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Long-term changes of zooplankton abundance in the Gulf of Riga

by
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Abstract

Zooplankton biomass and composition were determined on the basis of samples which were collected in different seasons (May, August, October) during1956-1992. Zooplankton abundance fluctuations are analysed in relation to water temperature and salinity,and herring stock size. Although the abundance variations are different for various species the presented data clearly shows increase of zooplankton productivity. It is specially distinct in summer and for species prefering warm water. On the contrary the abundance of species which prefer cold and clean water are diminishing. The changes of zooplankton influence the condition of herring stock.

Introduction

The main task of the Latvian Fisheries Research Institute is to make assessments for the commercial stocks in the Baltic sea. The investigations of zooplankton in the Gulf of Riga are the part of complex research work the aim of which is to give the characteristics and state of the fish ensurance with food.

The Gulf of Riga is relatively shallow with the average depth of 20 m, therefore the water temperature depends mainly on the air temperature in the previous 2-4 months. It is especially characteristic for spring (r =0.93) and autumn (r =0.81). In summer when a stable water stratification is formed, the water temperature dynamics are strongly influenced by wind and the correlation with air temperature is weaker. In the observed period we can deal out several periods of years with incresed (1971-1975, 1981-1984, 1988-1992) and decreased water temperature (1963-1970, 1976-1980, 1985-1987) in the cold half of the year.

The salinity is influenced by river runoff and the intensity of water exchange with the open part of the Baltic sea. The investigated period can be devided in two periods with contrary tendencies. Salinity was increasing from the beginning of sixties till 1977, and it is rapidly diminishing from 1978 having some rise in 1984-1985.

Herring is the main commercial fish in the Gulf of Riga and it is mainly feeding with zooplankton. Zooplankton species met in the Gulf of Riga have different importance as a food objects. *Copepoda* nauplii are eaten by fish larvae, younger herring prefer *Eurytemora* *hirundoides*, but older and bigger herring feed on bigger species as *Limnocalanus grimaldii* and nectobenthos which inhabit the near bottom layers.

Taking into account that zooplankton is strongly influenced by hydrometeorological conditions, the aim of our analysis is to reveal the qualitative and quantitatve changes that have taken place in the period of the research work in 1956-1992, to determine the main factors that have caused these changes and how the modern state of the zooplankton community can influence the herring stock.

The bulk of zooplankton met in the Gulf of Riga belong to the species typical for brackish waters of the Baltic sea with salinity 2-6 % . Species of *Copepoda* are the most important group of zooplankton which are the main food items for herring. This group includes *Acartia bifilosa*, *Eurytemora hirundoides* and *Limnocalanus grimaldii*. *A.bifilosa* is a polycyclic form which is able to breed and develop in a wide range of temperature, even in winter. It has 6-7 generations a year. *E.hirundoides* is also a polycyclic form but its reproduction demands a higher temperature and occurs in April-October. *L.grimaldii* is an arctic relic, which has one reproduction cycle and it multiplies in early spring when water temperature is 2-5 grad.C.

The species belonging to *Cladocera* - *Bosmina coregoni maritima*, *Podon polyphemoides*, *Evadne nordmanni* become very abundant in summer. All these species are polycyclical and their reproduction occurs in summer. *B.c.maritima* needs the highest temperature for its reproduction and when water temperature surpasses 15 grad.C its abundance rapidly increases. Fishes feed on *Cladocera* but as food items they are less important than *Copepoda*.

The third largest group of zooplankton is *Rotatoria* to which belong *Synchaeta spp.* (the most frequent is *S.baltica)* and *Keratella spp.* (the most frequent is *K.quadrata)*. *Synchaeta spp.* are met in the period from April till November with peaks in May-June and September-October. *Keratella spp.* have a fresh water origin. The species of *Rotatoria* have no importance as food items.

In summer some additional objects are found in the zooplankton. To them belong the larvae of *Bivalvia sp.* and *Balanus sp.*, as well as some fresh water species, which have come into the gulf with river waters. Some species typical for the Central Baltic are met in the northwestern part of the Gulf of Riga where they have been carried in with the sea waters.

Material and methods

The zooplankton surveys cover a period from 1956 till 1992. The material was regularly collected in May, August and October. The hydrological and zooplankton surveys were usually done paralelly. In some years the zooplanton was gathered also in February, April, June and July.

Zooplankton was collected with net of Jeddy type the upper opening of which is 37 cm in diameter and the mesh size of the filtering material is 0.16 mm. The surveys covered all regions of the Gulf of Riga and every seasonal survey included samples from 10-15 stations.

For the characterization of the hydrological regimen we have used the average temperature and salinity of the total gulf water mass, which are calculated from the measurements made in the surveys in May, August and October. The data about air temperature are taken from the observations of meteorological station in Riga.

The biomass of gulf herring is taken from the assessment made at the Working Group on Assessment of Pelagic Stocks in the Baltic (Anon,1993). The connections were analysed using statistical correlation methods.

Results.

The seasonal changes of hydrological conditions in the Gulf of Riga cause characteristic seasonal changes of zooplankton (tab.1).

The smallest diversity of species and the lowest biomasses are observed in winter. The abundance of zooplankton in winter depends on the amount of it in autumn and the existing water temperature, therefore it can be very different. In February in the layer of 0-40 m it can vary from 1.1thousand to 3.8 thousand ind./m3, and the biomass from 28.8 to 68.8 mg/m3. Winter zooplankton is mainly represented by *Acartia bifilosa*, which forms 58% of zooplankton in warm and mild winters and 68% in cold ones. 17-35% of zooplankton consists of *Eurytemora hirundoides* and 3-15% of *Limnocalanus grimaldii*. The distribution of zooplankton is rather even, because the water temperature is smoothed through all water mass.

The beginning of the *Copepoda* spring reproduction depends on the severity of winter and the course of spring. *A. bifilosa* and *E. hirundoides* begin to breed in the second half of March after mild and warm winter, the breeding continues in April and reaches its peak in the beginning of May. *L. grimaldii* multiplies in March-April. After cold winter and late spring the reproduction of *Copepoda* starts approximately month later. After the winter minimum the abundance of zooplankton starts to increase on general in April. Dependant on water temperature the abundance of zooplankton strongly differs by years and is in the ranges of 3.0 thousand- 24.0 thousand ind./m3 and biomass 23.2 -290.0 mg/m3. In May the most abundant is still *A. bifilosa* (60 - 75%). The share of *E. hirundoides* increases only in June (tab.1).

Synchaeta spp. are also very abundant in spring zooplankton (tab.1). *Cladocera* species appear in May - June , but their amount is still on a low level. The greatest part of the spring zooplankton (70 - 80%) is staying in the upper layer of 0 - 10m. The water temperature increases differently in various regions of the gulf therefore the zooplankton is distributed unequally. At the beginning of spring the zooplankton is more abundant in the open part of the gulf, but when the water temperature gradually rises the abundance of zooplankton in the coastal zone and in the open part become similar.

The highest number and biomass of zooplankton is observed in summer, when it is 4 - 5 times and in some years 7 - 10 times higher than in the spring (tab.1). *E. hirundoides* forms 70 - 80% of the total amount. *L. grimaldii* moves to the deeper and cooler waters. Reproduction of *Cladocera* takes place in the upper layer. *P. polyphemoides* is the most abundant in July when its share is approximately 75% from the total amount of *Cladocera*, but in August the dominant species is *B.c. maritima*. In some years the number of it reaches more than 100 thousand ind/m3. The vertical and horizontal distribution of zooplankton is very uneven in summer. Each species occupies the water layer with fit temperature, that provides also for the best feeding conditions. The zooplankton is most abundant in the layer of 0 - 20m. In the coastal zone the productivity of zooplankton is higher than in the open part of the gulf , especially in the regions of river mouthes. The zooplankton abundance in the coastal zone is strongly influenced by the wind action and the amount of it there can broadly vary.

In autumn the amount of zooplankton diminishes 3 to 4 times (tab.1). Depending mainly on water temperature it varies from 4.5 thousand to 33.6 thousand ind./m3, the biomass from 74.0 to 380.0 mg/m3. In autumn the zooplankton is distributed evenly in different layers and regions, because the water is intensively mixed during the autumn storms and the water temperature is smoothed. The species of *Cladocera* gradually dissappear, as the water temperature is falling. In the beginning of October occurs the last reproduction of *Copepoda* summer generations. The autumn generation of *E. hirundoides* winters till spring, but the one of *A. bifilosa* continues to develop and mature till the winter breeding cycle. *L. grimaldii* is scarse in autumn and it is constituted only by adult specimen. *Synchaeta spp.* become abundant in the autumn zooplankton.

The fluctuations of zooplankton abundance are closely connected with the seasonal and yearly changes of air and water temperature. The variations of total amount of *Crustacea* and water temperature can be seen in Figures 3 - 4, and the variations of abundance of some species in different seasons can be seen in Figures 5 - 7.

A close connection is observed between the air temperature in winter and the abundance of zooplankton (*Cladocera* and *Copepoda)* in May (fig.5). The noticable warm and cold periods are clearly connected with respective higher and lower abundances of zooplankton. Noteworthy that average amoount of zooplankton in warm (12.7 thousand ind./m3) and cold periods (7.0 thousand ind./m3) in the seventies and eighties was higher than in the corresponding periods in fifties and sixties (respectively 10.6 thousand and 5.3 thousand ind./m3). The main reasons might be that the climate has on average got warmer and the level of eutrophication has risen.

In eighties the increase of zooplankton abundance has descended mainly on account of *A.bifilosa* and *Synchaeta spp.* On the contrary the abundance of *L. grimaldii*, which prefers cool water, has drastically decreased in the last ten years. The correlation coefficients between water temperature in the layer of 0 - 50m in spring and the abundance of some species is showed in the table below.

Species	*A.bifilosa*	*E.hirundoides*	*L.grimaldii*	*Synchaeta spp.*
r	0.57	0.69	-0.36	0.64

In summer the zooplankton (*Crustacea*) abundance has tendency to grow (fig.2, 4). The zooplankton biomass has increased in the eighties in comparison with seventies 1,5 times and with sixties about 2 times. The increase of zooplankton productivity has taken place on account of *A. bifilosa* and *B. c.maritima.* In the last ten years the abundance of *Synchaeta spp* . has also strongly increased (fig.6). At the same time the abundance of *L.grimaldii* has diminished beginning with 1974 and now is on avery low level. The abundance of *L.grimaldii* has a negative correlation with the water temperature in the layer of 20-50 m (r =-0.51) as well as it was stated that the abundance of this species is negatively correlating with the stock size of herring, which has strongly increased in the last years (Kornilovs et al, 1992). A significant correlation is stated between the abundance of *A. bifilosa* and water temperature in the layer of 0 - 50m (r = 0.73). The rise of zooplankton productivity is undoubtedly tied with the eutrophication,which has caused the increase of primary production.

A less expressed rise of zooplankton productivity is observed in autumn (fig.7). In the last 20 years the abundance of *Synchaeta spp.*has increased 8 times, *A. bifilosa* 2 times and *E. hirundoides* 2.2 times in comparison with the previous period. The changes that have taken place in autumn zooplankton abundance can be explained only with the alterations of hydrometeorological conditions. The general warming has created favourable conditions for species prefering warm water.

The investigations at the eastern coast of the Gulf of Riga have revealed that the abundance of zooplankton in the coastal zone has increased even more rapidly than in the open part of the gulf (tab.3). In summer (July, August) the amount of zooplankton has there increased in the eighties in comparison with fifties and sixties respectively 2.6 and 1.3 times.

The influence of *L.grimaldii* abundance decrease on the diminishing of herring mean weight-at-age was shown earlier (Kornilovs et al,1992). It was also stated that the rise of herring stock was one of the factors which caused the decrease of *L.grimaldii* abundance. On the other side the growth of zooplankton productivity, especially *A.bifilosa* and *E.hirundoides*, have produced favourable feeding conditons for larvae and young herring, which has manifested in appearance of several rich year classes (1986, 1989-1992). In the beginning of eighties it was suppressed by cod, which was very abundant and which feed mainly on young herring.

Conclusions

1. In the period of 1956-1992 essential changes in long-term and seasonal aspect have occured with the zooplankton community of the Gulf of Riga.

2. The observed period can be devided in several ones with increased and lowered water temperature conditions, on general having in the last decades the tendency of hightened water temperature.

3. The salinity was increasing till 1977 and the highest salinity was recorded in the mid-seventies, while nowdays it has the lowest values.

4. A close connection exists between the zooplankton abundance and the air and water temperature as well as with eutrophication. The warm periods of the last twenty years have favoured the increase of zooplankton productivity, which have happened on account of species preféring warm water. On the contrary the abundance of species prefering cool and clean water is diminishing.

5. The changes of zooplankton influence the condition of the herring stock. Mean [illegible] nearest future. On the other side it has improved the feeding conditions of larvae and young herring which resulted in several rich year classes.

References

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Tab. 1. The abundance of zooplankton in the 0-40 m layer in different seasons in 1960-1987

Species	February		May		June		July		August		October	
	10^3 ind/m^3	mg/m^3	10^3 ind/m^3	mg/m^3	10^3 ind/m^3	mg/m^3	10^3 ind/m^3	mg/m^3	10^3 ind/m^3	mg/m^3	10^3 ind/m^3	mg/m^3
Acartia	1.4		4.7		3.9		4.2		6.4		7.4	
Eurytemora	0.8		2.7		4.3		15.6		14		8	
Limnocalanus	0.2		1.2		0.6		0.4		0.2		0.7	
Copepoda, total	**2.4**	**42.1**	**8.6**	**146.2**	**8.8**	**270.7**	**20.2**	**341.2**	**21.6**	**400**	**16.1**	**195.5**
Bosmina	0		0.02		0.06		0.8		16.7		0.01	
Evadne	0		0.005		0.2		1		0.6		0.03	
Podon	0		0.005		1		6.4		1.9		0.05	
Cladocera, total	**0**		**0.03**	**0.5**	**1.3**	**38.7**	**8.2**	**356**	**19.2**	**201**	**0.09**	**2.0**
Synchaeta	0		2.2		30.7		10.3		6.6		4.5	
Keratella	0		0.1		2.2		46.8		14.2		0.03	
Bivalvia larv.	0		0.1		1.2		0.6		0.4		0.02	
Balanus larv.	0		0		0		2.9		0.2		0.05	
Varia total	**0**		**2.4**	**14.1**	**34.1**	**198.7**	**60.6**	**129.3**	**21.4**	**59**	**4.6**	**27.3**
T O T A L	**2.4**	**42.1**	**11.03**	**160.8**	**44**	**508**	**89.4**	**826.5**	**62.2**	**660**	**20.8**	**224.8**

'* - The material includes observations in February for 10 years, in June for 6 years and in July for 9 years

Tab. 2. The abundance of zooplankton (1000 ind/m^3) at the eastern coast of rhe Gulf of Riga in July-August by periods of years in 1955-1986

Species	PERIODS 1955-1959	1960-1969	1981-1986
Acartia bifilosa	3.9	14.4	6.9
Eurytemora hirundoides	10	15.5	32.8
Copepoda nauplii	5.7	8.9	12.5
Copepoda, total	**19.6**	**38.8**	**52.2**
Bosmina coregoni maritima	2.1	9.5	43.8
Evadne nordmanni	0.8	0.4	1.9
Podon spp.	1.4	4.4	6.3
Cladocera, total	**4.3**	**14.3**	**52**
Synchaeta spp.	17.8	8.6	8.6
Keratella spp.	8.7	17.9	29.8
Rotatoria total	**26.5**	**26.5**	**38.4**
Balanus larv.	6.1	35.2	5.4
Molusca larv.	1.2	0.4	1.2
TOTAL	57.7	115.2	149.2

Tab. 3. The abundance of Crustacea (1000 ind/m^3) in the coastal and open parts of the Gulf of Riga by periods of years

Periods of years	Regions, layers (m) Coastal zone 0 - 10 m	Open 0 - 40 m	part 0 - 10 m
1955 - 1959	23.0	17.6	-
1960 - 1969	51.3	24.3	62.8
1970 - 1979	-	32.1	68.5
1981 - 1986	104.2	69.0	82.5

Fig.1. The average seasonal water temperature (Tw) of the 0-50 m layer in the Gulf of Riga

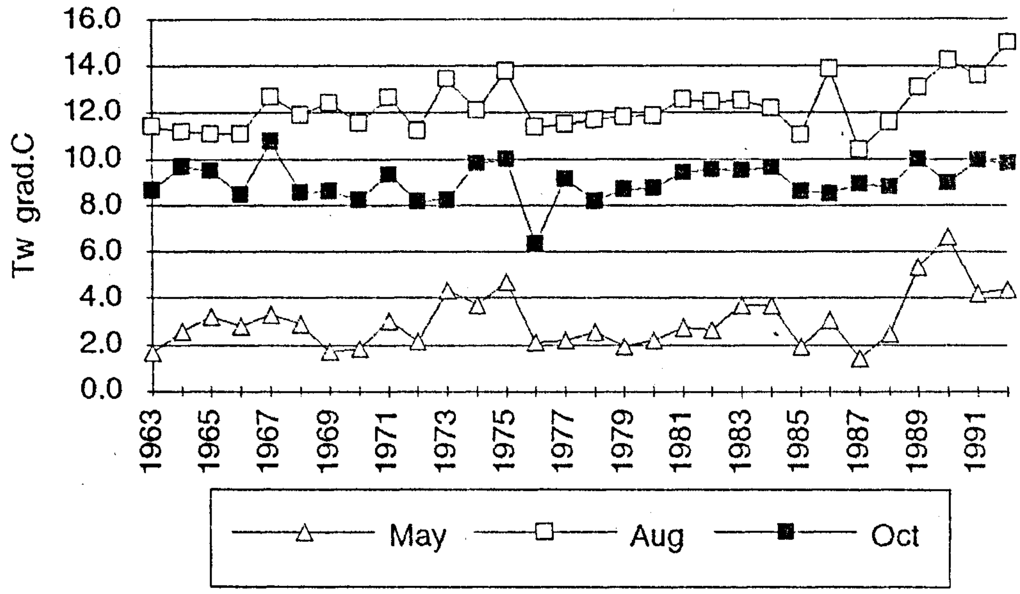

Fig.2. The average yearly salinity and amount of river runnoff (km^3/year) in the Gulf of Riga

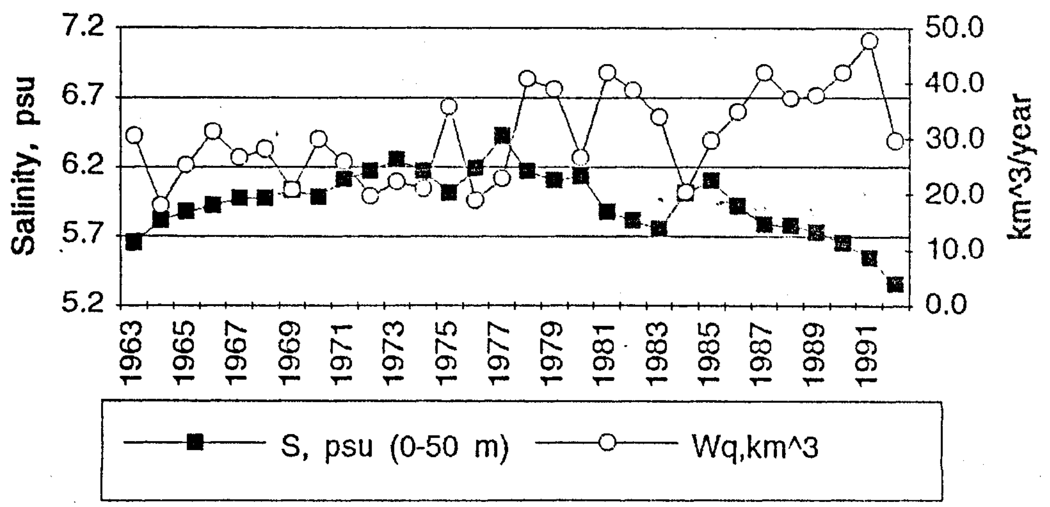

Fig.3. The abundance of Crustacea (ind/m^3) in the 0-40 m layer in May and average winter air temperature (Jan - Apr)

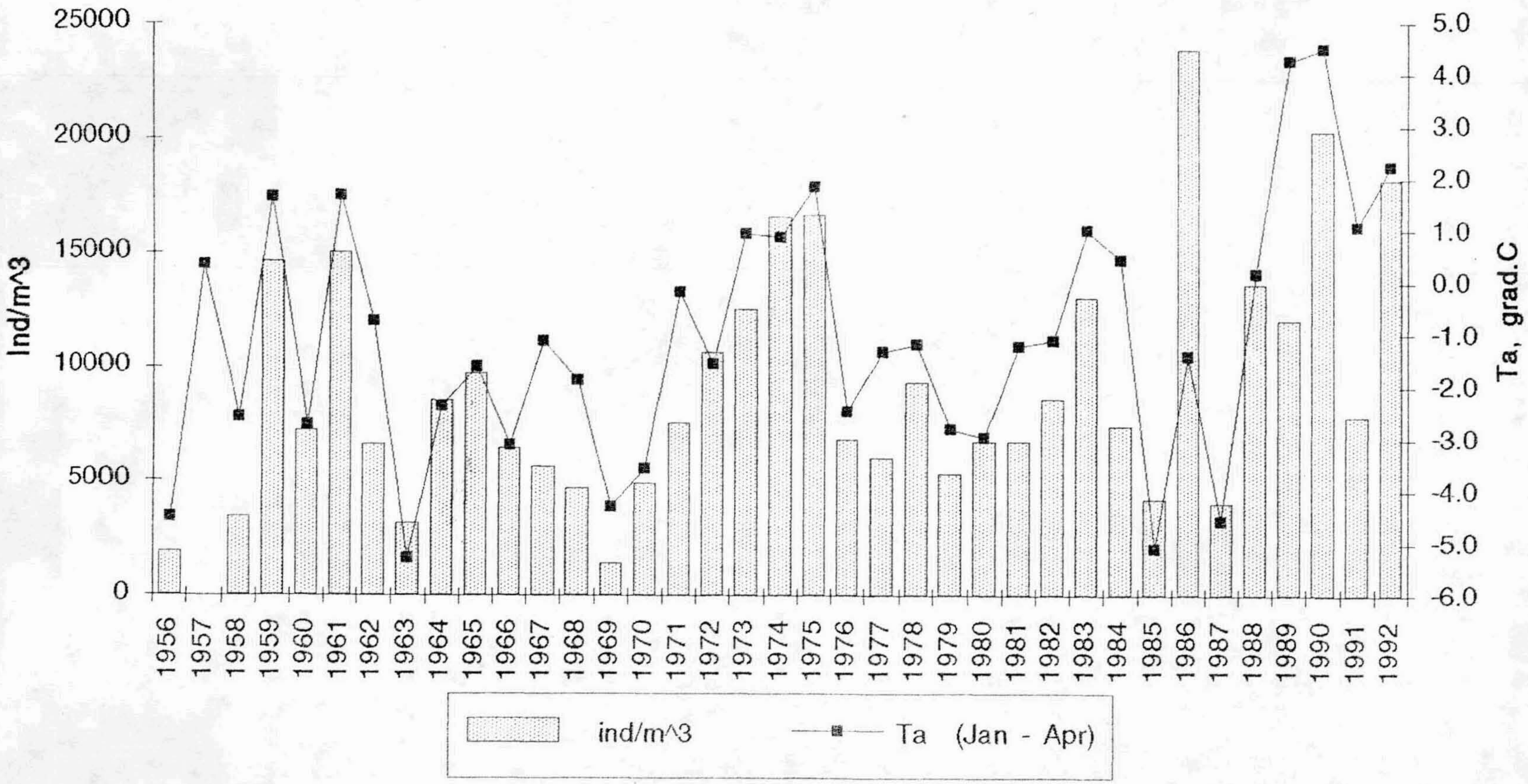

Fig.4. The abundance of Crustacea (mg/m^3) in the 0-40 m layer and average water temperature of the 0-20 m layer in August

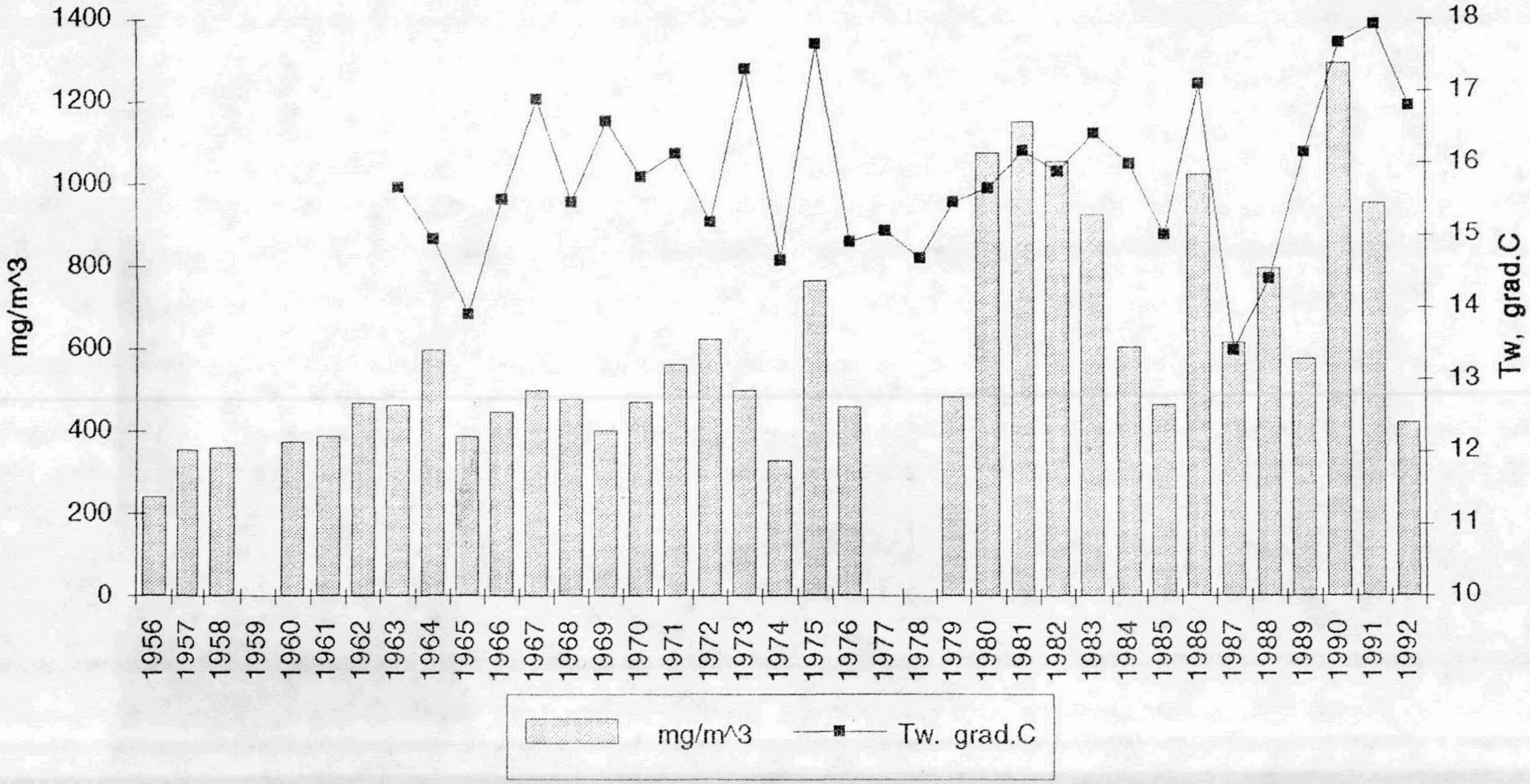

Fig. 5. The abundance of the main zooplankton species in the 0-40 m layer in May in the Gulf of Riga

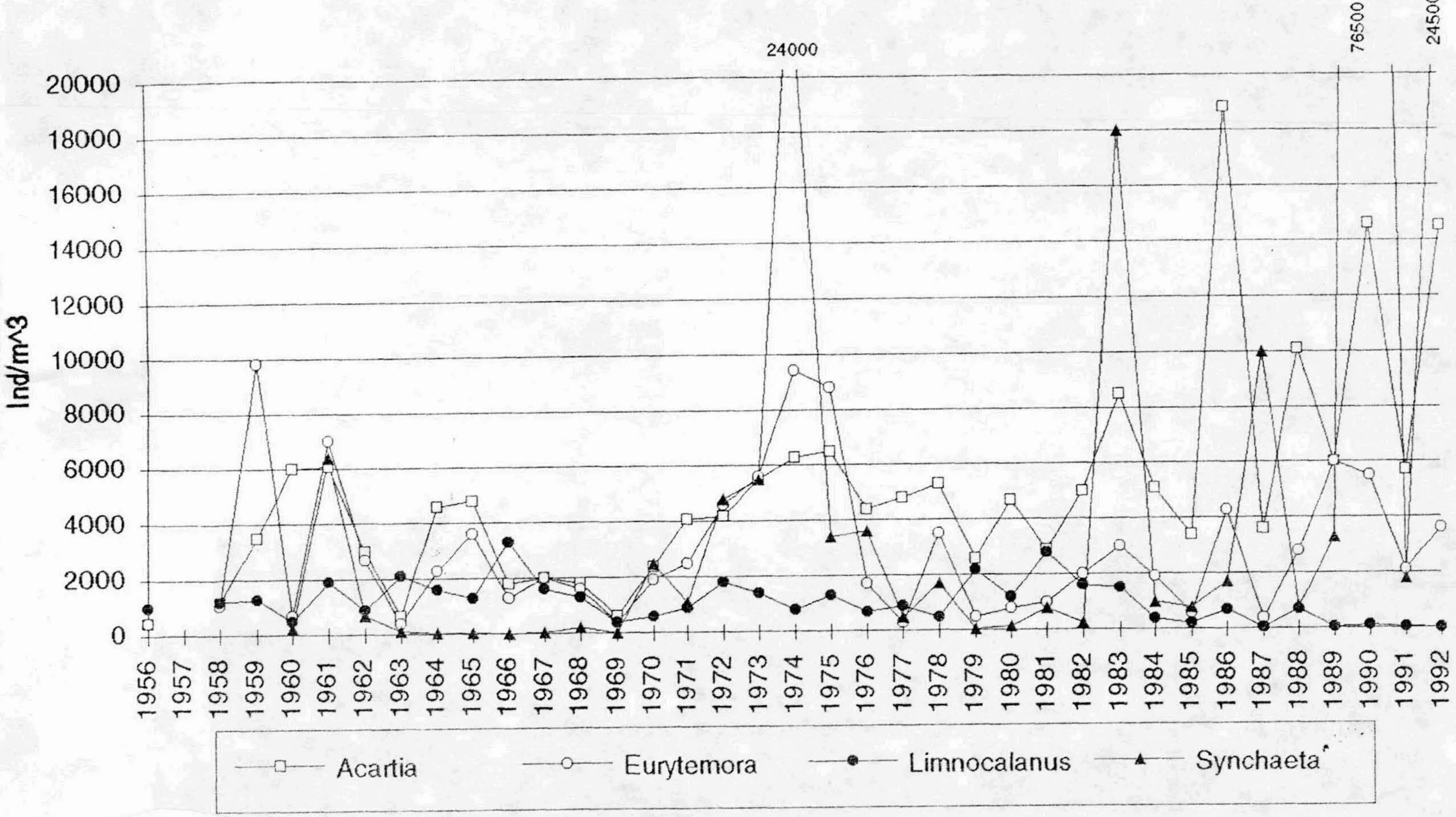

Fig. 6. The abundance of the main zooplankton species in the 0-40 m layer in August in the Gulf of Riga

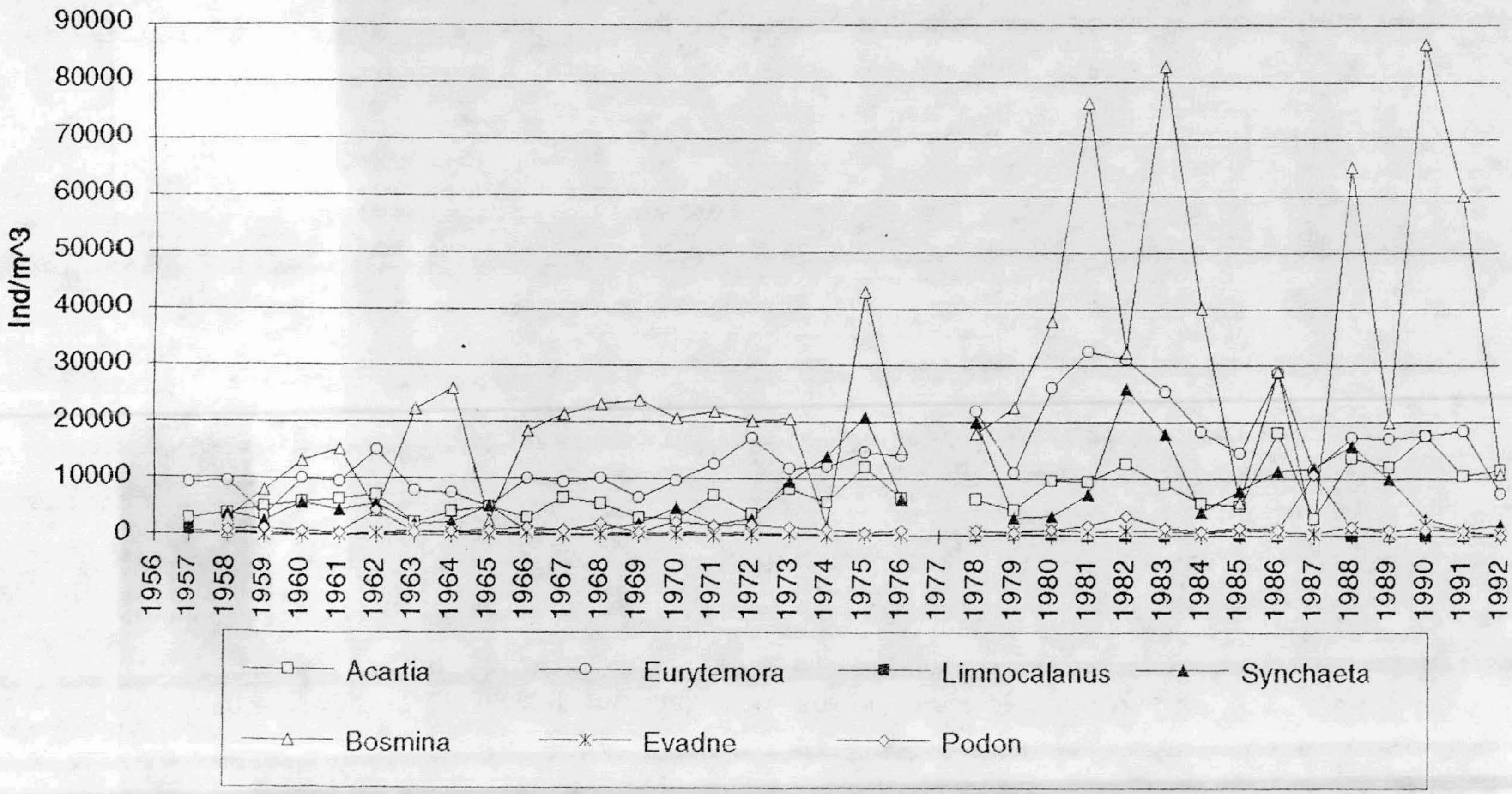

Fig. 7. The abundance of the main zooplankton species in the 0-40 m layer in October in the Gulf of Riga

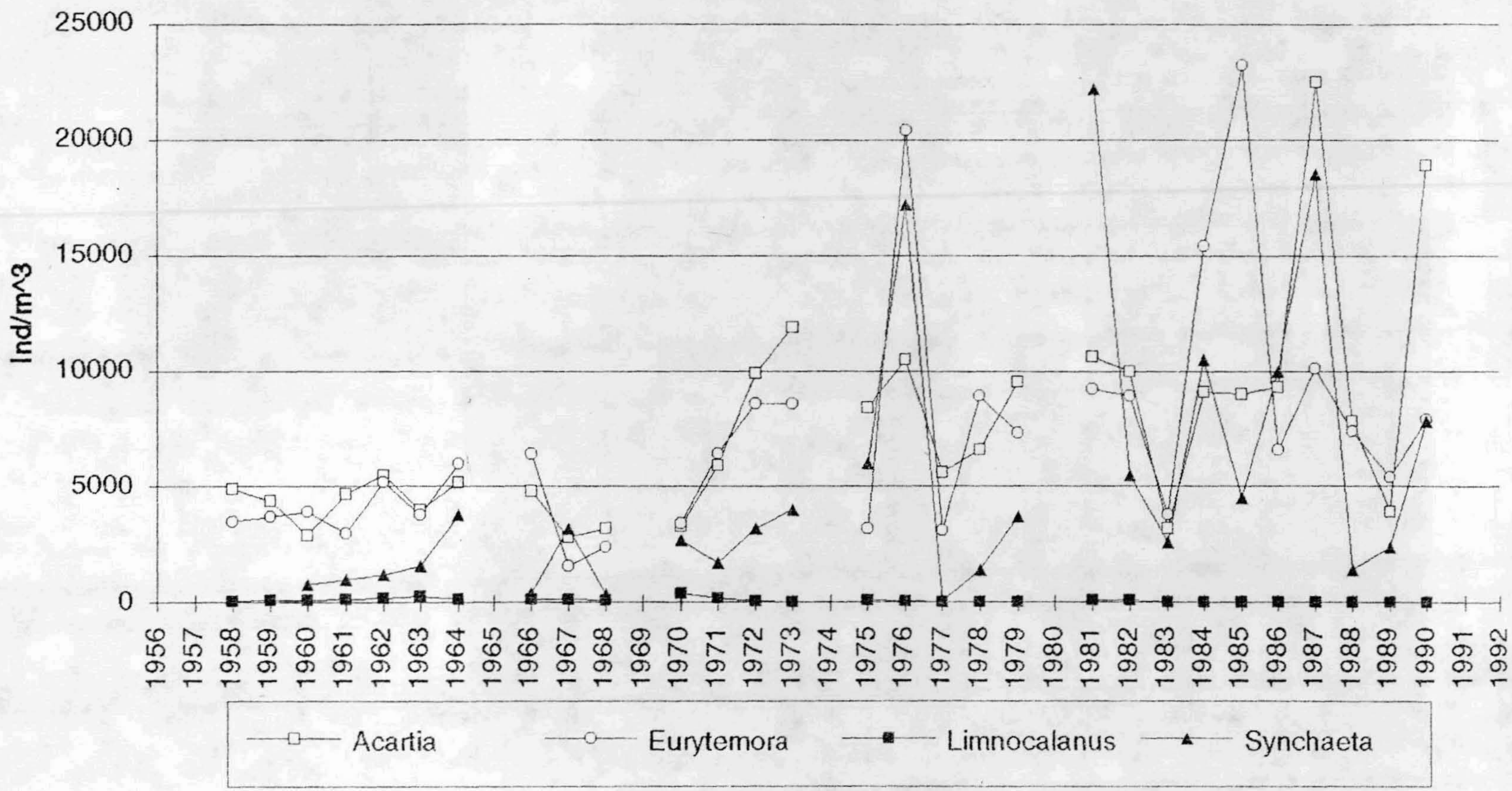

Fig.8. The abundance of Limnocalanus grimaldii and average water temperature of the 20-5o m layer in August in the Gulf of Riga