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# Quantitative changes in phytoplankton of the southern Baltic for 1971 - 1974

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## Introduction

The investigation on quantitative occurrence of phytoplankton of the southern Baltic started in 1971. The results which were based on investigation conducted during four years allowed the author to detect a close relation between the quantitative occurrence of phytoplankton and the environmental agents such as temperature, salinity and nutrient contents, especially the nitrate content. According to great variablity of the Baltic environment the eutriphication processes in this sea are not typical.

## Material and method of investigation

The material was taken in three southern Balitc regions /the Arkona Sea, Bornholm Deep and Gdańsk Deep/ in the period from February 1971 to November 1974.
This meterial was divided into seasonal groups the climatic seasons being as follows:

February - March - winter season,
April - June - spring season,
July - October - summer season, and
September - November - autumn season.

The elaboration of quantitative occurrence of species based upon samples taken with 5-litre "Hydro-Bios" sampler, at 0 m; 0,5 m; 5 m; 7,5 m; 10 m; 15 m and 20 m depths.

The cell numbers of particular species were counted by means of a 100 ml-cylindric cells in a reverse Utermöhl's microscope. The cell coefficient K[x/] for the samples worked on amounted to 8 400. In each cell 20 fields of vision were counted.
Qualitative composition of phytoplankton for the years under consideration has been presented in the contribution of M. Borysiak: "Qualitative changes in the composition or the phytoplankton against the hydrological background for 1971 - 1974 ".

Results of investigation

The predominat role as regards the number of plant cells per 1 $m^3$ of water, was played by the group of Chlorophyceae, though with respect to the number of species it was not the first of the range as it counted only 27 species. The quantitative preponderance of this group, however, was a substancial one, since one of the Chlorophyceae species, namely Kirchneriella obesa occurred in mas during all the four years of observations in all the areas investigated.
The next place as regards the number of cells beloned to the group of Cyanophyceae /20 species/ Microcystis aeruginosa being the species which occurred in mass in ceratin vegetation seasons.
Bacillariophyceae were considered to be the third group. In this group, which was the richest in species /67 species/ the quantitatively prevailing species varied in respect of number of cells accordingly to region, vegetation season and water depth. Here belonged: Sceletonema costatum, Cyclotella meneghiniana, C. stelligera, Thalassiosira decipiens, Chaetoceros wighami, Actinocyclus ehrenbergi, Coscinodiscus granii.

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x/ $K = R^2 : r^2$, where R = radius of the field of the cell
r = radius of the field of vision of the microscope /after K.Starmach, 1955/

Quantitative occurrence of Kirchneriella obesa

During the four year period of investigation two peaks of occurrence of this species were noted to take place in the Arkona Sea /Fig. 1/. The first of them was in March 1971 when the number of cells of this plant amounted to more than $3 \times 10^9/m^3$, the other peak fell on March - April 1974, exceeding the value of $7,5 \times 10^9/m^3$. In 1972 and 1973 Kirchneriella obesa occurred in quantities expressed in numbers of about $500-600 \times 10^6$ cells/$m^3$. In the area of the Bornholm Deep /Fig. 2/ the number of the cells of this species has increased since 1972. In 1973 there were peaks of quantity: one in June with over $3 \times 10^9$ cells/$m^3$, another - in August with $1,7 \times 10^9$ cells/$m^3$. In the meantime, i.e., in July, the number of Kirchneriella obesa cells dropped to about $500 \times 10^6/m^3$.
The highest number of cells of this species in the Bornholm Deep, however was noted in 1974. On turn of March the number of cells/$m^3$ amounted to over $3,5 \times 10^9$, thus constituing an analogy in quantitative occurrence of this species between the Arkona Sea and the Bornholm Deep in 1974, since in the same year and at the same time /i.e., in March and April/ in both of these regions the highest numbers of Kirchneriella obesa cells were found, though in the Arkona Sea the number in question was about two times as great as in the Bornholm Deep. In the Gdańsk Deep the above species reached a record number of cells/$m^3$ as compared with the other two regions during the four years concerend /Fig. 3/.
In 1971, during March and April the number of Kirchneriella obesa cells/$m^3$ was relatively small, amounting to about $4,5 \times 10^6$; in May 1972 it was not higher than $1,7 \times 10^9$; in April 1973 the number in question was already as high as over $15 \times 10^9$, thus constituing a record value in compa-

rison not only with the other species but also with the other regions of occurrence all over the investigation period of four years.
In July 1974 the cell number of Kirchneriella obesa in the Gdańsk Deep exceeded 7,5 x $10^9/m^3$. This value approximated the analogus one obtained for the Arkona Sea for the same year 1974 though the time of the year was not the same in both the cases: in the Arkona Sea it war March - April, whereas in the Gdańsk Deep the peak occurred in June and July. The investigation revealed the very vegetation season /the season with maximum number of cells/$m^3$/ for Kirchneriella obesa to be the winter-spring season /i.e.,March, April and May/ regardless on the region. In one case only another season of mass appearence of this species was noted, namely June 1974 in the Gdańsk Deep.

The depth at which the most numerous occurrence of Kirchneriella obesa was observed in particular years differend from on region to anotner.

Summarising the results of investigation on mass occurrence of Kirchneriella obesa species in the southern Baltic form the sea surface down to 20 m depth it may be said that only in the Gdańsk Deep the mass occurrence was observed at the sea surface whereas elsewhere the depths of mass occurrence markedly differed from year to year oscillating between 0.5 and 20 m depth.

Quantitative occurrence of Mircocystis aeruginosa

This species, the some as the one discussed above, was characterized by a mass and systematic occurrence, especially in the summer season. The presence of this species was observed in all the investigated regions.

Thus in the Arkona Sea the cell number per 1 $m^3$ of this species in September 1971 /Fig. 1/ /the occurrence has only been observed since this mounth/ exceeded 450 x $10^6$.

In the turn of July 1972 550 x $10^6$ cells/$m^3$ were found in this region. In 1973, also in summer, the value highest of all was noted, amounting to more than 1 x $10^9$ cells/$m^3$. In summer 1974 this number diminished. Thus in the Arkona Sea the numner of cells/$m^3$ oscilated between the least /450 x $10^6$/ and highest value /over 1000 x $10^6$/, the highest being noted in 1973.

In the Bornholm Deep /Fig. 2/ in September 1971 400 x $10^6$ cells of Microcystis aeruginosa per 1 $m^3$ were found. In 1972 there was a bsolute a quantity peak in July, when it reached about 1.5 x $10^9$. At the same time of 1973 the cell number was found to equal 1.2 x $10^9/m^3$. In 1974 - the minimum of cell number was noted /about 300 x 106 cell/$m^3$/ the same as in the Arkona Sea.

The Deep Gdańsk /Fig. 3/ was found to be the richest in the Microcystis aeruginosa species /the same as in Kirchneriella obesa/of all the regions investigated. The mass occurrence of Microcystis aeruginosa was noted without exception in July or August. In 1971 1,3 x $10^9$ cells/$m^3$ were counted there. In 1972 the cell number increased up to 2,2 x $10^9/m^3$.
In 1973 it amounted to 1,8 x $10^9$ and in 1974 it was relatively the lowest one as it equaled 1,25 x $10^9/m^3$.

If the species Microcystis aeruginosa in concerned the summer season /strictly: July and August/ must be considered a period of mass development at least during the period of 1971-1974, regardless of region.

Microcystis aeruginosa is peculiar by its eapacity to mass development both at the very sea surface and in deeper water layers.

Quantitative occurrence of certain species from the group of Bacillariophyceae

This group was the most numerous as regards the number of species which amounted to 69.
Quantitative distribution of particular species of this group allows us to say that certain of them occurred in mass and then disappeared according to vegetation season, region of occurrence and depth of water being afterwards displaced by other plant species.

In Figs. 4,5,6 are presented the quantitaties of particular species which were dominating down to 20 m depth in regions investigated.

Thus in the Arkona Sea the general quantity of diatoms during the period from 1971 do 1974 was decidedly less compared with other phytoplankton species. The relatively highest quantity of diatoms was found in 1973, as their number then amounted to 450 x $10^6$ cells/$m^3$. This number referred to Cyclotella meneghiniana. The next place as regards the cell number at the same time belonged to Rhizosolenia fragilissima /425 x $10^6/m^3$/. In 1974 the diatom /Cyclotella stelligera/ were less numerous as the maximum cell number was only 400 x $10^6/m^3$. The years 1971 and 1972 were in respect of quantitative occurrence of diatoms rather similar but the time of their maximum occurrence was different: in 1971 it was March and in 1972 - July, thus in both the years there were two different species making up the maxima: in 1971 there was a typically winter species Chaetoceros wighami and in 1972 - a typically summer species Cyclotella meneghiniana. In the Arkona Sea, the depth of the maximum occurrence of diatoms differed in consecutive years, but all of the peaks appeared of depths which did not exceed 10 m. It may generally be said that in the winter period the greatest density of plant cells was observed nearer to the sea surface.

In the region of the Bornholm Deep the number of diatom cells was notably higher /fig. 5/ as compared with that of the Arkona sea, though as compared with the other plankton plants of the Bornholm Deep this number was lower except for 1972. The maximum occurrence of diatoms in this region was noted in 1972, when two quantitative peaks were recorded: in March, with Sceletonema costatum, 1,3 x $10^9$ cells/$m^3$ and in Agust - with Cyclotella meneghiniana 1,6 x $10^9$ cells/$m^3$.

In 1973 the number of diatom cells in the Bornholm Deep did not exceed 550 x $10^6/m^3$, the concerned species being Cyclotella meneghiniana in summer. In Agust 1974 it was Cyclotella stelligera that reached the number of 1,4 x $10^9$ cells/$m^3$. The appearence of this species at this time in such a quantity proved that Cyclotella stelligera in 1974 found favourable conditions to thrive in the western regions of the southern Baltic Sea.
During the investigation time the depths of maximum occurrence of diatoms in the Bornholm Deep ranged from 7,5 to 20 m.

In the Gdańsk Deep the diatoms occurred in greatest quantities as compared with the other areas and all over the four year period under consideration.

In April 1971 /Fig.6/ a mass occurrence /about 4,5 x $10^9$ cells/$m^3$ of Thalassiosira decipiens was observed. In 1972 the number of diatom cells did not exceed 650 x $10^6/m^3$.
Two species contributed to this value: in May it was Diatoma elongata and in August - Cyclotella meneghiniana.
In 1973 there was the highest number of diatom cells/$m^3$ compared with the remaining three years of investigation.
In April Sceletonema costatum was extremely numerous /6,6 x $10^9$ cells/$m^3$/. In 1974 the quantitative peak of diatom occurrence appeared in June with Sceletonema costatum reaching a value of 2,5 x $10^9$ cells/$m^3$. In August of the some year a mass occurrence of Cyclotella stelligera was noted there as well as in the other Baltic regions. The cell number amounted then to 2 x $10^9/m^3$ hence a conclusion could be drown that the bloom of this species took place also in the eastern part of the sea.

The depths at which diatom cells in the Gdańsk Deep occurred most numerously differed according to vegetation season. In spring the diatom maxima occured at depths from 0,5 to 15 m, whereas in summer the diatoms were most numerous at 10 m depth.

The species of the group of Bacillariophyceae showed following pattern of occurrence: the most numerous species in the spring, in almost all the investigated areas, was Sceletonema costatum, in summer - it was Cyclotella meneghiniana, except for 1974, when this species was displaced by Cyclotella stelligera.

In autumn the most numerous species were found to be Actinocyclus ehrenbergii and Coscinodiscus granii.

In different regions the maxima of occurrence of diatoms fell on different years. Thus in the Arkona Sea the quantity peaks were noted in 1973 and 1974. In the Bornholm Deep They happend in 1972 and 1974, and in the Gdańsk Deep the years most rich in diatoms were 1971 and 1973.

Discussion

The results of quantitative analysis of the phytoplankton occurrence in the regions which were different in respect of hydrologic conditions during the investigation time 1971-1974 allowed the author to draw oncemore a conclusion about a close relation existing between phytoplankton development and hydrologic factors such as temperature, salinity and nutrient content of water /aspecielly the nitrate content/ at depths under consideration. All the quantity peaks attained by particular species were found to be due to propitious conditions of the environment. The maximum development as well particular species as of certain phytoplankton groups resulted from the astually favourable conditions.

In regions with relatively high water temepratures during the whole year, and there the salinity was relatively low and the nutrient content higher than elsewhere in the

Baltic aspecially due for example in the Gdańsk Deep a very large increase in quantity of fresh-water phytoplankton species was observed, whereas the species typical for brackish water did develop in lesser degree.

The reverse happened in regions where the relatively salt water deriving from influxes of the Nort Sea entered the Baltic in the first place, i.e., in the Arkona Sea and then in the Bornholm Deep. These influxes thougn carryinf certain amounts of nutrients disturbed the environment as regards temperature and salinity, and the effect of this process was quite negative for the phytoplankton development aspecially that of the fresh-water species.

In connection with this variability of the environment each region should separately be analysed since each of them exhibits its particular character.

Taking into consideration the hydrologic conditions /Filarski 72,73,74 Pastuszak 73,74, Głowińska 1975/ together with the periods of mass development of phytoplankton in the Arkona Sea in 1971 it could be found that in spite of surface temperature which in March of that year was the lowest during the whole period of investigation /amounting to about $1^{o}C$/ the phytoplankton there was rather rich /Fig.1 and 4/. This high number of phytoplankton cells/$m^3$ was probably due great concentrations of nitrogen compounds. There are no data about nutrients for March 1971 but the fact that as late as in summer, when the demand for nutrients by phytoplankton was covered, still remaind over a considerable amount of nutrient - about 1.8 ug-at N/1/. In winter months of 1971 the maximum number of diatom cells/$m^3$ was found in the Arkona Sea. In April, with the growing temperature of surface water, a species of Chloryphyceae, i.e., Kirchneriella obesa occurred in large quantity. In 1972 a strong influx of the North Sea water into the Baltic took place bringing with a very low

temperature, hence a decrease in the quantity of Chlorophyceae, whereas the number of diatom cells/$m^3$ rose in comparison with 1971. In summer there was observed an increase in quantity of Cyanophyceae cells. In 1973 a conspicuous increase in number of plankton cells as compared with 1972 was evident. The year 1973 showed temperatures decidedly higher than previous years /the winter temperature minimum amounted to 3-4°C. Also the nitrogen content of water was high /3 um-at N/l in February/. These favourable conditions of environment found their reflex in quantitative occurrence of phytoplankton. In 1974 the number of Kirchneriella obesa cells/$m^3$ in the Arkona Sea appeared to be the greatest as with preceding theree years. In that year the water temperature in early spring was only by about 1°C lower than in 1973 which was the warmer in this respect. In 1974 the top water layer of the sea underwent considerable though only local displacement resulting in natable fertilization of the environment previously impoverished. These conditions brought a mass occurrence of Kirchneriella obesa and also a considerable development of diatoms. Because there are unsufficient hydrological data for 1971, the correlation between environmental conditions and quantitative distribution of phytoplankton in the Bornholm Deep will only be considered since 1972.

The influx of the North Sea water in 1972 was extremely strong. It caused an uplift of deep waters, rich in nutrients, nearer to the surface. The effect of this uplift in the Bornholm Deep area was a very rich occurrence of all phytoplankton groups. Bacillariophyceae, for example, revealed two quantitative peaks in this year /Figs.2 and 5/. In the relatively very warm year 1972 the surface salinity was rather high. The nitrogen nutrient content of the top water layer did not exceed 2 ug-at /l, the phosphate content there

amounted to about 0.5 ug-at P/1. The rather nigh water temperature favoured quantitative development of phytoplankton, especially that of Chlorophyceae and Cyanophyceae, whereas the small nitrogen content checked the development of diatoms in remarkable degree. In 1974, when during the spring smoe bulk of surface water with high nutrient content underwent local movements along the stretch from West to the Bornholm Deep, a notable quantitative increase in phytoplankton was observed, especially as the species from the group of Chlorophyceae and Bacillariophyceae were concerned. The Gdańsk Deep region distinctly differed in respect of phytoplankton quantities form the remaining regions of the southern Baltic. During the 4 year period the greatest phytoplankton quantities were found to occur even nere /Figs.3 and 6/. This was the result of the relatively highest surface temperature, lowest surface salinity and highest nutrient contents of waters /especially nitrate content/ due to the river water discharge /Andrulewicz 74/. According to Polis research on quantitative distribution of nitrate for 1971-1974, the amount of this nutrient revealed a trend to increase till 1974. The quantitative peak of this year was as high as 1,08 mg/1. These increased amounts of nitrate as well as high temperature of surface water in 1973 fairly corresponded with amounts of phytoplankton. All the groups of phytoplankton reached in that year extremely high numbers of cells per 1 $m^3$.

Summing up the results obtained at quantitative study of distribution of the southern Balitc phytoplankton for the period 1971-1974 it may be said that the eutrophication of waters in the area concerend was not typical. The cause of this event should be considered the above described variability of marine environment.

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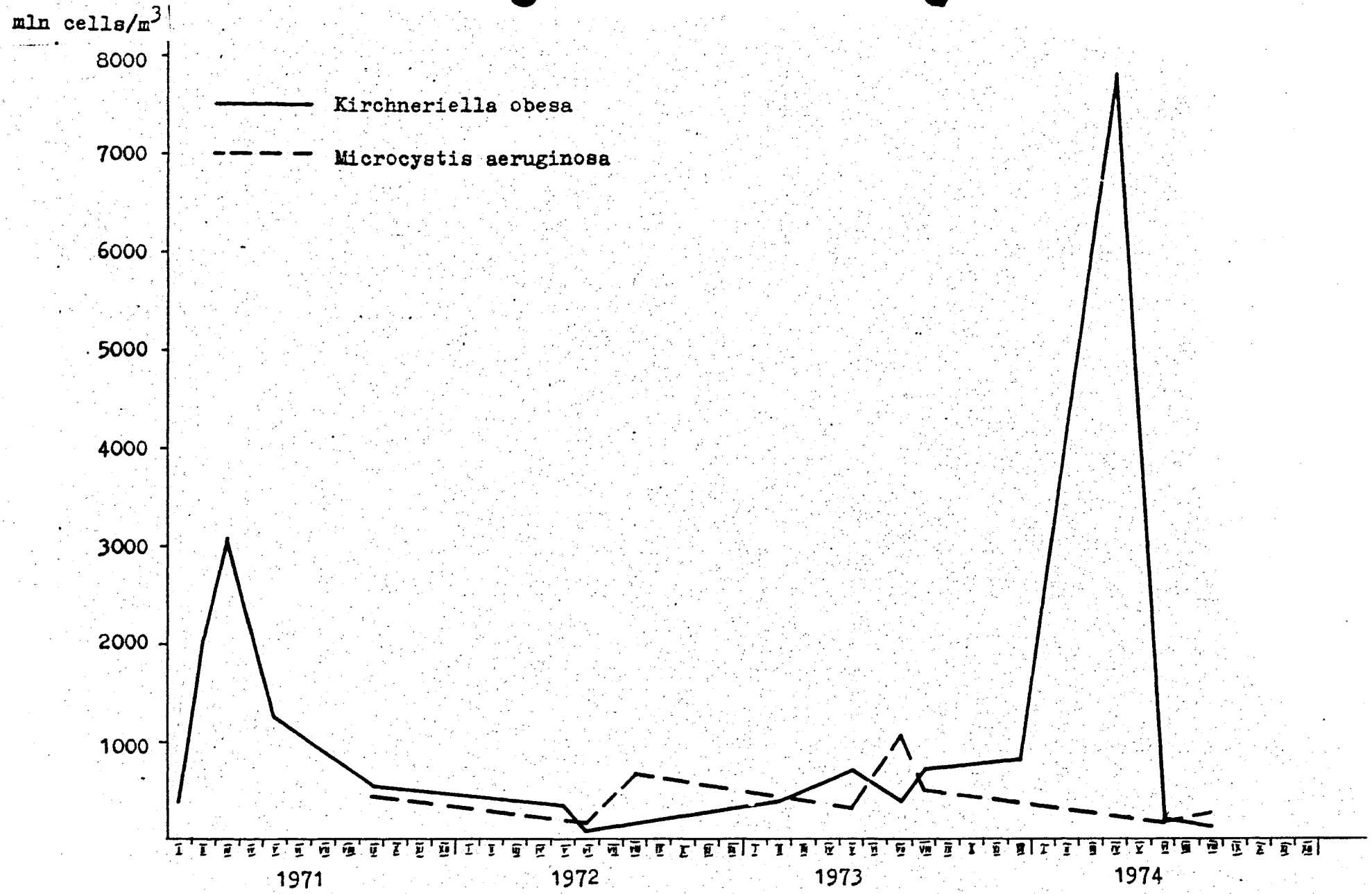


Fig. 1. The quantitative changes of phytoplankton in Arkona Deep.

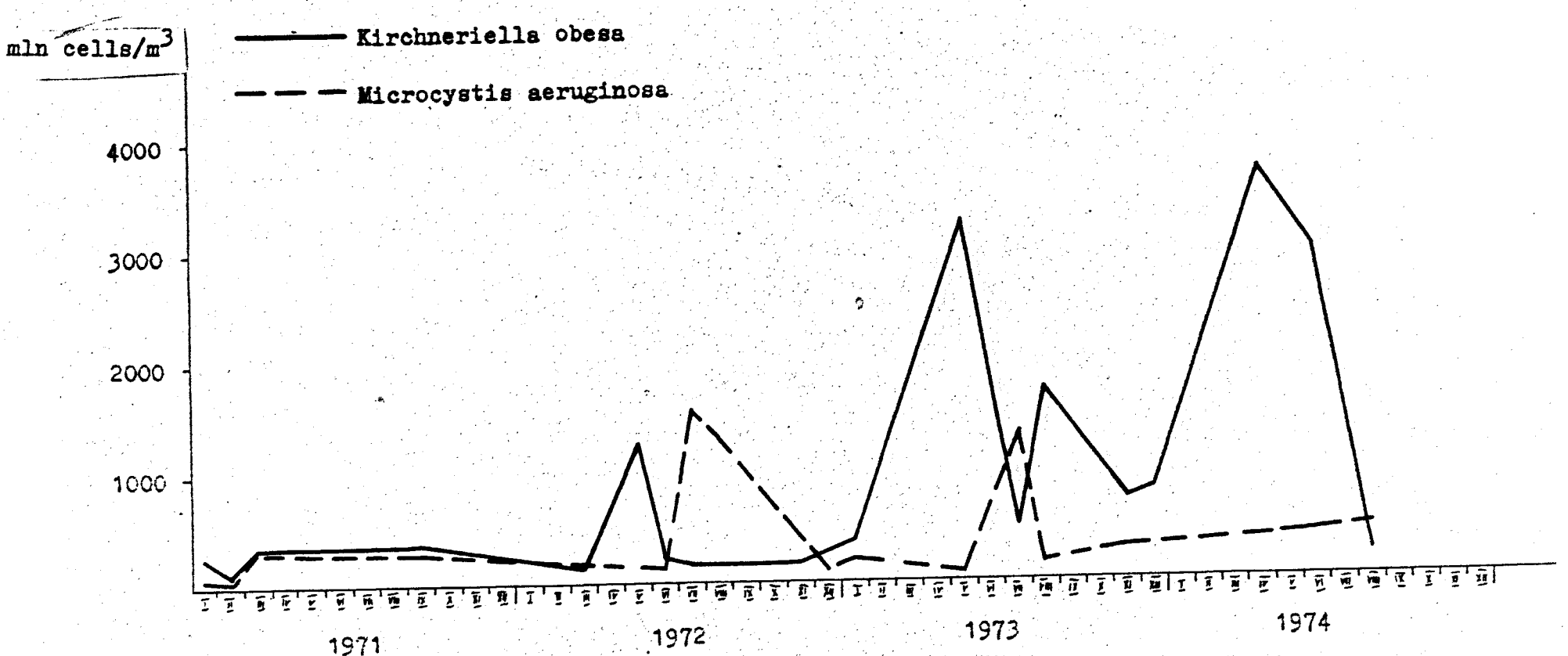


Fig. 2. The quantitative changes of phytoplankton in Bornholm Deep.

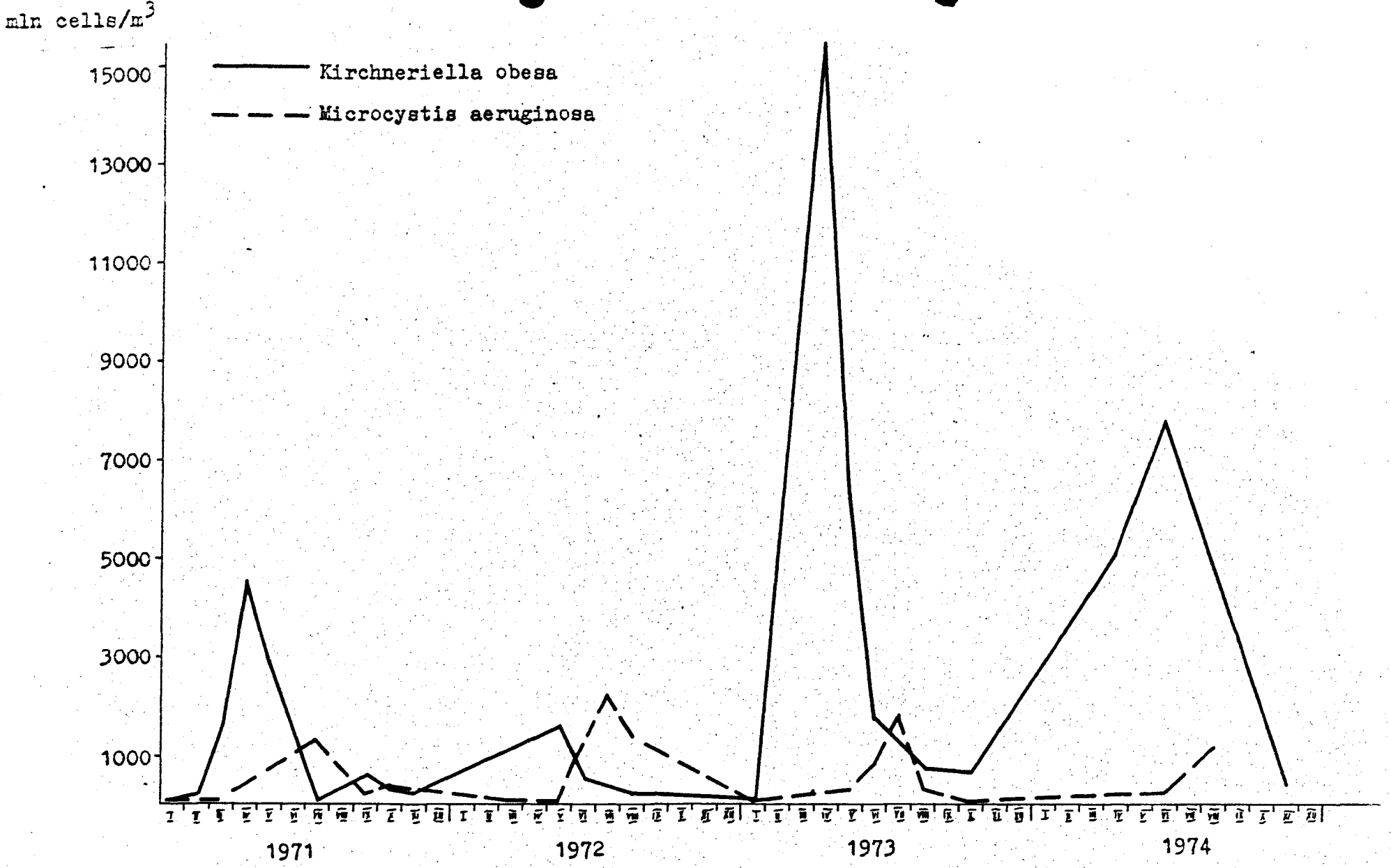


Fig. 3. The quantitative changes of phytoplankton in Gdańsk Deep.

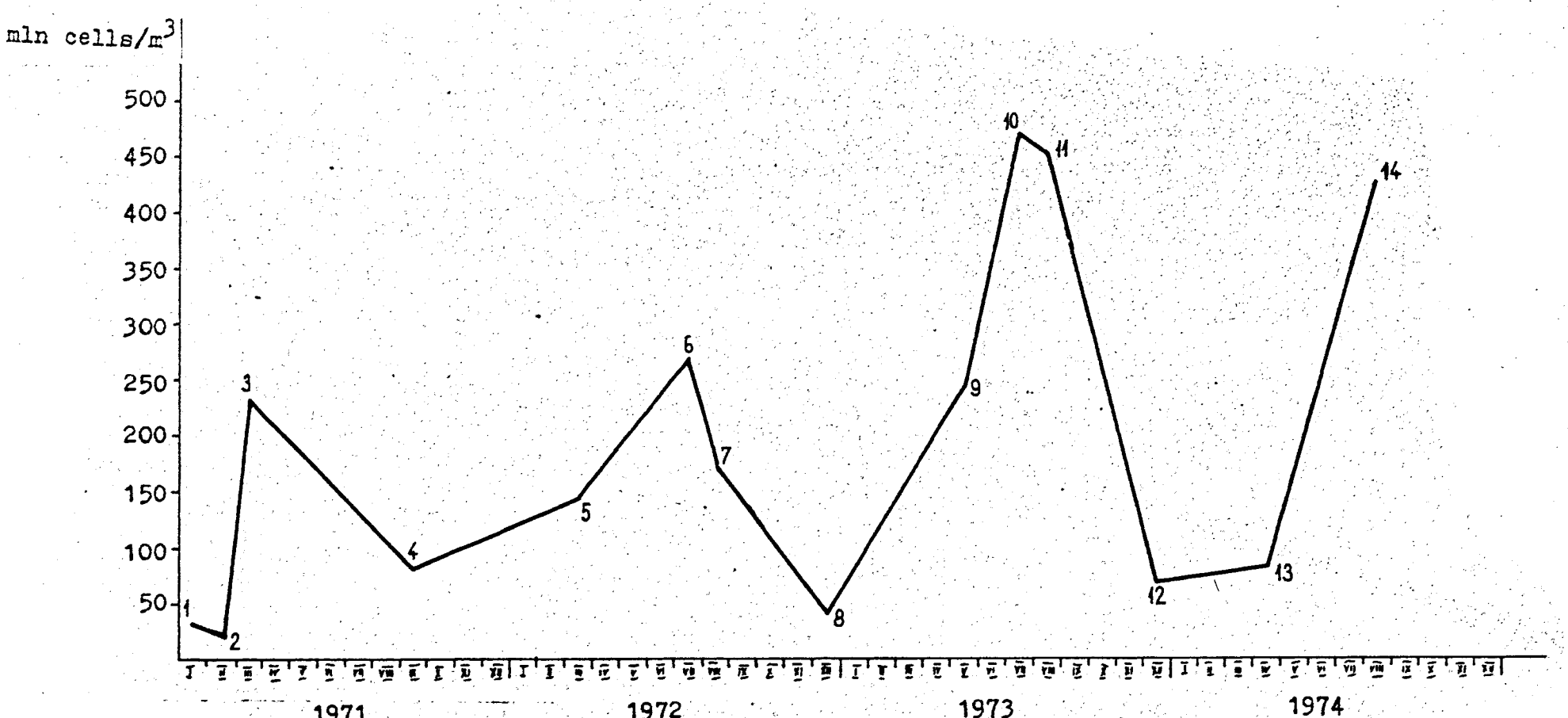


Fig. 4. The quantitative distribution of Bacillariophyceae in Arkona Deep.

1 - Actinocyclus ehrenbergi
2 - Sceletonema costatum
3 - Chaetoceros wighami
4 - Chaetoceros borealis
5 - Sceletonema costatum
6 - Cyclotella meneghiniana
7 - Nitzschia palea
8 - Actinocyclus ehrenbergi
9 - Chaetoceros borealis
10 - Cyclotella meneghiniana
11 - Rhizosolenia fragilissima
12 - Actinocyclus ehrenbergi
13 - Cyclotella melosiroides
14 - Cyclotella stelligera

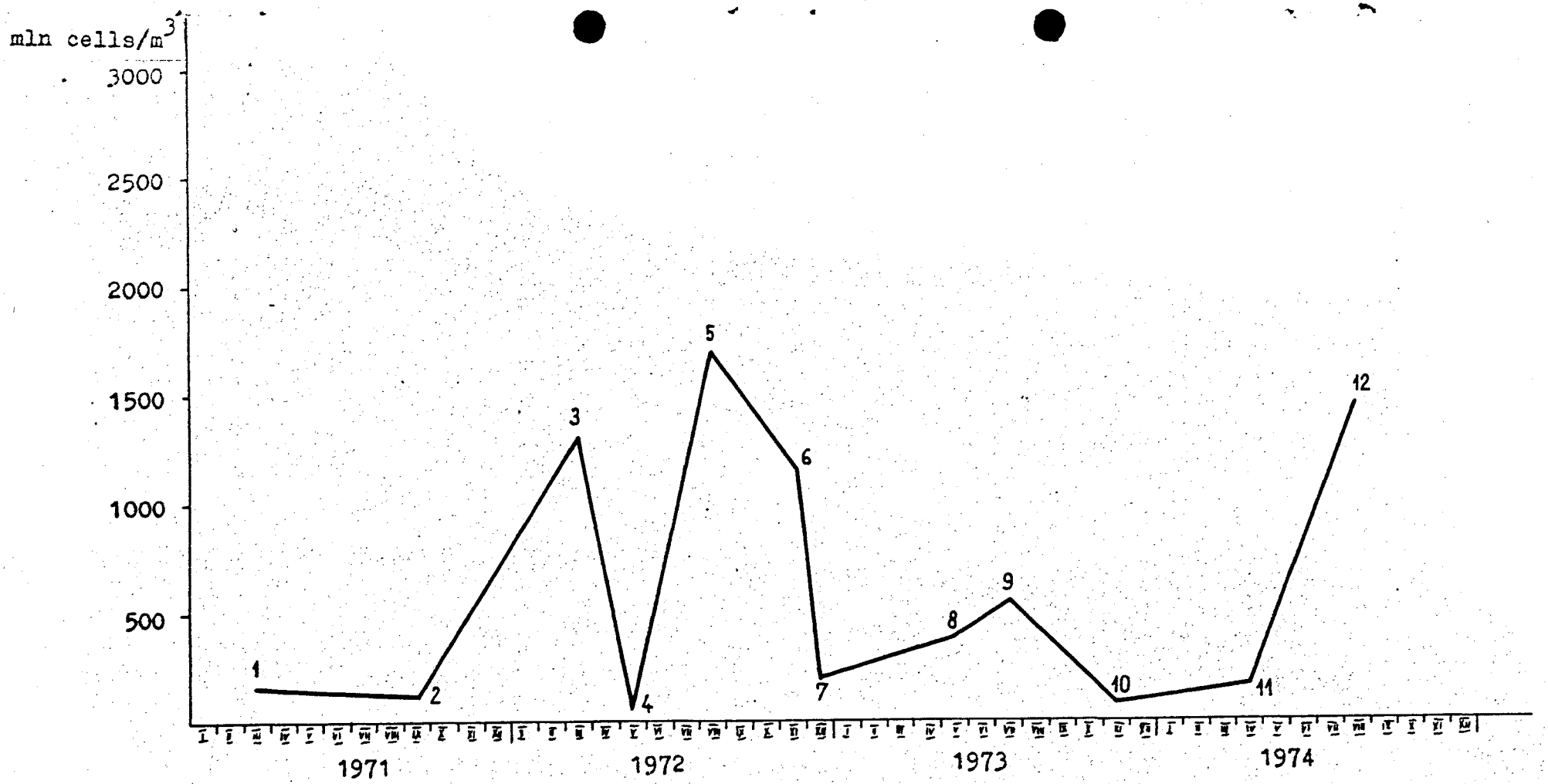


Fig. 5. The quantitative distribution of Bacillariophyceae in Bornholm Deep.

1 - Achnanthes taeniata
2 - Fragilaria sp.
3 - Sceletonema costatum
4 - " "
5 - Cyclotella meneghiniana
6 - Actinocyclus ehrenbergi
7 - Actinocyclus ehrenbergi
8 - Chaetoceros borealis
9 - Cyclotella meneghiniana
10 - Coscinodiscus granii
11 - Melosira nummuloides
12 - Cyclotella stelligera

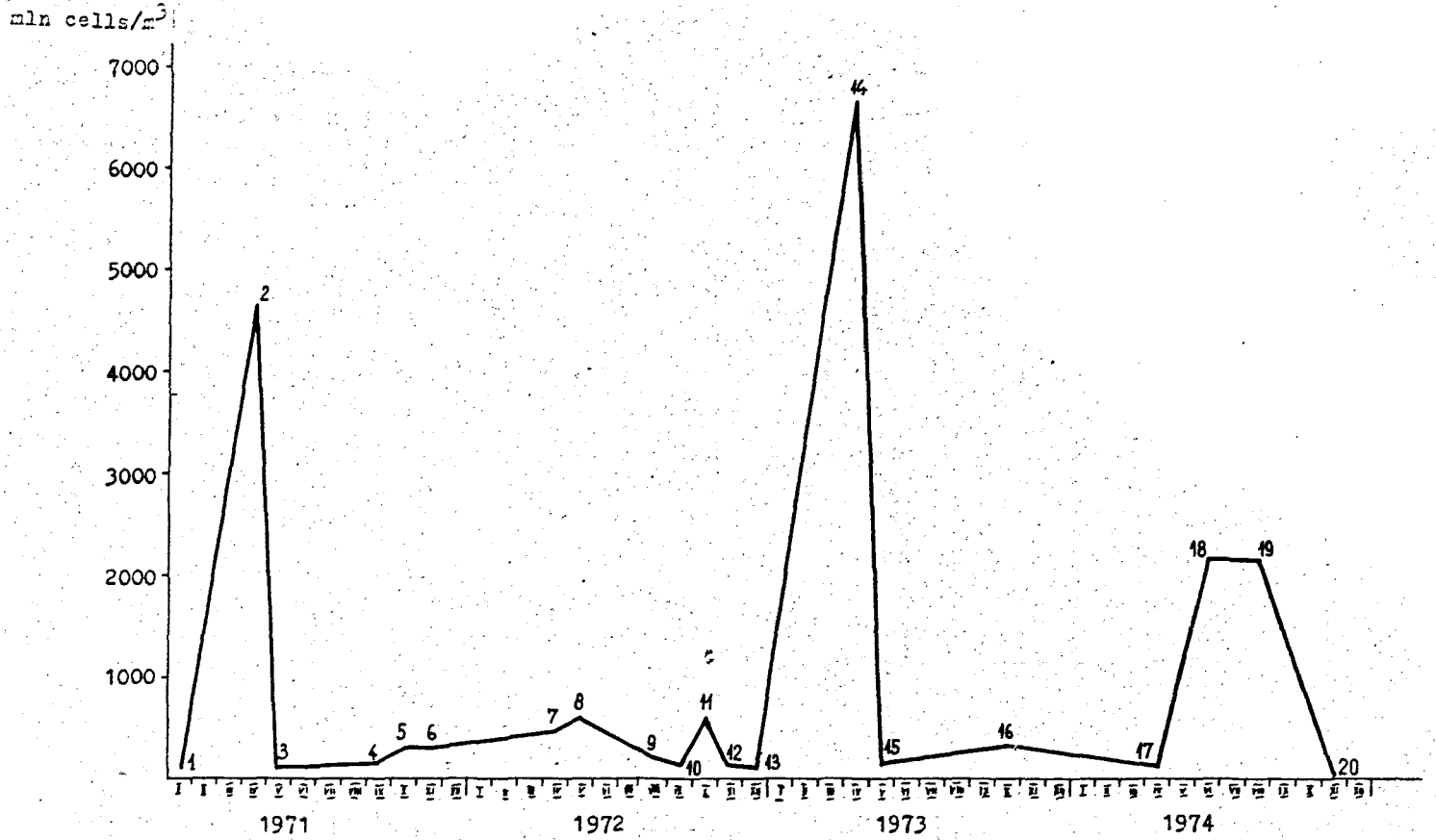


Fig. 6. The quantitative distribution of Bacillariophyceae in Gdańsk Deep.

1 - Actinocyclus ehrenbergi
2 - Thalassiosira decipiens
3 - Chaetoceros wighami
4 - Coscinodiscus granii
5 - " "
6 - " "
7 - Sceletonema costatum
8 - Diatoma elongatum
9 - Cyclotella meneghiniana
10 - " "
11 - Cyclotella meneghiniana
12 - Coscinodiscus granii
13 - Actinocyclus ehrenbergi
14 - Sceletonema costatum
15 - " "
16 - Coscinodiscus granii
17 - Sceletonema costatum
18 - " "
19 - Cyclotella stelligera
20 - Sceletonema costatum