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SPECIES COMPOSITION SEASONAL AND LONG-TERM DYNAMICS OF ZOOPLANKTON ABUNDANCE AND BIOMASS IN THE VISTULA LAGOON OF THE BALTIC SEA

by

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ABSTRACT

Faunistic composition of zooplankton in the Vistula Lagoon and seasonal and long-term dynamics of zooplankton abundance and biomass are analysed on the basis of tong-term observations, performed by the author in 1980-1994. It is shown that during the last 10-15 years the plankton assembly has been undergone structural changes stipulated by anthropogenous impact upon the ecosystem. Analysis of abiotic environmental factors defined the development of the Vistula Lagoon zooplankton is performed. The major role of water temperature is determining zooplankton biomass and salinity in determining species composition of the assembly is shown.

Introduction

Vistula Lagoon is semi-closed brackish water ecosystem in the Southern Baltic Sea. The major hydrological and hydrochemical parameters are shown in Table 1. One half of the basin is located in Russia and the other one - in Poland (fig. 1).

Since 1974 Atlantic Scientific Researh Institute of Marine Fisheries and Oceanography (AtlantNIRO) has carried out regular observations of zooplankton dynamics and hydrochemical conditions in the Vistula Lagoon.

The major task of the above work was to summarize the long-term data on species composition, seasonal and long-term dynamics of abundance and biomass of zooplankton in the Russian part of Vistula Lagoon, as well as to reveal factors, defining zooplankton development. Material, collected by the author during 1980-1993, was used in analysis.

Material and Methods

Zooplankton samples were collected at 3 stations (Fig. 1) by the Vovk's sampler (Vovk, 1948) of 10 l volume, from 3 layers (surface, intemediate and lower) totally once per month from April to November, and were fixed 4% formaline. Cameral treatment was carried out by the counting method (Hensen, 1887). Individuals of each species were counted, crustaceans were classified by age-length groups and appropriate development stages. Copepoda nauplii were classified into orthonauplii and methanauplii, copepods into stages I-III and IV-V, adult individuals - into males, females without egg sacks and with egg sacks.

Biomass was estimated according to relation of indivitual body weight and length (Balushkina, Vinberg, 1979). Zooplankton abundance and biomass is asessed in m³.

Results

Zooplankton community of the Vistula Lagoon is represented by 3 major groups, such as Rotatoria, Cladocera, Copepoda. In spring and summer some other invertebrates groups are found, such as Cyrripedia nauplii and Plolicheta methanauplii. Zooplankton is represented by 58 species and subspecies, including 36 species of Rotatoria, 9 of Cladocera, 13 of Copepoda (Table 2). The species number in those groups varied in relation to salinity gradient in different areas of Lagoon. The most species diversity was observed in brackish area near the Pregol rivers mouth. In the areas adjacent to the Baltic strait the number of zooplankton species decreased in associaton to salinity increase. The number of zooplankton species was maximum in July-August, when the highest temperature occured. During the years when salinity exceeded the long-term average, number of species in zooplankton community decreased and eurihaline invertebrates predominated . During low salinity periods fresh-water organizms distributed towards the Baltic strait. Nevertheless during the years with various hydrological conditions the group of species sustainable to salinity variations was observed, including such species as, Rotatoria: K.quadrata, K.cochlearis, B.calyciflorus, F.longiseta, H.fennica; Cladocera: D.brachyurum; Copepoda: E.affinis.

Copepoda predominated in zooplankton community amounted to 54% of total zooplankton abundance and 78% of biomass (Fig. 2). Rotatoria represents significant contribution (up to 44%) to zooplankton abundance, Cladocera amounts to 2% of total abundance and 12% of biomass. The group of species, found in samples during entire period of observation and contributed significantly zooplankton abundance and, biomass, includs such species as B.calyciflorus, K.quadrata, F.longiseta, E.affinis.

During the vegetation period peaks of species development were observed in the Vistula Lagoon zooplankton community, resulted in seasonal species groups formation. In spring peaks of development were observed in the following species: A.priodonta, B.angularis, B.calyciflorus, K.quadrata, H.fennica, Synhaeta spp., A.viridis, C.strenuus, E.affinis, Harpacticidae (Fig. 3). In summer peak of abundance were observed in all Cladocera as well as in Rotatoria, B.calyciflorus, B.angularis, B.urceus, E.dilatata, F.longiseta, K.cochlearis and in Copepoda: A.viridis, Acartia spp. (mainly A.tonsa). In autumn peak abundance occured in the following species: A.priodonta, Synchaeta spp., A bifilosa, E.affinis.

Two peaks were observed in the seasonal dynamics of zooplankton abundance and biomass, the spring one in April-May, and the summer one in August. As a rule, abundance and biomass peaks correlated in time (Fig. 4). During peak periods zooplankton abundance amounted to 272 thous.ind. m^{-3} , and biomass 1.8 $g.m^{-3}$. Long-term average zooplankton abundance and biomass during the vegetation period amounted to 145.6 thousand $ind.m^{-3}$ and 0.91 $g.m^{-3}$ respectively (Table 3).

Two peaks of abundance and biomass were observed in Rotatoria: spring one in May, and summer one in August. Summer peak was weak. Average abundance of Rotatoria amounted to 140 thous. $ind.m^{-3}$ and biomass 0.25 $g.m^{-3}$ during the period of peak. During the vegetation period average abundance of Rotatoria amounted to 63.5 thous. $ind.m^{-3}$ and biomass 0.09 $g.m^{-3}$ (Table 3).

Cladocera is characterized by one peak of development in August when average abundance amounted to 18 $thous.ind.m^{-3}$ and biomass 0.5 $g.m^{-3}$. Long-term data show that during vegetation period average abundance of the latter approached 3.5 $thous.ind.m^{-3}$ and biomass 0.11 $g.m^{-3}$ (Table 3). Seasonal dynamics of Copepoda abundance and biomass showed two peaks, in spring (April-May) and in autumn (August-September). During the spring maximum average abundance of Copepoda amounted to 142 thous.ind.m^{-3} , and biomass 1.5 g.m^{-3} . Peaks of abundance and biomass showed no correlation in time which was caused by the biological characteristics of Copepoda. The increase of abundance preceded the biomass peak. According to long-term data during the vegetation period the average abundance of Copepoda amounted to 78.6 thous. ind. m^{-3} , and biomass 0.71 g.m^{-3} (Table 3).

The passive experiment was carried out to analyse factors, defining zooplankton development. Average monthly and integral temperature and salinity values were used as independent variables, as well as the abundance of the Baltic herring larvae in May-June which became an index of predators pressure. Young Baltic herring is feeding in the Vistula Lagoon throughout the summer. In some years the Baltic herring abundance was considerable. In the years of strong Baltic herring year-classes, the sharp decrease of zooplankton density is observed (up to 0.1 g.m^{-3}). Data on the young Baltic herring abundance were kindly presented by N.V.Krasovskaya. Average monthly and integral zooplankton abundance and biomass values were used as a dependent varialbe. The analysis was carried out taking in account zooplankton size suitability to the young Baltic herring as the forage basis, therefore abundance and biomass of Rotatoria and early copepodites stages of Copepoda in May when they contribute the fish larvae food most significantly, were considered as a dependent variable.

A single-factor analysis revealed the higher correlation of zooplankton abundance and biomass to water temperature than to salinity. However multi-factor analysis showed that the cumulative effect of water temperature and salinity had emergentic properties (correlation factor was from 0.85 to 0.92) (Table 4). The young Baltic herring pressure affected zooplankton most significantly in June, when the young fish intensively consumed zooplankton (correlation factor - 0.78). In May correlation of the Baltic herring larvae abundance to zooplankton biomass was low. The correlation factor for Rotatoria was slightly higher. Cumulative effect of water temperature and young Baltic herring upon zooplankton abundance was stronger (correlation factor of 0.8-0.9).

On the long-term basis the analysis of zooplankton abundance and biomass variability was carried out by 5-year periods to eliminate the effect of factors, defining zooplankton development and to obtain the general pattern of zooplankton community dynamics. The material was subdivided by the following periods: 1975-1980, 1981-1985, 1986-1990 and 1991-1993. The data provided by O. Krylova (1985) were used for the period of 1975-1980. On the background of average zooplankton abundance and biomass values in the first and the second periods, a sharp increase of the latter parameters was observed ring 1986-1990. Besides, the biomass increase associated to the decrease of individuals weight in community. During the latest period (1991-1993) zooplankton development in the Vistula Lagoon may be defined as an average one. No variability of dominated species number was observed.

Discussion

Zooplankton of the Vistula Lagoon has been researched for a long period since the end of 19th century. The first researches were carried out by German scientists (Schroedder, 1866; Willer, 1925). In the second half of the 20th century zooplankton of the Polish part of the Vistula Lagoon was studied by Z.Rozanska (1963),B.Adamkiewicz-Chojnacka (1985, 1989, 1990) and that of the Russian part - by A.Zhudova (1978), O.Krylova (1985),E.Naumenko (1992).

According to the data of Polish scientists zooplankton of the Vistula Lagoon is represented by 3 major groups of invertebrates: Rotatoria, Cladocera, Copepoda. The number of species in above groups depends on the salinity gradient,. Thus according to Z.Rozanska (1964) in the most fresh-water part of the Lagoon (south-western) Rotatoria are represented by 29 species, Cladocera by 9 species, Copepoda by 7 species. Closer to the Baltic Strait salinity increases and the species number reduces: Rotatoria - 4 species, Cladocera - 4 species, Copepoda - 5 species. Totally 58 zooplankton species were found in the Polish part of the Lagoon, including 34 of Rotatoria, 13 of Cladocera and 11 of Copepoda.

In the Russian part of the Lagoon number of species also decreases towards the Baltic Strait. The most species diversity, according to O.Krylova, was observed in the brackish water adjacent to the mouth of Pregolya river. Total number of invertebrate species, found by O. Krylova, amounted to 30, including 12 Rotatoria, 11 Cladocera, 7 Copepoda. At present 80 species and subspecies are found in the Vistula Lagoon zooplankton, including 44 Rotatoria, 18 Cladocera, and 18 Copepoda (Table 1).

Different zooplankton fauna composition in Polish and Russian parts of the Vistula Lagoon is defined by the presence of fresh-water species complex in more fresh-water Polish part. Seasonal dynamics of zooplankton in Polish and Russian parts are similar (Adamkiewicz-Chojnacka, Rozanska, 1990). The dominated species composition of the Polish and Russian parts of the Lagoon is similar and typical for the brackish waters of the South Baltic area. Thus in the Darss-Zingst system such species as B.calycilorus, K.coclearis, F.longiseta, E.affinis are specified as the dominated ones (Heerkloss et al., 1991).

Zooplankton communities in the Baltic lagoons and estuaries are affected by the salinity gradient variations. Thus, in the Vistula Lagoon water salinity varies from 0.3 to 8.5%, in Polish part from 1.5 to 4.5%, estuaries of Darss-

Zingst from 1.5 to 8.5‰. Water salinity is an important factor, which defines zooplankton development. Salinity variations affect specific composition to the greater extent than abundance. Polish scientists confirm the above conclusion (Adamkiewicz-Chojnacka, Rozanska, 1985). It is reasonable, since salinity variations in those areas never exceed the "critical"value (Khlebovich, 1974).

Zooplankton quantitative development in the Russian part of Vistula Lagoon is lower than in the Polish part and some other estuaries of the South Baltic area. We consider the above event to be related to the more strong pressure of the young Baltic herring in the Russian part of the Lagoon, than in the Polish part. Low abundance and biomass of zooplankton during 1981-1985 is related to occurence of strong year-classes of the Baltic herring (Krasovskaya, 1992). Both qualitative (abundance, biomass, average individual weight) and structural (specific composition, proportion of taxonomic groups) indices were considered as the indicator of eutrophication. Increase of zooplankton abundance and biomass during 1986-1990 was associated to increase of Rotatoria abundance, decrease of the average individual and decrease of Copepoda proportion. It may evidence the taxonomic restructuring of zooplankton community related to growth of water nutrient load. Similar changes in other zooplankton communities associated to the nutrient content increase were noted by I.Andronnikova (1988), N.Kruchkova (1987). During the latest years the system is stabilizing, since depression in agriculture and industry results in a sharp decrease of nutrients input from fields. However, sharp outbursts of long-term zooplankton quantitative development in the Vistula Lagoon cause misgivings, sice they evidence the distabilization of the Lagoon ecosystem.

Conclusion

Zooplankton community of the Vistula Lagoon is represented by 80 species and subspecies, including Rotatoria 44, Cladocera 18, Copepoda 18. Euryhaline species predominate. Fresh-water species complex is observed only in the more fresh-water Polish part near Vistula delta, and in the Russian part near the Pregolja mouth. Copepoda predominates in the community which is common for lagoons and estuaries of the South Baltic area. Salinity variations affect zooplankton specific composition, and the quantitative development is defined by the temperature and young fish pressure in the Russian part. In the long-term dynamics of zooplankton the period of abundance and biomass sharp increase, is acompanied by decrease of the average individual weight, increase of Rotatoria relative abundance and decrease of Copepoda proportion which evidences destabilization of the Lagoon ecosystem.

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Table 1

Parameters characterizing morphometry hydrography and degree of eutrophication of the of Vistula Lagoon

Parameter	Russian part	Author	Polish part	Author
Area	472,5 km^2	Solovjev,1971	328 km^2	Heerkloss et all,1991
Mean depth	2,7 m	- " -	2,4 m	- " -
Salinity	0,3-8,5 %o	Juruvleva,Tschosinska, 1971	0,7-4,5 %o	- ' -
pH-value	6,4-9,2	- ' -	8,5 +	- ' -
Secchi-depth	0,5-1,2 m	Lysas,1971	0,3-1,0 m	- ' -
O_2	6,3-12,5 mg/l	Juruvleva,Tschosinska, 1971		
Phosphate	39 mkg/ l	- ' -		
NO_2^-	15 mkg/ l	- ' -		
NO_3^-	230 mkg/ l	- " -		

Table 3

Average value of zooplankton abundance (N, ths.ind./ m^3) and biomass (B,g/m^3) in the Vistula Lagoon (russian part) in 1980-1993 years

Croops	N	σ	B	σ
Rotatoria	63,5	62,6	0,09	0,09
Cladocera	3,5	6,6	0,11	0,18
Copepoda	78,6	42,2	0,71	0,40
Total	145,6	96,1	0,91	0,46

Table 2

Species composition of zooplankton community in the Vistula lagoon

Species	Author's data	Krylova, 1985	Rozanska, 1963
Rotatoria			
Anureopsis fissa (Gosse)			+
Ascomorpha sp. Perty			+
Asplanchna priodonta Gosse	+	+	+
Brachionus angularis Gosse	+	+	+
B.calyciflorus calyciflorus Pallas	+	+	+
B. -"- amphiceros	+		
B. -"- anureiformis Brehm.	+		
B. -"- spinosus Wierr.	+		
B.quadridentatus quadridentatus Herm.	+	+	+
B. -"- hyphalmyros Tschag.	+		
B. plicatiis plicatilis Mull.	+		
B. rubens Ehrb.	+		
B. urceus (L.)	+		+
Brachionus sp.			+
Colurella sp. Bory de St.Vincent			+
Euchlanis dilataia Ehrb.	+		+
Filinia brachiata (Rousselet)			+
F. longiseta (Ehrb.)	+	+	+
Hexartra fennica (Lev.)	+	+	+
Kellicottia longispina (Kell.)	+	+	+
Keratella cruciformis (Tompson)	+		+
K. cochlearis cochlearis (Gosse)	+	+	+
K. -"- testa (Gosse)	+	+	+
K. quadrata (Mull.)	+	+	+
K. valga (Ehrb.)			+
Lecane lunaris (Ehrb.)			+
L. luna (Mull.)			+
Lepadella patella (Mull.)			+
Notholca acuminata (Ehrb.)	+	+	+
N. foliacea (Ehrb.)			+
N. labis Gosse			+
N. limnetica (Lev.)			+
N. squamula squamula (Mull.)	+		+
N. striata (Mull.)			+
Polyartra vulgaris Carlin	+	+	+
Ptigura sp. Ehrb.			+
Rotaria rotatoria (Pallas)	+		
Synchaeta litoralis Rous.			+
Synchaeta spp.	+		+
Testudinella patina (Herm.)	+	+	+
Trichocerca (s,str.) capucina (Wierzejska et Zacharias)	+		

Table 2 (continued)

Species	Author's data	Krylova, 1985	Rozanska, 1963
T. (s.str.) pocillum (Mull.)			+
Trichocerca spp. Lamark	+		+
Cladocera			
Alona sp. Baird			+
Alonella exigua Lill.			+
Bosmina coregoni Baird	+	+	
B. -"- maritima P.E.Muller	+		+
B. longirostris (O.F.Muller)	+	+	+
Ceriodaphnia quadrangula O.F.Muller			+
C. pulchella G.O.Sars			+
C. reticulata (Jurine)		+	
Chydorus sphaericus O.F.Muller	+	+	+
Daphnia crystata Sars		+	
D.cucullata G.O.Sars	+	+	+
D. longispina O.F.Muller	+	+	
Diaphanosoma brachyurum Liev.	+	+	+
Evadne nordmanni Loven	+	+	
Leptodora kindtii (Focke)		+	+
Pleuroxus sp. Baird			+
Podon polyphemoides Leuckart	+	+	+
Streblocerus sp.			+
Copepoda			
Acantocyclops vernalis (Fischer)		+	
A.viridis Jurine	+	+	+
Acartia bifilosa Giesbrecht	+	+	+
A. longiremis (Lill.)	+		+
A. tonsa Dana	+		+
Canthocamptus staphylinus Jurine	+		
Cyclops sp. Muller (copepodit)			+
C. strenuus Fischer	+	+	
C. vicinus Ulian.	+		+
Eucyclops (s.str.) serrulatus (Fischer)	+		
Eudiaptomus gracilis Sars			+
E. graciloides Lill.	+		
Eurytemora affinis Poppe	+	+	+
E. hirundoides Nord	+		
Harpacticoida spp.	+	+	+
Mesocyclops leuckarti (Claus)	+	+	
Pseudocalanus elongatus Boeck			+
Temora longicornis Muller	+		+

Table 4

REGRESSION EQUATION OF ZOOPLANKTON ABUNDANCE (N, thous.ind./ m^3) AND BIOMASS (B, g/m^3) AND WATER TEMPERATURE (T, °C) AND SALINITY (S, ‰) IN THE VISTULA LAGOON (numbers at variables show month, r - correlation index)

$$N_{year} = 665{,}0 - 77{,}3\ T_4 - 0{,}95\ S_{3-4} \qquad r = -0{,}85$$

$$B_{year} = 3{,}05 - 0{,}37\ T_4 + 0{,}08\ S_{3-4} \qquad r = -0{,}84$$

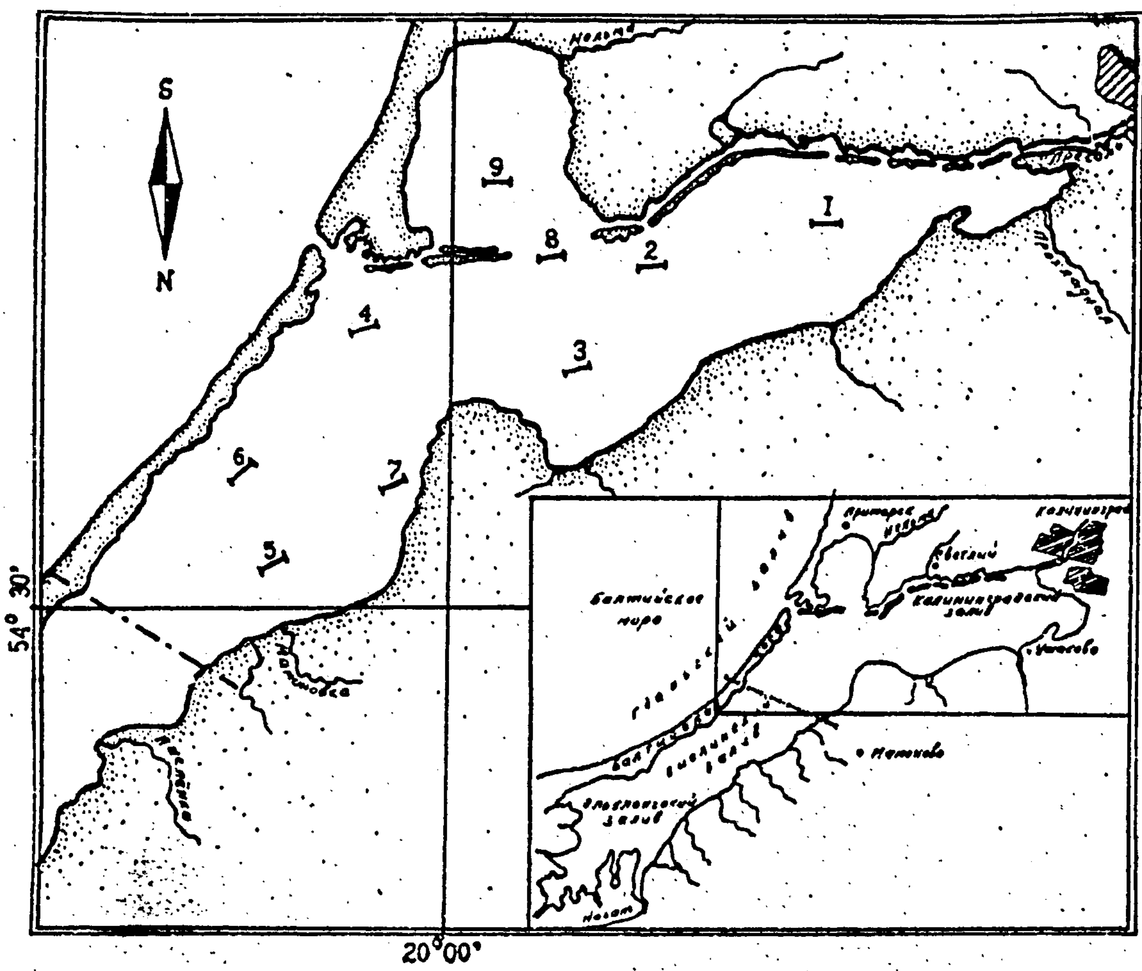

Fig.1. Map of zooplankton sampling in the Vistula Lagoon.

Fig.2. STRUCTURE OF ZOOPLANKTON COMMUNITY IN THE VISTULA LAGOON

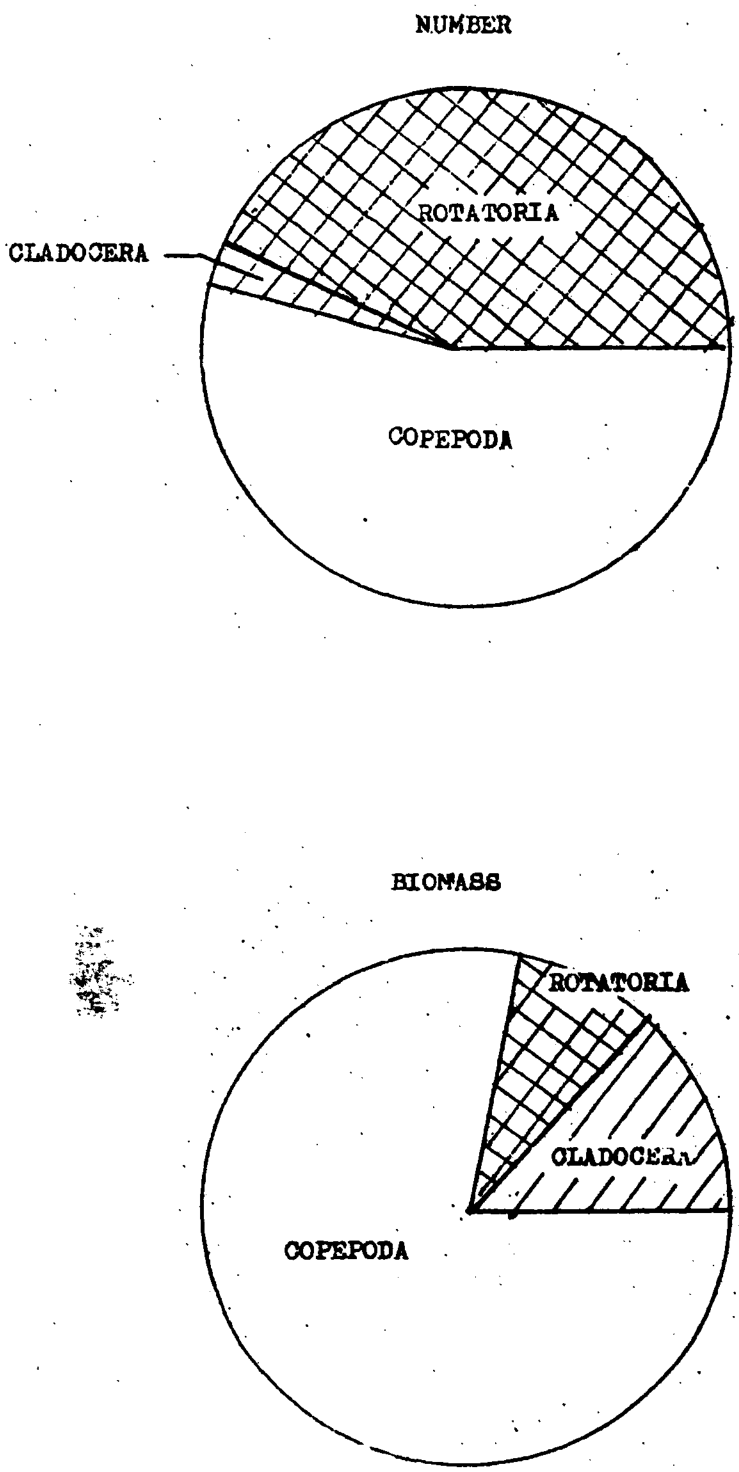

Fig.3. Seasonal dynamics of abundance (a) and biomass (b) of zooplankton in the Vistula Lagoon. 1 - Rotatoria, 2 - Cladocera, 3 - Copepoda, 4 - Total. Axis: absciss- mounths, ordinate - % of sum of meanyear value.

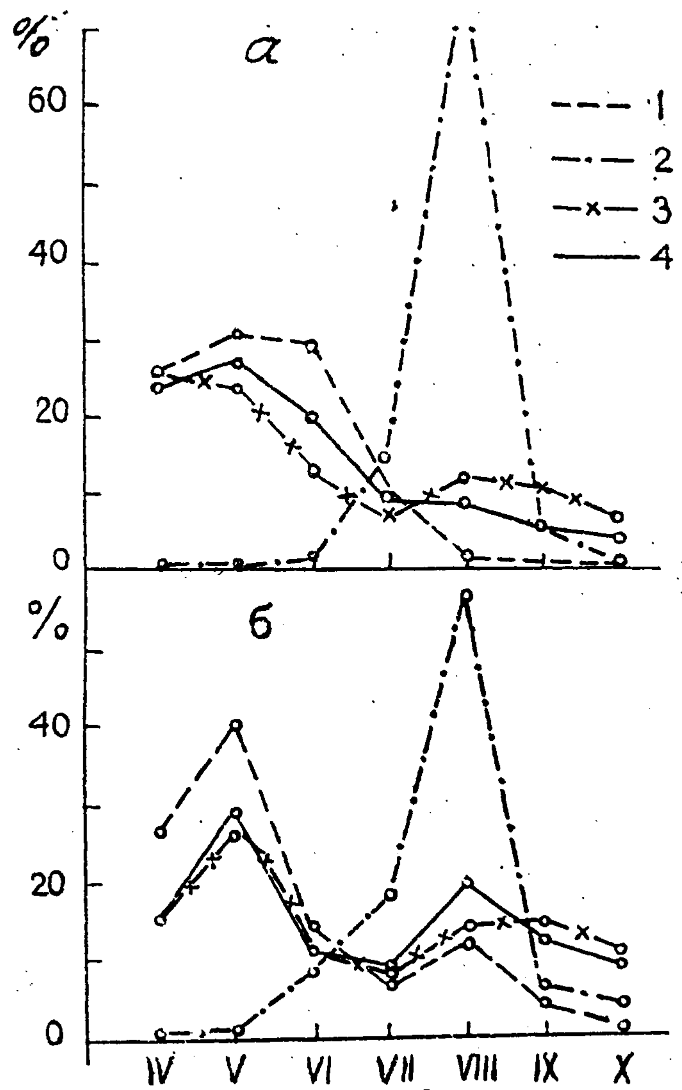

Fig. 4. Long-term dynamics of zooplankton abundance (N, thous.sp./ m^3) and biomass (B, g/m^3) in the Vistula Lagoon.