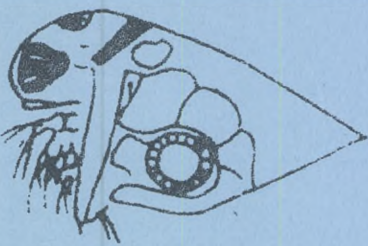

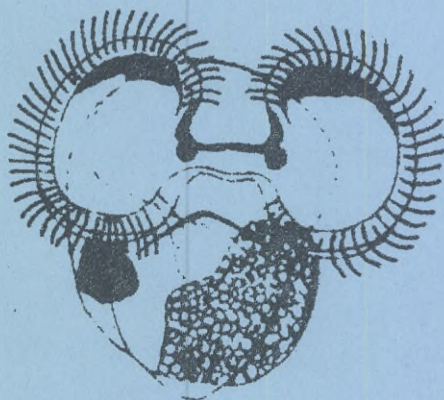

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by

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with an Appendix

QUALITATIVE ANALYSIS OF PHYTOPLANKTON

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ABSTRACT

Primary production, chlorophyll and phytoplankton studies were carried out at 4 offshore stations in the Baltic from the Hanö Bight in the south (N 55°40', E 15°20') to Sydostbrotten in the north (N 63°25' E 20°20'). The sampling occurred at 50 occasions from February to November in 1973.

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 primary production was measured with the ^{14}C-technique _in situ_ using 4-hours incubation-time at 10 depths. The production at the most southern station in the Hanö Bight (station 1) was 105 gC m^{-2} $year^{-1}$, at station 2 east of Gotland 91 gC m^{-2} $year^{-1}$, at station 3 in the Åland Sea 94 gC m^{-2} $year^{-1}$ and at the most northern station (station 4) 71 gC m^{-2} $year^{-1}$. The third quarter of the year (July-September) was the most productive or about 50 % of the yearly production. 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 mgC m^{-3} h^{-1} and the highest daily production was 725 mgC m^{-2}, which occurred in August.

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 stations 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.

This report deals with the results of the primary production studies made in the Baltic proper and the Bothnian Sea by the Institute of Marin Research in Lysekil during 1973. The work began in January 1973 and has continued since then.

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 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.

The investigation is supported by the National Environmental Protection Board; SNV 7-100/72c, 7-100/73 and 7-100/74.

The authors want to thank the crews of the rescue cruisers "Grängesberg", "Östergarn","Gustav Dalén", "Sigurd Golje" and the research vessel "Clupea", for their cooperative help during the many sampling occasions.

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.

Station 1: Hanö Bight; N 55°40' E 15°20'. 20 miles from land. Mr Lars Edler, Lund, has carried out the measurements on board the rescue cruiser "GRÄNGESBERG". In 1973 18 measurements and in 1974 15 measurements were made. The aim at this stations is 18 measurements per year.

Station 2: East Gotland; N 57°25' E 19°15'. 10 miles from land. Until the end of 1974, Mr Odd Lindahl, Lysekil, has done the measurements, but from January 1975 Mrs Britta Gormitzka, Lärbo, will do the work. The rescue cruiser "ÖSTERGARN" has been used. In 1973 10 measurements were done and in 1974 9 measurements. The aim at this station is also 18 measurements per year.

Station 3: Until November 1974 Åland Sea;N 59°50' E 19°35'. 15 miles from land.
Station 3': From December 1974 Landsort Area;N 58°35' E 18°10'. 20 miles from land. The position of the station was moved in the end of November 1974 due to practical reasons. Mr Nils Kautsky, Askö,has carried out the measurements. Until the station was moved the rescue cruiser "GUSTAV DALÉN" was used but after the change the research vessel "AURELIA" has been used. In 1973 9 measurements and in 1974 only 7 measurements were made. The aim at the station is 15 measurements per year.

Station 4: Sydostbrotten; N $63^{\circ}25'$ E $20^{\circ}20'$. 15 miles from land. Mrs Margaretha Frech, Norrbyskär, is responsible for this station. The research vessel "CLUPEA" and the rescue cruiser "SIGURD GOLJE" have been used. In 1973 12 and in 1974 11 measurements were made. The aim at the station is 12 measurements per year.

Measuring frequency

One of the main problems with the whole investigation is to get measurements close enough during the whole year. As the measurements are carried out on relatively small vessels the weather is a very important factor for success. Though the ships can be hired at very short notice, even on Saturdays and Sundays, it is sometimes for long periods impossible to carry out measurements due to bad weather. This is the main reason why the aim is not properly fulfilled at all stations. During expected blooming periods the intentionis to sample at least every second week and during the rest of the year about once a month. When there is an ice cover no measurements are possible.

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 meters depth. At station 1, 2 and 3 pH is measured down to 20 meters 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.

Chlorophyll measurements

The water-samples are taken with a hose as an intergral sample from surface down to 15 metres depth. The filtering procedures and analyses are carried out according to Carlberg (1972). This means that the SCOR/UNESCO method for chlorophyll measurements is applied.

Phytoplankton biomass

The water-sample is taken as described above. The sample is preserved in Keefee's solution. The phytoplankton is analysed according to the Utermöhl technique and the cellvolume for each species is calculated.

The C:N:P content of the phytoplankton

The water-sample is taken as described above and filtered through a fibre-glass filter. The filters are stored in a deepfreezer. Unfortunately no analysis of the C:N:P content have been done yet.

Qualitative phytoplankton samples

The samples are collected with a vertical haul down to 20 metres depth. The mesh-size of the net is 25 µ. The samples are preserved with Keefer´s solution.

Radiation measurements

All stations are equipped with a Kipp & Zonen solarimeter integrator type CC 1. 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}.

When radiation measurements are missing of one reason or another, values from the nearest solarimeter belonging to the Swedish Meteorological and Hydrological Institute (SMHI) are used. These solarimeters are situated at Svalöv, Visby, Erken and Teg for station 1-4 respectively (cf. fig 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. However, the methods had to be slightly modified due to practical reasons.

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 negligiblein 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 [$mgC\ m^{-2}\ h^{-1}$] into daily production [$mgC\ m^{-2}\ d^{-1}$]. The factor used for this transformation is called the lightfactor (LF). $LF = \frac{TR_d}{TR_m}$, where TR_d is the incoming total radiation during the day and TR_m is the incoming total radiation during the measurement. Schindler (1971) has tested 4 hours incubation versus longer incubation times and he has 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 radioactivity has been measured with a GM (Geiger Müller) counting equipment but will probably be replaced by a liquid scintillation counter during 1975.

RESULTS

On 50 occasions different parameters were investigated at offshore stations - one in the Hanö Bight, one east of Gotland in the Baltic proper, one station in the Åland Sea and one station in the Sydostbrotten area between the Bothnian Sea and the Bothnian Bay in 1973 (fig. 1). All the stations are situated at least 10 n. miles from the coast. The distribution in time of those investigations is evident in fig. 2. In the same fig. the frequency of measurements in 1974 is also reproduced.

At station 1 in the Hanö Bight 18 investigations were carried out in 1973 from February until October (tab. 1). At stations 2, 3 and 4; 10, 9 and 12 investigations were made (tab. 2-4).

a. Primary production

The calculated daily production at station 1 fluctuated between 44 in February to 700 $mgC\ m^{-2}\ d^{-1}$ in September. In March the values are in the magnitude of 100 $mgC\ m^{-2}\ d^{-1}$ and later in April. The values increased to about 500 $mgC\ m^{-2}\ d^{-1}$. In May the production decreased to about 350 $mgC\ m^{-2}\ d^{-1}$. From June and onward the production is about 450 $mgC\ m^{-2}\ d^{-1}$ or exceeds that value until October when the calculated production was estimated to 200 $mgC\ m^{-2}\ d^{-1}$. From fig. 3 it is obvious that the main part of the production appeared during the third quarter of the year (July-September). At station 2 there was no peak value at all in the spring (tab. 2). The value in March was 62 $mgC\ m^{-2}\ d^{-1}$, in April 153 $mgC\ m^{-2}\ d^{-1}$ and in May 330 $mgC\ m^{-2}\ d^{-1}$. In June the production value was in the same magnitude. Not until July the values exceeded 450 $mgC\ m^{-2}\ d^{-1}$ and the peak appeared in July when the calculated production was

672 mgC m^{-2} d^{-1}. In September the values decreased to 417 mgC m^{-2} d^{-1}. In November the production was as low as in March or about 50 mgC m^{-2} d^{-1}. At station 3 the production increased from 30 mgC m^{-2} d^{-1} in February to 272 mgC m^{-2} d^{-1} in March (tab. 3). The peak value in the spring appeared in April when the value was as high as 616 mgC m^{-2} d^{-1}. There was an obvious decrease in production in June and July. In the beginning of August another peak value appeared. The highest production value at all stations that year, 725 mgC m^{-2} d^{-1}, appeared in the beginning of August. Later in August and in October the values were in the magnitude of 300-400 mgC m^{-2} d^{-1}. The production exceeded 450 mgC m^{-2} d^{-1} only in April-May and in August. From station 4 there are no values of the primary production until April (tab. 4, fig. 3). At this very northern station in the Baltic the spring maximum value appeared later then at the other stations. Not until the middle of May the peak value (500 mgC m^{-2} d^{-1}) appeared. Later in May and in June the values decreased and at 4 subsequent occasions the production was in the order of 250-350 mgC m^{-2} d^{-1}. In August the highest production value appeared, which was calculated to 593 mgC m^{-2} d^{-1}. Later in August the production was much lower or about 250 mgC m^{-2} d^{-1}. In September the values fluctuated between 350 and 133 mgC m^{-2} d^{-1}. On the last sampling occasion in the beginning of November the production was only 18 mgC m^{-2} d^{-1}.

A rough description of the fluctuations during the year of 1973 gives the following figures in mgC m^{-2} d^{-1}.

January	(~30)	July	(300-700)
February	(30- 50)	August	(250-700)
March	(50-250)	September	(150-700)
April	(150-600)	October	(200-300)
May	(200-500)	November	(20- 50)
June	(200-500)	December	(~30)

The quarterly and yearly production was estimated in the following way: between two sampling occasions the middle day is defined. That day divides the period into two parts of equal length. The number of days of the first period are multiplied by the value from the first measurement and the number of days of the second period with the value from the second measurement.

The days in the winter months are considered to contribute to the production with only 30 mgC m^{-2} d^{-1} if no measurements are available. For the months December-February the whole production is thus only estimated to 2.7 gC m^{-2}.

The estimate of the quarterly and yearly production is reproduced in tab. 5. In brackets the corresponding values for the 2 first quarters in 1974 are also given.

The most southern station in the Hanö Bight had the highest production or 105 gC m^{-2} $year^{-1}$ and the most northern station between the Bothnian Bay and the Bothnian Sea the lowest production or 71 gC m^{-2} $year^{-1}$. East of Gotland the yearly production was estimated to 91 g and in the Åland Sea to 94 g m^{-2} $year^{-1}$. The most productive quarter was the third at all stations. The production in July-September was estimated to 44-55 % of the yearly production. The contribution of the second quarter was 27-41 %. If we add the production figures from those two quarters the production from April-September was estimated to 82-92 % of the yearly production. The contribution to the production from the months October-March is thus comparatively small.

The preliminary figures for the two quarters in 1974 indicate that the total yearly production in 1974 will probably be higher than in 1973 for the two southern stations.

The production versus depth is reported from station 1 in figs. 4-5. The water visibility was estimated with a secchi-disc. The cloudiness are indicated with circles in eights. The maximum production always occurred above 5 m level except on two occasions in May-June with maximum between 5 and 10 meters. On three very cloudy days (July, 27; August, 30; September, 20) the maximum production appeared very close to the surface (1-2 m). But even on very bright days with full sunshine (August) the maximum production occurred rather close to the surface although the main production were deeper in the water (3-6 m). There was thus an obvious difference between cloudy and bright days.

The main part of the production appeared above the 15 % level (the secchi depth is considered to be the level, where still 15 % of the incoming light at surface is available). In June, July and August, however, an important part of the production also occurred below the secchi depth. All production below 20 m is considered negligiblewhich is verified by figs. 4-5. In June, 1973, the highest value or 1 mgC m^{-3} h^{-1} was estimated at 20 m level.

The values at the maximum level (mgC m^{-3} h^{-1}) in the different months were: 0.8 (February), 1.4 (March), 7.7 (April), 4.0 (May), 4.0 (June), 7.3 (July), 9.1 (August), 7.7 (September), 4.0 (October). The range of values are thus 0.8-9.1 mgC m^{-3} h^{-1}, with maximum in August and minimum in February.

b. Chlorophyll a

At all stations chlorophyll a measurements were performed according to the SCOR/UNESCO method. The filters were stored in a deep freezer until they were analysed. Unfortunately the filters from station 2 were stored in a deep freezer with missing electric power on two occasions. This might influence the result.

The results are evident in tab. 1-4 and in fig. 6. In general the highest chlorophyll content was found at the most northern station (no 4) which had the lowest production. At stations 1, 3 and 4 the highest value appeared in April. At station 1 most values are in the magnitude 10-20 mg m^{-2} with a maximum value in April (37.6 mg m^{-2}) and a minimum value in February (4.0 mg m^{-2}) (tab. 1). The results from station 2 can not be considered very seriously due to the accident with the deep freezer. The chlorophyll a values at station 3 show a conspicuous peak in April (tab. 3, fig. 6). The maximum value was estimated to 52 mg m^{-2}. Most other values during the year is in the order 10-20 mg except in the end of March when the chlorophyll content was 31 mg m^{-2}. The chlorophyll values at station 4 are generally in the order of 20-30 mg m^{-2}, i.e. about 10 mg m^{-2} higher than at the other stations (tab. 4, fig. 6). Three very high values appeared in April-May, 42-57 mg m^{-2}.

c. Phytoplankton

The biomass of phytoplankton is reproduced in tab. 1-4 and in fig. 7. Detailed information about the components of the phytoplankton biomass is reproduced in tab. 6-9.

The biomass of phytoplankton at station 1 was rather even during the whole year. Very small amounts of phytoplankton appeared in all 15 samples. The maximum value was 3 g m^{-2} and the minimum value 0.2 g m^{-2} (tab. 1). At station 2 the few analysed samples showed very low amounts except in the end of July, when 3.8 g m^{-2} occurred in one sample.

Both at station 3 and 4 there were rather high amounts of phytoplankton in the spring bloom (tab. 3-4, fig. 6). On four occasions the amounts were 10 g or higher.

The blue-green algae, the diatoms and the monads dominated at station 1 (tab. 6). The diatoms were abundant through the whole year and contributed most to the biomass at this station. In April dominated Sceletonema costatum and later in May Chaetoceros spp. In summer and autumn an unidentified diatom species was most frequent.

The blue-green algae were frequent in June-July and in September. Aphanizomenon flos-aquae and Nodularia spumigena were most abundant.

The monads were not identified to species. They were frequent in February-March and in July-September.

At station 2 the blue-green algae, the diatoms and the dinoflagellates dominated. The blue-green algae were most frequent in March and May-July, when they made 23-94 % of the total phytoplankton biomass. The greatest part of the yearly biomass consisted of blue-green algae. The same species dominated as at station 1, viz. Aphanizomenon flos-aquae and Nodularia spumigena.

The diatoms consisted most of the unidentified species when they were frequent in February-March. From May to July the dinoflagellates were frequent, especially Dincphysis spp., Gonyaulax catenata and Gyrodinium spirale.

At station 3 blue-green algae, diatoms, dinoflagellates and monads were dominant (tab. 8). The diatoms contributed most to the yearly biomass in our samples. They were frequent from February to July. Sceletonema costatum and Thalassiosira baltica were the dominating species. The dinoflagellates were represented by Gonyaulax catenata which was par préference the most frequent species with a real spring burst in April.

The blue-green algae were most abundant in July to October. The only important species was Aphanizomenon flos-aquae. The monads were most frequent in August-October.

At station 4 the diatoms were very important and to a lesser extent monads and dinoflagellates (tab. 9).

Among the diatoms Chaetoceros spp. and Thalassiosira baltica were most frequent. Achnantes taeniata and Sceletonema costatum were also frequent. The diatoms were abundant in all samples from February to September.

The dinoflagellates were frequent in February-May. Gonyaulax catenata made more than 95 % of the biomass of the dinoflagellates.

Green algae were rather frequent in June. The dominating species was Ankistrodesmus talcatus. The monads were dominant in June-September.

d. Temperature, salinity and pH.

The winter in 1973 was very mild in comparisons with a normal winter. Even at the most northern station there was no fast ice and drift-ice only occurred occasionally. The isopleths at the various stations are reproduced in fig. 8. For a period of more than one month the temperature in the surface water was higher than 18°C at station 1, 2 and 3 which is unusual. There was, however, an upwelling of cold water in the middle of summer at station 2 and 3. The difference between the warm surface water and the cold water below 10 m at station 3 is obvious.

At station 4 the temperature in summer was about 14°C or 2-4°C colder than at the more southern stations.

The Baltic is a brackish water sea with low and stable salinity at surface. On most occasions the salinity was homogeneous from surface to 20 m level. There were, however, differences between the sampling occasions in some cases. At station 1 the salinity fluctuated between 6.5 and 9.5 ‰. At station 2 the corresponding fluctuations were 7.4-8.2 ‰, at station 3, 5.5-6.3 ‰, and at station 4, 4.4-5.4 ‰.

The pH values were around 8.0 at all stations.

DISCUSSION

The phytoplankton biomass at station 1 in the Hanö Bight and at station 2 east of Gotland did not show any great fluctuations during the year (fig. 7), 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 gC m^{-2}). It is striking that there is no high production value in spring. The real spring bloom might have occurred between two sampling occasion.

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 mgC m^{-2} d^{-1}. In August the maximum primary production was 600 mgC 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.

Bagge and Lehmusluote (1971) discussed the annual production in relation to eutrophication along the Finnish coast. They considered values above 120 gC m^{-2} $year^{-1}$ as typical for heavily eutrophic waters, 80-120 gC m^{-2} $year^{-1}$ for eutrophic waters, 40-80 gC m^{-2} $year^{-1}$ for slightly eutrophic waters and less than 40 gC m^{-2} $year^{-1}$ for oligotrophic waters. This means that in 1973 the conditions at station 3 (94 gC m^{-2} $year^{-1}$) have been eutrophic and the conditions at station 4 (71 gC m^{-2} $year^{-1}$) slightly eutrophic if we compare with the same latitude i.e. the same temperature conditions. However, it might be doubtful to make such comparisons as our stations are offshore and since different methods were used.

Kaiser and 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 gC m^{-2} $year^{-1}$ (Arkona Sea), 138.0-59.0 (Bornholm Sea) and 69.4-35.0 (Gotland Sea). From our point ofview 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 gC m^{-2} $year^{-1}$ in the Landsort area (station 3', fig. 1).

An investigation in the Baltic proper by Sen Gupta (1972) with even lower values (29.4-30.6 gC m^{-2} $year^{-1}$) was carried out with an incubator (potential production) on board. The samples were preserved with $HgCl_2$ 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 gC m^{-2} $year^{-1}$ from a lightship in the northern part of the Baltic proper at about the same latitude as station 3 (91 gC m^{-2} $year^{-1}$). 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 (unpubl.) 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 production in order to keep a fish production at the present level in the Baltic proper must be at least 100 gC 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 about 50 % 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 22-41 % 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 authors and Gunilla Brattberg, University of Uppsala, have carried out two independent investigations in the Åland Sea at stations nearby each other (cf. table 10, fig.9). The primary production values are in accordance with each others. The general picture of the primary production, when the results of both investigations are put together, is illustrated in fig. 9. The result of the comparison of the two investigations is surprisingly good.

Concerning the results of the chlorophyll a measurements the tendancy is quite obvious, though the Brattberg investigation shows slightly higher values all the time. The differences can be explained by different measuring technique. In this context it is worth mentioning that Lassig & Niemi (1973) carried out chlorophyll a measurements in June-July, 1969 and 1970 in the same area. The values are in the same magnitude as the authors´and Brattberg´s chlorophyll a values from 1973.

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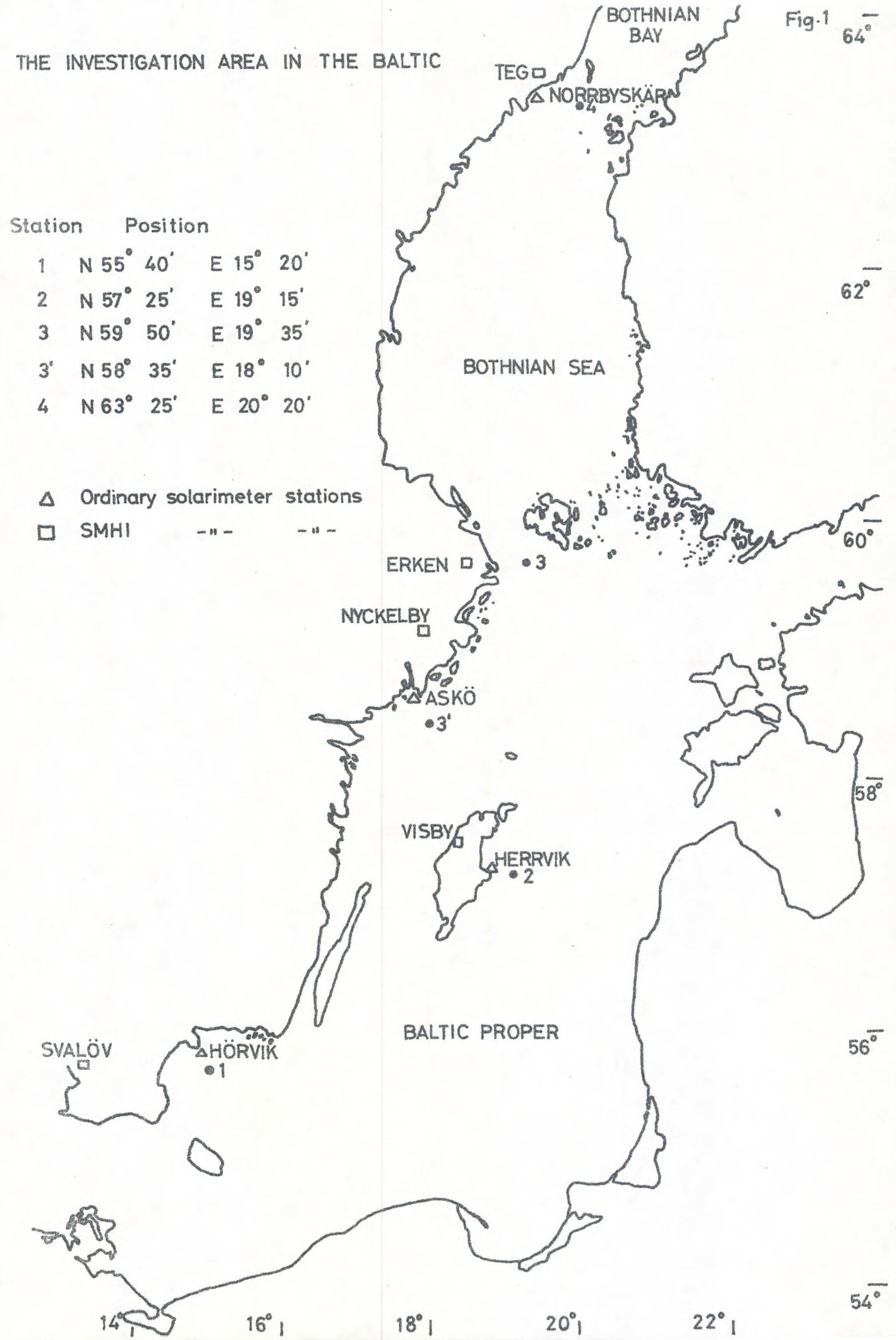


Fig.1
THE INVESTIGATION AREA IN THE BALTIC
Station Position
1 N 55° 40' E 15° 20'
2 N 57° 25' E 19° 15'
3 N 59° 50' E 19° 35'
3' N 58° 35' E 18° 10'
4 N 63° 25' E 20° 20'
△ Ordinary solarimeter stations
□ SMHI -"- -"-
BOTHNIAN BAY
TEG
NORRBYSKÄR
4
BOTHNIAN SEA
ERKEN
3
NYCKELBY
ASKÖ
3'
VISBY
HERRVIK
2
BALTIC PROPER
SVALÖV
HÖRVIK
1
64°
62°
60°
58°
56°
54°
14°
16°
18°
20°
22°

Fig. 2

MEASUREMENTS CARRIED OUT IN 1973 AND 1974

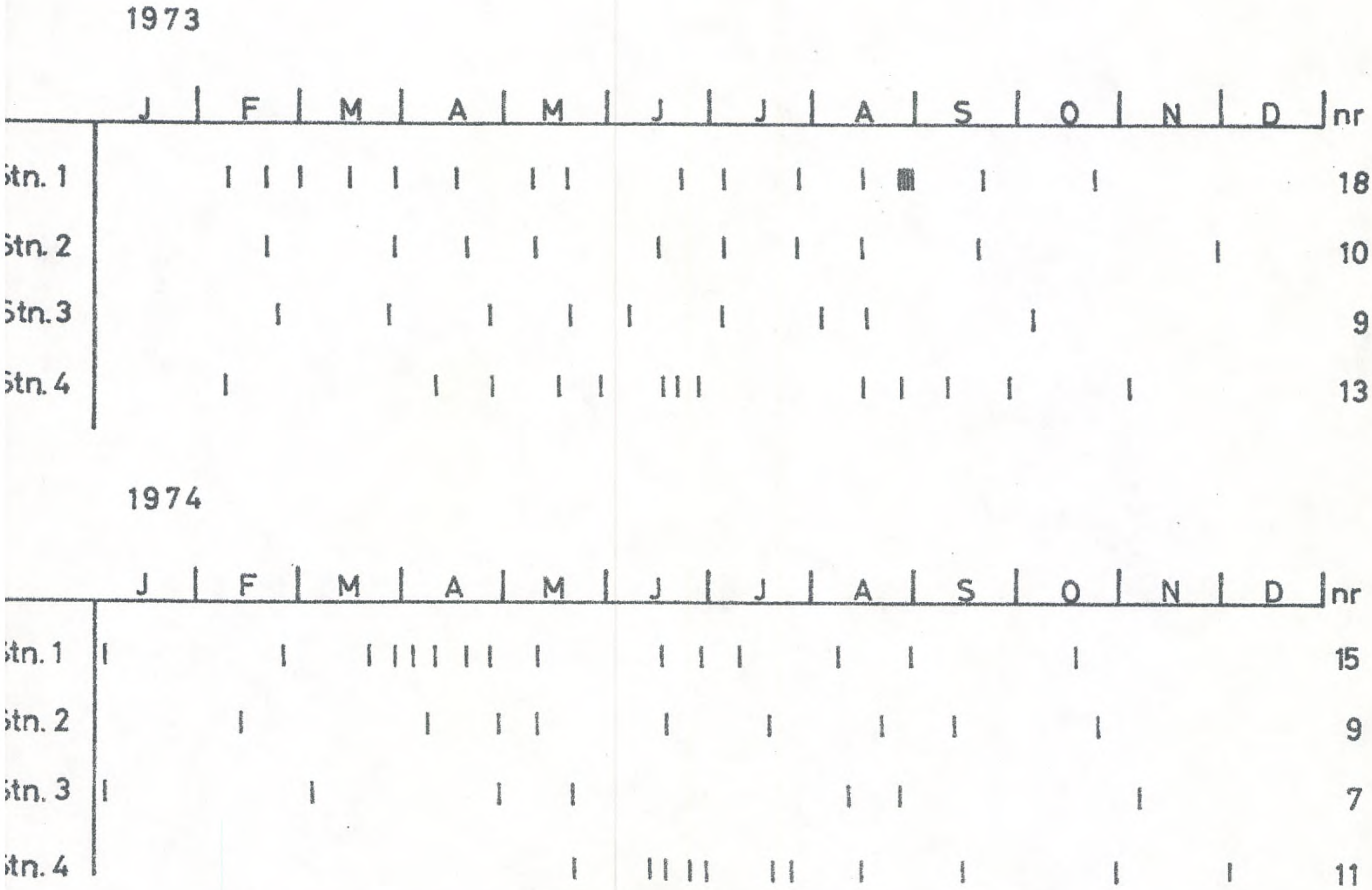
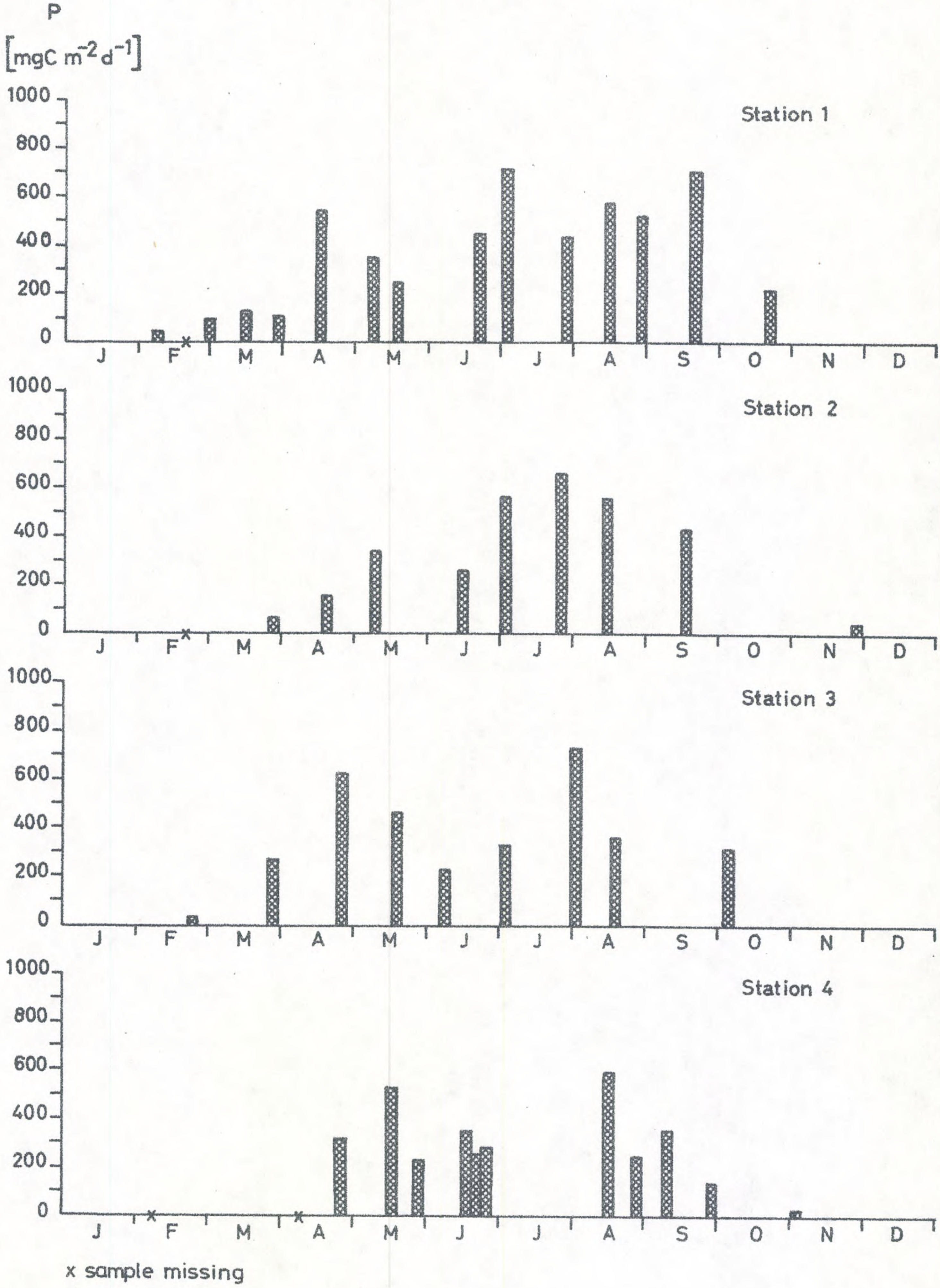
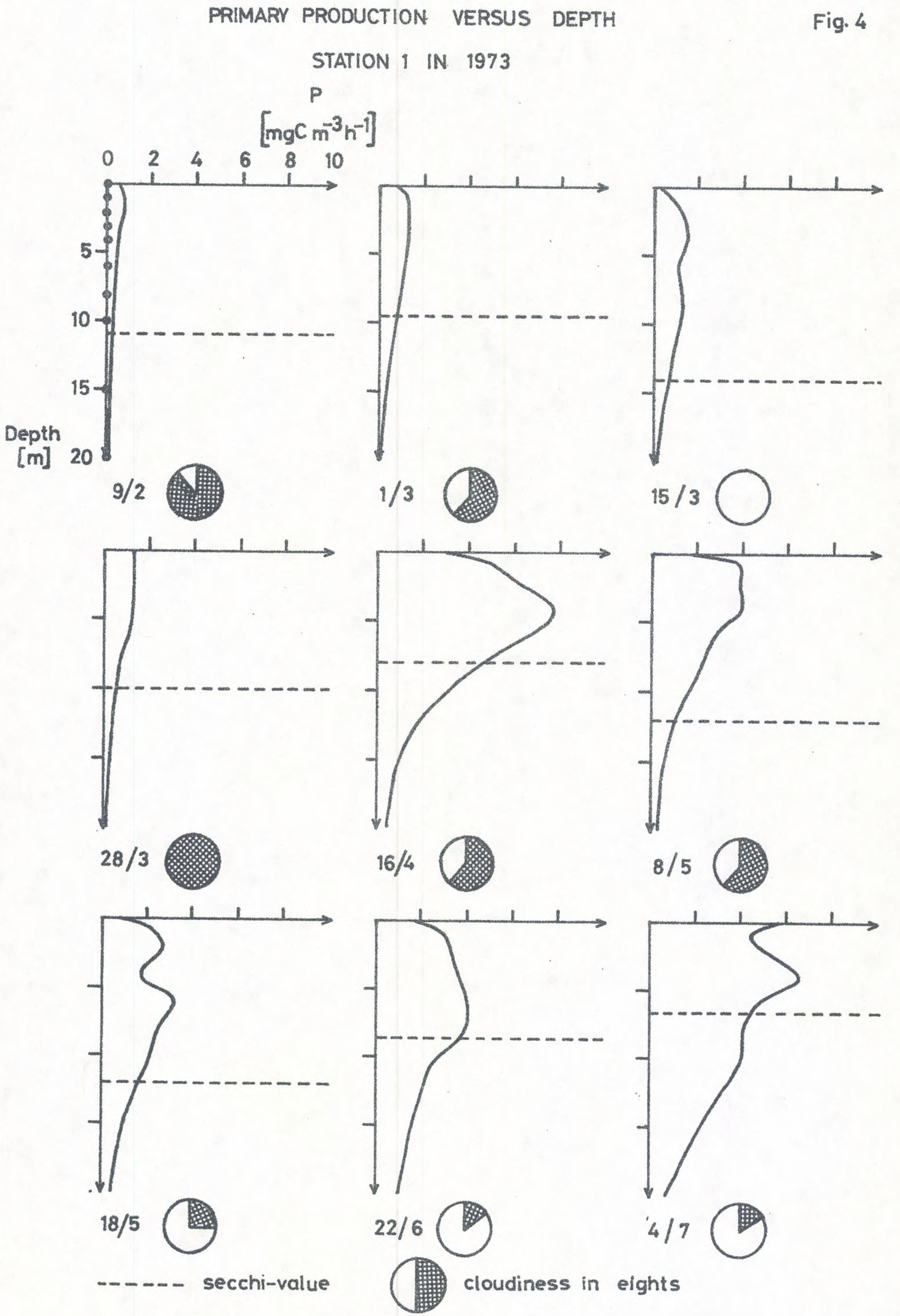


Fig. 3

PRIMARY PRODUCTION 0 - 20 M IN THE BALTIC 1973




PRIMARY PRODUCTION VERSUS DEPTH
Fig. 4
STATION 1 IN 1973
P
[mgC m^-3 h^-1]
0
2
4
6
8
10
5
10
15
Depth
[m]
20
9/2
1/3
15/3
28/3
16/4
8/5
18/5
22/6
4/7
secchi-value
cloudiness in eights

PRIMARY PRODUCTION VERSUS DEPTH

Fig.5

STATION 1 IN 1973

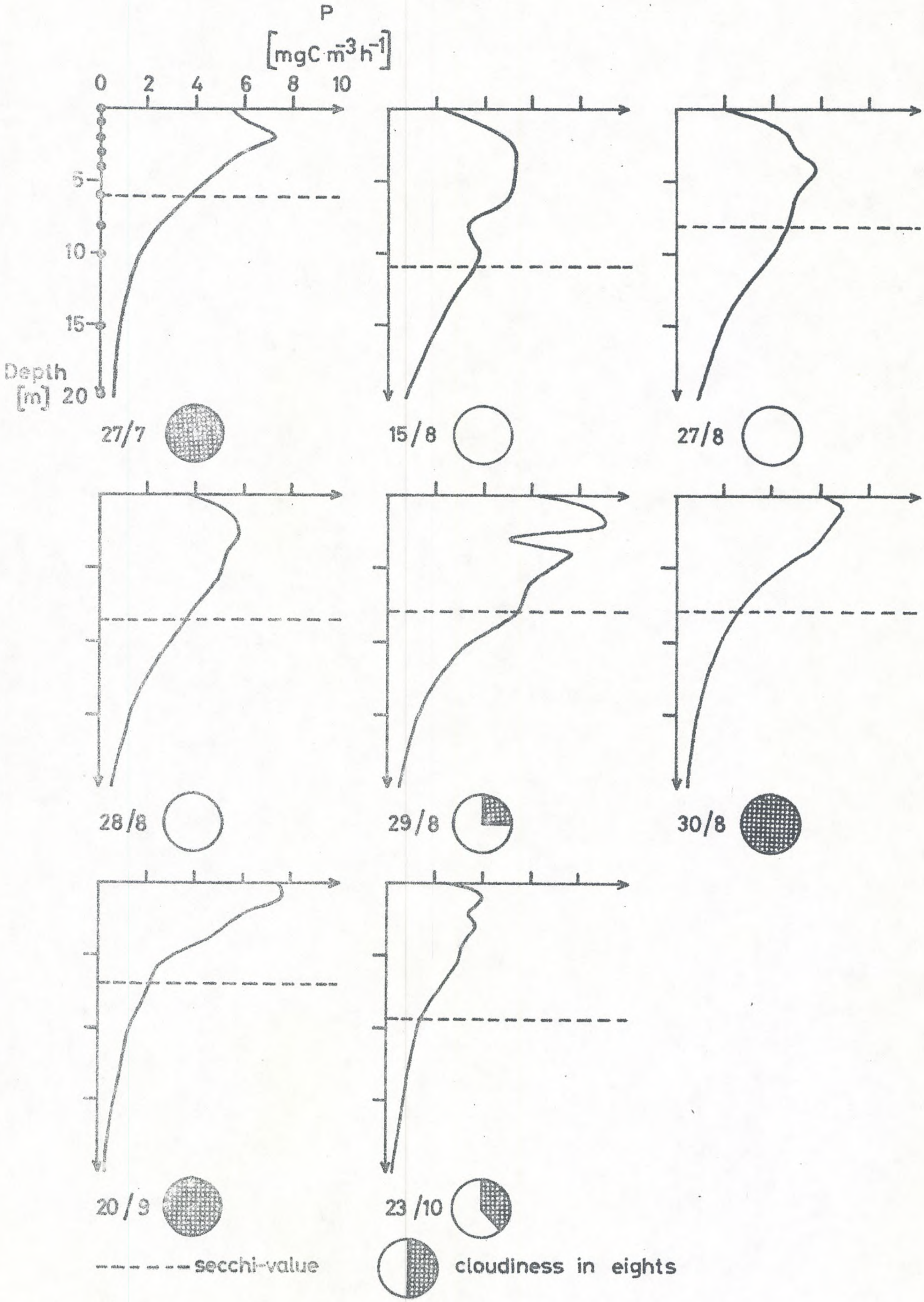


Fig. 6

CHLOROPHYLL a 0-15 M IN THE BALTIC 1973

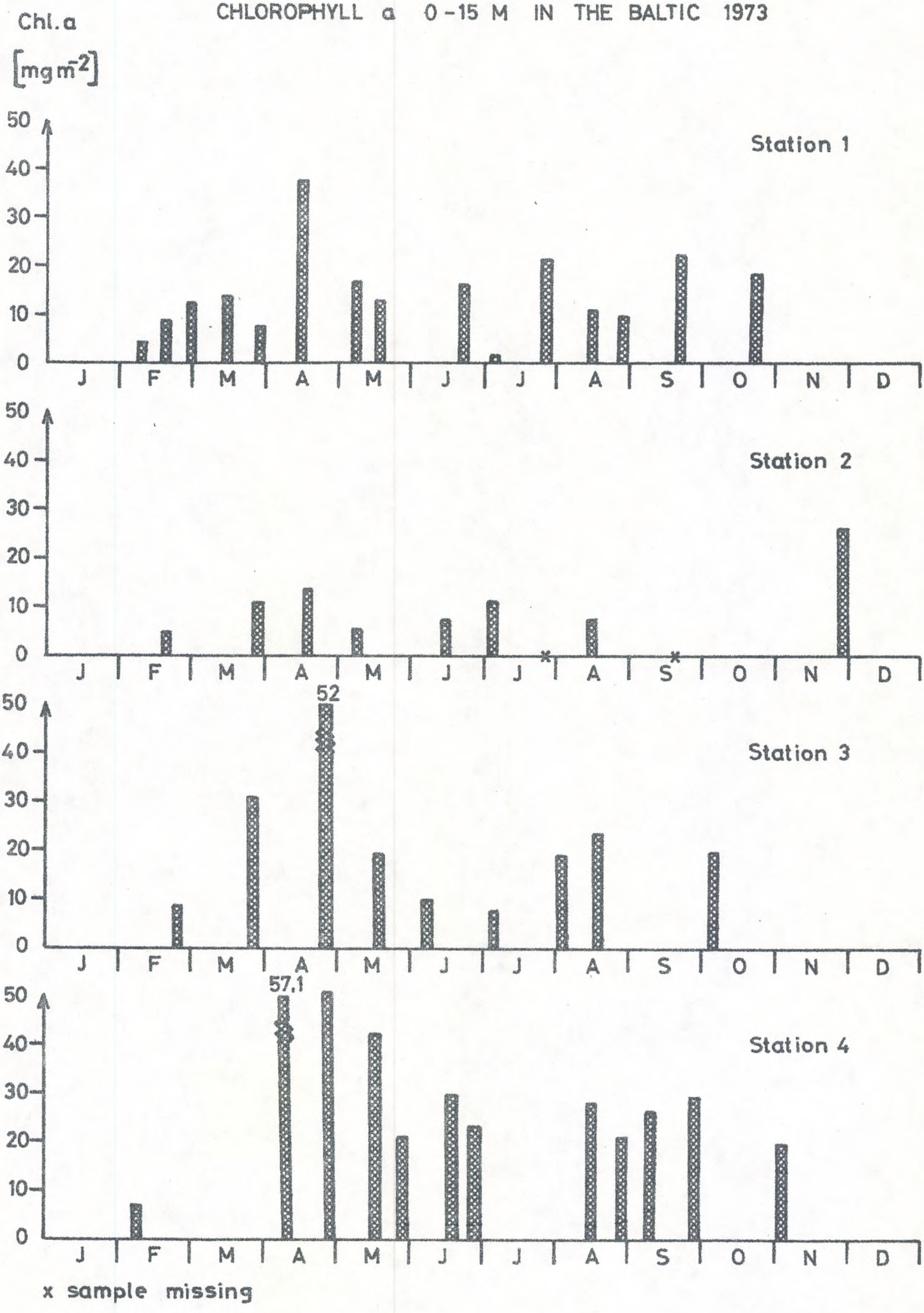
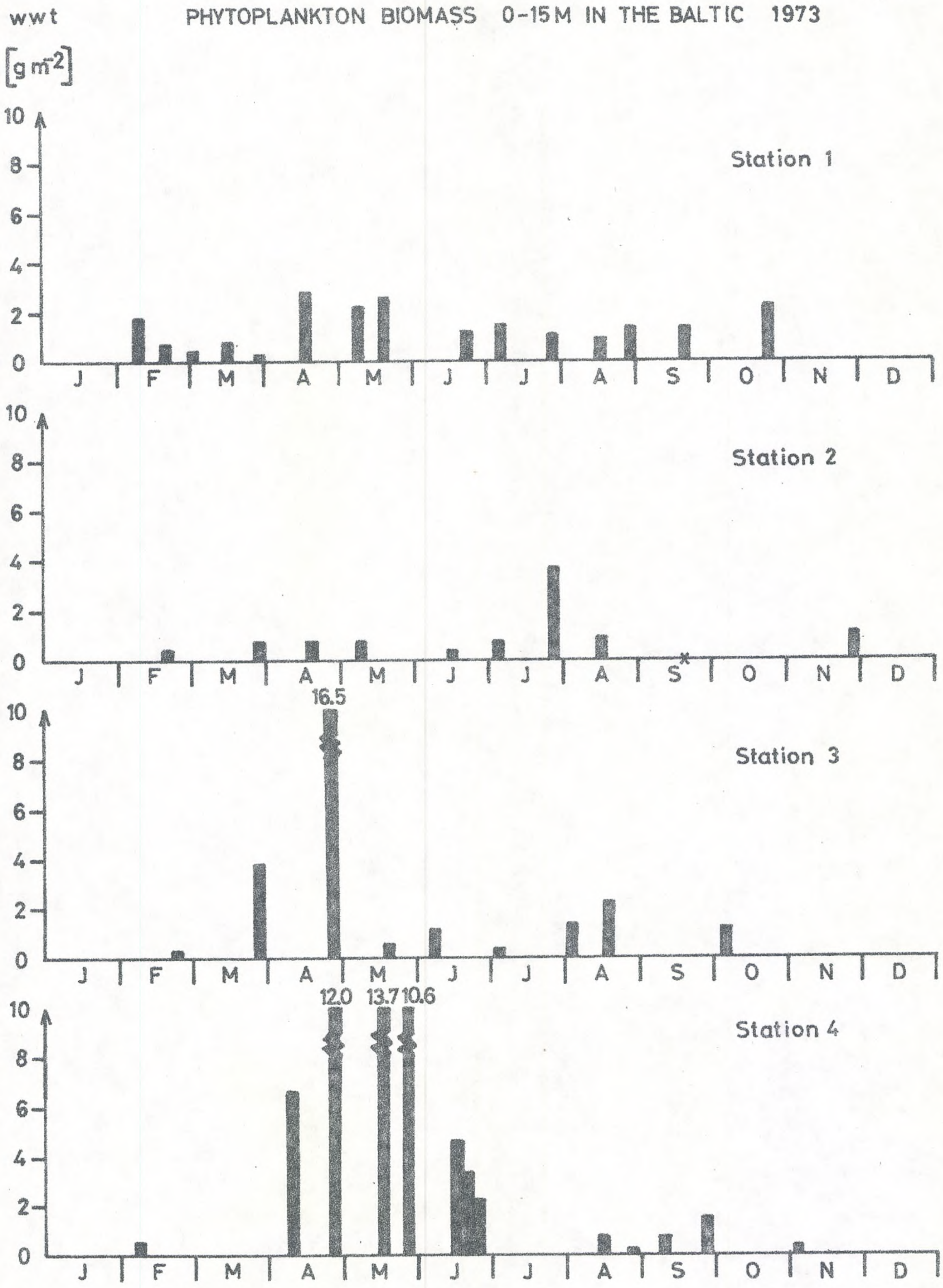


Fig. 7



x sample missing

Fig. 8

TEMPERATURE (°C) 0-20 M IN THE BALTIC 1973

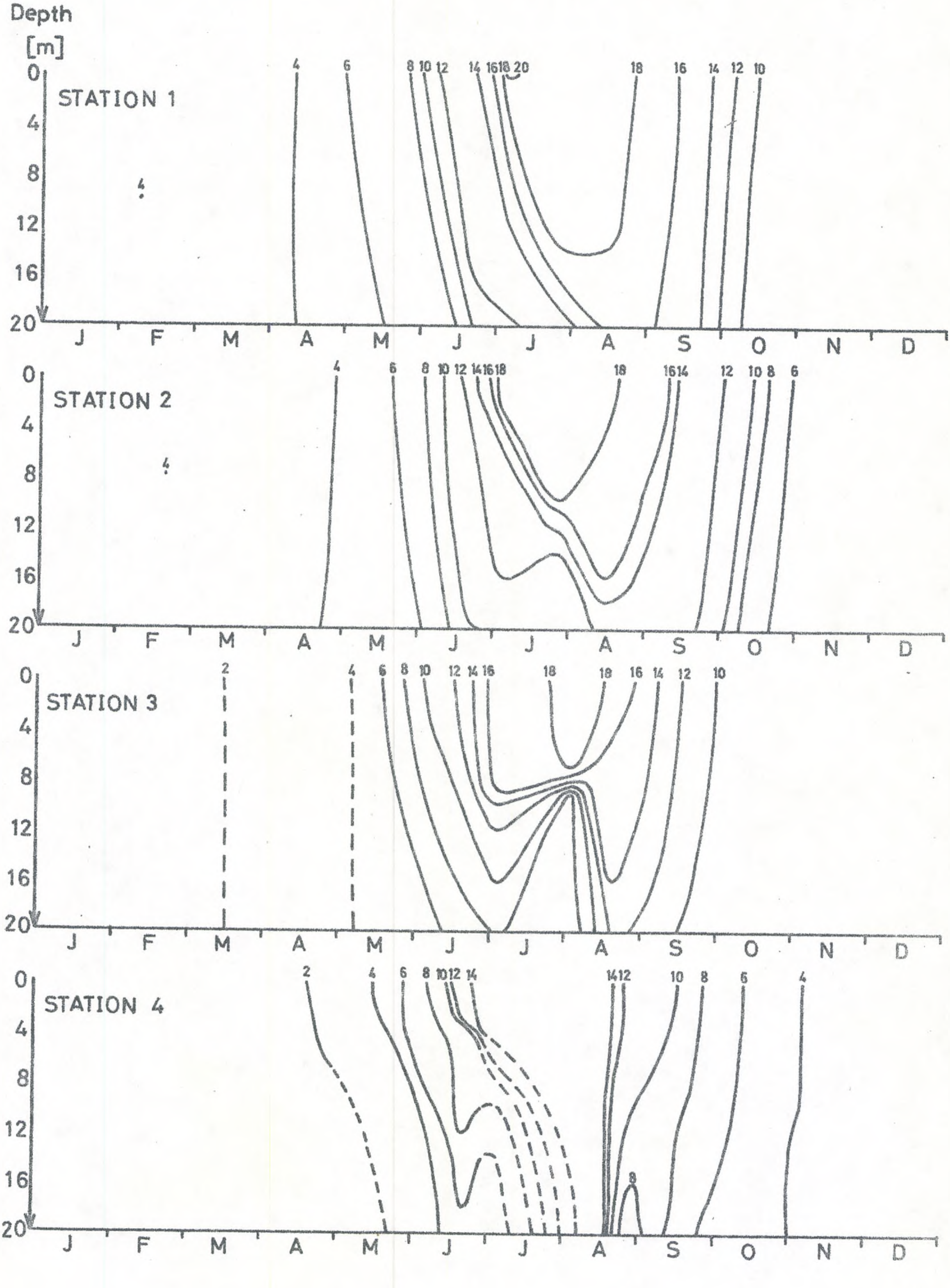


Fig. 9

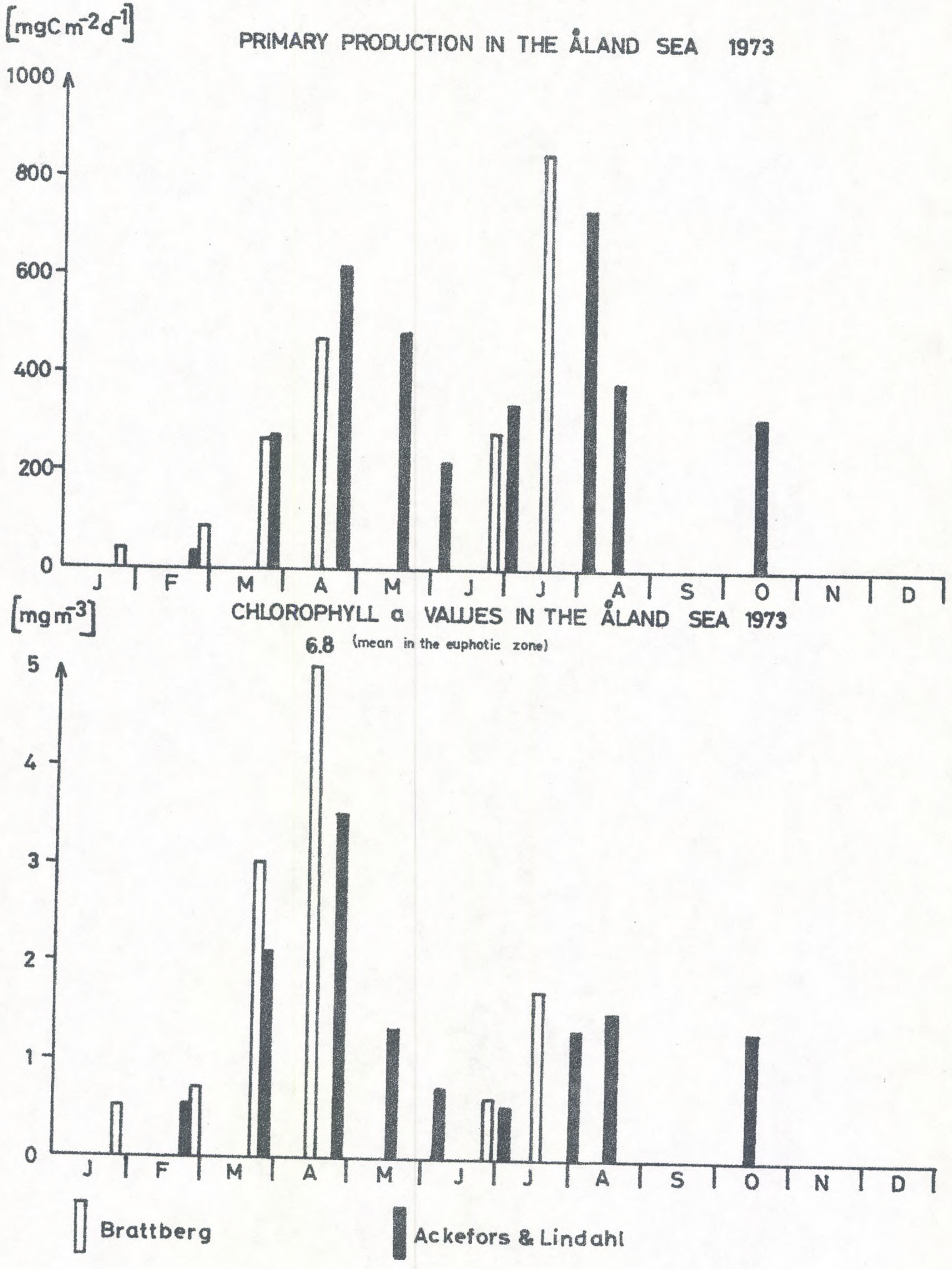

[mgC m-2 d-1]
PRIMARY PRODUCTION IN THE ÅLAND SEA 1973
1000
800
600
400
200
0
J F M A M J J A S O N D
[mg m-3]
CHLOROPHYLL a VALUES IN THE ÅLAND SEA 1973
6.8 (mean in the euphotic zone)
5
4
3
2
1
0
J F M A M J J A S O N D
Brattberg
Ackefors & Lindahl

Table 1. Total incoming radiation, measured production, calculated production, chlorophyll a values, phytoplankton biomass values at station 1, 1973.

Date	Radiation mWh cm^{-2}	Measured production mgC $m^{-2}h^{-1}$	Calculated production mgC $m^{-2}d^{-1}$	Chlorophyll a mg m^{-2}	Phytoplankton biomass g m^{-2} wwt
730209	37	6.9	44	4.0	1.7
730220	-	-	-	8.0	0.7
730301	168	14.3	96	12.5	0.5
730315	374	18.0	131	13.6	0.5
730328	72	14.2	105	7.4	0.2
730416	241	67.3	480	37.6	2.9
730508	294	36.3	352	16.2	2.2
730518	422	32.5	244	13.0	2.6
730622	783	49.5	460	15.4	1.2
730704	611	66.6	686	0.9 (?)	1.5
730727	444	47.9	446	21.0	1.0
730815	652	58.2	523	10.6	0.9
730827	587	60.9	524	9.9	-
730828	558	55.5	538	-	1.3
730829	449	70.3	577	-	1.3
730830	168	53.0	451	-	-
730920	72	44.6	700	22.0	-
731023	232	33.0	211	18.2	2.2

Calculated yearly production: 105 gC m^{-2} $year^{-1}$.

Table 2. Total incoming radiation, measured production, calculated production, chlorophyll a values, phytoplankton biomass values at station 2, 1973.

Date	Radiation $mWh\ cm^{-2}$	Measured production $mgC\ m^{-2}h^{-1}$	Calculated production $mgC\ m^{-2}d^{-1}$	Chlorophyll a $mg\ m^{-2}$	Phytoplankton biomass $g\ m^{-2}$ wwt
730220	-	-	-	4.9	0.3
730328	171	7.7	62	10.8	0.8
730419	344	17.4	153	13.0	0.8
730509	577	33.7	330	5.0	0.8
730615	814	26.3	266	7.0	0.4
730704	722	52.1	568	10.9	0.7
730726	695	67.9	672	-	3.8
730815	651	60.3	561	7.2	0.9
730919	371	54.1	417	-	-
731129	39	8.6	43	25.4	1.0

Calculated yearly production: 91 $gC\ m^{-2}\ year^{-1}$.

Table 3. Total incoming radiation, measured production, calculated production, chlorophyll a values, phytoplankton biomass values at station 3, 1973.

Date	Radiation $mWh\ cm^{-2}$	Measured production $mgC\ m^{-2}h^{-1}$	Calculated production $mgC\ m^{-2}d^{-1}$	Chlorophyll a $mg\ m^{-2}$	Phytoplankton biomass $g\ m^{-2}$ wwt
730224	256	4.5	30	8.4	0.3
730327	181	34.9	272	31.0	3.9
730426	189	41.9	616	52.0	16.5
730519	166	32.1	472	19.1	0.5
730607	815	21.2	214	10.0	1.1
730704	787	32.6	336	7.5	0.4
730803	661	78.0	725	18.9	1.3
730817	592	41.2	379	22.9	2.4
731005	279	39.8	310	19.3	1.3

Calculated yearly production: 94 $gC\ m^{-2}\ year^{-1}$.

Table 4. Total incoming radiation, measured production, calculated production, chlorophyll a values, phytoplankton biomass values at station 4, 1973.

Date	Radiation mWh cm^{-2}	Measured production mgC $m^{-2}h^{-1}$	Calculated production mgC $m^{-2}d^{-1}$	Chlorophyll a mg m^{-2}	Phytoplankton biomass g m^{-2} wwt
730209	-	-	-	6.9	0.6
730410	-	-	-	57.1	6.7
730427	-	30.8	308	50.1	12.0
730516	651	49.0	524	42.3	13.7
730528	294	20.3	231	21.2	10.6
730617	817	31.5	343	29.8	4.7
730621	719	23.7	258	20.8	3.2
730627	661	30.5	290	23.4	2.3
730815	511	60.5	593	27.5	0.7
730827	173	24.4	232	20.9	0.1
730910	310	43.8	350	25.9	0.9
730928	51	23.7	133	28.9	1.5
731103	20	3.4	18	19.4	0.3

Calculated yearly production: 71 gC m^{-2} $year^{-1}$.

Table 5. Quarterly and yearly production in gC m^{-2} in 1973 in the Baltic. In brachets values for 1974.

	I	II	III	IV	Total
Station 1	6 (8)	34 (50)	53	12	105
Station 2	4 (6)	25 (37)	50	12	91
Station 3	8 (7)	37 (-)	41	8	94
Station 4	3 (Ice)	29 (17)	36	4	71

Table 6. The components of phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt). Station 1, 1973.

Date	Blue-green Algae %	Diatoms %	Silico-flagellates %	Dino-flagellates %	Green Algae %	Euglenids %	Monads %	Total wwt g m^{-2}
730209	0.4	50.9	0	42.5	0	0	6.8	1.65
730220	0	71.0	0	0	0	1.8	27.2	0.68
730301	0	69.2	0	0	0.3	7.2	23.3	0.52
730315	6.7	34.3	0	1.7	0	6.7	50.6	0.71
730328	0	63.1	0	3.0	0	3.7	29.9	0.20
730416	3.5	91.5	1.1	0.7	0.1	0.4	2.7	2.91
730508	4.4	79.7	6.6	1.9	0	0	7.4	2.20
730518	0.5	92.2	0.5	2.1	0	0	4.7	2.58
730622	51.4	20.7	1.0	7.8	1.2	0.3	17.6	1.16
730704	26.9	38.5	2.3	0.8	6.0	0.1	25.4	1.47
730727	28.4	30.3	1.2	0	0	0	40.1	1.02
730815	14.1	58.4	0	0.9	0.2	0.2	26.2	0.92
730828	6.5	28.5	2.8	3.0	0.1	0.1	59.0	1.28
730920	29.0	0.7	4.6	2.3	0	0.5	62.9	1.30
731023	4.9	87.9	0	0.3	0.3	0.1	6.5	2.19

Table 7. The components of phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt). Station 2, 1973.

Date	Blue-green Algae %	Diatoms %	Silico-flagellates %	Dino-flagellates %	Green Algae %	Euglenids %	Monads %	Total wwt g m^{-2}
730220	12.1	81.0	0	0	0	0	6.9	0.30
730328	53.9	37.3	0	0	1.5	2.1	5.2	0.78
730419	0	84.1	0	0	0	3.2	12.7	0.81
730509	23.3	10.7	1.6	59.4	0	0	5.0	0.82
730615	86.6	0	1.1	6.8	0.4	0	5.1	0.40
730704	39.2	10.9	12.0	25.6	3.6	0	8.7	0.70
730726	93.8	0.5	3.2	1.2	0.8	0	0.5	3.78
730815	38.1	0	3.9	0	0	0	58.0	0.91
730919	no sample							-
731129	21.3	71.2	0	1.2	0.3	0	6.0	1.0

Table 8. The components of phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt). Station 3, 1973.

Date	Blue-green Algae %	Diatoms %	Silico-flagellates %	Dino-flagellates %	Green Algae %	Euglenids %	Monads %	Total wwt g m^{-2}
730224	4.6	46.3	0	25.5	0	0	23.6	0.26
730327	0.6	80.9	0	15.3	0	0.1	3.1	3.88
730426	0	33.1	0.4	66.0	0	0.1	0.4	16.52
730519	2.6	52.5	0	11.5	0	0	33.4	0.46
730607	1.1	77.8	0	13.5	0	0.1	7.5	1.09
730704	34.6	52.3	1.3	0	0	0	11.8	0.35
730803	59.3	1.4	4.6	10.5	0.5	0.5	23.2	1.32
730817	55.7	0.9	12.6	2.5	0	0	28.3	2.38
731005	52.7	9.3	0.9	0	0.6	0.1	36.4	1.29

Table 9. The components of phytoplankton biomass expressed as percentage of the total. The total values are given as g m^{-2} (wwt). Station 4, 1973.

Date	Blue-green Algae %	Diatoms %	Silico-flagellates %	Dino-flagellates %	Green Algae %	Euglenids %	Monads %	Total wwt g m^{-2}
730209	17.2	21.5	0	32.1	0	0	29.2	0.56
730410	0.4	62.6	0.4	35.0	0	0	1.6	6.65
730427	0	67.4	0.2	28.0	0.1	0	4.3	11.95
730516	0.5	64.2	0	31.3	2.4	0	1.6	13.69
730528	0	88.2	0.1	8.1	1.7	0	1.9	10.62
730617	0.3	83.7	0	1.1	11.4	0	3.5	4.70
730621	1.1	69.9	0	0	12.9	0	16.1	3.17
730627	0	74.6	0	0	9.6	0	15.8	2.32
730815	41.6	17.7	3.5	0	1.9	0	35.3	0.69
730827	0	0	0	0	0.7	0	99.3	0.10
730910	30.7	31.1	8.4	5.6	0.5	0	23.7	0.86
730928	17.5	71.8	0.8	3.2	1.3	0	5.4	1.51
731103	4.7	15.4	4.7	19.0	15.1	0.6	40.5	0.25

Table 10. Primary production and chlorophyll a in the Åland Sea in 1973. Comparisons with the present investigation (AL) and an unpublished investigation carried out by Gunilla Brattberg, University of Uppsala (B). Chlorophyll a values in mg m^{-3} as a mean in the euphotic zone.

Date		Calculated production $mgC\ m^{-2}d^{-1}$	Chlorophyll a $mg\ m^{-3}$	Investigation
January,	24	35	0.5	B
February,	24	30	0.6	AL
"	28	81	0.7	B
March,	23	264	3.0	B
"	27	272	2.1	AL
April,	15	463	6.8	B
"	26	616	3.5	AL
May,	19	472	1.3	AL
June,	7	214	0.7	AL
"	27	278	0.6	B
July,	4	336	0.5	AL
"	18	847	1.7	B
August,	3	725	1.3	AL
"	17	379	1.5	AL
September				
October,	5	310	1.3	AL

APPENDIX

QUALITATIVE ANALYSIS OF PHYTOPLANKTON

by

LARS EDLER

Besides the production measurements and quantitative analysis, a qualitative analysis of phytoplankton has been performed. This analysis was considered to be important, since it is the first time four "off-shore"-stations are visited in such a frequent manner in the Baltic. The seasonal changes of the species composition can of course be seen in the quantitative analysis, but a great deal of the small and delicate cells are easily overlooked when counting the organisms. The intensity of production is not only dependent of the quantity of organisms, the specific species composition must be important as well.

Most of the dominating species during the investigations were classified in the quantitative analysis, some however were determined only to genus and some were obviously overlooked.

Net hauls were taken from 20 to 0 m, using a net with a mesh size of 25 µm. The samples were preserved in Keefe´s solution and the microscopical examination was made on water mounts and Clerax mounts, using a light microscope with phase contrast.

RESULTS

Seasonal changes of the phytoplankton.

Station 1.

In February more than 90 % of the population consisted of two species, Actinocyclus ehrenbergii and Gymnodinium spp..The latter was abundant only in the beginning of February and made up nearly half the biomass, but had disappereed in the end of the month. A. ehrenbergii on the other hand was the most abundant species until the spring bloom in April. Already in February Chaetoceros danicus was observed in the net hauls in considerably amounts. It continued to be present the whole year and from the net hauls it seemed to be one of the most frequent species at station 1. It was, however, found only in very small amounts in April and May in the quantitative samples.

In the middle of March the increase of the production and the amount chlorophyll was accompanied by an increasing number of species. The biomass did not follow this evolution, instead it was decreasing. The possible explanation for this is that the new species were all very small in size, e.g. Chaetoceros wighamii, Nitzschia spp., Skeletonema costatum and Oocystis spp..

In April the spring bloom took place. The species responsible for the high values of production, chlorophyll and biomass was Skeletonema costatum which made up about 85 % of the population. It was accompanied by a few other very abundant species, e.g. Aphanizomenon flos-aquae and Chaetoceros wighamii. Other species present during this bloom were Chaetoceros ceratosporum, Coscinodiscus concinnus, Dinophysis lachmanii, Gonyaulax diacantha, Peridinium spp. and Ebria tripartita.
The dominance of Skeletonema costatum was in the beginning of May replaced by Chaetoceros wighamii and C. holsaticus and in the end of the month these two species together with C. danicus. The accompanying species were the same as in April. During April and May Dinobryon balticum was observed in great abundance.

The summer maximum in the beginning of July was due to blue-green algae. The predominant species was Nodularia spumigena which rapidly disappeared after its intense bloom. Among the trichoms of N. Spumigena a great mass of Nitzshia closterium was found. Actinocyclus ehrenbergii showed a second maximum reaching almost the same abundance as in February. Also Ebria tripartita and Aphanizomenon flos-aquae had their second maxima of the year.

Chaetoceros danicus reached a maximum during August. Dominating species during this period was however Actinocyclus ehrenbergii. In the end of August a great number of dying C. danicus was observed accompanied by several pennate diatoms, Amphiprora cf. paludosa, Ampora spp., Navicula spp., Nitzschia actinastroides and Nitzschia spp..
In late August and in September the only observation of Ceratium tripos were made. Nodularia spumigena and Aphanizomenon flos-aquae reached another maximum in September followed by a diatom-maximum in October with Actinocyclus ehrenbergii, Chaetoceros danicus and Coscinodiscus concinnus as dominating species.

Station 2.

The first samples of the year in February and March had a very restrict-ed phytoplankton flora. The few cells of Aphanizomenon flos-aquae in February developed in a month to a great population making up more than 50 % of the biomass. During this time a population of Actinocyclus ehrenbergii showed a constant abundance. Chaetoceros spp. (e.g. C. danicus), Skeletonema costatum, Dichtyosphaerium spp. and Nodularia spumigena were observed in minute numbers.

In April Aphanizomenon flos-aquae was still dominating, but the small population of Skeletonema costatum had reached an obvious maximum. Also Chaetocerus wighamii and Gymnodinium spp. were abundant, while Chaetoceros danicus and Nodularia spumigena were present in very low concentrations.

From abscence in April, Gonyaulus catenata developed to one of the dominating species in May. It was accompanied by a number of species, e.g. Chaetoceros danicus, C. septentrionalis, C. wighamii, Skeletonema costatum, Thalassiosira baltica, Gyrodinium spirale, Peridinum sp., Minuscula bipes, Dinobryon balticum and Aphanizomenon flos-aquae. This relatively rich species composition was not longer present in June, Aphanizomenon flos-aquae again was dominating. An increase of blue-green algae (Anabaena spp. and Nodularia spumigena) was observed. Remains of the previous population were still present, e.g. Chaetoceros danicus, C. wighamii, Gymnodinium spp. and Dinobryon balticum.

The blue-green algae reached their maximum in July, Nodularia spumigena being the dominating species, accompanied by Anabaena spp., Aphanizomenon flos-aquae and Oscillatoria spp.. Also Chaetoceras danicus, Ebria tripartia, Dinoptysis lachmannii, D. norvegica and a large number of Nitzschia actinastroides were observed.

From August and the rest of the year very few species were observed. Chaetoceras danicus and Aphanizomenon flos-aquae were dominating accompanied by small amounts of Nodularia spumigena. In August Nitzschia actinastroides was still present by disappeared in September. The dominating species were in November accompanied by a large Coscinodiscus consinnus population and a small amount of Actinocyclus ehrenbergii.

Station 3.

Throughout the year station 3 showed the greatest species composition. In

February very small amounts of the different species was observed. Thalassiosira baltica, Gonyaulax catenata, Gymnodinium spp. and Aphanizomenon flos-aquae were dominating. In the end of March, (obviously the very start of the spring bloom) a considerable number of species were present. The predominant species were Skeletonema costatum, Thalassiosira baltica and Gonyaulax catenata. They were accompanied by Chaetoceros ceratosporum, C. danicus, C. septentrionalis, C. wighamii, Coscinodiscus lacustris, Melosira arctica, Nitzschia spp., Thalassiosira sp., Gymnodinium spp., Peridinium spp. and Aphanizomenon flos-aquae, which all remained during April.

The spring bloom in April was dominated by the same species as in March. Also Chaetoceras wighamii and Ebria tripartita were very frequent. Still in May and June the species composition was almost the same. Skeletonema costatum, however, was not longer present and Diatoma elongatum, Dinophysis lachmannii, Peridinium brevipes, Dinobryon balticum and Nodularia spumigena were added.

In July the last remains of the Thalassiosira baltica population was observed, however, being one of the dominating species together with Aphanizomenon flos-aquae and Chaetoceras wighamii. The marked spring species Dinobryon balticum was still present accompanied by Chaetoceros danicus, Peridinium breve and Ebria tripartita. Aphanizomenon flos-aquae reached a maximum in the middle of August and decreased slightly throughout the autumn. Chaetoceros danicus, Dinophysis lachmannii, Ebria tripartita and Anabaena sp. were all observed in August but had disappeared in October when Aphanizomenon flos-aquae was the dominating species accompanied by a new development of Thalassiosira baltica and a small number of Ebria tripartita, Dictyosphaerium spp., Oocystis spp. and Gomphosphaeria lacustris.

Station 4.

In earlyFebruary the dinoflagellates Gonyaulax catenata and Gymnodinium spp. dominated the flora. Besides a few Aphanizomenon flos-aquae and Thalassiosira baltica were present. Gonyaulax catenata together with Chaetoceras wighamii and Thalassiosira baltica developed during April and culminated in May with an intense bloom. During April the species composition was dominated by diatoms, e.g. Achnanthes taeniata, Chaetoceros ceratosporum, C. danicus, C. septentrionalis, C. wighamii, Diatoma elongatum, Melosira arctica, Nitzschia spp. and Skeletonema costatum. The latter species reached its maximum in the end of April and decreased slowly the following months. In the end of June the last remains of it was observed.

With the onset of May Ankistrodesmus falcatus and Aphanizomenon flos-aquae started to develop as well as Chaetoceras wighamii, which clearly dominated during May and June. In May the only observation of Dinobryon petiolatum was made, as one of the few of Gonyaulax tricantha. Nitzschia actinastroides was present only throughout the summer, while most of the species observed in June were observed in September, e.g. Chaetoceras danicus, C. wighamii, Thalassiosira baltica, Dinophysis lachmannii, Ankistroidesmus falcatus and Aphanizomenon flos-aquae. Thalassiosira baltica and Aphanizomenon flos-aquae were the dominating species during the autumn. In September they were accompanied by the species just mentioned, but in November only Chaetoceras danicus and C. wighamii were remaining.

LIST OF SPECIES

BACILLARIOPHYTA

Achnanthes taeniata Grun.

Actinocyclus ehrenbergii Ralfs.

Amphiprora paludosa cf. W.Sm.

Amphora spp. Ehrenberg.

Asterionella formosa Hass.

Chaetoceros ceratosporum Ostenf.

" danicus Cleve.

" holsaticus Schütt.

" septentrionalis Oestrup.

" subtilis Cleve.

" wighamii Brightwell.

Cocconeis scutellum Ehrenberg.

Coscinodiscus granii Gough.

" lacustris Grun.

" sp. Ehrenberg.

Diatoma elongatum (Lyngbye) Agardh.

Melosira arctica (Ehr.) Dick.

" nummuloides (Dillwyn.) Agardh.

Navicula spp. Bory.

Nitzschia actinastroides (Lemm.) van Goor.

" closterium (Ehr.) Wm. Smith.

" spp. Hassall.

Skeletonema costatum (Greville) Cleve.

Synedra spp. Ehrenberg.

Thalassiosira baltica (Grun.) Ostenf.

" sp. Cleve.

PYRROPHYTA

Ceratium tripos (O.F. Müller) Nitzsch.

Dinophysis lachmannii Paulsen

" norvegica Clap. et Lachm.

" rotundata Clap. et Lachm.

Gonyaulax catenata (Lev.) Kof.

" diacantha (Meun.) J. Schiller.

" triacantha Jörg.

Gymnodinium spp. Stein.

Gyrodinium spirale (Bergh.) Kof. et. Swezy.

" spp. Kof. et. Swezy.

Peridinium breve Paulsen.
" brevipes Paulsen.
" cruvipes Ostenf.
" pellucidum (Bergh.) Schütt.
" sp. Ehrenberg.
Scrippsiella faeroeense (Paulsen) Balech et Oliveira Soares.

CHRYSOPHYTA

Dinobryon balticum (Schütt) Lemm.
" petiolatum Willen.
Ebria tripartita (Schum.) Lemm.

CHLOROPHYTA

Ankistrodesmus falcatus (Chorda) Ralfa.
" spiralis (Turner) Lemm.
Dictyosphaerium spp. Nägeli.
Oocystis spp. Nägeli.

EUGLENOPHYTA

Euglena spp. Ehrenberg.

CYANOPHYTA

Anabaena spp. Bory.
Aphanizomenon flos-aquae (L.) Ralfs.
Gomphosphaeria lacustris Chodat.
Nodularia spumigena Mertens.
Oscillatoria spp. Vaucher.

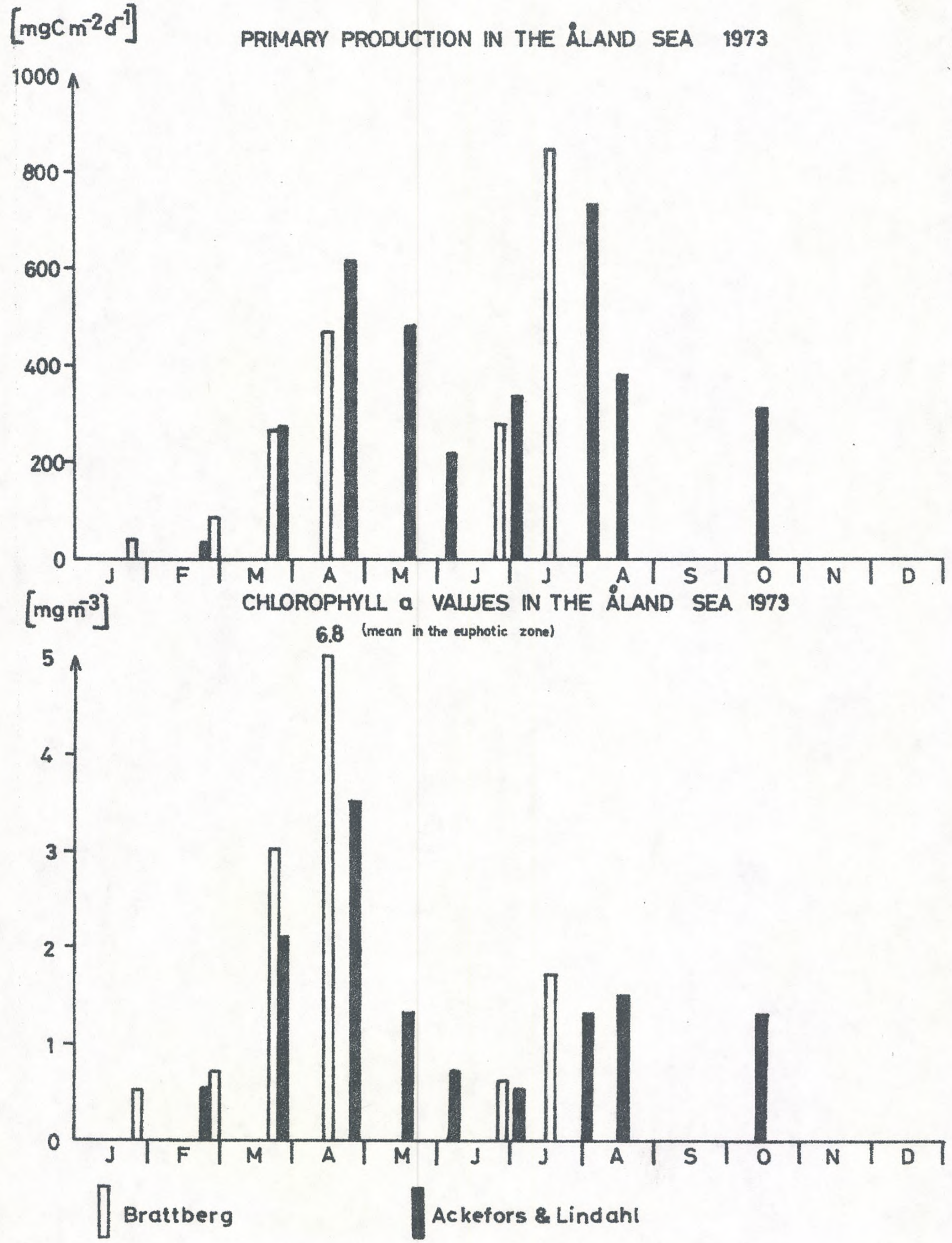
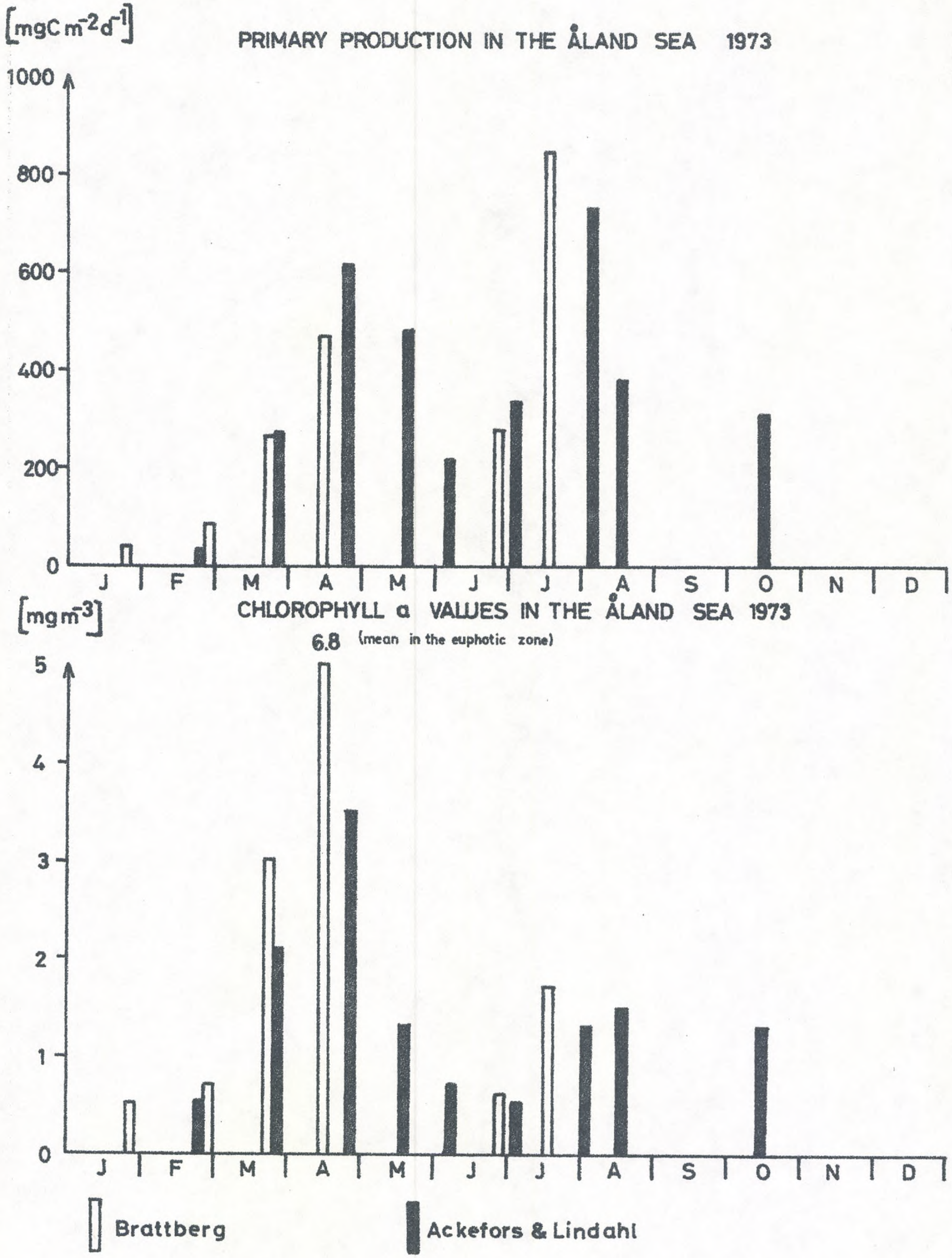

[mgC m⁻²d⁻¹]
PRIMARY PRODUCTION IN THE ÅLAND SEA 1973
1000
800
600
400
200
0
J F M A M J J A S O N D
[mg m⁻³]
CHLOROPHYLL a VALUES IN THE ÅLAND SEA 1973
6.8 (mean in the euphotic zone)
5
4
3
2
1
0
J F M A M J J A S O N D
Brattberg
Ackefors & Lindahl

Fig. 9



[mgC m^{-2}d^{-1}]
PRIMARY PRODUCTION IN THE ÅLAND SEA 1973
1000
800
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400
200
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J
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[mg m^{-3}]
CHLOROPHYLL a VALUES IN THE ÅLAND SEA 1973
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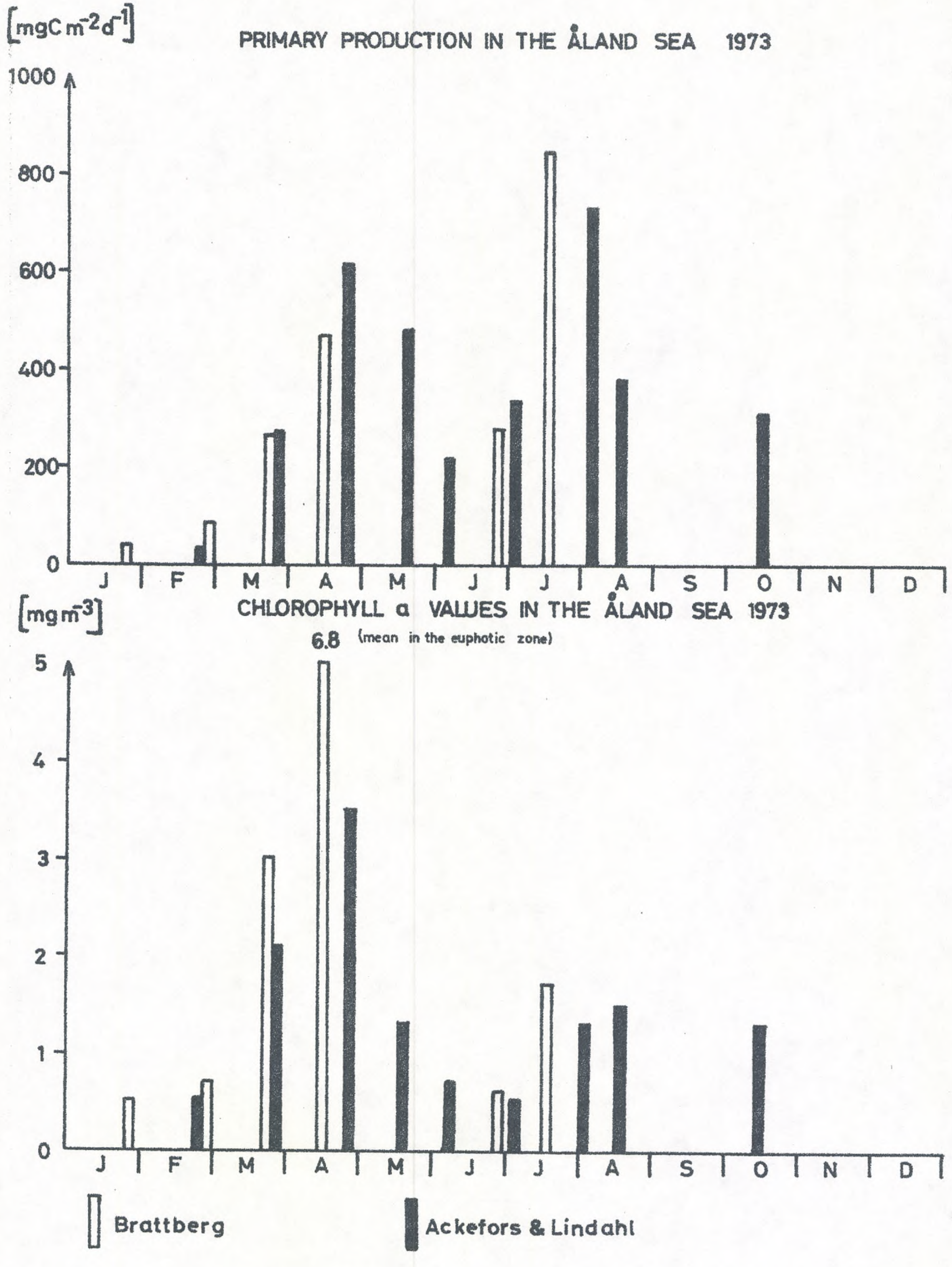
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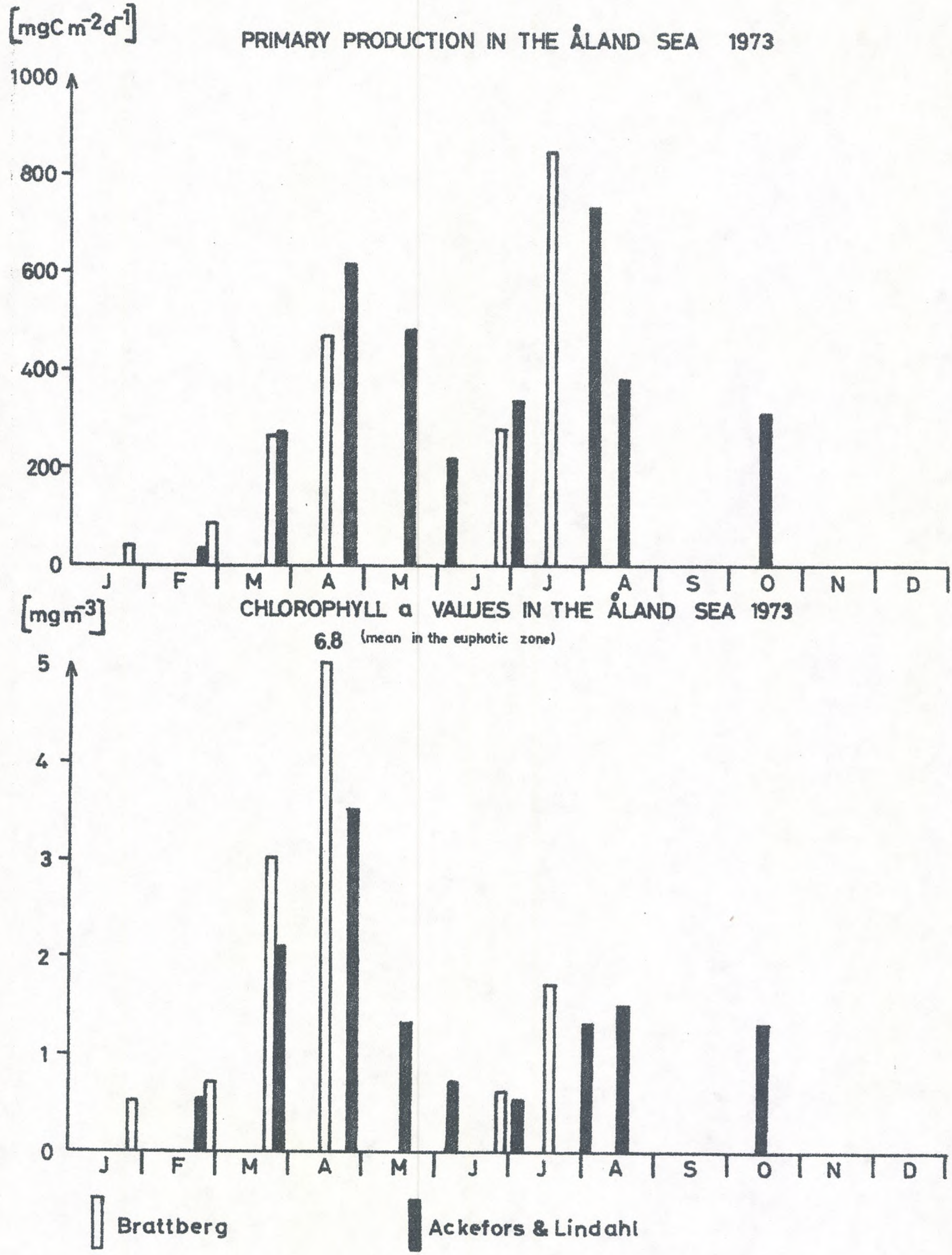

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