

PHYTOPLANKTON OF SHELF ZONE OF THE NORTH-EAST PACIFIC OCEAN

Contents: 1. Introduction, 2. Material and methods of investigation, 3. Results of investigations and discussion, 4. Conclusions; Streszczenie; References.

1. INTRODUCTION

The north-eastern region of the Pacific Ocean was penetrated in 1977 by the r.v. „Profesor Siedlecki”. Until that time this region had never been the subject of studies in Polish oceanography. There were some Soviet [8, 9] and American [5] expeditions to various regions of the Pacific Ocean in the past, but the results of their biological studies are not easily available. Hence, Polish studies in the shelf zone of the north-east Pacific Ocean were undertaken in order to define the hydrological and biological conditions in this region and to use them for future assessments of the fish food resources and the fish stocks. Data available from literature, together with some Polish data, show that the highest amounts of phytoplankton are noted above the pycnocline, and that zooplankton is present in water layers rich in chlorophyll (i.e. above the pycnocline), forming dense communities there [3, 5]. Apart from obtaining data supporting these facts, the aim of this study was to supply further information on the biology and ecology of the first link in the trophic chain, i.e. on phytoplankton, against the background of hydrological conditions.

2. MATERIAL AND METHODS OF INVESTIGATION

The r.v. „Profesor Siedlecki” took part in a scientific expedition to the north-east Pacific from July till September 1977. The expedition was organized to carry out hydrobiological and biological studies in shelf zone. The research area was divided into 3 regions due to its extensive geographic range and differentiation of the hydrology, bottom

and shore topography, climatic and meteorological conditions. The three regions are discussed separately:

- 1) shelf region of the Gulf of Alaska,
- 2) shelf region of the western coast of the USA,
- 3) region of Vancouver Island.

During the expedition plankton material was collected at selected stations in particular regions of the north-east Pacific. A 25 standard Copenhagen net was used to collect phytoplankton samples. Samples were taken from the thermocline upward, to the surface. Altogether, 22 samples were collected and preserved in 4% formalin. In order to analyse the quantitative and qualitative composition of the phytoplankton [1, 4, 6, 7] four sub-samples were taken from each sample and analysed using a magnification of about 400X.

3. RESULTS OF INVESTIGATIONS AND DISCUSSION

During the expedition to the north-east Pacific, 13 plankton stations were established. 116 phytoplankton species were found in the materials collected at these stations (Tab.). These species were classified as follows:

the class of *Bacillariophyceae* — 74 species

the class of *Pyrrophyceae* — 34 species

the class of *Chlorophyceae* — 5 species

the class of *Silicoflagellatae* — 3 species.

4 species belonging to the class of *Coccolithophoraceae* were not classified due to the lack of professional literature.

In analysing the species composition of the phytoplankton it was noted, first of all, that diatoms constituted a dominating group in the period and region studied. Of 116 species of phytoplankton, 74 were represented by diatoms. They belonged mainly to the group *Centricae*, with the exception of 10 species which belonged to *Pennatae*. *Centricae* are characteristic for oceanic and marine (brackish) waters.

The next most numerous group was *Pyrrophyceae* which was represented by 34 species. They were also typical marine forms. Other classes of phytoplankton distinguished, i.e. *Chlorophyceae* and *Silicoflagellatae*, represented by 5 and 3 species respectively, were of no significance in the phytoplankton composition of the north-east Pacific. In some regions they appeared only in negligible amounts or did not occur at all (Figs. 1 and 3).

Particular regions of the north-east Pacific differed not only as regards the hydrological or morphological conditions, but also the species composition of the phytoplankton in surface water layers (Tab.). Some species were present in all the regions of the Pacific Ocean surveyed. In the north-east Pacific, 17 such species were found, mainly

Species composition of phytoplankton in particular regions of the north Pacific Ocean, July and August 1977

Skład gatunkowy fitoplanktonu w poszczególnych rejonach północnego Pacyfiku w okresie lipiec, sierpień 1977

Species Gatunki	Alaska shelf Szelf Alaski	USA west coast shelf Szelf Zach. Wybrz. USA	Vancouver Island shelf Szelf wyspy Vancouver
1	2	3	4
<i>Coscinodiscus excentricus</i> A. Smith	+	+	+
<i>Ceratium fusus</i> (Ehr.)	+	+	+
<i>Peridinium depressum</i> (Bail)	+	+	+
<i>Thalassionema nitzschoides</i> Grun.	+	+	+
<i>Thalassiosira hyalina</i> (Grun.)	+	+	+
<i>Rhizosolenia hebetata</i> (Bail)	+	+	+
<i>Rhizosolenia hebetata f. hiemalis</i> Gran.	+	+	+
<i>Rhizosolenia alata</i> BTW	+	+	+
<i>Nitzschia seriata</i> Cleve	+	+	+
<i>Chaetoceros concavicornis</i> Mang.	+	+	+
<i>Chaetoceros decipiens</i> Ol.	+	+	+
<i>Chaetoceros atlanticus</i> Ol.	+	+	+
<i>Chaetoceros debilis</i> Cl.	+	+	+
<i>Stephanopyxis turris</i> (Grev. Arn.) Ralfs	+	+	+
<i>Actinoptychus undulatus</i> (Bail) Ralfs	+	+	+
<i>Asterionella japonica</i> Cleve	+	+	+
<i>Fragilaria oceanica</i> Cleve	+	+	+
<i>Ceratium tripos</i> (O.F.M.) Nitzsch	+	+	
<i>Ceratium longipes v. oceanica</i> Ostenfeld	+	+	
<i>Ceratium furca</i> (Rhb) Clap. Lemm	+	+	
<i>Dinophysis ovum</i> Schutt	+	+	
<i>Peridinium oceanicum</i> Vauh.	+	+	
<i>Peridinium granii</i> Ostf.	+	+	
<i>Thalassiosira nordenskoldii</i> Cl.	+	+	
<i>Thalassiosira condensata</i> Cl.	+	+	
<i>Rhizosolenia shrubsolei</i> Cleve	+	+	
<i>Rhizosolenia robusta</i> Norm	+	+	
<i>Corethron criophilum</i> Castr.	+	+	
<i>Chaetoceros breve</i> Schutt	+	+	
<i>Actinocyclus ehrenbergii</i> Ralfs	+	+	
<i>Trochiscia brachiolata</i> (Mob) Lemm	+	+	
<i>Chaetoceros lacinosus</i> Schutt	+	+	
<i>Chaetoceros affinis</i> Laud	+	+	
<i>Chaetoceros curvisetus</i> Cl.	+	+	
<i>Coscinodiscus centralis</i> E	+	+	
<i>Coscinodiscus subbuliens</i> Jörg	+	+	
<i>Distephanus speculum</i> (Ehrenb) Haeckel	+	+	
<i>Hyaldiscus stelliger</i> Bail	+	+	
<i>Paralia sulcata</i> (Ehr)	+	+	
<i>Bidulphia sinensis</i> Grev.	+	+	
<i>Peridinium pellucidum</i> Gran	+		+
<i>Skeletonema costatum</i> (Grev)	+		+

Table — continued

1	2	3	4
<i>Ditylium brightwelli</i> (Wert)	+		+
<i>Thalassiosira gravida</i> Cleve	+		+
<i>Climacodium frauenfeldianum</i> Grun.	+		+
<i>Rhizosolenia styliformis</i> Brightw	+		+
<i>Chaetoceros holsaticus</i> Schutt	+		+
<i>Schroederella schroederri</i> (Bergot)	+		+
<i>Dinophysis ovum</i> Schutt	+		+
<i>Dinophysis rotundata</i> Levand	+		
<i>Dinophysis norvegica</i> Clap. Lachm	+		
<i>Dinophysis acuminata</i> Clap. Lachm	+		
<i>Goniaulax levanderi</i> (Lemm) Paula	+		
<i>Goniaulax apiculata</i> (Pen) Entz	+		
<i>Goniaulax longispina</i> n. sp.	+		
<i>Peridinium excentricum</i> Paulsen	+		
<i>Peridinium triqueta</i> (Stein)	+		
<i>Phalacroma rudgei</i> Murr. Whitt.	+		
<i>Phalacroma pulchellum</i> Lebour	+		
<i>Pyrocystis lunula</i> Schutt	+		
<i>Rhizosolenia stolterfothii</i> Perag	+		
<i>Rhizosolenia bergonii</i> Perag	+		
<i>Rhizosolenia obtusa</i> Hensen	+		
<i>Nitzschia closterium</i> (Ehr)	+		
<i>Lithodesmium undulatum</i> Ehr.	+		
<i>Chaetoceros borealis</i> Bail	+		
<i>Chaetoceros didymus</i> E.	+		
<i>Chaetoceros diadema</i> (Ehr)	+		
<i>Chaetoceros compressus</i> Lemm	+		
<i>Licmophora lyngbei</i> (Kutz) Grun.	+		
<i>Lithodesmium undulatum</i> E.	+		
<i>Cerataulina bergonii</i> Per.	+		
<i>Guinardia flaccida</i> (Castr) Perag	+		
<i>Gymmodinium rhomboides</i> Schutt	+		
<i>Coscinosira polychorda</i> Gran.	+		
<i>Melosira borneri</i> Grev.	+		
<i>Fragilaria striatula</i> Lyngh.	+		
<i>Thalassiothrix longissima</i> Cleve	+		
<i>Trochiscia multispinosa</i> (Moeb) Lemm	+		
<i>Trochiscia clevej</i> Lemm	+		
<i>Trochiscia vanhoeffenii</i> (Joerg.) Lemm	+		
<i>Dictyocha fibula</i> Ehrenb.	+		
<i>Chaetoceros pseudocrinitus</i> Ostf.	+		
<i>Chaetoceros wighami</i> Brightw.	+		
<i>Chaetoceros compressus</i> Laud	+		
<i>Gonyaulac polygramma</i> Stein	+		
<i>Gyrosigma angulatum</i> W. Sm.	+		
<i>Ceratium macroceros</i> Schrank	+		
<i>Ebria tripartita</i> (Schum.) Lemm	+		
<i>Goniaulax spirifera</i> (Clap., Lachm) Dies	+		
<i>Rhabdonema adriaticum</i> Kutz.	+		

Table — continued

1	2	3	4
<i>Lauderia borealis</i> Gran		+	+
<i>Bidulphia mobiliensis</i> (Bail)		+	+
<i>Navicula vanhoeffeni</i> Gran		+	+
<i>Rhizosolenia setigera</i> V. Heerck			
<i>Ceratium tripos f. lata</i> Lohm		+	
<i>Ceratium azoricum</i> Cleve		+	
<i>Dinophysis acuta</i> Ehbq.		+	
<i>Phalacrocoma rotundatum</i> (Clap. and Lachm)		+	
<i>Bacteriastrum delicatulum</i> Cl		+	
<i>Coscinodiscus granii</i> Gough		+	
<i>Coscinodiscus radiatus</i> Ehr.		+	
<i>Peridinium divergens</i> Ehbq.		+	
<i>Thalassiosira subtilis</i> (Ostf.) Gran		+	
<i>Nitzschia delicatissima</i> Cleve		+	
<i>Thalassiosira decipiens</i> (Grun) Jurg		+	
<i>Peridinium pallidum</i> Ost.		+	
<i>Thalassiosira subtilis</i> (Ostf.) Gran		+	
<i>Peridinium longipes v. oceanicum</i> Ostenfeld		+	
<i>Pyrophacus horologicum</i> Stein		+	
<i>Tröchiscia moebiussi</i> (Jerg) Lemm		+	
<i>Peridinium stenii</i> Jorg		+	
<i>Eucampia zoodiacus</i> Ehr			+
<i>Navicula membranaceae</i> Cleve			+
<i>Amphiprora hyperborea</i> (Grun)			+

diatoms. These can be defined as typical for this region. In addition, there were species common to certain regions, for instance — two neighbouring or two separate regions. These species may be defined as being highly differentiated. Finally, some species were found only in one region and nowhere else. These were defined as characteristic of the region studied. As can be seen in Table there were 42 such species characteristic of the region of Alaska, 18 — the west coast of the USA, and 3 — the region of Vancouver Island.

Due to the significant differentiation between particular regions as regards species composition of the phytoplankton and hydrological conditions, each region will be discussed separately.

PHYTOPLANKTON IN THE REGION OF THE GULF OF ALASKA SHELF

The region of the Gulf of Alaska shelf may be considered as the richest one as regards species composition of planktonic plants during the period of investigations. Of the 116 species identified in this period, 91 were found in this region. Their classification is as follows:

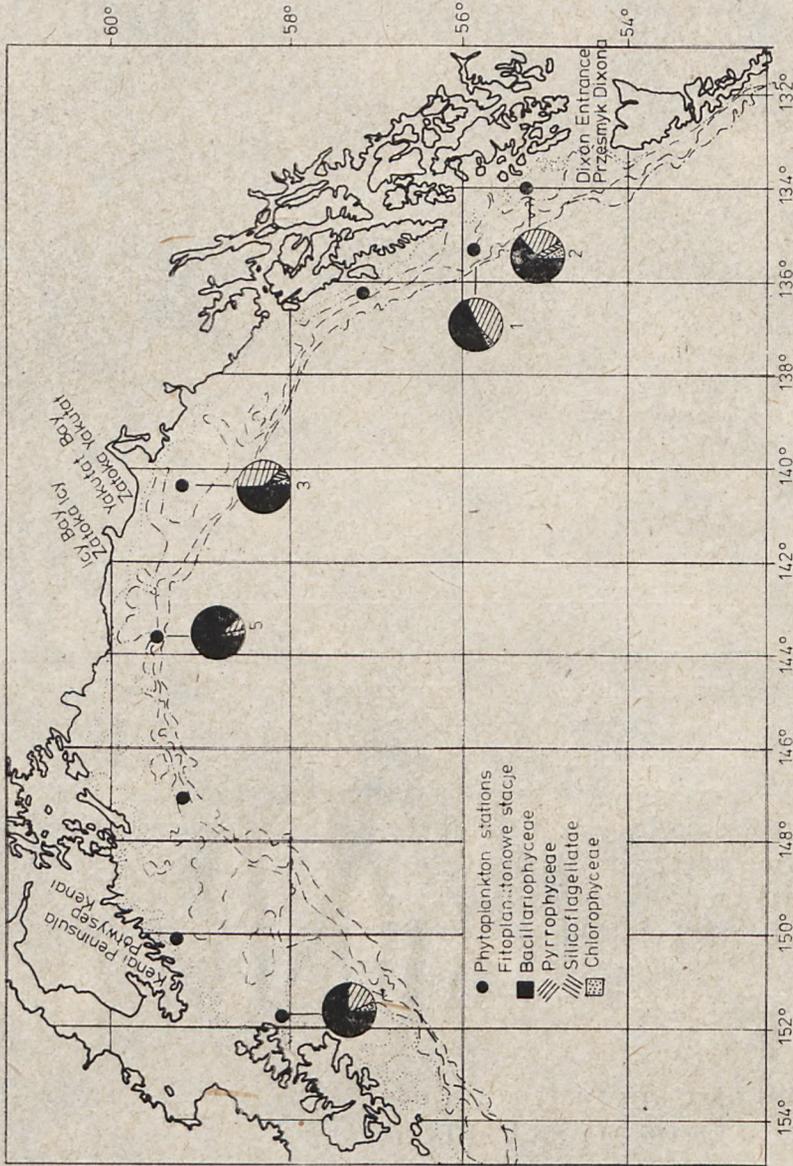


Fig. 1. Distribution of sampling stations in the region of Alaska shelf, and percentage of particular phytoplankton classes at these stations

Rys. 1. Rozmieszczenie stacji planktonowych w rejonie szelfu Alaski i procentowy udział poszczególnych gromad roślin planktonowych na danych stacjach

the class of *Bacillariophyceae* was represented by 54 species, the class of *Pyrrophyceae* was represented by 25 species, the class of *Chlorophyceae* was represented by 4 species, the class of *Silicoflagellatae* was represented by 3 species.

This differentiated and wealth of species of the phytoplankton was — to some an extent — due to the fact this region was covered by the greatest number of sampling stations, but also and mainly to environmental conditions which favoured the development of planktonic plants. These conditions included the fairly high (12 - 15°C) and constant temperature of the water, substantial insolation due to weak water movements (bays, islands, peninsulas, fiords), favourable shaping of the shore line, relatively low and steady level of water salinity (31.5 - 32‰), the presence of nutrients [2]. All these factors resulted in the fact that the species composition of the dominants did not differ essentially between particular stations of the Gulf of Alaska shelf. On the other hand, the percentage of particular classes in the phytoplankton differed (Fig. 1). Phytoplankton blooms were also caused by different species at the individual sampling stations, although they were always diatoms. Thus, in the south-eastern area, i.e. the Ist hydrological region [2] *Nitzschia seriata* and *Skeletonema costatum* were responsible for the bloom. In the IInd hydrological region the diatom *Thalassionema nitzschooides* was most numerous, whereas in the IIIrd hydrological region, situated in the northern part of the Gulf of Alaska, the bloom was caused by *Chaetoceros lacinosus*. The latter area also had the highest salinity (32‰) which was most probably responsible for the bloom of this oceanic diatom.

PHYTOPLANKTON IN THE USA WEST COAST SHELF REGION

Taxonomic analysis of materials from 4 sampling stations in the region (Fig. 2) gave the following results:

the class of *Bacillariophyceae* was represented by 71 species,
the class of *Pyrrophyceae* was represented by 8 species,
the class of *Chlorophyceae* was represented by 1 species,
the class of *Silicoflagellatae* was represented by 1 species.

The number of species distinguished in this region amounted to 81, and was thus also high. As in case of the Gulf of Alaska, diatoms predominated. It should be stressed that although the shore line of the west coast differs significantly from that of the Gulf of Alaska (peninsulas are present in the southern area, and the Columbia River estuary

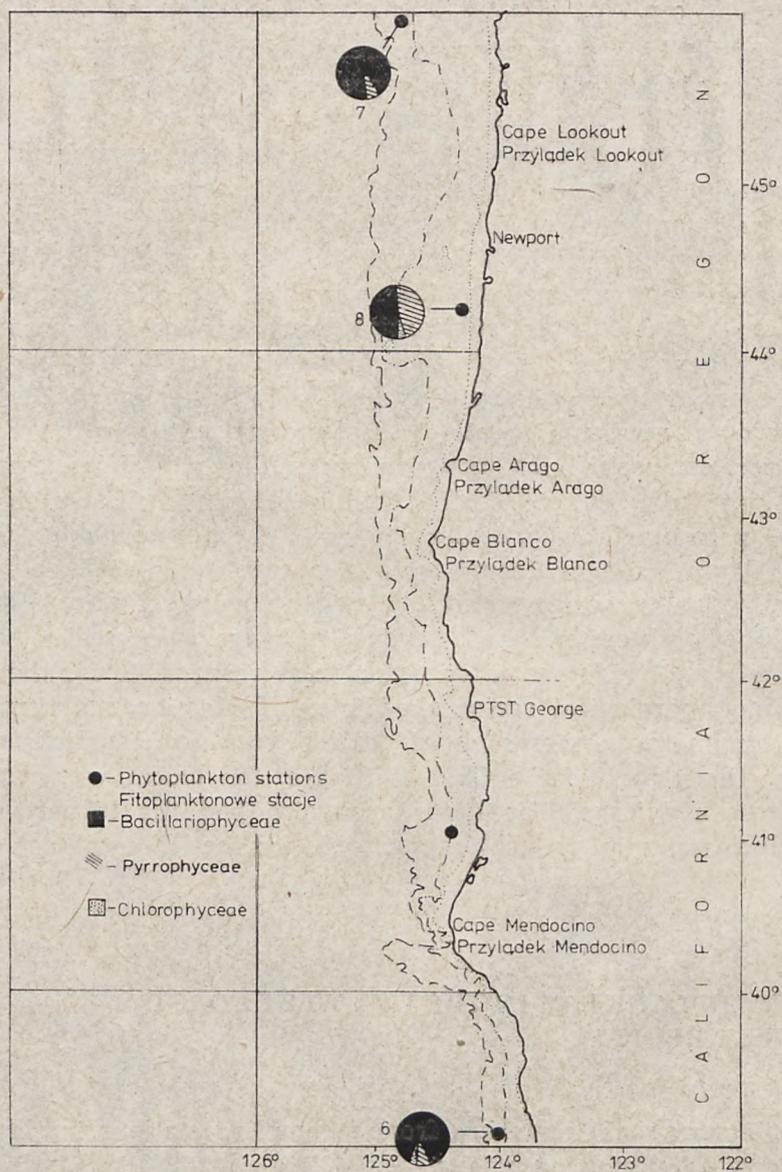


Fig. 2. Distribution of sampling stations in the region of the USA west coast, and percentage of particular phytoplankton classes at these stations

Rys. 2. Rozmieszczenie stacji planktonowych w rejonie szelfu Zachodniego Wybrzeża USA i procentowy udział poszczególnych gromad roślin planktonowych na danych stacjach

in the north), as many as 40 species were common to both these regions. 21 species were defined as being typical of the shelf region of the USA west coast (Table).

Hydrological conditions in the shelf region of the USA west coast differed slightly from those in the Gulf of Alaska. The temperature of the surface water was higher, reaching 16.5°C in the IIInd area of this region [2], and so was salinity, attaining a maximum value of 33.6‰ in the southern part. Here there were no extensive plankton blooms at sampling stations. The most numerous species were typical saline diatoms *Corethren criophilum* and *Thalassionema nitzschoides*.

This hydrological dissimilarity resulted in the appearance of phytoplankton species typical of the region. Studies showed that as regards the percentage of particular phytoplankton classes (Fig. 2) *Silicoflagellatae* dominated at three sampling stations.

At stations at which phytoplankton blooms did occur, the dominating species also differed from those in the Gulf of Alaska. In the IVth hydrological region (the coast of California, [2]) *Chaetoceros debilis* and *Nitzschia delicatissima* were responsible for the blooms.

PHYTOPLANKTON ON VANCOUVER ISLAND SHELF

Only 31 phytoplankton species were distinguished in this region (Tab.) (two sampling stations), of these 29 species belonged to the class of *Bacillariophyceae*, and 2 species — to the class of *Pyrrophyceae*. This region thus had the lowest numbers of phytoplankton, although the shoreline was quite well developed. In the south the island is washed by waters of Juan de Fuca strait. The shelf is 7.5 km wide in the north, and 81.5 km at the opening of Juan de Fuca strait. Conditions for the development of phytoplankton in this region would seem perfect, were it not for a cold-water stream (below 12°C) along the coast, and low salinity of the water (31.4‰), due to the inflow of inland waters [2]. Most probably these factors were responsible for the poor species composition of the phytoplankton.

Despite these facts, 17 species common to all regions investigated were present on the shelf of Vancouver Island. This phenomenon may be explained by cosmopolitan character of the phytoplankton.

The following species were considered characteristic of this region: *Eucampia zodiacus*, *Navicula membranacea*, and *Amphiprora hyperborea*. No phytoplankton blooms were noted in this region, only some species occurred more frequently than others. These were: *Chaetoceros debilis*, *Chaetoceros concavicornis*, *Landeria borealis*. No species belonging to the classes of *Chlorophyceae* and *Silicoflagellatae* were noted.

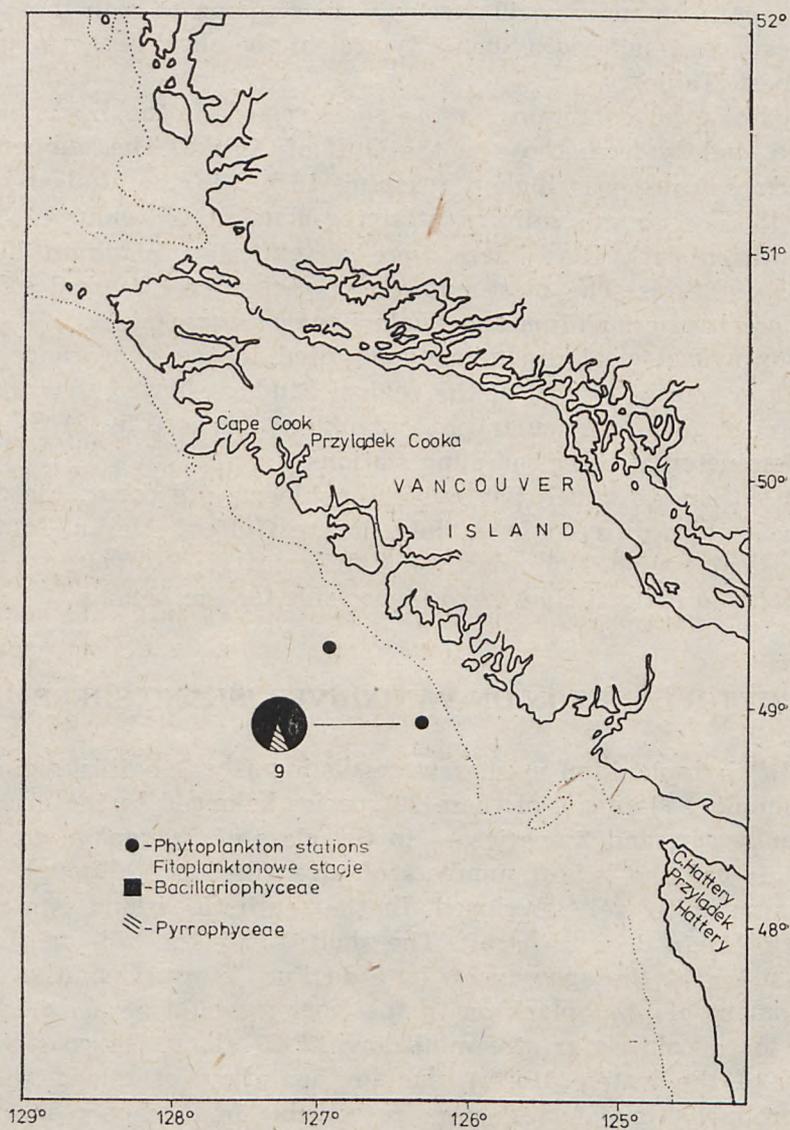


Fig. 3. Distribution of sampling stations in the region of Vancouver Island shelf, and percentage of particular phytoplankton classes at these stations

Rys. 3. Rozmieszczenie stacji planktonowych w rejonie szelfu w rejonie wyspy Vancouver i procentowy udział poszczególnych gromad roślin planktonowych na danej stacji

4. CONCLUSIONS

On the basis of phytoplankton material collected during the expedition of r.v. „Profesor Siedlecki” into the region of the north-east Pacific, it was found that:

1. The results point to the fertility of waters on the shelf of the north-east Pacific, this being reflected in the rich species composition of the phytoplankton, embracing a total of 116 species. The most numerous were these belonging to the class of *Bacillariophyceae*, represented by 74 species.

2. The regions investigated, i.e. the shelves of the Gulf of Alaska, the USA west coast, and Vancouver Island, have different phytoplankton community structure. The most differentiated as regards species composition is the region of the Gulf of Alaska (86 phytoplankton species), this being due to its hydrological and environmental conditions. In second place is the USA west coast shelf (81 species). The poorest region is the Vancouver Island shelf (31 species).

3. The regions investigated showed significant biocenotic differentiations which were reflected in the following phenomena: different species were responsible for phytoplankton blooms in particular regions; different characteristic species were found in particular regions; some species were common to all regions — these were species typical for the north-east Pacific; cosmopolitan species were also found; the quantitative share of various phytoplankton classes varied at particular sampling stations.

4. The observations suggest that studies on fish stock in these regions should also be most promising.

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FITOPŁANKTON STREFY SZELFOWEJ PACYFIKU PÓŁNOCNO-WSCHODNIEGO

Streszczenie

Statek badawczy Morskiego Instytutu Rybackiego „Profesor Siedlecki” w r. 1977, od lipca do września, brał udział w ekspedycji naukowej na wody Pacyfiku północno-wschodniego, w celu przeprowadzenia badań hydrologiczno-biologicznych w strefie szelfowej. Na podstawie wyników badań stwierdzono, że Pacyfik północ-

no-wschodni jest rejonem o znacznej żyzności biologicznej. Objawia się to bogactwem gatunków fitoplanktonu (116 gatunków). Najliczniej spośród występujących gromad roślin reprezentowana była gromada okrzemek (114 gatunków). Każdy rejon badawczy: szelf zatoki Alaska, szelf Zachodniego Wybrzeża USA, szelf wyspy Vancouver — wykazywał wyraźną, odrębną strukturę biocenotyczną uzewnętrzniającą się szeregiem cech gatunkowych (gatunki charakterystyczne, typowe, kosmopolityczne).

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