| Baltic Coastal Zone<br>No. 3 | |
|---|---|
| (89-101)<br>1999 | Institute of Biology and Environmental Protection<br>University of Education<br>of Słupsk |

# THE INFLUENCE OF WATER MASS DYNAMICS ON THE CHANGES OF INVERTEBRATES NUMBER IN LAKE GARDNO

Ewa Paturej, Izabela Jabłońska

*Department of Ecology and Hydrobiology, Warmińsko-Mazurski University*
*Oczapowskiego St. 5, 10-957 Olsztyn, Poland*

**Abstract**

Gardno is an estuarial, β-oligohaline, coastal lake separated from the Baltic Sea by a narrow strip of a land. This shallow reservoir is strongly exposed to the wind due to its large area. Factors above result in frequent and easy mixing of water mass. The wind, and exactly water movements caused by the wind in such a shallow, polymictic reservoir, is the main factor limiting the number and species diversity of invertebrates.

The aim of the study is to estimate the influence of abiotic factors on changes of invertebrates abundance in Lake Gardno. The material was taken at six sites. Biological material was collected and divided into three taxonomic groups of zooplankton (*Rotatoria*, *Cladocera*, *Copepoda*) and five zoobenthos taxonomic groups of different systematic importance (*Chironomidae*, *Oligochaeta*, *Gastropoda*, *Bivalvia*, *Trichoptera*, *Amphipoda*).

There is a significant relationship between zooplankton communities (*Cladocera*, *Rotatoria*) and physical factors (0.8846), a weaker relationship was observed between the dynamics of *Oligochaeta* and *Copepoda* number (0.6351). The significant influence of the wind velocity and water temperature on the occurrence of *Oligochaeta* and *Copepoda* was found. The negative relationship appeared between the number of chironomids larvae and other components of the analysis (-0.4412).

**Key words**: zooplankton, zoobenthos, coastal lakes, abiotic factors;

## INTRODUCTION

Lake Gardno is situated in the middle part of the Polish coast. It is a part of Słowinski National Park. Considering the area it is the second coastal lake in Poland (2,468.1 ha; IRS Olsztyn 1966). This shallow reservoir is separated from the Baltic Sea by a strip of land (2-8 km). That forms a sandbar covered by various, not high hills and pine forests. There is a protected area called "Wyspa Kamienna" in the central part of the studied reservoir. The island is famous for its breeding-grounds of cormorant (*Phalacrocorax carbo*) the only place in Poland where they build their nests on the ground (Pajkert and Pajkert 1991). These water-muddy areas of Słowiński National Park are taken into protection in accordance with the Ramsar Convention.

Lake Gardno is an estuarial, strongly polymictic reservoir; a distance of a free run of water [km] - D = 5.7; a maximum depth of 2.6 m; a theoretical depth of the epilimnion [m] - E = 10.5; that is nearly three times bigger than the value of the maximum lake's depth. Such a shallow reservoir is under a strong impact of the wind mixing to the bottom. There is no thermal and oxygen stratification in the studied reservoir. This reservoir has good oxygen conditions. During the studied period of time the minimum content of oxygen reached the value of 70%.

A current level of water mass salinity depends on the surface flow, the direction of winds and the frequency of marine water inflows. Consequently, this kind of reservoirs are the habitat of euryhaline marine species, eury- and holeuryhaline freshwater species able to exist in a wide range of salinity and typical brackish water species.

The aim of this study was to estimate the influence of water mass dynamics on changes of number and species diversity of zooplankton communities and the main groups of zoobenthos in polymictic Lake Gardno.

## MATERIAL AND METHODS

Samples were taken monthly from March to October 1998 from six sites (Fig. 1). Totally, 96 zooplankton and zoobenthos samples were collected. Zooplankton samples were taken by means of a 5 $dm^3$ Patalas sampler. It was taken 10 $dm^3$ of water from each site. In laboratory 48 samples were analysed. The material was prepared and counted according to Starmach (1955).

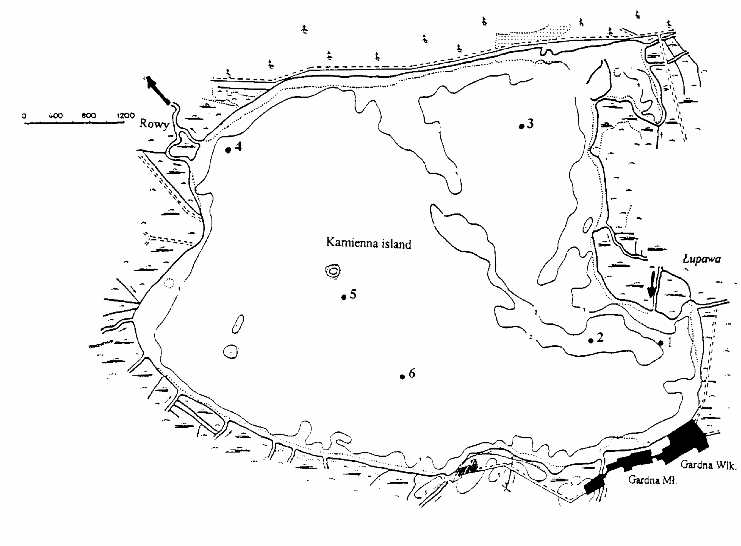


Fig. 1. Location of sample sites in Lake Gardno

A single benthic sample was obtained as a material taken three times at the same site using an Eckman-Birge sampler of a total area of 675 $cm^2$. Then the material was sieved through a 0.25 x 0.25 mesh and sorted out by means of a stereoscopic microscope. The size of a mesh was chosen to record real changes of benthic invertebrates life-cycles. Taxonomic keys to the larval forms (Wiederholm, 1983) have been used to determine the taxonomical composition of collected material. The form described by the author as *Chironomus* sp. I was identified by Romaniszyn (1958) as *plumosus* (basing on larval features) whereas *Chironomus* sp. II as *semireductus.*

Simultaneously, the temperature of surface and near the bottom water was measured. The temporary temperature data were recorded at the moment of taking the samples for invertebrates analysis and can be recognized as a mean values for the whole lake. Data on wind velocity and its direction were obtained from the Institute of Meteorology and Water Economy (IMiGW) in Gdynia (Table 1) as the mean values for particular months.

Table 1

Selected physical parameters of Lake Gardno in the following seasons of 1998

| Physical parameters | | Spring | | | Summer | | | Autumn | |
|---|---|---|---|---|---|---|---|---|---|
| | | III | IV | V | VI | VII | VIII | IX | X |
| Mean wind velocity ($m\ s^{-1}$)* | | 8 | 3 | 2 | 2 | 3 | 5 | 6 | 10 |
| Mean water temperature (°C) | Surface | 6.5 | 10.4 | 14.4 | 18.2 | 19.5 | 21.8 | 15.0 | 6.0 |
| | Bottom | 6.0 | 10.0 | 14.1 | 17.8 | 19.0 | 21.6 | 15.0 | 5.5 |

* according to IMGW in Gdynia

For analysis of received data underwent standard procedures using the NTSYS system of numerical computer programs. Characters were standarized before the computation of matrices of distance and correlation coefficients between OTUs. These matrices were clustered using the UPGMA (unweighted pair group methods with arithmetic averaging). Standard methods were used to change matrices of data as follows: matrices columns (suitable features) were standardized due to the formula:

$$y' = (y - a/b) + c \qquad \text{where:}$$

a - YBAR - the mean of each character, b - non-standard deviation, c - constant,
y - characters value

Transformed values of matrices of data were used to calculate the matrix of Euclidean distance. Cluster analysis was carried out using SAHN algorithm and UPGMA method where the distance between two clusters was calculated as a mean distance between all parameters of objects of two different clusters. It has been obtained a graphical result called dendrogram.

## RESULTS

The study of zooplankton abundance and the measurement of physical features of Lake Gardno were carried out during the spring, summer and autumn. Three taxonomic groups, rotifers, cladocerans and copepods, were determined in collected material. The species diversity remarkably varied among *Rotatoria* (7-15 taxa) but for *Cladocera* and *Copepoda* ranged from 4 to 5 taxa of the former and from 3 to 5 taxa of the latter group.

Considering the number of particular species in studied seasons there were determined rare species of a low density and those that reached high abundance appearing in all studied periods. The first group was represented by *Brachionus angularis aestivus, Polyarthra* sp., *Bosmina coregoni maritima, Daphnia longispina* and *Acanthocyclops vernalis* (maturate, female form). The most abundant, second group included the following species: *Pompholyx* sp., *Keratella cochlearis* f. *tecta, Chydorus sphaericus, Daphnia cuculata* and juvenile forms of *Copepoda* (nauplii) and copepodits of *Cyclops vicinus* (Table 2).

Table 2

The abundance of zooplankton (ind. $dm^{-3}$) and zoobenthos (ind. $m^{-2}$) in Lake Gardno in the following seasons of 1998

| Taxon | Spring | | Summer | | Autumn | |
|---|---|---|---|---|---|---|
| | ind. $dm^{-3}$ | % | ind. $dm^{-3}$ | % | ind. $dm^{-3}$ | % |
| *Rotatoria*: | | | | | | |
| *Asplanchna priodonta* | 2 | <1 | 4 | 1 | 19 | 3 |
| *Brachionus angularis angularis* | 40 | 3 | 77 | 13 | 28 | 4 |
| *Brachionus angularis aestivus* | 1 | <1 | 0 | 0 | 0 | 0 |
| *Brachionus calyciflorus amphiceros* | 12 | 1 | 0 | 0 | 0 | 0 |
| *Brachinus calyciflorus calyciflorus* | 18 | 1 | 0 | 0 | 0 | 0 |
| *Colurella colurus* | 4 | 1 | 0 | 0 | 0 | 0 |
| *Euchlanis dilatata* | 4 | 1 | 2 | 0 | 0 | 0 |
| *Filinia longiseta* | 8 | 1 | 0 | 0 | 0 | 0 |
| *Keratella cochlearis cochlearis* | 107 | 8 | 19 | 3 | 12 | 1 |
| *Keratella cochlearis tecta* | 206 | 16 | 215 | 36 | 166 | 23 |
| *Keratella guadrata guadrata* | 88 | 7 | 41 | 7 | 50 | 7 |
| *Polyartha* sp. | 3 | <1 | 0 | 0 | 0 | 0 |
| *Pompholyx* sp. | 304 | 24 | 86 | 14 | 202 | 27 |
| *Trichocerca pusilla* | 293 | 23 | 86 | 14 | 142 | 19 |
| Total *Rotatoria* | 1,090 | 86 | 530 | 88 | 619 | 84 |
| *Cladocera* | | | | | | |
| *Bosmina coregoni maritima* | 0 | 0 | 0 | 0 | 17 | 2 |
| *Bosmina longirostris* | 1 | <1 | 3 | 1 | 12 | 2 |
| *Chydorus sphearicus* | 53 | 4 | 6 | 1 | 5 | 1 |
| *Daphnia cucullata* | 1 | <1 | 20 | 3 | 29 | 4 |
| *Daphnia longispina* | 0 | 0 | 10 | 2 | 0 | 0 |
| *Leptodora kindtii* | 2 | 0 | 1 | <1 | 0 | 0 |
| Total *Cladocera* | 57 | 4 | 40 | 7 | 63 | 9 |
| *Copepoda* | | | | | | |
| *Copepoda* (*nauplii*) | 99 | 9 | 11 | 2 | 24 | 3 |

continuation Table 2

| | | | | | | |
|---|---|---|---|---|---|---|
| *Cyclops vicinus: copepodits* | 2 | <1 | 21 | 3 | 13 | 2 |
| *maturate female form* | 2 | <1 | 0 | 0 | 6 | 1 |
| *Acanthocyclops vernalis: copepodits* | 18 | 1 | 1 | 0 | 5 | <1 |
| *maturate female form* | 0 | 0 | 0 | 0 | 6 | 1 |
| Total *Copepoda* | 121 | *10* | 33 | *5* | 54 | *7* |
| **Total zooplankton** | **1,268** | **100** | **603** | **100** | **736** | **100** |
| | ind. $m^{-2}$ | % | ind. $m^{-2}$ | % | ind. $m^{-2}$ | % |
| *Insecta* | | | | | | |
| *Ephemeroptera* | 13 | <1 | 9 | <1 | 3 | <1 |
| *Trichoptera* | 5 | <1 | 0 | 0 | 0 | 0 |
| *Diptera* | | | | | | |
| *Chironomidae* | | | | | | |
| *Tanypodinae* | | | | | | |
| *Tanypus kraatzi* | 10 | <1 | 0 | 0 | 0 | 0 |
| *Procladius* spp. | 100 | 6 | 11 | 1 | 105 | 18 |
| *Chironominae* | | | | | | |
| *Chironomus* sp.I (f.l. *plumosus*) | 125 | 7 | 9 | <1 | 80 | 13 |
| *Chironomus* sp.II (f.l. *semireductus*) | 10 | <1 | 0 | 0 | 0 | 0 |
| *Dicrotendipes* sp. | 10 | <1 | 0 | 0 | 50 | 17 |
| *Einfeldia* sp. | 55 | 3 | 4 | <1 | 0 | 0 |
| *Cryptochironomus* sp. | 15 | <1 | 2 | <1 | 30 | 5 |
| *Cladopelma* sp. | 5 | <1 | 2 | <1 | 3 | <1 |
| *Polypedilum* sp. | 10 | <1 | 0 | 0 | 29 | 5 |
| *Tanytarsus mancus* | 400 | 22 | 8 | <1 | 90 | 15 |
| *Tanytarsus gregarius* | 20 | 1 | 2 | <1 | 4 | <1 |
| *Diamesinae* | | | | | | |
| *Prodiamesa olivacea* | 0 | 0 | 0 | 0 | 18 | 3 |
| Total *Chironomidae* | 760 | 42 | 38 | 4 | 409 | 68 |
| *Oligochaeta* | | | | | | |
| *Potamothrix hammoniensis* | 50 | 3 | 30 | 3 | 20 | 3 |
| *Potamothrix moldaviensis* | 30 | 2 | 10 | 1 | 12 | 2 |
| *Potamothrix n.d.* | 150 | 8 | 160 | 16 | 15 | 3 |
| *Limnodrilus n.d.* | 180 | 10 | 180 | 18 | 50 | 8 |
| *Psammoryctides* sp. | 50 | 3 | 10 | 1 | 3 | <1 |
| *Stylaria lacustris* | 30 | 2 | 5 | <1 | 0 | 0 |
| *Oligochaeta* non det. | 500 | 28 | 490 | 45 | 75 | 13 |
| Total *Oligochaeta* | 990 | 55 | 885 | 89 | 175 | 29 |
| *Bivalvia* | 20 | 1 | 50 | 5 | 10 | 2 |
| *Gastropoda* | 10 | <1 | 5 | <1 | 3 | <1 |
| *Malacostraca*: | | | | | | |
| *Amphipoda* | 0 | 0 | 50 | 5 | 0 | 0 |
| **Total zoobentos** | **1,798** | **100** | **997** | **100** | **600** | **100** |

Taking into account the seasonal distribution of rotifers number it was found that the maximum of their development was recorded during the spring. In March as well as in May (Fig. 2) their density reached a value twice higher than in summer and autumn. The period of early spring (March) and late autumn (October) favoured cladocerans development. Comparable values of density were obtained (Fig. 3). Among copepods the highest abundance was recorded in March. It was four times higher than in May, August and October (Fig. 4).

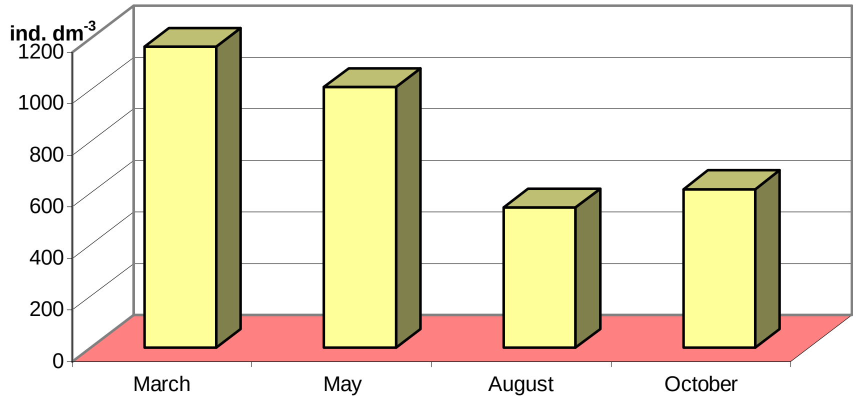


Fig. 2. Seasonal distribution of *Rotatoria* (ind. $dm^{-3}$) abundance in Lake Gardno

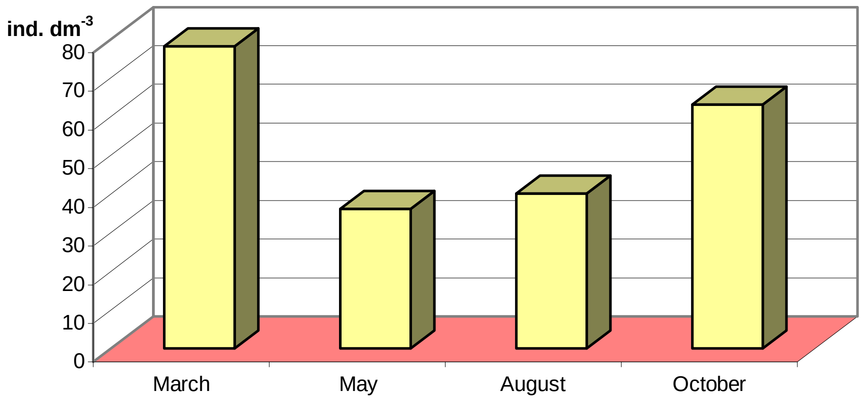


Fig. 3. Seasonal distribution of *Cladocera* (ind. $dm^{-3}$) abundance in Lake Gardno

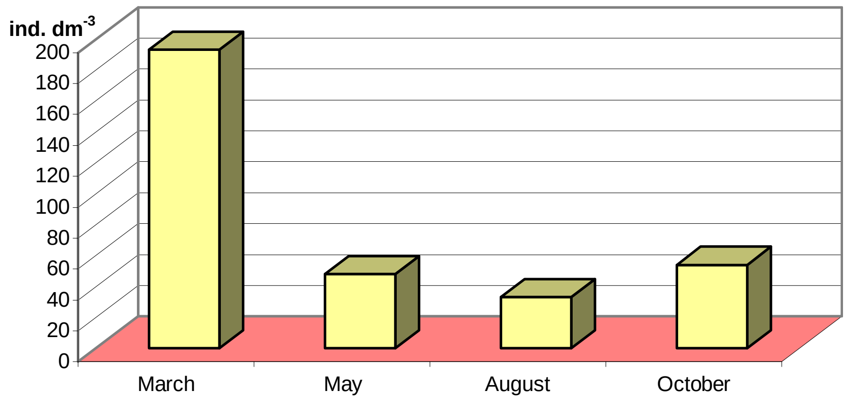


Fig. 4. Seasonal distribution of *Copepoda* (ind. $dm^{-3}$) abundance in Lake Gardno

The maximum zooplankton abundance was recorded in spring (1,268 ind. dm$^{-3}$) and comparable values were obtained in summer and autumn (603 ind. dm$^{-3}$ and 736 ind. dm$^{-3}$). Taking into account the percentage of the main systematical groups it was noticed that the zooplankton community was dominated by rotifers (86 - 88% of a total number of organisms).

Benthic invertebrates of a studied area were mainly represented by *Diptera* larvae of *Chironomidae* family and *Oligochaeta*. Other orders of insects (*Ephemeroptera, Trichoptera*) were recorded in a smaller amount. *Gastropoda, Bivalvia* and *Amphipoda* have also been found.

The density of fauna at all sites during the studied period was low (1,132 ind. m$^{-2}$ ) and ranged from 600 to 1,798 ind. m$^{-2}$. The community was dominated by *Chironomidae* (4 - 68% of a total amount) and *Oligochaeta* (respectivly 29 - 89%) - Fig. 5, 6; other taxa appeared in remarkably lower number (often below 1% of total abundance) or even occasionally (Table 2). The mean number of Oligochaeta of a studied reservoir reached value 683 ind. m$^{-2}$ and chironomids larvae - 402 ind. m$^{-2}$.

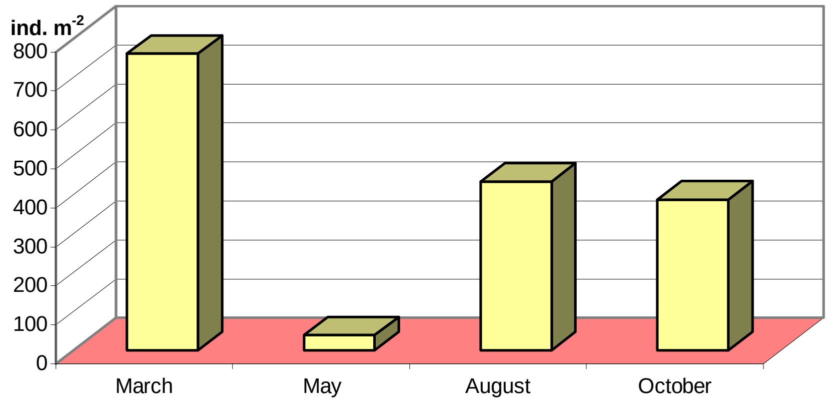


Fig. 5. Seasonal distribution of *Chironomidae* (ind. m$^{-2}$) abundance in Lake Gardno

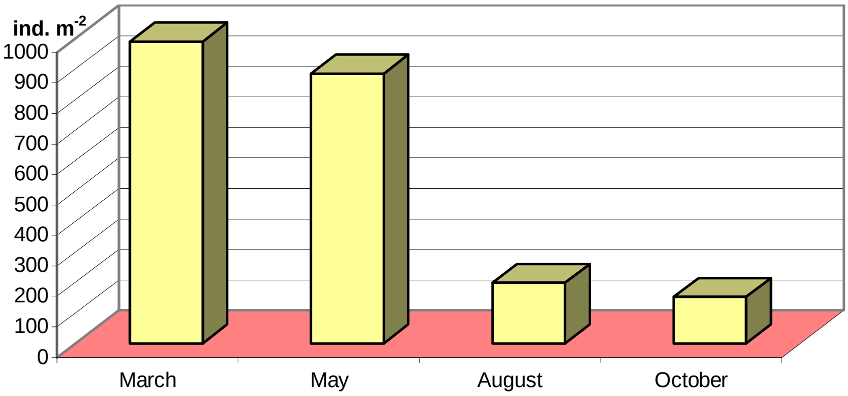


Fig. 6. Seasonal distribution of *Oligochaeta* (ind. m$^{-2}$) abundance in Lake Gardno

Among *Chironomidae* the domination of *Procladius* spp., *Chironomus* sp. 1 *(plumosus)* and *Tanytarsus* sp. was observed. Considering *Oligochaeta*, the main components of faunal community were *Potamothrix* sp. and *Limnodrilus* sp.

The analysis of features similarity (invertebrates abundance, water mass temperature, the wind velocity) revealed the strongest similarity between the wind velocity and the temperature (0.9699) and between *Cladocera* and *Rotatoria* assemblies (0.8846) and physical features above (Fig. 7).

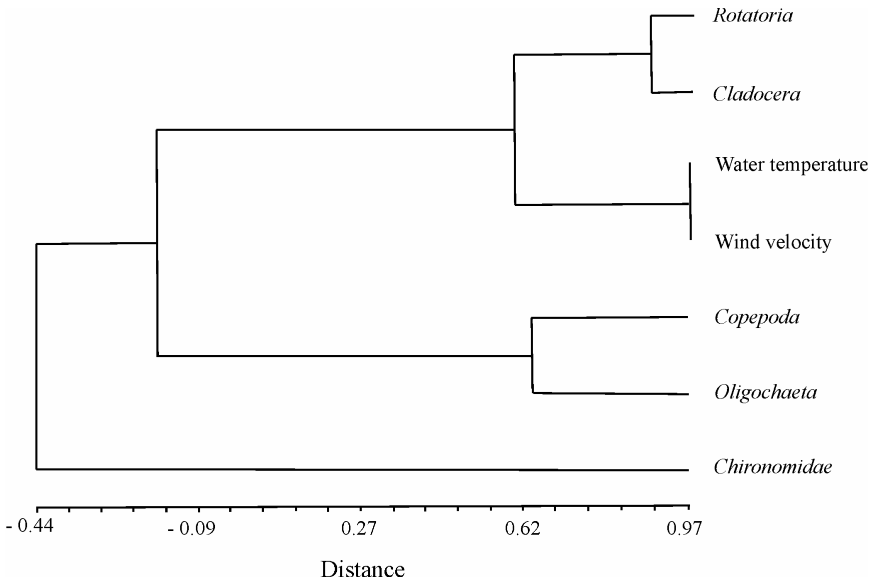


Fig. 7. Dendrogram of distance between chosen features

The thermal stratification of the studied lake has not been observed. The maximum temperature diversity of surface and near the bottom layers was recorded in early spring and late autumn (0.5ºC) - Table 1. The mean temperature in the water column from the surface to the bottom reached values: in spring - 10.2ºC, summer - 19.6ºC and autumn - 10.4ºC. Surprisingly, the wind velocity was twice stronger in spring but water temperature was nearly the same in spring and autumn.

## DISCUSSION

Lake Gardno has a specific physical and chemical feature which mainly results from wind mixing and thermal conditions of the surrounding air-mass. The above factors have a strong impact on the abundance of zooplankton and zoobenthos invertebrates.

Water temperature is one of the most important environmental factors controlling vital functions of zooplankton. Each taxonomic group (*Rotatoria* and *Cladocera*) as well as species (*Keratella cochlearis* f. *tecta, Brachionus angularis, Daph-*

*nia cucullata*) have a specific temperature range for an optimal growth. Thermal conditions in late spring (14.4°C) and summer (19.8° C) are supposed to be conducive to development of thermophilous species among *Rotatoria* and *Cladocera*. However, our investigations showed that these taxonomic groups were the most abundant in spring and autumn (Table 1, 2; Fig. 2, 3). A similar relationship was noticed by Różańska (1972) during the studies of mesozooplankton of the Szczecin Lagoon. Whereas Adamkiewicz-Chojnacka (1978) ascertained that the ratio of *Rotatoria* to *Cladocera* in the Vistula Lagoon was quite high. The same author during her later investigations (1985) indicated that the temperature was the main factor stimulating variations in the number of summer zooplankton.

In our research, *Rotatoria* are the main component of the zooplankton community (84-88% of all). As a result of studies of the Polish, estuarial, coastal lakes, Żmudziński *et al*. (1991) pointed out that the convenient temperature had a remarkable influence on *Rotatoria* development and much weaker on the occurrence of *Cladocera* and *Copepoda*. In Lake Gardno a significant share in total abundance of copepods was recorded in early spring (6.5°C) and late autumn (5.5°C). The percentage of both taxonomic groups varied between 7 and 10%.

Another factor determining the occurrence of many taxa is the depth of a reservoir. Relatively shallow Lake Gardno (the mean depth of 1.3 m) gets warm quite fast which provides a rapid development of *Rotatoria* and *Cladocera*. Bittel (1957) in his investigations of shallow Lake Drużno and Adamkiewicz-Chojnacka (1978) in the studies of the Vistula Lagoon (both reservoirs of a similar depth) recorded that the number of *Rotatoria* had increased to a high level. Our research showed that *Cladocera* and *Copepoda* reached a lower value of abundance than *Rotatoria* (Fig. 2-4). The mean percentage of rotifers was calculated to be 86% and relatively of *Copepoda* and *Cladocera* - 7% of each. The low number of *Crustacea* could be a consequence of an intensive grazing pressure of fish or a diapause stage. That stage, particulary in a summer period, is known as a way of avoiding grazing by predators. Experiments have shown that diapause also helps to avoid intraspecific competition (Santer, Lampert 1995).

The research of benthic invertebrates indicated a prevailing role of *Oligochaeta* in number and biomass (Table 2). *Chironomidae* larvae were an important component of reservoir′s benthic fauna too. Other taxa were more random. The average number of *Oligochaeta* was 683 ind. $m^{-2}$ and chironomids larvae - 402 ind. $m^{-2}$. Values above should be considered as low for eutrophic reservoir. Wolnomiejski (1994) indicated a mean density of a benthic fauna of 8.384 ind. $m^{-2}$ in the shallow, eutrophic Szczecin Lagoon. Dusoge (1989) recorded a density of chironomids larvae alone of a few thousands individuals per $m^2$ in Zegrzyński Reservoir. Kajak (1977), during his investigations of a shallow, eutrophic lake, recorded the minimal density of *Chironomus plumosus* alone of 1.400 ind. $m^{-2}$ (in Lake Gardno respectively 34 ind. $m^{-2}$ - Table 2). According to investigations of Moss and Timms (1987) it could be claimed that the main factor limiting benthos variety in Lake Gardno is the dynamics of water mass that causes a resuspension of bottom sediments. The authors indicates that a strong wind generating surface waves is a probable cause of a repeated decrease of the number and biodiversity of animals.

Since the research carried out by Dobrowolski (1996) the total number of species has changed in a studied reservoir. He had found 24 chironomid larval forms whereas the authors of that paper found 12 taxa of a different systematical importance. But the structure of domination among chironomids has not been changed. *Procladius* spp, *Chironomus* sp. I (*plumosus*) and *Tanytarsus* sp. were dominants then as well as during the previous studies that had been conducted by Dobrowolski in the eighties. Seasonal changes in abundance of chironomids larvae are a direct consequence of the life cycle of these insects (Fig. 5). The summer minimum results from outlet imagines. The time of metamorphosis strongly depends on water temperature which is a consequence of air-mass temperature. However, changes in the number of *Oligochaeta* are not simultaneous with the life-cycle of that invertebrates (Fig. 5). Therefore the authors made an attempt to explain that fact. As we mentioned before, Lake Gardno has a good oxygen conditions. The oxygen level not only reached 100% but exceeded higher values. Oxygen microstratification is fairly possible in that lake due to its morphometry and even short oxygen deficiencies cannot have a remarkable influence on invertebrates of eutrophic reservoir. Organisms that exist there are physiologicaly and behaviourally adapted to a temporary oxygen deficiency. Kornijów (1998) claims that summer, strong oxygen deficiencies are not able to cause a decline of benthos number. The analysis of the abundance of that systematical group showed a linear decrease during the year from 990 to 175 ind. $m^{-2}$ in autumn. Such a decline can not be explained as a result of intensive fish grazing. Moreover, ichtiofauna pressure on invertebrates was limited thanks to fish catching since May 1998.

The wind mixing seems to be an important factor of strong influence on a number and distribution of taxonomic groups mentioned above. Żmudziński *et al*. (1990) in Lake Łebsko recorded that a density of organisms had significantly increased near the canal connecting the lake with the sea. It was a result of a periodic, refreshing inflow of marine water. Whereas Patalas (1954) during his research in Lake Charzykowo noticed the fact that water current tears planktonic organisms and moves them to other layers.

As a result of our research, the correlation between the wind velocity and temperature (0.9699) and between sets of *Cladocera* and *Rotatoria* (0.8846) and physical factors (Fig. 7) were found. A lower relationship was observed between dynamics of *Oligochaeta* number and *Copepoda* (0.6351). There was no relationship between the larvae of *Chironomidae* and other analysed factors.

Considering the wind and its impact on water-level, the intensity of water mass mixing, and salinity distribution they have a strong influence on invertebrates translocation in Lake Gardno. During the summer period the wind is rather weak (Table 1), so consequently a refreshing inflow of marine water happens quite seldom. *Cladocera* and *Rotatoria* as a small-bodied organisms of a low body weight are easly "transported" by the wind-generated mixing. Large-bodied *Copepoda* and benthic organisms are not moved and as a result obtained correlation coefficients were negative.

## CONCLUSIONS

1. The zooplankton population in estuarial Lake Gardno was abundant in spring and autumn periods with a clear domination of *Rotatoria*.
2. Changes of environmental factors (temperature, the wind velocity) have a strong impact on the number of zooplankton of studied reservoir. Statistical analysis has shown a strong relationship between *Cladocera* and *Rotatoria* communities and physical factors (0.8846).
3. Changes of abundance of *Chironomidae* larvae and their dynamics are the result of outlet imagines and development of the larval stage that depend on water temperature but not on water mass dynamics.
4. Considering *Oligochaeta* it has not been found a clear explanation of changes in abundance.

## REFERENCES


Adamkiewicz-Chojnacka, B. 1978. Występowanie i skład gatunkowy zooplanktonu Zalewu Wiślanego w latach 1974-1975 [Occurrence and composition of the zooplankton in the Vistula Lagoon in years 1974-1975] PAN, Kom. Bad.Morza, Stud. Mat. Oceanol., 21, 123-144.

Adamkiewicz-Chojnacka, B., Różańska, Z., Więcławski, F. 1985. Zależności funkcyjne między liczebnością zooplanktonu a wybranymi czynnikami środowiskowymi w słonawych wodach Zalewu Wiślanego [Functional relationship between the abundance of zooplankton and selected environmental factors in brackish water of the Vistula Lagoon.] Zesz. nauk. ART, Olsztyn, 14, 75-98.

Bittel, L. 1957. Plankton skorupiakowy jeziora Drużno [Crustaceans in zooplankton in Lake Drużno.] Ekol. pol. A, 5, 182-213.

Dobrowolski, Z. 1996. Species composition and co-occurrence of *Chironomidae* larvae in mid-lake benthos of several coastal Baltic lakes. Ekol. pol., 44, 53-72.

Dusoge, K. 1989. Distribution and structure of benthos in the lowland Zegrzyński Reservoir. Ekol. pol., 37, 281-298.

Kajak, Z. 1997. *Chironomus plumosus* - what regulates its abundance in shallow reservoir? Hydrobiologia, 342/343, 133-142.

Kornijów, R. 1998. Czy nocne deficyty tlenowe przyczyniają się latem do spadku liczebności zoobentosu w małych jeziorach? [Can night oxygen deficiencies cause summer decreases in abundance of zoobenthos in small lakes?] V Ogólnopolskie Warsztaty Bentologiczne, Bromierzyk, 4-7 czerwca 1998.

Moss, B., Timms, M. 1989. Predation, sediment stability and food availability as determinants of the benthic invertebrate fauna in two shallow lakes. Hydrobiologia, 185, 249-257.

Pajkert, Z., Pajkert, W. 1991. Naziemne lęgi kormorana czarnego na Wyspie Kamiennej na jeziorze Gardno w Słowińskim Parku Narodowym [Black cormorant ground hatching on Kamienna Island of Lake Gardno in Słowiński National Park] Słupskie pr. mat.-przyrod., 6B, 151-156.

Patalas, K. 1954. Zespół skorupiaków pelagicznych 28 jezior pomorskich [Pelagic crustaceans community in 28 coastal lakes] Ekol. pol., 2, 61-92.

Patalas, K. 1954. Zespół skorupiaków pelagicznych 28 jezior pomorskich [The community of pelagic crustaceans of 28 coastal lakes]. Ekol. pol., 2, 61-92.

Romaniszyn, W. 1958. Klucze do oznaczania owadów Polski. Muchówki - *Diptera*, Ochotkowate - *Tendipedidae*. Część XXVIII [Taxonomic keys to insects of Poland. Dipterans - *Diptera*, Chironomids - *Tendipedidae*. Part XXVIII].

Różańska, Z. 1972. Zooplankton zalewów przybałtyckich [Zooplankton of the Baltic Sea lagoons]. Stud. Mat. Oceanol., 3, 141-149.

Santer, B., Lampert, W. 1995. Summer diapause in cyclopoid copepods: adaptive response to fish predation or food bottleneck. J. Anim. Ecol., 64.

Starmach, K. 1955. Metody badania planktonu [Methods of zooplankton research] PWRiL, Warszawa.

Wiederholm, T. (Ed.) 1983. Chironomidae of Holarctic region. Keys and diagnoses. Part 1 - Larvae. Ent. Scand., Suppl. 19.

Wolnomiejski, N. 1994. Ekologiczne studium makrofauny dna mulistego Zalewu Szczecińskiego (1982-92r) [Ecological study of macrofauna of water-muddy bottom in the Szczecin Lagoon]. Stud. Mater., A, 31, Mor. Inst. Ryb., Gdynia.

Żmudziński, L., Cyberski, J., Dobrowolski, Z., Labuda, M., Paturej, E., Trojanowska, Cz. 1990. Dynamika liczebności fauny bezkręgowej na tle zmienności warunków środowiskowych w estuariowym jeziorze Łebsko [Dynamics of invertebrates abundance in Lake Łebsko regarding its environmental conditions.] SGGW-AR Warszawa, Zielona Seria, 41, 135-155.

Żmudziński, L., Dobrowolski, Z., Labuda, M., Mudryk, Z., Paturej, E., Trojanowska, Cz. 1991. Dynamic of seasonal changes in biocoenosis of polytrophic, beta-oligohaline Baltic Sea estuary lake. Proc. 26$^{th}$ Symp. EMB, 130 p., Middelburg, The Netherlands.

## WPŁYW DYNAMIKI MAS WODNYCH NA ZMIANY LICZEBNOŚCI BEZKRĘGOWCÓW JEZIORA GARDNO

### Streszczenie

Jezioro Gardno jest estuariowym, beta-oligohalinowym jeziorem przymorskim oddzielonym od Bałtyku wąskim pasem lądu. Zbiornik ten silnie eksponowany na działanie wiatru, ma dużą powierzchnię oraz małą głębokość. Te czynniki sprawiają, że masy wodne łatwo podlegają mieszaniu. Wiatr, a dokładnie falowanie wiatrowe, w takich płytkich i polimiktycznych zbiornikach, jest głównym czynnikiem ograniczającym liczebność, a także różnorodność gatunkową bezkręgowców.

Niniejsza praca dotyczy wpływu czynników abiotycznych na zmiany liczebności bezkręgowców jeziora Gardno. Materiał do badań pozyskano z sześciu stanowisk badawczych. W zebranym materiale biologicznym oznaczono w zakresie zooplanktonu trzy grupy taksonomiczne (*Rotatoria*, *Cladocera*, *Copepoda*) oraz w zoobentosie pięć grup taksonomicznych o różnej randze systematycznej (*Chironomi-*

*dae*, *Oligochaeta*, *Gastropoda*, *Bivalvia*, *Trichoptera*, *Amphipoda*).

Stwierdzono istotną zależność między zooplanktonem (*Cladocera*, *Rotatoria*) a czynnikami fizycznymi (0,8846). Słabszą zależność zaobserwowano dla dynamiki zmian liczebności *Oligochaeta* i *Copepoda* (0,6351). Stwierdzono istotny wpływ siły wiatru i temperatury wody na występowanie *Oligochaeta* i *Copepoda*, natomiast negatywny związek pomiędzy liczebnością larw *Chironomidae* i pozostałymi analizowanymi komponentami (-0,4412).