$ was found. In the second half of April the primary production increased rapidly and a maximum of 919 mgC $m^{-2}d^{-1}$ was found (Apr. 20). The mean production of this peak value and another measurement made in the second half of April (Apr. 26) was 777 mgC $m^{-2}d^{-1}$. In May and June only one measurement was made each month. On both occasions a daily primary production of 509 mgC $m^{-2}d^{-1}$ was found. In previous years of this investigation, a more or less pronunced minimum in the primary production was found in early summer. In 1976, however, no such minimum was observed at station 1. Unfortunately, there were few measurements made during the summer. In the beginning of July (July 2) a production of 401 mgC $m^{-2}d^{-1}$ was found. Two measurements were made in August (Aug. 5 and 30). A very high production was measured on these occasions and the mean production was found to be 1028 mgC $m^{-2}d^{-1}$. Finally, two measurements were made in November with a mean production of 88 mgC $m^{-2}d^{-1}$. When calculating the annual production, the lack of measurements in September and October was annoying. A fictiuous value was therefore created: October 1, 300 mgC $m^{-2}d^{-1}$. This value, like other fictitious values needed for calculating the annual production, is based upon four years of persoanl experience of work in the Baltic. When calculating the quarterly and annual production, three more fictitious values were used (Jan. 1; 30 mgC $m^{-2}d^{-1}$, Dec. 1; 40 mgC $m^{-2}d^{-1}$ and Dec. 31; 30 mgC $m^{-2}d^{-1}$).

The annual primary production at station 1 was calculated to be 132 gC m^{-2}.

Station 2, east of Gotland: 27 measurements were made in 1976 (table 4 and fig. 5). This is the highest number of measurements made in a year at any station during the whole programme. The first measurement of the year was made in late January (Jan. 30), and the daily primary production was found to be 43 mgC $m^{-2}d^{-1}$. No measurements were made in February. In March, three measurements were made, with a mean production of 85 mgC $m^{-2}d^{-1}$. Two measurements were made in April, with a mean production of 116 mgC $m^{-2}d^{-1}$. The peak of the vernal bloom was found on the next measuring occasion (May 6; 765 mgC $m^{-2}d^{-1}$). Altogether four measurements were made in May, with a mean value of 566 mgC $m^{-2}d^{-1}$. In early June (June 3) a production value of 236 mgC $m^{-2}d^{-1}$ was found. This low value was a typical "early summer minimum" value, probably due to a lack of nutrients created by the vernal bloom. The minimum can also be a result of intense grazing. In the second half of June and in July, a total of six measurements were made. The production on these six occasions varied between 318 and 467 mgC $m^{-2}d^{-1}$, with a mean of 382. Two measurements made in the beginning of August (Aug. 5 and 12) had a mean production of 487 mgC $m^{-2}d^{-1}$, while two measurements in the second half (Aug. 18 and 26) had a mean value of 638. Two measurements from September and one from the first of October had a mean primary production of 405 mgC $m^{-2}d^{-1}$. Measurements were made at the end of October (Oct. 29) and in the middle of November (Nov. 12). The production on these occasions was around 45 mgC $m^{-2}d^{-1}$. The last measurement of the year was made in December (Dec. 9). The daily primary production was then found to be only 6 mgC $m^{-2}d^{-1}$. However, December 9th was a very dark day. When calculating the quarterly and annual production, two fictitious values were used (Jan. 1 and Dec. 31; 30 mgC $m^{-2}d^{-1}$).

The annual primary production at station 2 was calculated to be 87 gC m^{-2}.

Station 3', the Åland Sea: 22 measurements were made in 1976 (table 5 and fig. 5). At the time of the first measurement of the year, in the middle of January (Jan. 15) the primary production was only 8 mgC $m^{-2}d^{-1}$. Due to ice cover in the archipelago and drifting ice at sea, no measurements was made until the beginning of April (Apr. 8). The production on this occasion was 277 mgC $m^{-2}d^{-1}$. One more measurement was made in April, but the primary production gears were lost on this occasion. Five measurements were made in May with a mean production of 265 mgC $m^{-2}d^{-1}$. The highest value of these five was 397 mgC $m^{-2}d^{-1}$ and was found on May 12th. In June three measurements were made. The production found on these occasions was even, with a mean value of 234 mgC $m^{-2}d^{-1}$. In July four measurements were made, and the production varied between 308 and 432 mgC $m^{-2}d^{-1}$, with a mean of 369. Unfortunately no measurements were made in August. Three measurements were made in September, but the gears were lost on one occasion. The two remaining values from September were even, with a mean of 395 mgC $m^{-2}d^{-1}$. Two measurements from October showed a trend for a decrease in the primary production (Oct. 7 and 20; 132 and 41 mgC $m^{-2}d^{-1}$ respectively). A measurement in November (Nov. 12) gave a production of 17 mgC $m^{-2}d^{-1}$. The last measurement of the whole four year long programme was made on December 18th. The production found on this occasion was the lowest found during the four years, with a value of only 1 mgC $m^{-2}d^{-1}$. When calculating the annual production the lack of measurements in February and March was annoying. Therefore a value was created: March 31; 50 mgC $m^{-2}d^{-1}$. Two more fictious values were used (Jan. 1 and Dec. 31; 10 mgC $m^{-2}d^{-1}$).

The annual primary production at station 3' was calculated to be 65 gC m^{-2}.

The quarterly primary production has been calculated in order to make it easy to compare the results from different parts of the year (table 6). It must be pointed out that quarters are an artifical division of biological results. No better division except months, however, has been found.

Table 6. Quarterly and annual primary production in gC m^{-2} at station 1 - 3' in 1976.

Station No.	I	II	III	IV	Total
1	6	45	71	10	132
2	5	35	40	7	87
3'	2	24	36	3	65

The contribution of the second quarter was 34 - 37 %. The most productive quarter of the year was the third, at all stations. This is the same situation as for 1973-75. The production in July-September was estimated to be 46 - 55 % of the annual production. The production from the second and third quarter was consequently 86 - 92 % of the annual production. The contribution to the annual production by the months January-March and October-December was thus comparatively small.

Chlorophyll a

The results of the chlorophyll a measurements are shown in tables 3 - 5 and in figure 6.

At station 1, the amount of chlorophyll a in the uppermost 15 m varied between 5 and 20 mg m^{-2} for most of the year. However, during the vernal bloom, values of about 30 mg m^{-2} were found. Compared with stations 2 and 3', the amount of chlorophyll a at station 1 was lower, except at the end of the year.

At station 2, it was impossible to measure the samples from the first quarter of the year, due to a precipitate in the cell of the photometer. The missing values were certainly low, as the chlorophyll a values on the two measuring occasions in April were only about 10 mg m^{-2}. In the beginning of May (May 6) a conspicuous peak value of 72.8 mg m^{-2} was found. This peak for the chlorophyll a content coincides with the primary production peak and the peak for the phytoplankton biomass. This chlorophyll a peak is the highest recorded at this station during the whole investigation. From then until the end of October, the values varied between 9 and 36 mg m^{-2} with a mean of 22. At the end of the year low values of around 7 mg m^{-2} were recorded.

At station 3' large amounts of chlorophyll a were found in April and in the beginning of May. A peak value of 80.7 was found in May (May 6). This is the highest amount of chlorophyll found at any station during the whole programme. Subsequently, the amount of chlorophyll fluctuated almost in accordance with the primary production fluctuations. The mean amount of chlorophyll a during

during this period was 23 mg m^{-2}. However, a remarkable peak of 50.9 mg m^{-2} was observed on September 23rd.

Phytoplankton

The phytoplankton biomass and the composition of the flora on each sampling occasion are shown in figure 7 and tables 3 - 5 and 7 - 9.

At station 1 (table 7), the phytoplankton biomass was less than 1 g m^{-2} during the first quarter of the year. However, in April (Apr. 20), on the same day as the maximum value for spring production was recorded, an abundant biomass was sampled. The biomass was as much as 98.3 g m^{-2}, and 98 % consisted of monads and flagellates. This biomass is the highest found in the whole investigation. Only six days later (Apr. 26) the biomass was reduced to 10.4 g m^{-2}. During the rest of the year the biomass fluctuated around 2.5 g m^{-2}.

During the first quarter, the biomass was mainly composed of bluegreen algae, diatoms, monads and flagellates. During the second quarter diatoms, monads and flagellates were most important. *Skeletonema costatum*, *Chaetoceros wighamii* and *Thalassiosira baltica* were the dominating diatom species. From June to August, monads and flagellates were most important, though large amounts of bluegreen algae occurred in July and Agust. *Nodularia spumigena* and *Aphanizomenon flos-aquae* were dominant in the beginning of August but did not develop massblooms. The temperature, which did not exceed 16 °C, was probably the limiting factor. At the end of August, however, when the temperature was 17 - 17.5 °C no *Nodularia spumigena* was obtained, which is in contrast with the results from previous years. At the end of the year diatoms were most abundant, being represented mainly by *Cosinodisius granii*.

At station 2 (table 8), low phytoplankton biomass values were recorded from January until April. However, in May (May 6), on the same day as the maximum spring production was recorded, a peak for the phytoplankton biomass was also recorded. The peak value was 38.9 g m^{-2}. This is by far the highest biomass ever recorded at this station in this investigation. A very fluctuating biomass was recorded from this occasion onwards until the beginning of August. The biomass varied between 0.4 and 30.4 g m^{-2} with rapid changes. During the last quarter, low biomass values were found.

Diatoms made up 90 % of the large biomass on May 6th. *Chaetoceros wighamii*, *Skeletonema costatum* and *Achnantes taeniata* were the important species. In one week *Achnantes taeniata* disappeared and *Chaetoceros wighamii* was reduced to half of abundance. In the middle of May the dinoflagellate *Gonyaulax catenata* was the most important species. June and July were, as mentioned above, characterized by a small biomass interrupted by blooms of monads and flagellates. During this period *Chaetoceros subtilis*, *Ebria tripartita* and *Aphanizomenon flos-aquae* also had minor blooms. Bluegreen algae had their annual maximum in August. During the rest of the year monads and flagellates dominated the flora, though diatoms like *Actinocyclus octinarius* and *Chaetoceros danicus* displayed peak values in October and November.

At station 3' (table 9), samples were taken on only one occasion (Jan. 15) during the first quarter. The biomass on this occasion was only 0.1 g m^{-2}. In April and May, rather high biomass values were recorded. The biomass varied between 12.0 and 35.5 g m^{-2} with a mean value of 23 g m^{-2}. In June and July, the biomass was smaller and fluctuated around 7 g m^{-2}. During the rest of the year mainly low values were recorded.

In April, the dinoflagellate *Gonyaulax catenata* had an early bloom. This species decreased in number in late April, but reappeared in a second bloom in May. Diatoms like *Thalassiosira baltica*, *Skeletonema costatum* and *Chaetoceros wighamii* were also numerous in April and the beginning of May. During the rest of the year monads and flagellates dominated the flora. However, in the autumn, bluegreen algae such as *Aphanizomenon flos-aquae* and *Nodularia spumigena* and some diatoms were of some importance.

Zooplankton

a. Composition and biomass of the zooplankton fauna.

At station 1 in the Hanö Bight, the net hauls were made from 30 m to the surface. Due to unfortunate circumstances, the sampling in 1976 was temporarily unevenly distributed. Consequently, a description of the annual cycle of species, biomass and production is difficult.

During the winter, only one sample was taken (Febr. 2). The dominant species were the copepods Pseudocalanus m. elongatus and Acartia longiremis, which together constituted more than 90 % of the total biomass (fig. 9). Practically all specimens of Pseudocalanus were in stage C. IV - V and the population of Acartia was dominated by adult females and nauplii. These results are well in agreement with previous experience (Hernroth - Ackefors, in print) viz. P. m. elongatus mainly overwinters as stage C. IV - V and the reproduction of Acartia spp. starts in February - March.

The months of April, May and early June were well represented with samples (fig. 8). During this period P. m. elongatus was still the most important species (fig. 9) but as the water temperature started to rise, its importance gradually decreased. Other copepods of significance were Acartia spp., Temora longicornis and to some extent Centropages hamatus. The appendicularian Fritillaria borealis acuta was found on all sampling occasions and was extremely abundant at the end of May (500 000 ind. m^{-2}). The relative importance of the different species during this period was almost identical with that found during the corresponding period in 1975 (Lindahl 1977). However, the mean biomass was higher in 1976 compared to 1975 (8.7 and 3.0 g m^{-2} wwt resp.).

During the summer and early autumn no samples were taken. The only sampling that occurred during the second half of the year took place on November 2. As was the case in 1975, Acartia spp. was now the dominant species followed by Temora longicornis, Pseudocalanus m. elongatus and Centropages hamatus. The biomass (5.9 g m^{-2}) was somewhat higher than in the corresponding period in 1975 (4 g m^{-2}).

Station 2 has, in contrast to station 1, been covered extremely well during 1976. Samples have been taken on 21 different occasions and all months except February have been represented. As was described previously (Lindahl 1977), station 2 is deeper (55 m) than station 1 (30 m) and the biomass was therefore somewhat higher. The difference is mainly caused by the copepod Pseudocalanus m. elongatus, which at station 2 has the possibility of remaining in cold water throughout the year.

The composition of species at station 2 (fig. 10) is rather similar to that at station 1 (cf. fig. 9 and Lindahl 1977). During the winter, when the whole water-mass is cold (1 - 3 °C) the fauna is totally dominated by the two species Pseudocalanus m. elongatus (C. IV - V) and Acartia longiremis (♀♀). These species constituted more than 90 % of the whole biomass which was in the range of 2.7 - 6.7 g m^{-2} (wwt).

In May, the water temperature started to rise and so did the number of nauplii from Pseudocalanus and Acartia. A maximum for both species was reached by the end of May with 180 000 nauplii per m^2 for Acartia and 360 000 for Pseudocalanus. A third very important zooplankton species also occurred during the spring e.g. Fritillaria borealis acuta. This species was very abundant from the beginning of May until the end of June. The maximum abundance occurred in the middle of May when it constituted as much as 60 % of the total biomass. In June, when the surface temperature had reached 8 - 11 °C, a few other species such as Synchaeta spp. and Evadne nordmanni began to appear abundantly. The total biomass during the second quarter of the year was in the range of 2 - 24 g m^{-2} with a mean of 9.6 g m^{-2} (wwt).

During the summer, the relative importance of Pseudocalanus m. elongatus decreased and instead, two typical summer copepods, Temora longicornis and Centropages hamatus began to appear in great numbers. These species also had their main reproduction during the summer months. Nauplii of Temora were abundant from the middle of May until the middle of September with a maximum of 105 000 ind. m^{-2} in mid-August. The nauplii of Centropages were more confined to the period of maximum surface temperature viz. August and early September. The main increase in the number of cladocerans usually takes place during the summer. This was also the case at station 2 in 1976. Both Evadne nordmanni and

Podon intermedius were abundant. However, the most important cladoceran was Bosmina cor. maritima, which was extremly abundant from the end of August until the end of September. The maximum occurred in the beginning of September when no less than 2.2 milj. ind. m^{-2} were found! This is well in accordance with facts stated by Hernroth & Ackefors (in print), that the maximum abundance of B. cor. maritima usually occurs a few weeks after the maximum water temperature in the area has been reached. If the temperature at that time exceeds 15 - 16 °C, the occurrense of B. cor. maritima can be very abundant. The total biomass during the third quarter was in the range of 19 - 48 g m^{-2} with a mean of 24.7.

During October, November and December, the importance of both the cladocerans and the copepod Centropages hamatus decreased rapidly. The majority of the fauna consisted of Pseudocalanus m. elongatus, Acartia spp. and to some extent Temora longicornis. The total biomass during this period also decreased, the range being 6 - 15 g m^{-2} with a mean of 9.5.

At the most northerly station, 3', the composition of the fauna was quite different from that at the two other stations (fig. 11). The low salinity (5.5 - 6.0 ‰) and the shallowness of the station (40 m) obviously prevent the development of any larger population of species like Pseudocalanus m. elongatus, Acartia longiremis, Centropages hamatus and Fritillaria borealis acuta. On the other hand, the conditions are favourable for such species as Eurytemora sp. and Limnocalanus macrurus.

The sampling at station 3' was also very dense in 1976. In the middle of January, just before ice developed, one haul was made. On this occasion, the major constituents of the fauna were Eurytemora sp. and Acartia bifilosa. Eurytemora was mostly represented by over-wintering stages C. IV - V and A. Bifilosa as nauplii. Some specimens of Limnocalanus macrurus were also present. The total biomass was small, only 2.6 g m^{-2} (wwt).

At the next sampling occasion, in the beginning of April, a dynamic period had obviously started. The build-up of a first generation of Acartia bifilosa was in full progress, with a high number of nauplii. The spring development of Synchaeta sp. had just started and the development of Eurytemora C. IV - V into adults had taken place. Occasional specimens of Fritillaria borealis acuta were also present. On the sampling occasions in May and early June the above mentioned process was very well represented. The first generation of Acartia bifilosa was thus fully developed by the beginning of June. The first generation of Eurytemora sp. started to develop in the latter part of May and was fully developed by the end of June. The rotifer Synchaeta sp. was important all through spring and its maximum (1 mil. ind. m^{-2}) was reached by the end of June when the water temperature was roughly 9 °C. From the end of May onwards, two additional components in the fauna became significant viz. Evadne nordmanni and larvae of bivalves. The total biomass during the second quarter of the year was in the range of 0.6 - 6.4 g m^{-2} with a mean of 3.0.

In July, the total biomass increased rapidly (fig. 8). The main reason for this was the growth of the second generation of Acartia bifilosa. This generation was initiated in the latter part of June and the maximum biomass of the population was reached a month later, when most specimens had developed into copepodite stages IV - VI. The growth of the second generation of Eurytemora sp. occurred about four weeks later than that of A. bifilosa. The maximum biomass of the Eurytemora population was found in early September but the lack of samples from August makes it impossible to determine whether this was the true maximum or not. Synchaeta sp. was still important in the beginning of July but when the water temperature rose above 11 - 12 °C its abundance decreased. Not until the water started to cool off by the middle of September did the abundance start to increase again.

The cladocerans were relatively unimportant at station 3' although the number of species was high. Evadne nordmanni occurred all through the summer and early autumn and so did Pleopsis polyphemoides and Bosmina cor. maritima. The population of B. cor. maritima never reached any great abundance, probably because the summer water temperature was too low. A few specimens of Podon leuckarti appeared in mid-July and Podon intermedius was present from the beginning of September until the beginning of October.

From the beginning of September onwards the growth of a new generation of both Acartia bifilosa and Temora longicornis was obvious. For A. bifilosa this was the third generation of the year and its maximum biomass was reached by the beginning of November. For T. longicornis, this was the first noticable generation of the year in the area. Adults started to appear at the end of July and nauplii at the beginning of September. The development was obviously rather slow since the maximum biomass for the population was not reached until the end of October. Due to the comprehensive development of copepods during the third quarter of the year the total biomass was high. The range was 10.7 - 34.9 g m^{-2} and with a mean of 22.4.

During the last three months of the year the water temperature gradualy decreased from approx. 10.5 to 3.5 ^{o}C. Both the rotifers and the cladocerans were now of negligible importance and the fauna was dominated by the copepods Acartia bifilosa, Eurytemora sp. and Temora longicornis. At the end of the year a small population of Pseudocalanus m. elongatus was also present. For A. bifilosa this was the above mentioned third generation. For Eurytemora sp. this was also the third generation, which started to grow in late September and was fully developed by November - December. The population of T. longicornis exhibited, as above mentioned, long lasting and slow growth, which occurred from the end of July throughout the autumn. The total biomass during the last quarter of year was in the range of 1.9 - 12.5 g m^{-2} with a mean of 8.2.

b. Zooplankton production

The zooplankton production has been calculated according to the method described by Winberg (1971). This method uses the ratio of production to biomass, the so called P/B coefficient. This coefficient is specific for each species and is influenced by both water temperature and the developmental stage of the specimens. Consequently, the coefficient does not remain constant, but represents only a certain mean value, true for a defined period of time only. The calculations made in this paper must only be regarded as a rough estimate, since some of the P/B coefficients are literature values calculated from rather different environments.

In 1976, no calculation of the annual production at station 1 was made. The heterogeneous sampling activity makes it difficult to apply the Winberg method in this case. However, at stations 2 and 3' the sampling activity was very intense and the results are therefore well suited for production estimates.

At station 2 east of Gotland, the production during the winter months February, March, April and in the beginning of May was low and stable (4 - 7 mgC $m^{-2}d^{-1}$, fig. 12). As the water temperature started to rise in the end of May, new generations of copepods started to develop and consequently, the production rapidly increased. There was a steady increase during June, July and the first part of August. The production was then in the order of 60 - 70 mgC $m^{-2}d^{-1}$. These results are in good agreement with the situation found during the same period in 1975. The results from September and October however, indicate extremely large differences between the years. In 1976, an explosive development of *Bosmina cor. maritima* was noted from the end of August until the end of September. During this period *B. cor. maritima* produced approx. 4 gC $m^{-2}d^{-1}$. In 1975, one sample was taken in the beginning of September and the next in the middle of November. The long interval between samples made the calculations of production very uncertain and this probably led to an underestimation of the production during September-October 1975 (cf. Lindahl 1977). If the sampling had been carried out more frequently during this period, it is likely that a high abundance of *B. cor. maritima* and thus a high production, would have been found. In November-December, when the importance of *Bosmina* was negligible, the zooplankton production rapidly decreased to values in the range of 10 - 30 mgC $m^{-2}d^{-1}$.

The annual zooplankton production at station 2 was estimated to be 14 gC m^{-2} (268 g wwt).This is twice as much as was found in 1975 but the low value from 1975 is most probably due to the lack of samples from September-October which is an extremely important zooplankton period in the Baltic proper.

At station 3' the winter values for zooplankton production were low (< 5 mgC $m^{-2}d^{-1}$, fig. 12). During April and early May, there was a well defined period of high production (15 - 30 mgC $m^{-2}d^{-1}$)

caused by a rapid increase in the population of the rotifer Synchaeta spp. This period was not found in 1975 for the simple reason that the sampling did not start until the end of May. During June and July the copepods began to develop rapidly. The rotifers were still relatively important and the number of cladocerans increased. Combined, these circumstances caused a steep increase in daily production from about 10 mgC $m^{-2}d^{-1}$ in the beginning of June to 115 mg in the middle of August. In August and September, the majority of the large production was caused by the development of copepods, Acartia bifilosa and Eurytemora sp. in particular. Compared with 1975, the summer production in 1976 was almost twice as high. The lower sampling activity during the same period 1975 may be one of the reasons for the diverging results. Another reason may be the fact that the production actually was higher during the summer of 1976. During the autumn the production rapidly decreased and by November-December the rate was about 10 - 20 mgC $m^{-2}d^{-1}$.

The annual production at station 3' was estimated to be 14 gC m^{-2} (268 g wwt). This is twice as much as was calculated for the period June-November 1975. The explanation for the differing results is probably found in the longer period of investigation (January-December) which included the spring rotifer production, a higher sampling frequency and an eventual higher summer production in 1976.

SUMMARY OF THE RESULTS FROM THE PERIOD 1973-76

When summarising the results obtained during the period 1973-76, some general characteristics of the different areas are evident. However, the conclusions must be considered as preliminary, since the lack of both time and personnel has prevented the author from doing any analyses of separate mechanisms within the plankton community. More detailed results from 1973-75 can be found in Ackefors & Lindahl 1975a, 1975b and Lindahl 1977.

Temperature and salinity

The temperature fluctuations during the four years showed roughly the same seasonal pattern. The temperature began to rise in April or in the beginning of May. The rise in temperature occurred later, the further to the north the station was situated. The maximum water temperature was reached in August or in the beginning of September. The annual maximum temperature at the Sydostbrotten and Åland Sea stations was about 2 °C lower than at the Gotland and Hanö Bight stations. The years 1974 and 1976 were the coldest, with maximum temperatures around 14 - 18 °C, while 1975 was the warmest, with maximum temperatures around 16 - 22 °C. The water temperature in 1973 had values intermediate to those from the other years.

No notable changes in the salinity of the water down to 20 m depth were detected during the four year study. The following mean salinities (0 - 20 m) were estimated: the Hanö Bight; 7.5 ‰, east of Gotland; 7.7 ‰, the Åland Sea; 5.9 ‰ and the Sydostbrotten area; 4.5 ‰.

Primary production

The quarterly and annual primary production at stations 1 - 4 in the period 1973-76 can be studied in tables 11 and 12 and in figures 13 - 15.

Table 11. The quarterly primary production in gC m^{-2} at stations 1 - 4 from 1973-76.

Station	1973				1974				1975				1976			
no.	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	6	34	53	12	8	50	54	9	9	36	73	14	6	45	71	10
2	4	25	50	12	6	37	64	9	6	38	42	10	5	35	40	7
3	8	37	41	8	7	27	-	-	-	-	-	-	-	-	-	-
3'	-	-	-	-	-	-	-	-	4	23	34	6	2	24	36	6
4	3	29	36	4	-	17	47	6	-	-	-	-	-	-	-	-

Table 12. The annual primary production in gC m^{-2} at stations 1 - 4 from 1973-76.

Station no.	1973	1974	1975	1976
1	105	121	132	132
2	91	116	96	87
3	94	-	-	-
3'	-	-	67	65
4	71	70	-	-

Looking at table 12, it is obvious that the annual primary production was lower, the further to the north the station was situated. Likewise, the highest rates of photosynthesis were found at the most southern station and decreased towards the north (fig. 14 and 15). The vernal bloom of the phytoplanktons was in general delayed, the further to the north the station was situated.

As mentioned above, the highest production was found at the most southerly station i.e. station 1 in the Hanö Bight. The annual production varied between 105 and 132 gC m^{-2} with a mean of 123. As can be seen in table 12, there was a trend towards increasing primary production at this station during the period of investigation. No such trend was found at any of the other stations. It is doubtful, however, if this increase is statistically significant. The high annual production in 1975-76 (132 gC m^{-2}), was caused mainly by an increase in the production in the third quarter. Upwelling occurs occasionally in the area (Thompson, Udin & Omstedt 1974). This could explain the higher production at this station. Another possible explanation for the high primary production in the area is the outflow of nutrients from the coasts of Skåne and Blekinge. The Nymölla papermill, for instance, discharges more than 100 kg of phosphate each day. (County Government Board of Kristianstad, pers.comm.) However, the most probable explanation for the high production at station 1 is a combination of upwelling and a large supply of nutrients. This leads to the conclusion that the calculated primary production values are valid for the Hanö Bight and restricted surrounding areas only, and not for the whole southern Baltic.

Station 2, east of Gotland, was probably the station with the most pronounced off-shore characteristics. However, according to Thompson, Udin & Omstedt (1974) upwelling occurs occasionally along the east coast of Gotland. This would certainly increase the production to some extent. The calculated annual primary production was rather consistent during the four years, and varied between 87 and 116 gC m^{-2}, with a mean of 95 (tabl. 12). That is a production about 20 % lower than at station 1. As most of the parameters measured were in approximately the same range at stations 1 and 2, the difference in production might be a result of less nutrients in the water east of Gotland. The largest divergence from the annual mean value occured in 1974. This divergence was caused entirely by an increase in the production during the third quarter (tab. 11 and fig. 13 and 14). In 1973-74 the production was much higher in the third quarter than in the second. However, in 1975-76 the production was more stable, when comparing the second and third quarters. At station 1, the situation was the opposite during the same period. No reasonable explanation for these results has been found.

In 1973, the measurements in the Åland Sea were made at station 3. The annual production found during this year (94 gC m^{-2}) was of the same magnitude as at station 2,east of Gotland (tab. 12). Compared with 1973, the first and second quarters of 1974 showed a lower production (tab. 11, fig. 13 and 15). Unfortunately, no more results are available from 1974, making it impossible to say whether the whole annual production in 1974 was also lower.

Station 3 was moved 25 nautical miles NNW at the end of 1974, due to practical reasons. The primary production in 1975-76 at this new station (called 3'), was considerably lower compared with that found in 1973 at station 3. The mean annual production at station 3' in 1975-76 was 66 gC m^{-2}. However, it is impossible to find out whether these lower values were caused by the transfer of the station, or by any other factor. Although the Åland Sea is known as a hydrographically restless area, the results from 1975-76 were suprisingly consistent.

In the Sydostbrotten area, measurements were made only in 1973-74. The annual primary production was similar in these two years, but the quarterly distribution of the production differed great-ly during the same years (tab. 11 and 12 and fig. 15). Consequently, it is hard to say whether station 4 was representative for the area and if 1973-74 were representative years or not. It is interesting to compare the annual production found in 1973-74 (71 and 70 gC m^{-2} resp.) at station 4, with the values found in 1975-76 (67 and 65 gC m^{-2} resp.) at station 3'. The values are nearly in accordance although the stations were situated far away from eachother. However, the comparison may be deceptive as the values are for different years.

Discussion of the methods and materials used for measuring primary production

When studying primary production results, there are some very fundamental problems which have to be considered. These problems are always discussed among scientists working with primary production. Many of the problems, demand scientific, technical, practical and economical solutions at the same time. This is especially true when work is carried out off-shore from small vessels. Therefore, some of the methods used during this investigation are perhaps a little questionable, from a theoretical point of view. However, when the programme was planned, no other methods were available, or practical reasons determined the methods which were used. It was also decided at the start of the programme not to change methods during the programme, if the change could cause differences in the results. Some of the problems and their solutions will be discussed below.

In this investigation, the *in situ* technique for measuring primary production was chosen as the only method possible. An incubation time of half a light-day (from sunrise to true noon or from true noon to sunset) is recommended by Dybern *et al.* (1976). However, it was impossible to follow this recommendation due to both practical and economical reasons. Instead, an incubation time of four hours had to be used. The calculations used when transforming the four hour values into daily production values are described in methods and material. However, some comments based upon the author's experience can be offered concerning the four hours method.

The four hours method seems to give almost reasonable values as long as the irradiance is not so low, that an inhibition of the production in the surface water can be observed. However, on days with very varying irradiance and on dark days (irradiance less than 150 mWh $cm^{-2}d^{-1}$) the method seems to be less accurate. The lightfactor can, under such circumstances, attain absurd values. Furthermore, the method probably over-estimates the production on very light days. The main advantage of the method is that it is simple. However, the author of this paper believes that more sophisticated methods have to be used if the results are to accord with the true production.

The measurement of primary production using the *in situ* technique, is very much dependant upon good weather when using small ships, like the rescue cruisers used in this investigation. It soon became apparent that it was not possible to make correct measurements when the wind speed exceeded 6 - 8 m s^{-1}. As a result, most of the measurements were made on days with rather calm weather. It is unfortunately impossible to estimate how this has influenced the annual primary production values.

In order to acquire solid knowledge about the primary (and secondary) production, it is very important to make frequent measurements. Each measurement is normally expensive, but as the absence of a measurement at a productive time of the year is devastating, no efforts should be spared in making as many measurements as are financially possible. In order to acquire fairly accurate annual values for the Baltic, the author recommends the following measuring frequency:

Apr. and May	: every week
March, June, July, Aug., Sept. and Oct.	: every second week
Jan., Feb., Nov. and Dec.	: every third week

The above recommendation may perhaps be too ambitious, but it should be remembered that the weather and many other factors, impossible to predict, may obstruct even the most ambitious scientist, and reduce the number of measurements. The lack of measurements during dynamic periods in the plankton community is certainly the reason why several results in this investigation are hard to understand and explain.

When the programme was started in 1973, the only technique available at the Institute of Marine Research, for measuring the radioactivity of the algaes on the filters was the Geiger-Müller (GM) counting technique. However, the GM-technique has been much criticized due to low efficiency when used in primary production studies. The liquid scintilation (LS) technique is preferable because of the much higher counting efficiency. An investigation carried out at the Askö Laboratory has shown that the GM-technique gives about 30 % lower annual primary production values compared with the LS-technique. (Larsson 1977). On the other hand, it has been found that the GM-technique can give the same results as the LS-technique, when diatoms dominate the flora. This has been found specifically for fresh water diatoms (Brattberg & Lindahl, 1977). Several new methods now being developed for measuring the radioactivity of algaes incubated in ^{14}C-experiments, will certainly provide better solutions for the problems (Larsson 1977).

Chlorophyll a

It is difficult to link the fluctuations of the chlorophyll a values with the variations in phytoplankton biomass during longer periods. There are no distinct correlations between chlorophyll a and primary production values either, for more than short periods of time. The reason for these results is that when the composition of the flora, the supply of nutriants or the irradiance are althered, the relationship between chlorophyll, biomass and primary production will also be altered. Such changes in the flora can take place in a very short period (cf. p. 12 and 13). However, some general comments upon the chlorophyll a values found in this investigation will be given below.

The amount of chlorophyll a increased the further to the north the station was situated. In 1975-76 for instance, the amount of chlorophyll was almost twice as high at station 3' than at station 1. The maximum values each year were always found during the vernal bloom. A second, but much lower maximum was normally found in August or September. At all stations, higher amounts were found in 1975-76 than in 1973-74. This result, however, may depend upon the change of filters, which took place at the turn of the year

1974-75. The filters were changed from Millipore Cellotate to Whatman GF/C.

Phytoplankton

It would be too far-reaching to describe in this summary the succession of different phytoplankton species. Most of the species were, in general, found at predicted times and in predicted areas. Bluegreen algaes, diatoms, dinoflagellates, monads and flagellates have been, more or less, the dominating algae groups at all stations.

The phytoplankton biomass fluctuations have been characterized by rapid changes. Several of the conspicuous peaks have consisted of almost one species (cf. p. 12), having a short but very intense bloom. Consequently, it is very difficult in short, to describe the biomass variations. However, at all stations in almost every year one common result was observed, viz. the biomass has its maximum during the vernal bloom. This biomass maximum was probably partly caused by the absence of intense grazing, as the zooplankton abundance always was low during the vernal bloom of phytoplankton.

Zooplankton

The study of zooplankton was added to this investigation only during the last two years. A summary of results will therefore cover only the years 1975 and 1976. A more through investigation of the zooplankton fauna of the Baltic proper has been presented by two other members of the Institute's production department (Hernroth & Ackefors, in print).

In comparison with the results obtained in that investigation, it is obvious that station 2 (east of Gotland) and 3' (Åland Sea) represent rather well the middle and northern Baltic proper respectively. The composition of species and the biomass values are in good accordance with the results presented by Hernroth & Ackefors. However, station 1 in the Hanö Bight can not be called representative of the southern Baltic proper. The biomass values were much lower in the Hanö Bight and the composition of species was also somewhat different. The shallowness of the station (30 m) is probably the main reason for this discrepancy.

When summarizing the general impressions gained from this zooplankton study, it must be pointed out what a great influence on the results the frequency of sampling has. Although the dynamics of the zooplankton fauna is not as rapid as that of the plankton flora, long intervals between the sampling occasions cause great errors in the calculations of production and seasonal variation. Sampling intervals of longer than two weeks can not be recommended during the productive period of the years.

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Table 2. Irradiation in mWh cm^{-2} at station 1 - 3' in 1976.

MONTH	Station 1 (Hörvik)	Station 2 (Herrvik)	Station 3' (Öregrund)
January	1 873	1 732	920
February	2 607	2 617	2 376
March	7 969+	6 803	6 331
April	11 439	11 728	11 098
May	15 187	15 218	14 596
June	18 433	18 273	18 405
July	16 732	17 445	16 509
August	15 160	15 840	14 476
September	7 898	8 088	7 471
October	2 405+	3 110	3 098
November	1 806+	1 271	839
December	1 132+	791+	493+
QUARTER			
I	12 449	11 152	9 627
II	45 059	45 219	44 099
III	39 790	41 373	38 456
IV	5 343	5 172	4 430
YEAR	102 641	102 916	96 612
ANNUAL MEAN	Svalöv	Visby	Erken
1961-1975	101 139	107 115	96 486
DIFFERENCE			
1976	+ 1 %	- 4 %	± 0 %

+ values from SMHI

Table 3. Irradiation, measured production, calculated production, chlorophyll a, phytoplankton biomass and zooplankton biomass.

Station 1, 1976

Date	Irradiation mWh $cm^{-2}d^{-1}$	Measured production mgC $m^{-2}h^{-1}$ (0-20 m)	Calculated production mgC $m^{-2}d^{-1}$ (0-20 m)	Chlorophyll a mg m^{-2} (0-15 m)	Phytoplankton biomass g m^{-2} wwt (0-15 m)	Zooplankton biomass g m^{-2} wwt (0-30 m)
760202	23	4.0	23	5.6	0.1	5.5
760316	279+	14.6	111	7.9	>0.1	-
760323	298	12,7	98	7.3	0.2	-
760409	537	43.0	357	19.8	2.0	9.5
760415	231	25.9	210	-	-	13.8
760420	615	103.3	919	30.2	98.3	2.9
760426	607	73.8	635	32.4	10.4	6.7
760521	645	51.9	509	14.9	0.8	11.1
760604	636	62.1	509	22.5	2.1	8.1
760702	784	39.7	401	7.5	2.8	-
760805	497	81.6	1028	13.2	5.9	-
760830	470	125.2	1027	21.4	2.8	-
761102	13	11.7	85	13.0	2.1	5.9
761119	96	18.5	91	14.4	1.5	-

Calculated annual primary production: 132 gC m^{-2}

Calculated annual secondary production: -

+ SMHI value

Table 4. Irradiation, measured production, calculated production, chlorophyll a , phytoplankton biomass and zooplankton biomass.

Station 2, 1976

Date	Irradiation	Measured production	Calculated production	Chlorophyll a	Phytoplankton biomass	Zooplankton biomass
	$mWh\ cm^{-2}d^{-1}$	$mgC\ m^{-2}h^{-1}$ (0-20 m)	$mgC\ m^{-2}d^{-1}$ (0-20 m)	$mg\ m^{-2}$ (0-15 m)	$g\ m^{-2}$ wwt (0-15 m)	$g\ m^{-2}$ wwt (0-30 m)
760130	92	6.3	43	-	0.3	6.7
760311	231	8.7	64	-	0.9	2.7
760319	293	13.0	94	-	0.6	3.9
760324	266	10.9	98	-	0.1	6.8
760408	424	18.9	151	10.3	0.7	-
760414	112	12.0	80	9.5	0.3	5.9
760506	630	86.9	765	72.8	38.9	2.1
760512	371	47.2	552	35.9	22.8	3.5
760518	709	41.5	407	21.5	8.1	3.7
760525	658	56.0	538	33.9	3.8	10.2
760603	830	22.9	236	13.9	0.4	-
760618	691	40.5	417	26.1	0.9	17.8
760623	820	33.9	363	13.1	30.4	24.0
760702	794	33.1	341	9.0	1.6	-
760709	144	27.7	388	15.3	2.9	-
760715	750	48.1	467	13.8	5.8	22.0
760722	104	41.3	318	24.6	28.3	-
760805	691	52.4	482	24.4	22.2	22.6
760812	529	60.7	492	24.1	6.1	19.7
760818	575	73.7	656	31.7	8.9	23.0
760826	320	92.6	620	29.5	7.4	19.3
760909	152	53.6	354	25.1	8.3	48.2
760921	322	59.7	525	18.1	13.8	18.3
761001	243	45.6	337	21.1	7.2	15.4
761029	23	6.8	41	10.1	1.2	-
761112	59	9.4	48	8.5	0.7	6.1
761209	20	1.3	6	5.6	0.3	7.1

Calculated annual primary production: 87 $gC\ m^{-2}$

Calculated annual secondary production: 14 $gC\ m^{-2}$

Table 5. Irradiation, measured production, calculated production, chlorophyll a, phytoplankton biomass and zooplankton biomass.

Station 3', 1976

Date	Irradiation	Measured production	Calculated production	Chlorophyll a	Phytoplankton biomass	Zooplankton biomass
	mWh $cm^{-2}d^{-1}$	mgC $m^{-2}h^{-1}$ (0-20 m)	mgC $m^{-2}d^{-1}$ (0-20 m)	mg m^{-2} (0-15 m)	g m^{-2} wwt (0-15 m)	g m^{-2} wwt (0-30 m)
760115	26	1.6	8	10	0.6	2.6
760408	451	27.4	277	55.1	23.4	0.6
760421c	-	-	-	70.2	33.5	-
760506	473+	29.7	303	80.7	30.4	6.4
760512	437	41.4	397	47.8	18.0	2.7
760520	694	16.4	166	33.4	15.2	3.9
760524	722	24.2	249	26.3	12.0	2.0
760531	308	13.6	209	36.0	28.9	2.0
760608	654	16.9	220	19.8	8.9	3.0
760617	709	19.3	230	18.3	2.5	1.4
760622	590	23.4	253	16.1	12.1	4.8
760701	799	32.9	368	16.8	3.7	10.7
760712	748	27.3	308	16.5	3.8	14.7
760722	394	16.9	367	20.2	6.0	10.8
760726	508	37.2	432	26.1	8.7	34.9
760902	479	46.1	401	28.7	2.8	32.9
760915	21	-	-	27.3	2.2	27.2
760923	304	44.2	389	50.9	6.2	25.5
761007	161	23.1	132	17.1	1.4	11.6
761020	65	6.3	41	9.9	0.6	12.5
761112	6	3.6	17	9.2	1.8	6.8
761218	18	0.3	1	-	2.4	1.9

Calculated annual primary production: 65 gC m^{-2}

Calculated annual secondary production: 14 gC m^{-2}

+ SMHI

Table 7. The components of the phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt).

Station 1, 1976

Date	Blue-green algae	Diatoms	Dinoflagellates	Chrysophyceans	Green algae	Monads and flagellates	Total
	%	%	%	%	%	%	g m^{-2} wwt
760202	64	0	0	0	0	36	0.055
760316	29	45	0	0	0	26	0.042
760323	2	11	0	24	4	59	0.245
760409	5	77	0	3	0	15	1.957
760420	0	2	0	0	0	98	98.316
760426	0	82	0	1	0	17	10.435
760521	1	92	3	3	0	1	0.836
760604	0	37	6	4	0	53	2.118
760702	18	2	1	15	7	57	2.808
760805	28	4	20	8	2	38	5.928
760830	8	6	5	0	0	81	2.843
761102	8	73	6	1	0	12	2.106
761119	1	97	0	0	0	2	1.490

Table 8. The components of the phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt)

Station 2, 1976

Date	Blue-green algae	Diatoms	Dinoflagellates	Chrysophyceans	Green algae	Monads and flagellates	Total
	%	%	%	%	%	%	g m^{-2} wwt
760130	15	68	0	0	0	17	0.265
760311	2	4	0	0	0	94	0.888
760319	3	10	0	0	0	87	0.557
760324	19	27	0	0	0	54	0.133
760408	6	4	0	4	0	86	0.669
760414	7	14	0	55	0	24	0.322
760506	0	92	2	0	0	6	38.873
760512	1	87	5	2	0	5	22.805
760518	0	41	47	1	0	11	8.106
760525	1	61	11	3	0	24	3.830
760603	36	16	24	9	0	15	0.372
760618	3	36	27	14	0	20	0.863
760623	2	9	1	0	1	87	30.375
760702	11	50	19	13	2	5	1.628
760709	9	7	25	10	2	47	2.933
760715	7	7	0	30	0	56	5.804
760722	4	0	0	4	0	92	28.325
760805	11	0	0	2	0	87	22.243
760812	38	0	1	4	0	57	6.134
760818	29	0	0	0	0	71	8.876
760826	35	1	0	0	0	65	7.429
760909	4	2	0	4	0	90	8.317
760921	0	0	0	0	0	100	13.755
761001	0	26	0	2	0	72	7.209
761029	4	10	1	0	0	85	1.222
761112	10	65	0	0	0	25	0.726
761209	27	0	0	0	0	73	0.296

Table 9. The components of the phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt).

Station 3', 1976

Date	Blue-green algae	Diatoms	Dinoflagellates	Chrysophyceans	Greem algae	Monads and flagellates	Total
	%	%	%	%	%	%	g m^{-2} wwt
760115	10	85	0	0	0	5	0.619
760408	1	39	47	0	0	13	23.369
760421	0	73	5	1	0	21	33.460
760506	0	59	30	0	0	11	30.387
760512	0	11	78	0	0	11	18.008
760520	0	17	46	0	0	37	15.175
760524	0	1	47	0	0	52	12.006
760531	0	37	57	1	0	5	28.902
760608	0	19	36	0	0	45	8.890
760617	2	18	3	1	0	77	2.462
760622	0	5	2	0	0	93	12.144
760701	2	6	3	8	0	81	3.675
760712	1	4	0	2	0	93	3.808
760722	2	1	0	10	1	86	6.021
760726	5	0	0	5	0	90	8.660
760902	19	14	4	13	0	50	2.758
760915	19	24	1	3	1	52	2.245
760923	9	22	1	2	0	66	6.207
761007	20	19	2	0	0	59	1.363
761020	39	26	3	0	0	32	0.556
761112	5	6	0	11	0	78	1.841
761218	3	8	1	0	0	88	2.367

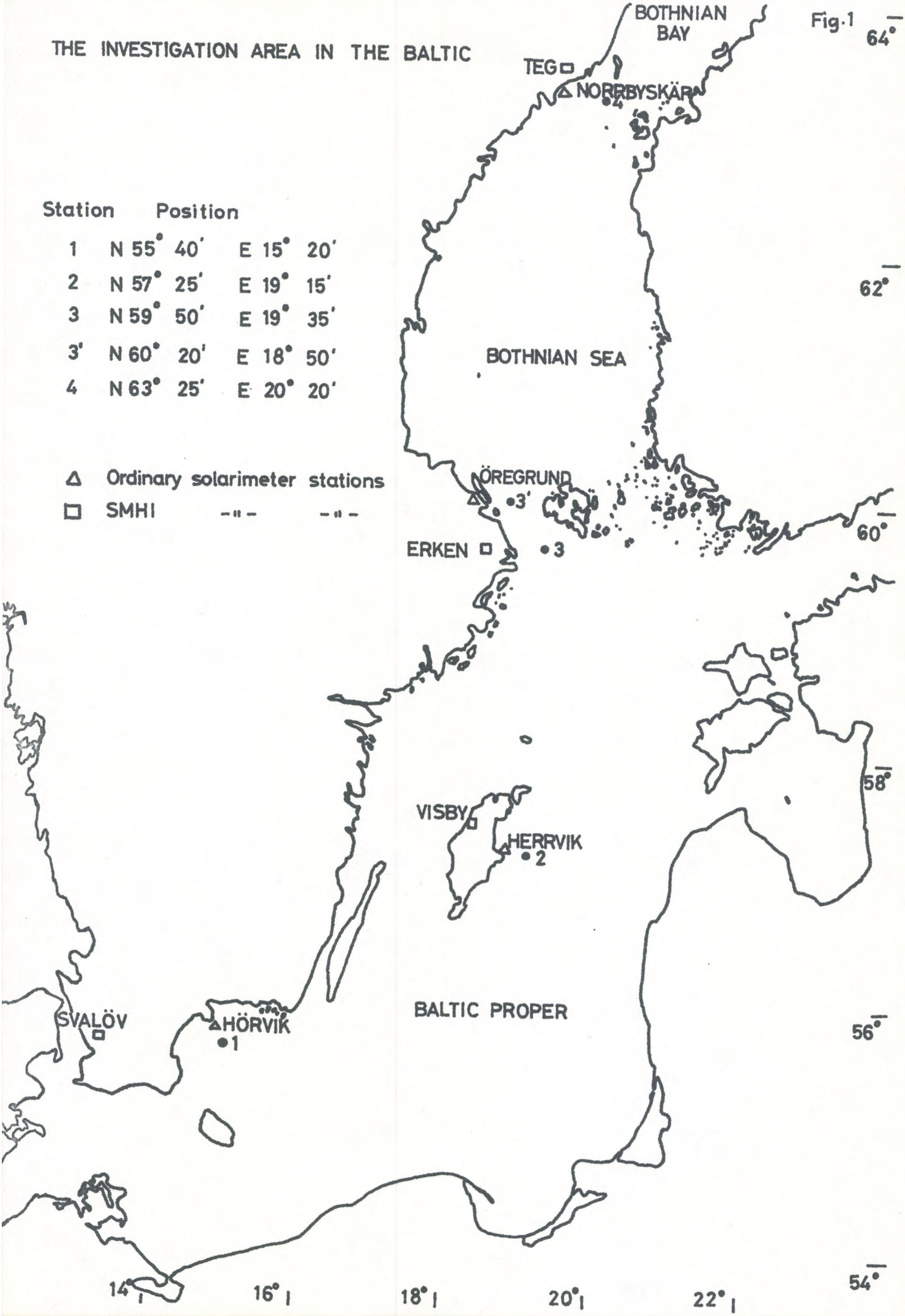


Fig. 1
THE INVESTIGATION AREA IN THE BALTIC
Station Position
1 N 55° 40' E 15° 20'
2 N 57° 25' E 19° 15'
3 N 59° 50' E 19° 35'
3' N 60° 20' E 18° 50'
4 N 63° 25' E 20° 20'
Δ Ordinary solarimeter stations
□ SMHI -"- -"-
BOTHNIAN BAY
TEG
NORRBYSKÄR
4
BOTHNIAN SEA
ÖREGRUND
3'
ERKEN
3
VISBY
HERRVIK
2
BALTIC PROPER
SVALÖV
HÖRVIK
1
64°
62°
60°
58°
56°
54°
14°
16°
18°
20°
22°

Fig.2

MEASUREMENTS CARRIED OUT IN 1973, 1974, 1975 AND 1976

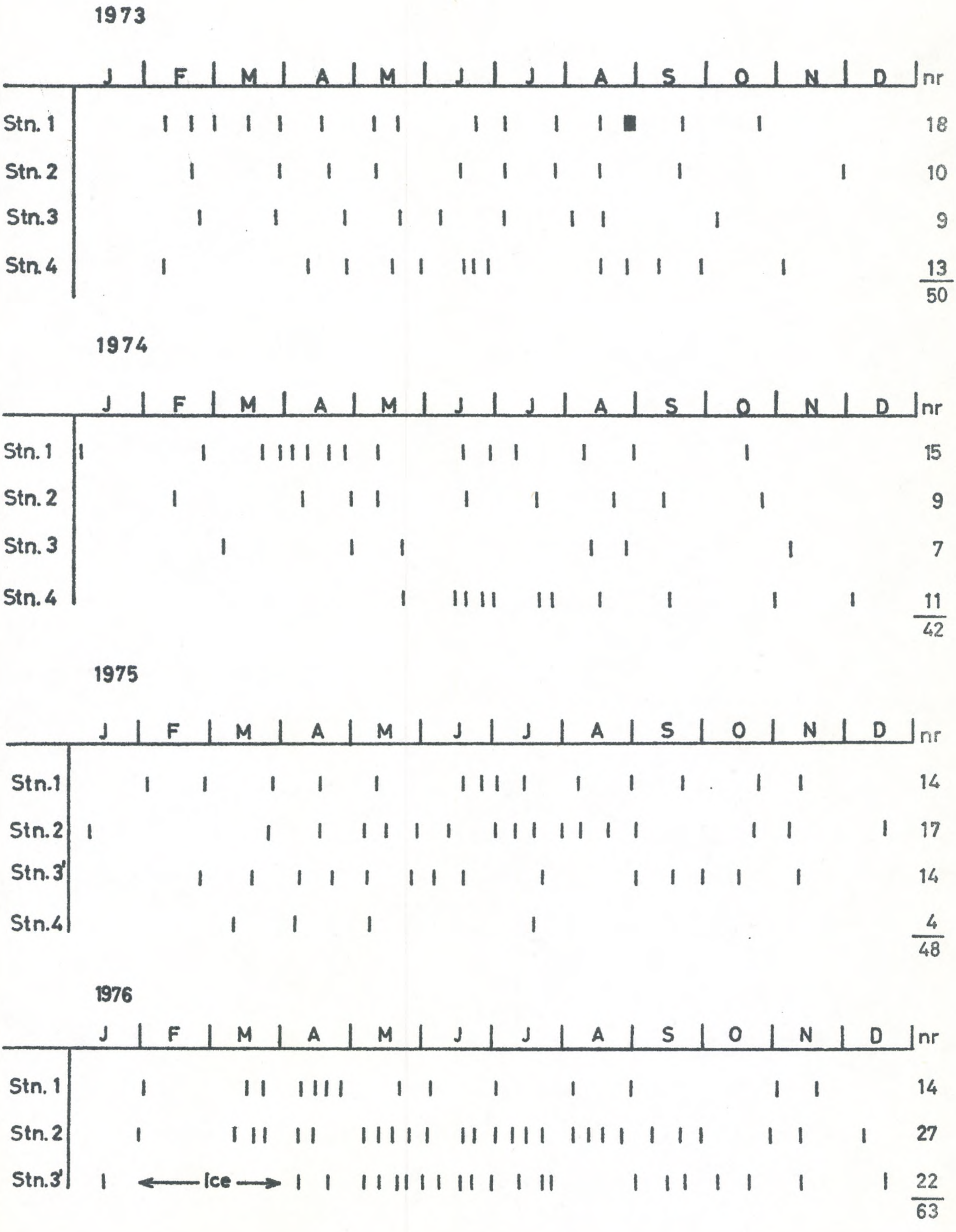
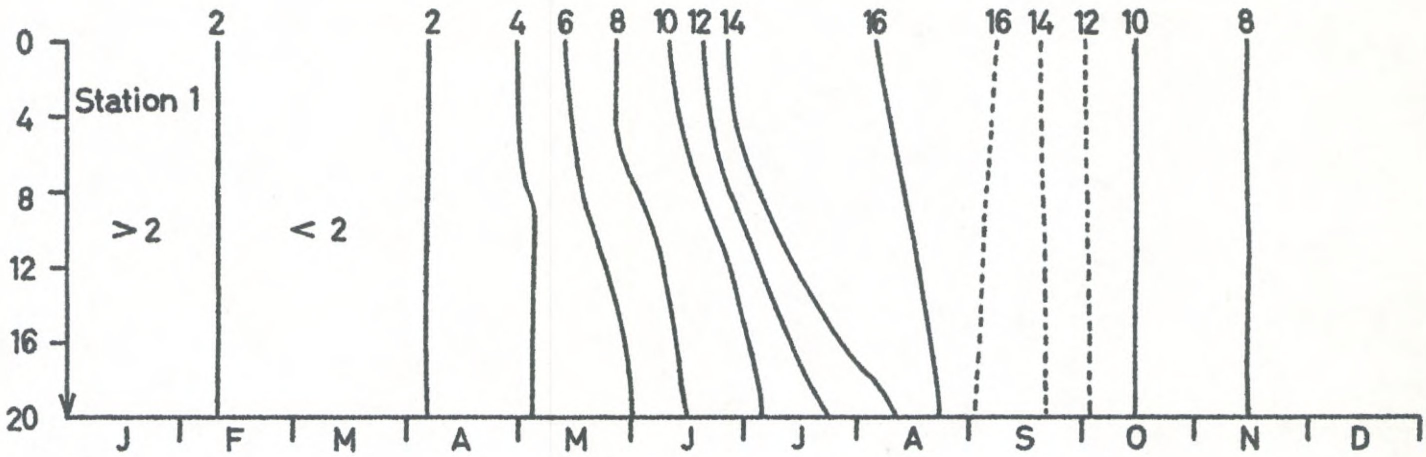
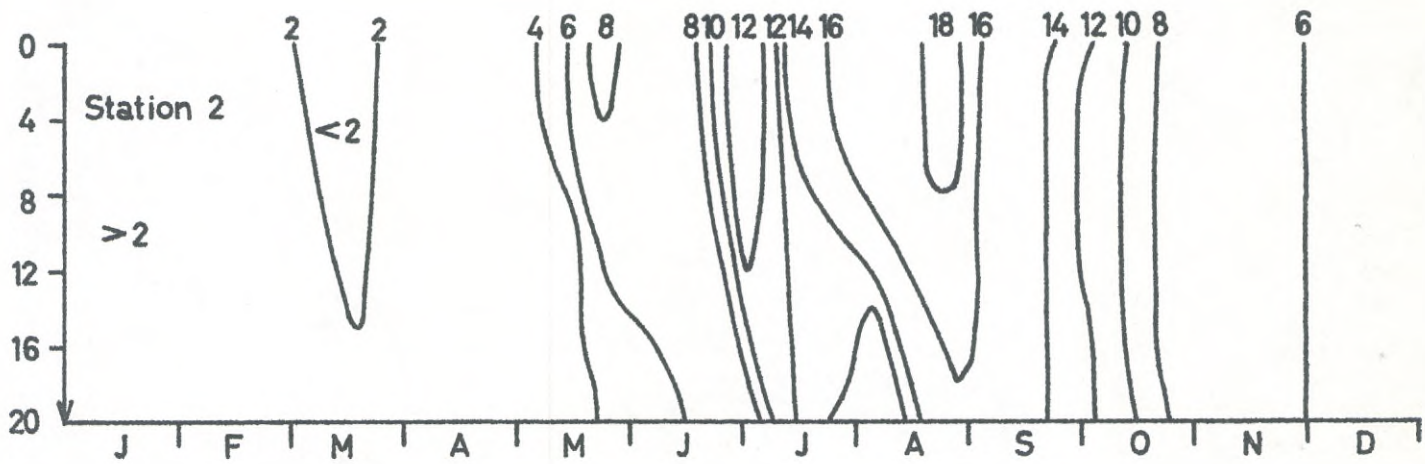


Fig. 3

TEMPERATURE (°C) 0-20 M IN THE BALTIC 1976





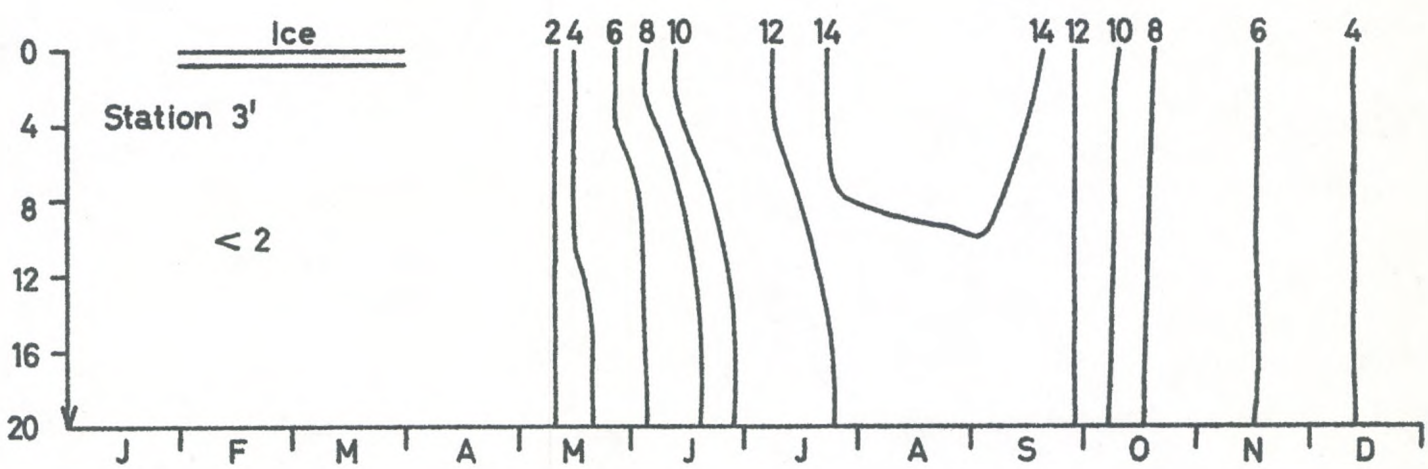


Fig. 4

IRRADIATION ON THE BALTIC IN 1976

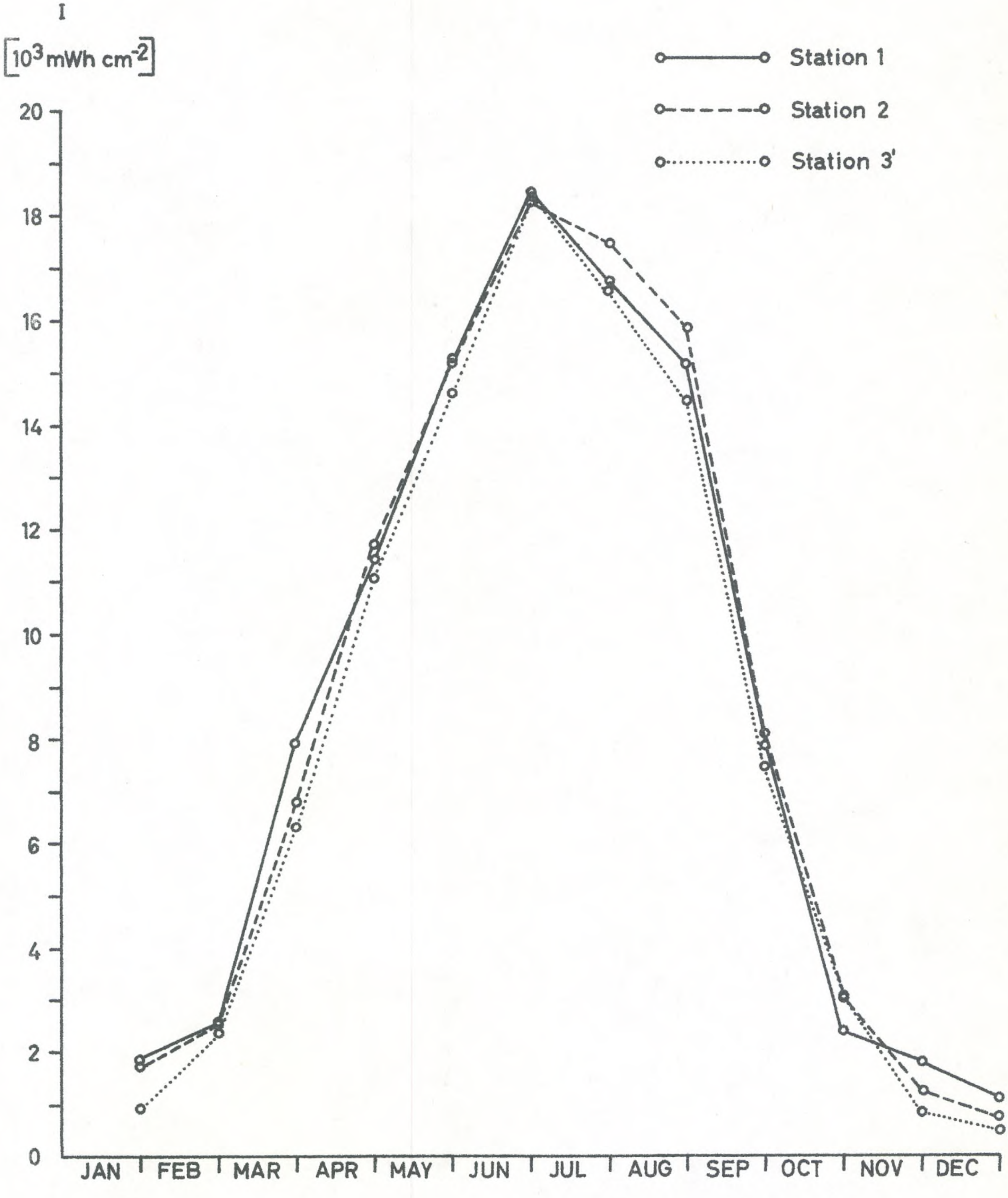


Fig.5

PRIMARY PRODUCTION 0-20 M IN THE BALTIC

1976

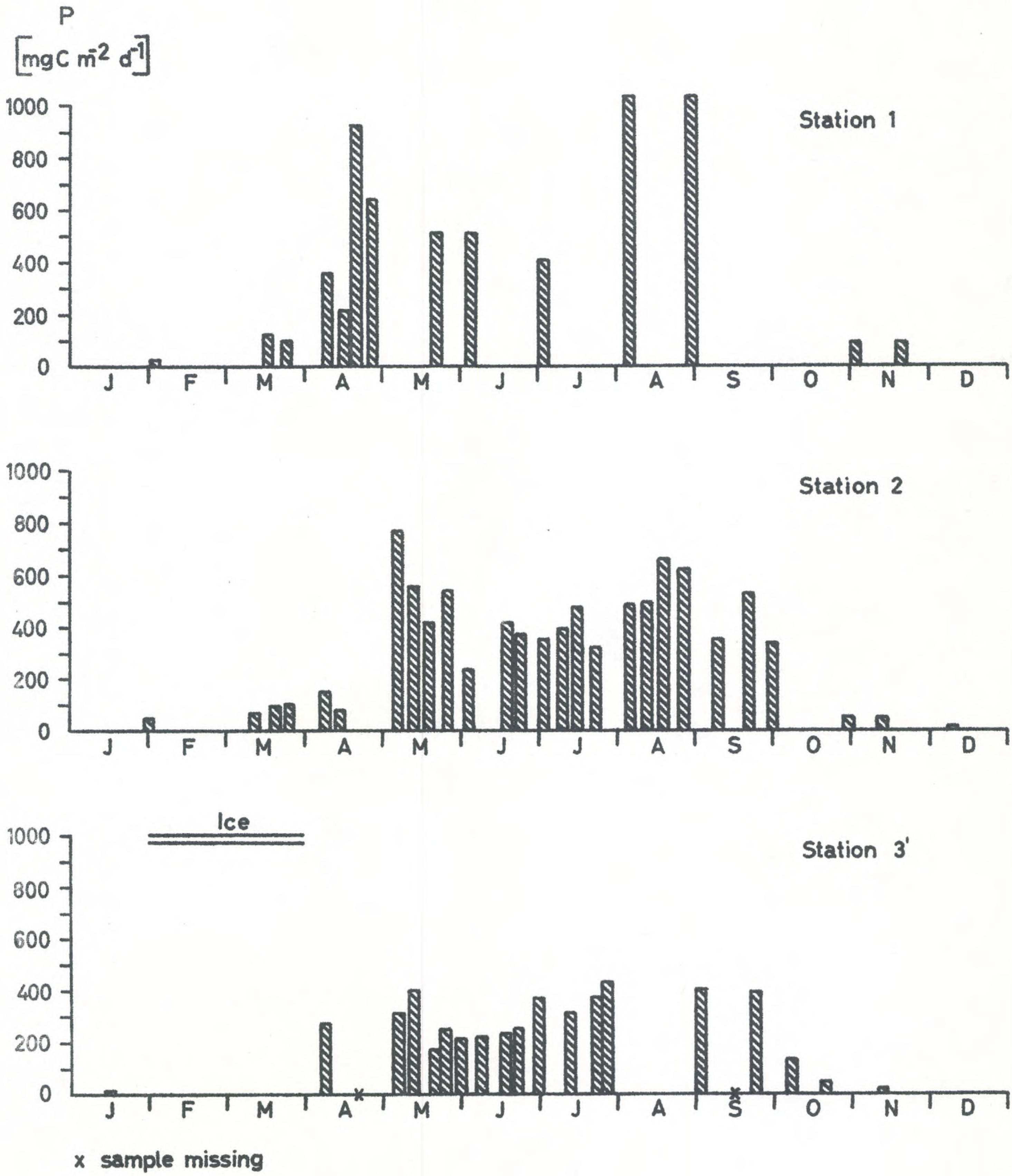
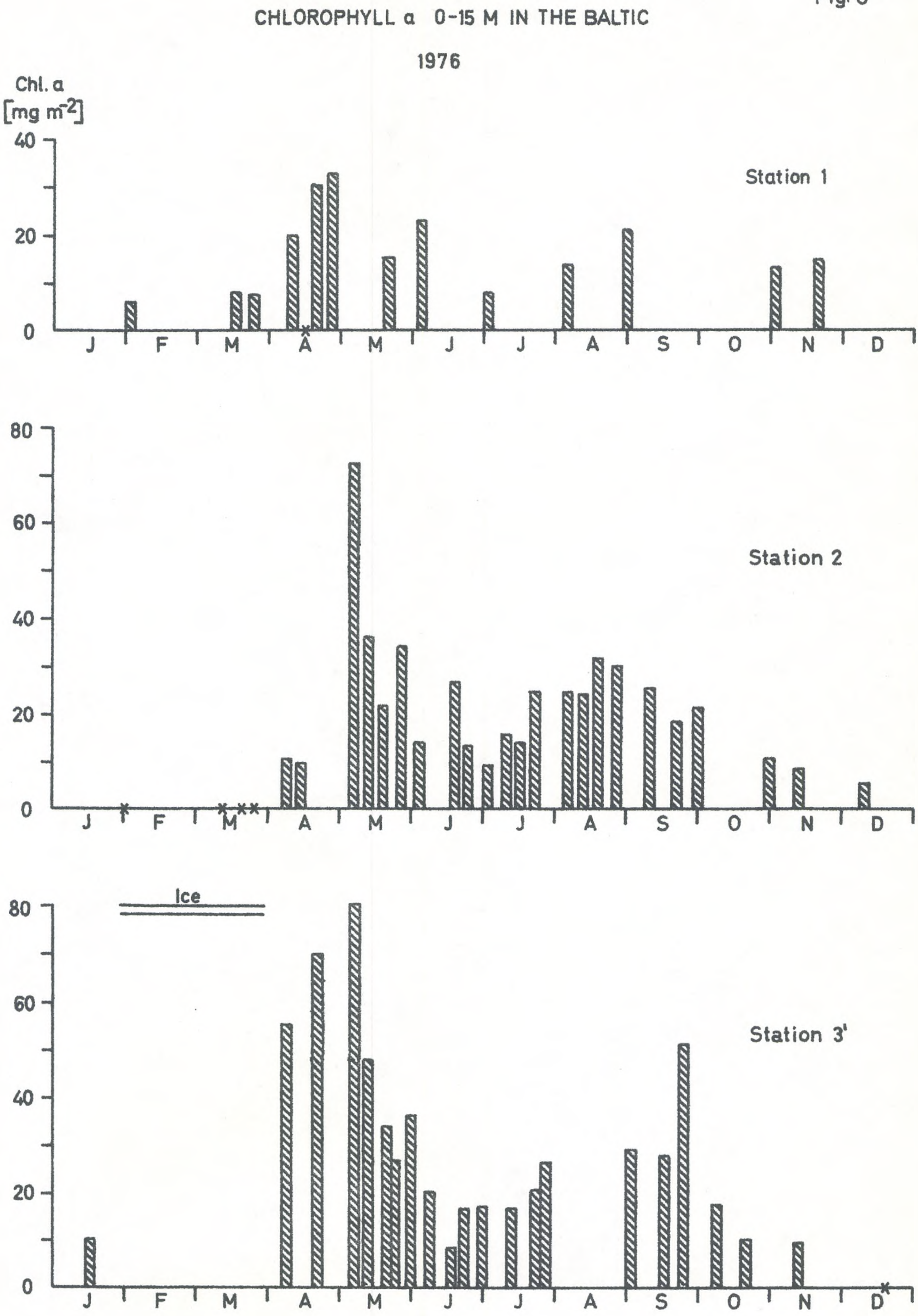


Fig. 6



x sample missing

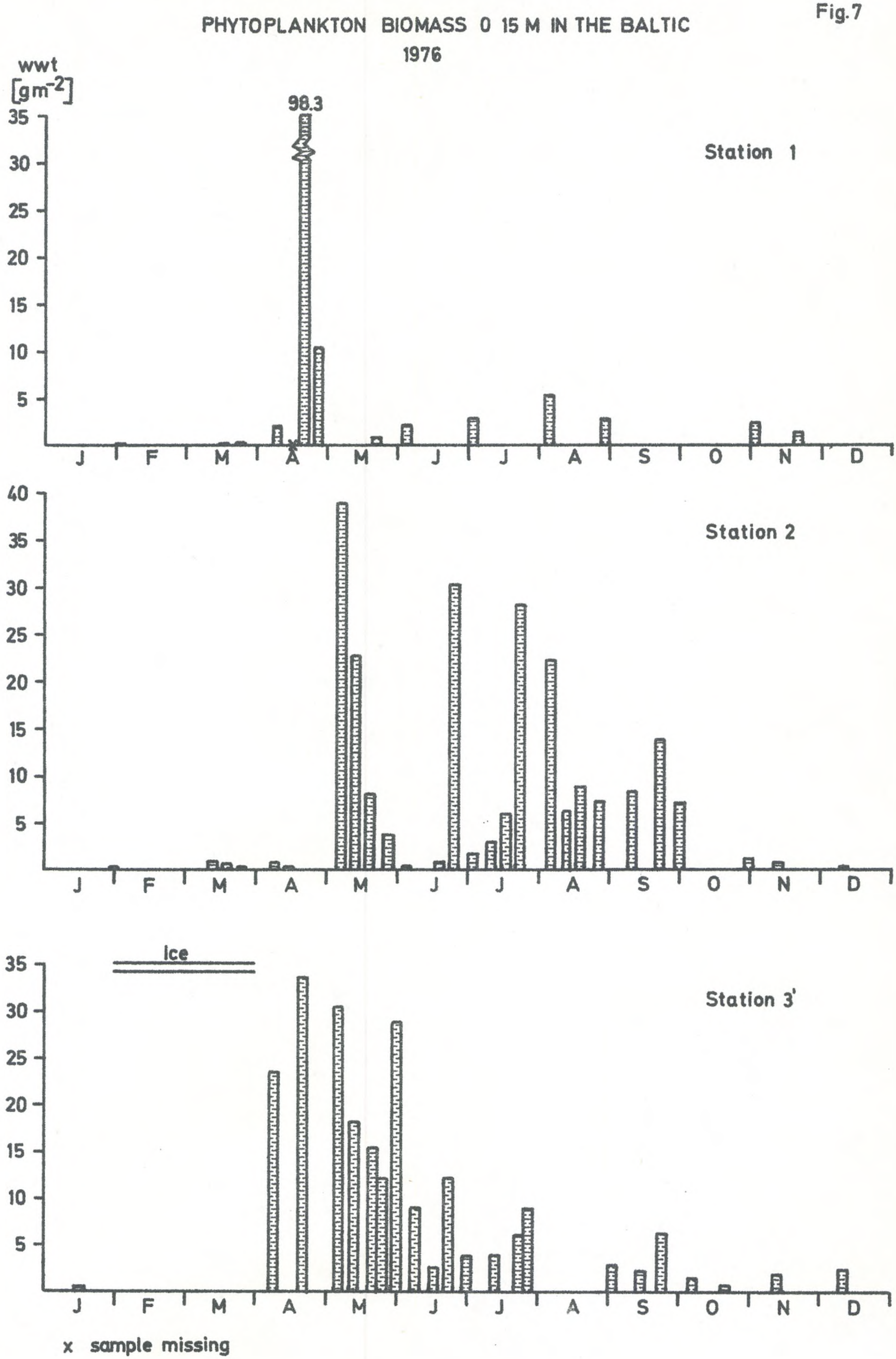
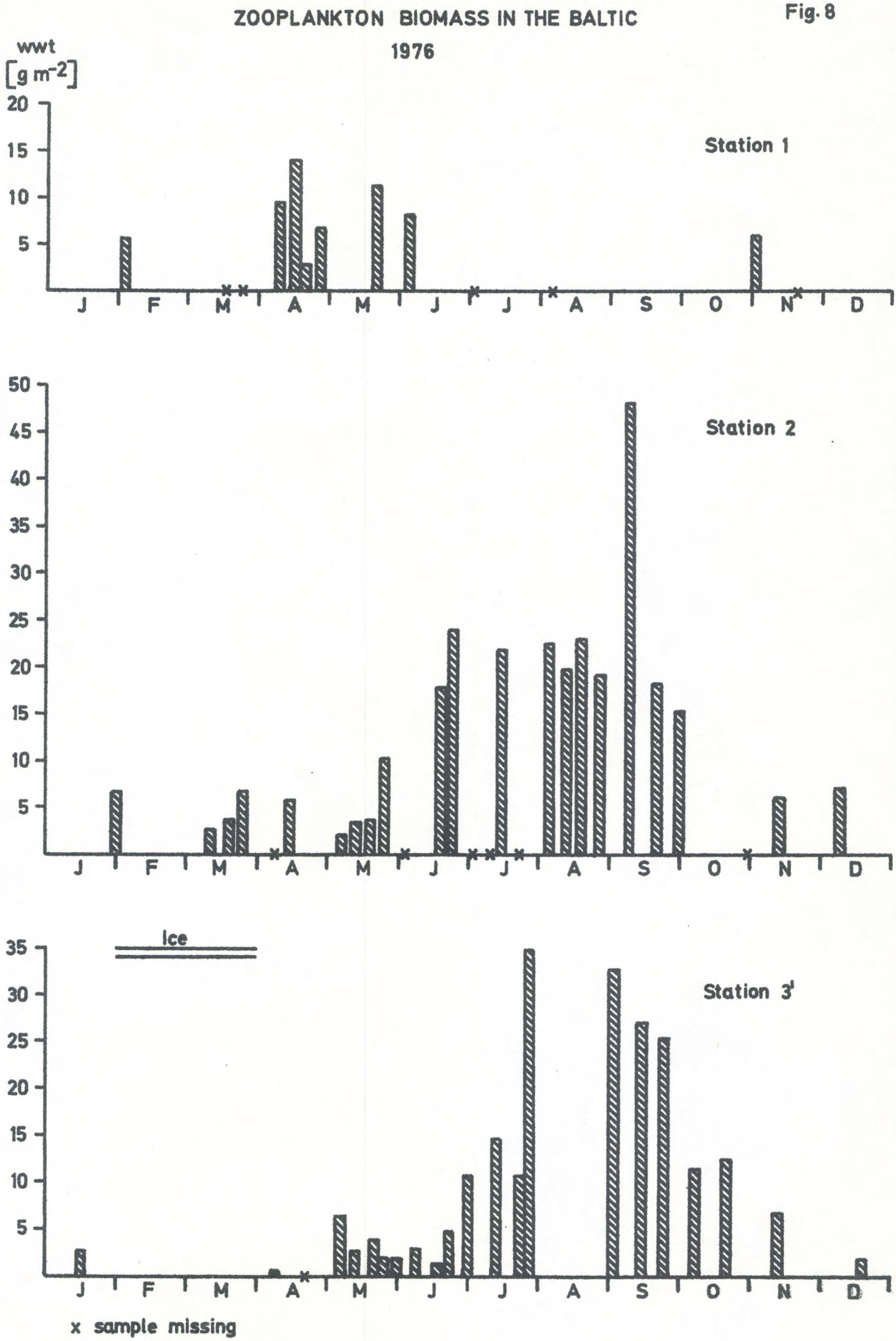


Fig.7
PHYTOPLANKTON BIOMASS 0 15 M IN THE BALTIC
1976
wwt
[gm-2]
98.3
Station 1
Station 2
Station 3'
ice
J F M A M J J A S O N D
x sample missing

Fig. 8


ZOOPLANKTON BIOMASS IN THE BALTIC
1976
wwt
[g m-2]
20
15
10
5
Station 1
J F M A M J J A S O N D
50
45
40
35
30
25
20
15
10
5
Station 2
J F M A M J J A S O N D
Ice
35
30
25
20
15
10
5
Station 3'
J F M A M J J A S O N D
x sample missing

QUATERLY BIOMASS AND RELATIVE IMPORTANCE OF DIFFERENT SPECIES AT STATION 1
1976

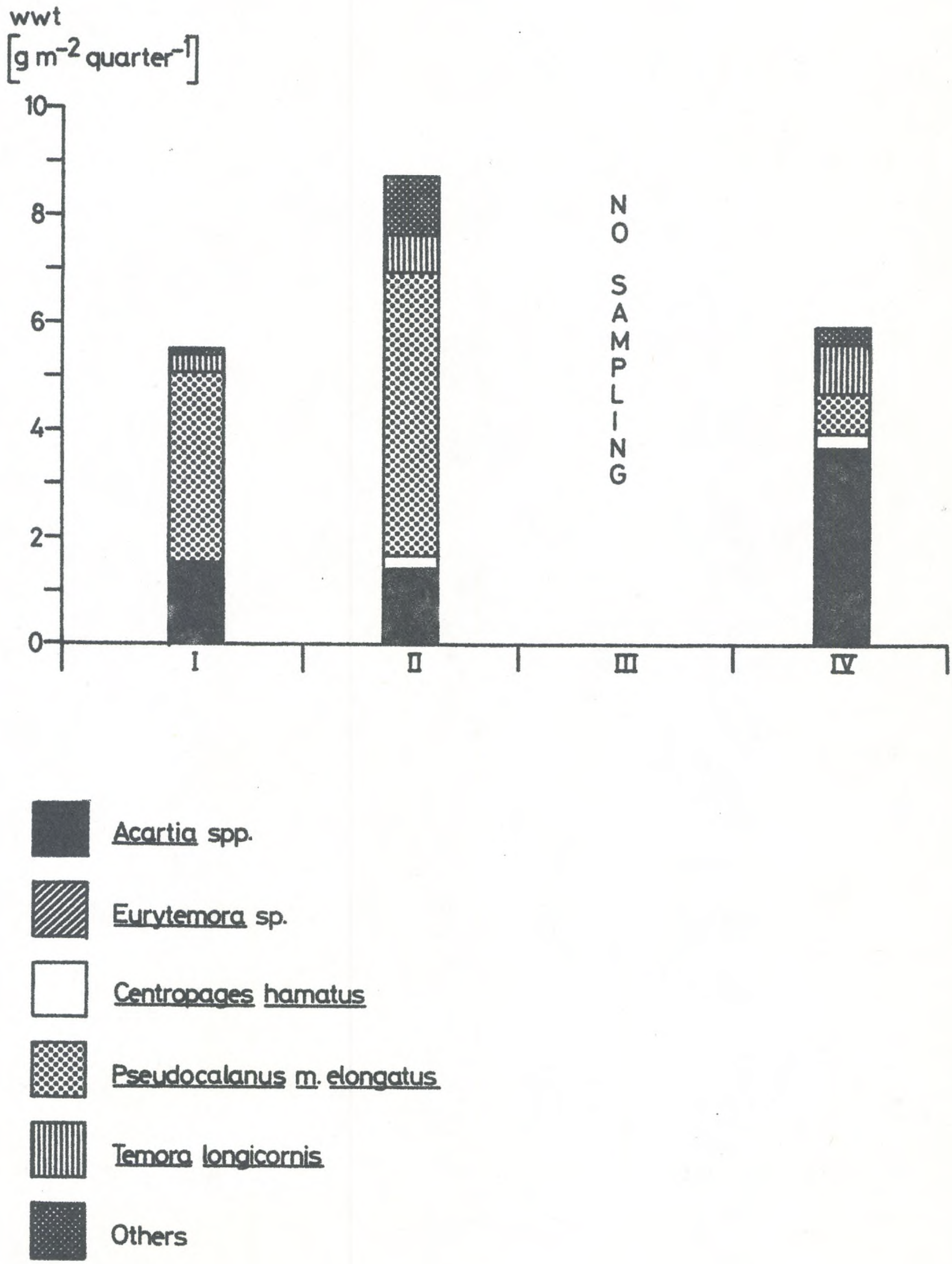


Fig. 10

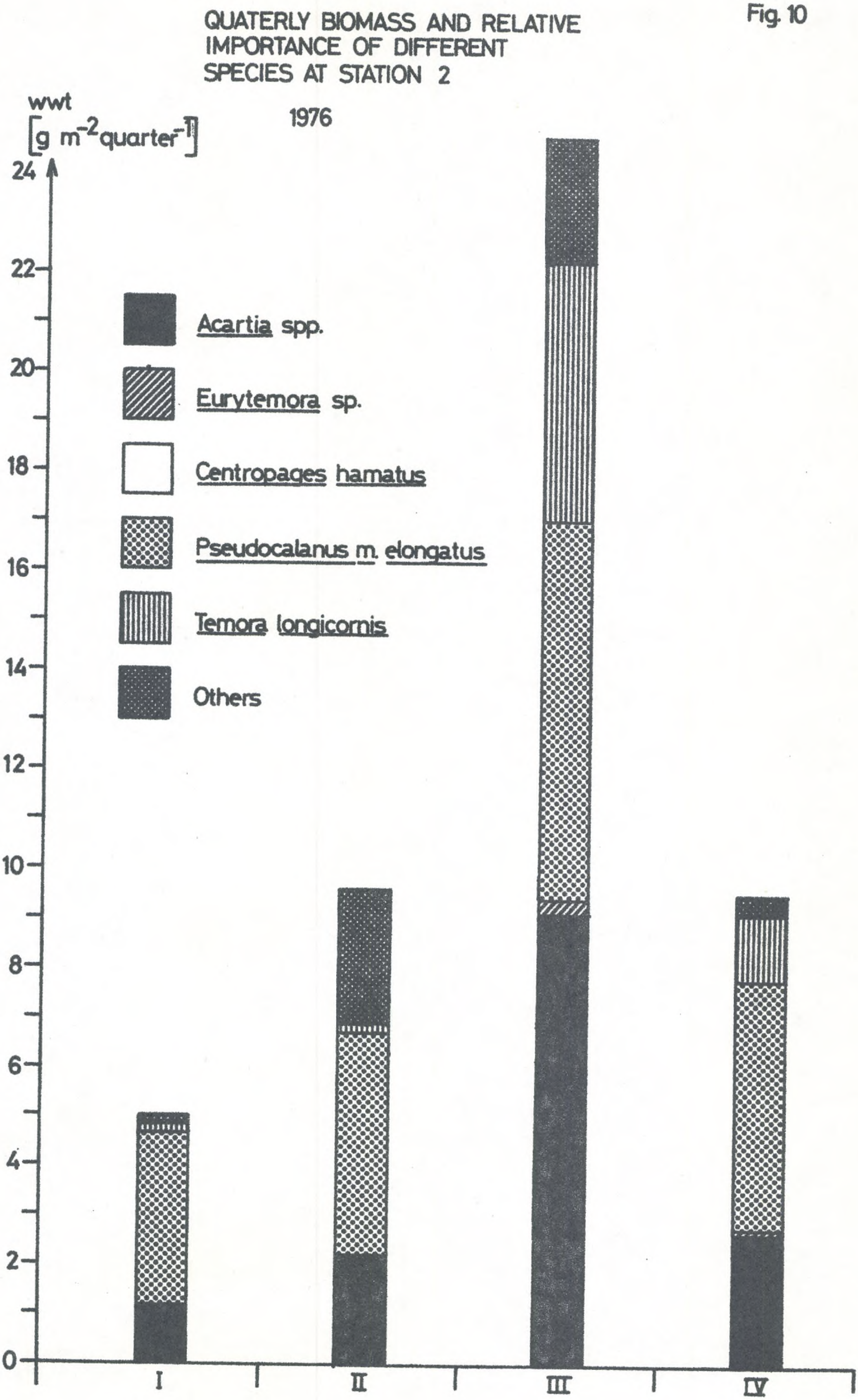

QUATERLY BIOMASS AND RELATIVE IMPORTANCE OF DIFFERENT SPECIES AT STATION 2
1976
wwt
[g m-2 quarter-1]
24
22
20
18
16
14
12
10
8
6
4
2
0
Acartia spp.
Eurytemora sp.
Centropages hamatus
Pseudocalanus m. elongatus
Temora longicornis
Others
I
II
III
IV

Fig. 11

QUATERLY BIOMASS AND RELATIVE IMPORTANCE OF DIFFERENT SPECIES AT STATION 3'

1976

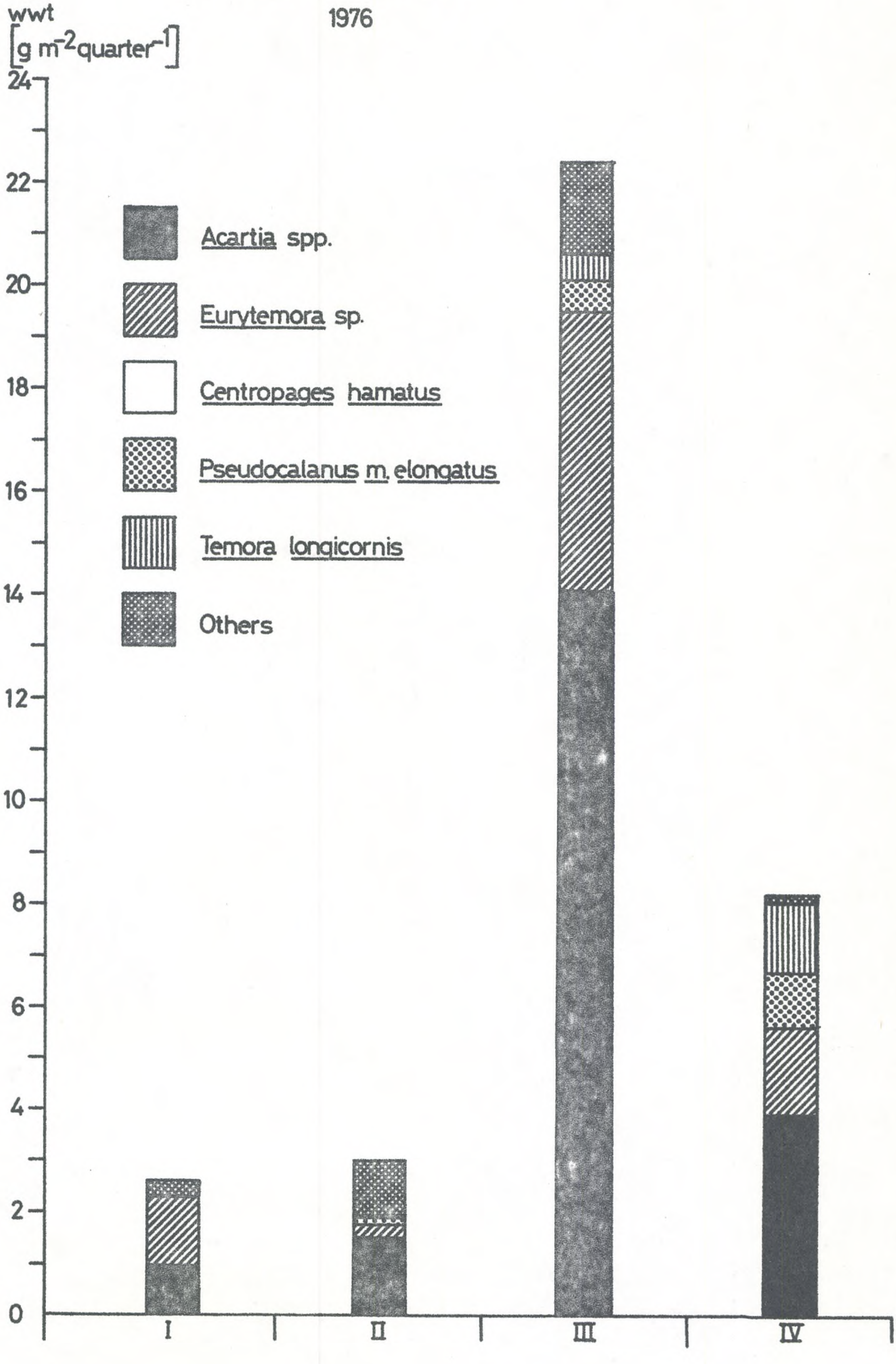


Fig. 12

ZOOPLANKTON PRODUCTION IN THE BALTIC

1976

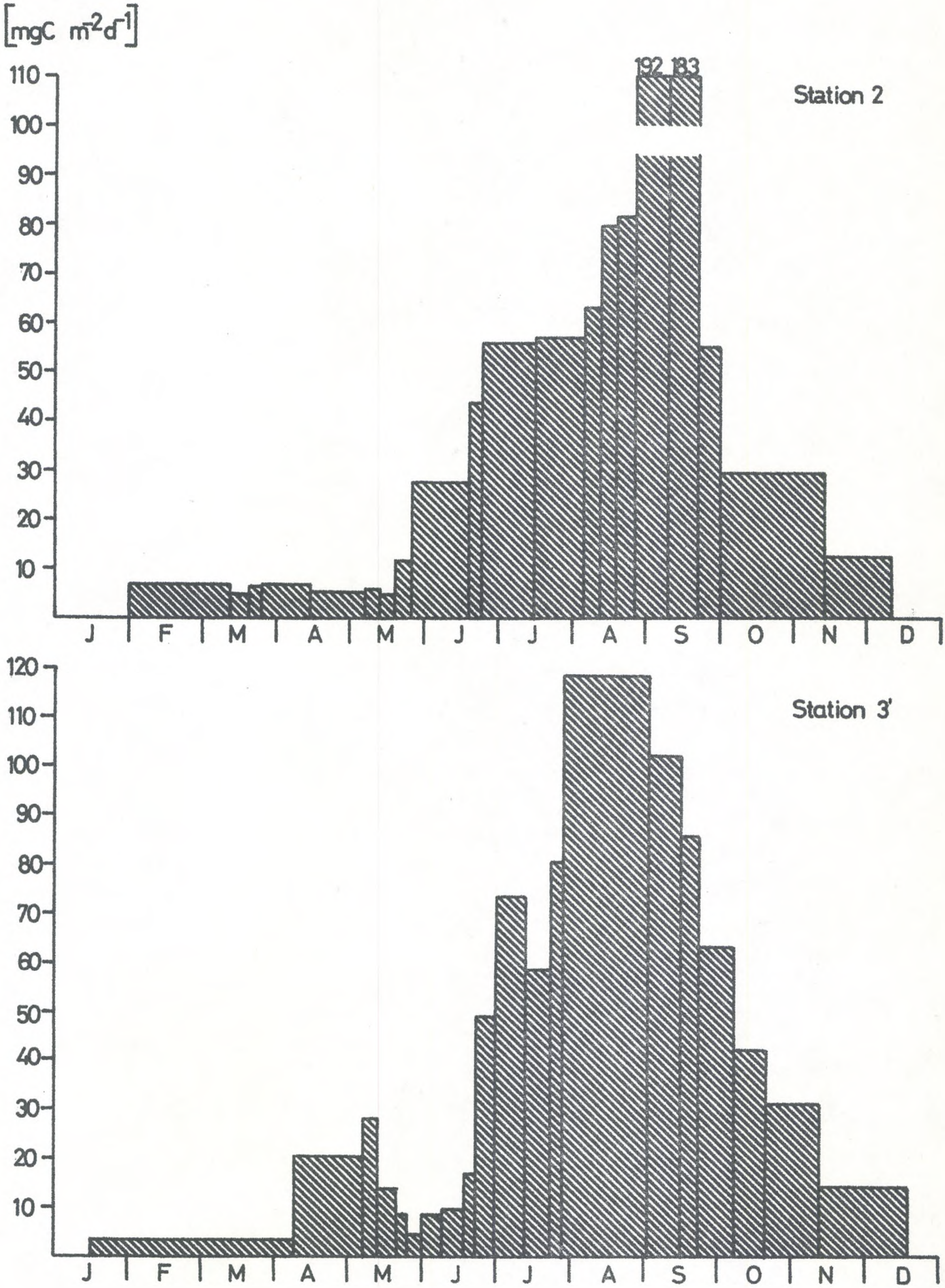


Fig. 13

QUARTERLY PRIMARY PRODUCTION IN THE BALTIC
1973 - 1976

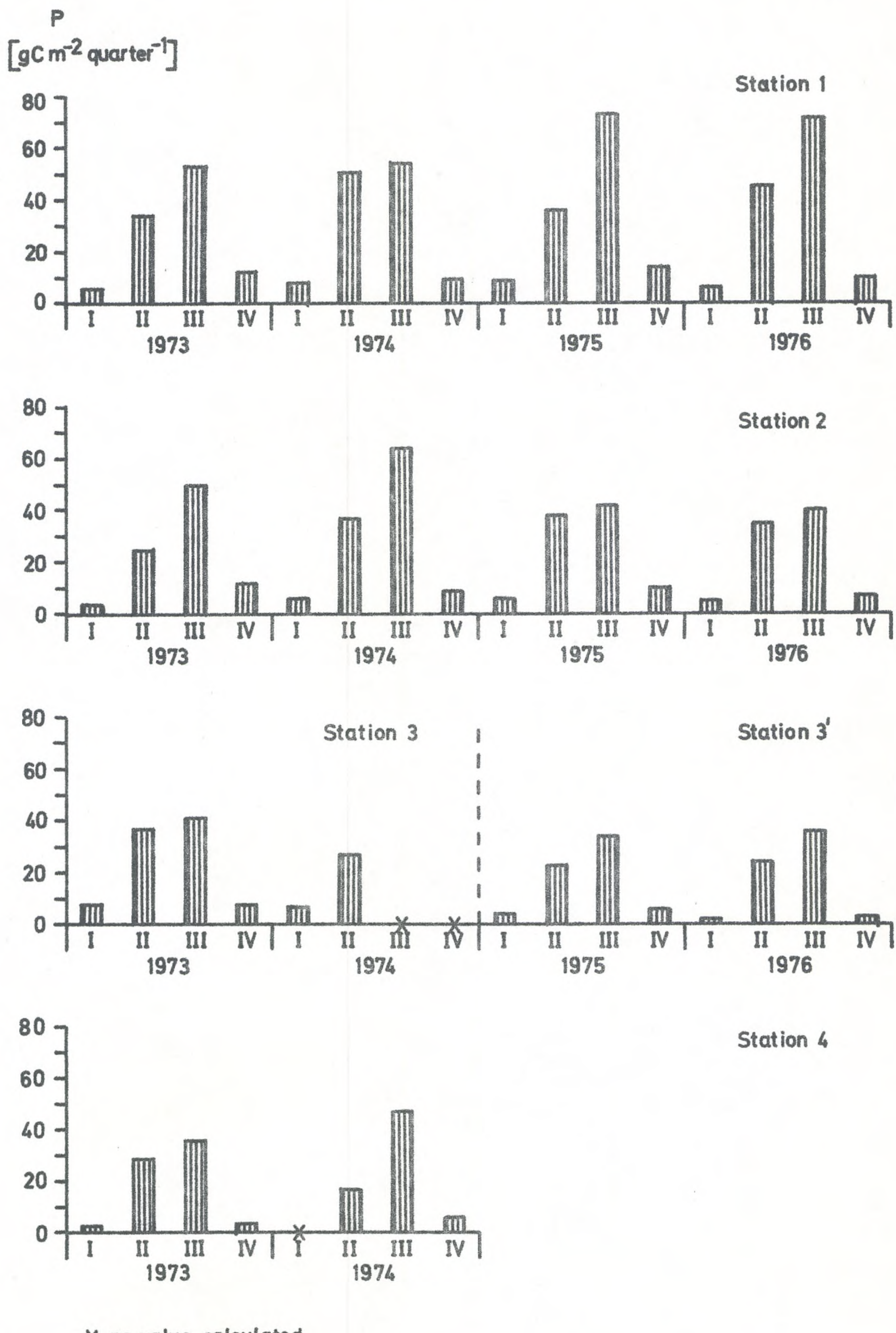


Fig. 14

PRIMARY PRODUCTION 0-20 m IN THE BALTIC

1973-1976

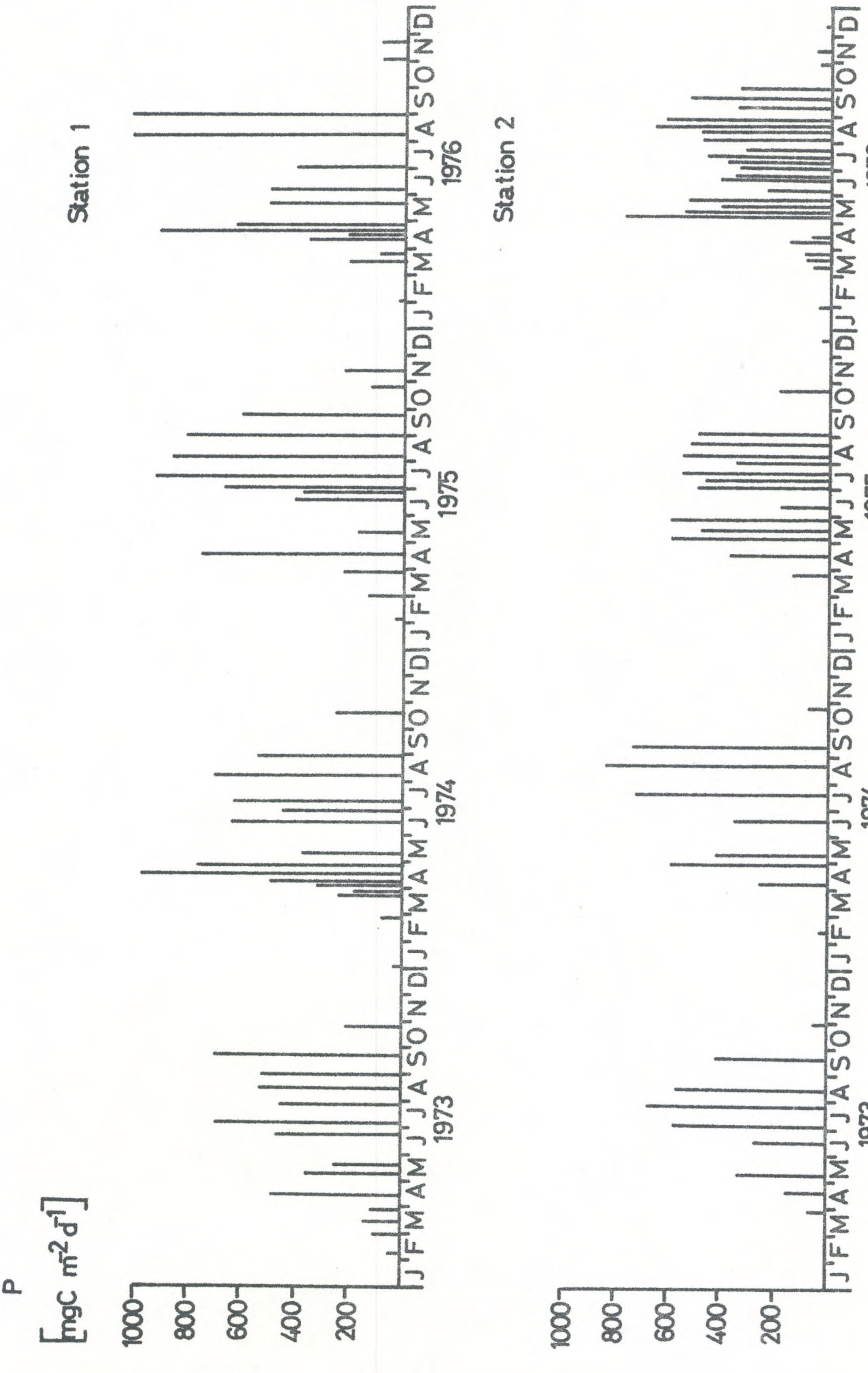


Fig. 15

PRIMARY PRODUCTION 0-20 m IN THE BALTIC

1973 - 1976