

EKOLOGIA POLSKA (Ekol. pol.)	31	3	761-780	1983
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BIOTIC STRUCTURE AND PROCESSES IN THE LAKE SYSTEM
OF R. JORKA WATERSHED (MASURIAN LAKELAND, POLAND)
IX. OCCURRENCE AND DISTRIBUTION OF MOLLUSCS WITH SPECIAL
CONSIDERATION TO DREISSENA POLYMORPHA (PALL.) *

ABSTRACT: The occurrence of molluscs in 5 lakes joined by the r. Jorka has been investigated. In all lakes the mussel Dreissena polymorpha dominated. This species varied greatly in particular lakes. D. polymorpha varied both as regards individual characters (size, shell and body weight, growth) and population characters (numbers of planktonic larvae and settled individuals, range of distribution, biomass, age structure).

KEY WORDS: Lakes, molluscs, mussels Dreissena polymorpha, distribution, numbers, age structure.

* Praca wykonana w ramach problemu międzyresortowego MR II/15 (grupa tematyczna „Ekologiczne podstawy jakości i czystości wód powierzchniowych”).

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1. INTRODUCTION

Among molluscs, in the littoral of the majority of Masurian lakes, the mussel Dreissena polymorpha is an obvious dominant. Preliminary investigations also show that it is also the most frequently found mollusc in the r. Jorka watershed. Therefore, the population of D. polymorpha (larvae and adult individuals) has been analysed first of all, and problems concerning other molluscs in lesser detail.

The aim here has been the comparison of species composition and occurrence of molluscs, as well as the density, distribution, biomass, age structure of the population and growth of D. polymorpha in particular lakes of the r. Jorka watershed. All this in order to indicate which characters of D. polymorpha compared may reflect the distinct trophic character of examined sequence of lakes.

2. AREA AND METHODS

The studies were conducted in five lakes being a chain system linked by a small watercourse - the r. Jorka (about 12 km long) falling into Lake Tałty (the system of Great Masurian Lakes, Masurian Lakeland, Poland). These are the following lakes (in the order of water runoff): Majcz Wielki (area - 1.74 km², max. depth - 16.4 m, mean depth - 6.0 m), Inulec (area - 1.63 km², max. depth -

10.1 m, mean depth - 4.6 m), Głębokie (area - 0.46 km², max. depth - 34.3 m, mean depth - 11.8 m), Zeźwążek (area - 0.12 km², max. depth - 7.4 m, mean depth - 3.7 m) and Jorzec (area - 9.41 km², max. depth - 11.6 m, mean depth - 5.5 m). More detailed limnological information about these lakes can be found in the paper by P l a n t e r, Ł a w a c z and T a t u r (1983).

Lake Majcz Wielki, situated the highest in the watershed examined, is of a mesotrophic character (mostly forest watershed, lack of more significant pollution). Remaining lakes are in the agricultural part of the watershed and receive numerous seasonal and permanent watercourses, including a number of highly polluted ones (H i l l b r i c h t - I l k o w s k a, G o s z c z y ń s k a and P l a n t e r 1981, Ł a w a c z, K u r o w s k i and T o m a s z e w s k i 1981). The highest P loading rate - 1.27 g · m⁻² · yr⁻¹ - is in Głębokie Lake with the rainbow trout cage culture (P e n c z a k et al. - in press). Shallow Lake Inulec is the most eutrophic as well as the lowest situated Lake Jorzec, polluted by permanent farm watercourse.

The molluscs in these lakes were studied in the years 1976-1979. The intensity of studies varied according to particular lakes.

The occurrence of molluscs was estimated by taking samples in the littoral of each lake - in lakes Majcz Wielki and Inulec on 10 sites, in Głębokie Lake on 8 sites, in Lake Zeźwążek on 6 sites and in Lake Jorzec on 8 sites. On each site, samples were taken at three depths: 30-50 cm, 2 m and 4 m. In shallow places the occurrence of molluscs was estimated using a 0.25 m² frame limiting the surface area, and the molluscs were picked by hand. At greater depths the samples were taken by means of a bottom dredge drawn behind the boat on a determined surface area of the bottom, thus allowing to obtain quantitative data (L e w a n d o w s k i and S t a ń c z y k o w s k a 1975). Several tens of qualitative samples of molluscs living on plants were taken additionally in 1979.

In order to obtain more precise data on the distribution of D. polymorpha in three of the lakes examined, i.e., Głębokie, Zeźwążek and Jorzec, diver carried out underwater studies in 1976. On each site samples were taken every 1 m down to the depth, where D. polymorpha no longer occurred, i.e., at 6-7 m. D. polymorpha

was hand picked by diver from the surface area of the bottom, limited by the frame (0.25 m^2), and placed 3 times at random at each depth examined.

The occurrence of larvae of D. polymorpha was analysed in all 5 lakes in 1976, in three lakes (Majcz Wielki, Głębokie, Jorzec) in 1977, and only in Lake Majcz Wielki in 1978. In 1976, samples were taken every fortnight between April and November, in four lakes from two pelagic sites, and in Lake Zełwążek from one pelagic site only. Samples were taken in the epi-, meta- and hypolimnion, and additionally in lakes: Majcz Wielki, Inulec, Jorzec - in the littoral above the shoals of adult D. polymorpha. In each of the three lakes examined, in 1977 and in 1978, the number of sites increased to four: two similarly as in 1976 in the pelagial, and two - in the littoral. Samples were taken only from the epilimnion, but more frequently than in the first year of investigations, i.e., every 4-6 days between June and the end of September. In all years the 5-litre Bernatowicz sampler was used. The water samples taken every metre were poured through the plankton net.

The planktonic larvae and bottom animals, were prepared (dried, weighed, measured, etc.) according to methods described by Stańczykowska (1977).

3. RESULTS

3.1. Composition and species differentiation of molluscs

The species composition of molluscs occurring in five lakes examined of the r. Jorka watershed was basically similar (Table I). The differences in species composition were frequently greater within one lake, i.e., on various sites, than when comparing particular lakes. This concerned especially the molluscs living on plants, connected with specific types of macrophyte communities, frequently unevenly distributed in the lake, or with specific depth or character of the bottom.

Also the estimated numbers of particular mollusc species in five lakes examined did not show greater differences (Table I). D. polymorpha distinctly dominated in all lakes. Also abundant

Table I. Occurrence of molluscs in lakes of the r. Jorka watershed
 +++ - very frequent, ++ - frequent, + - rare, - - no occurrence

Taxons	Majcz Wielki	Inulec	Głębo- kie	Zelwążek	Jorzec
Prosobranchia					
<u>Theodoxus fluviatilis</u> (L.)	++	+	++	+	+
<u>Viviparus viviparus</u> (L.)	+	+	+	-	+
<u>Valvata cristata</u> O. F. Müll.	+	+	+	+	+
<u>V. pulchella</u> Studer	+	-	+	+	-
<u>V. piscinalis</u> O. F. Müll.	++	++	++	++	+
<u>Lithoglyphus naticoides</u> C. Pfeiffer	+	-	-	-	+
<u>Bithynia tentaculata</u> (L.)	++	+++	++	++	++
<u>B. leachi</u> (Sheppard)	+	+	+	+	+
Pulmonata					
<u>Physa fontinalis</u> (L.)	+	+	+	+	+
<u>Lymnaea stagnalis</u> (L.)	+	+	+	+	+
<u>L. peregra</u> (L.)	+	+	+	+	+
<u>L. auricularia</u> (L.)	++	+	+	+	+
<u>L. corvus</u> (Gmelin) = <u>Galba palustris</u> O. F. Müll.	-	+	-	-	+
<u>Planorbis carinatus</u> O. F. Müll.	+	++	+	+	+
<u>Anisus vortex</u> (L.)	++	++	+	+	+
<u>Gyraulus albus</u> (O. F. Müll.)	+	++	++	+	+
<u>Armiger crista</u> (L.)	+	+	+	-	+
<u>Planorbarius corneus</u> (L.)	+	+	+	+	+
<u>Ancylus fluviatilis</u> O. F. Müll.	+	+	+	-	+
<u>Acroloxus lacustris</u> (L.)	+	+	+	-	+
Bivalvia					
<u>Dreissena polymorpha</u> (Pall.)	+++	+++	+++	++	+++
<u>Anodonta piscinalis</u> Nils.	++	+	+	+	++
<u>A. cygnea</u> (L.)	-	-	-	+	+
<u>Pseudoanodonta complanata</u> Zeigler	+	-	-	+	++
<u>Unio tumidus</u> Retz.	+	+	+	-	+
<u>U. pictorum</u> (L.)	+	-	+	+	++
<u>Sphaeriidae</u>	++	++	++	++	++

were: Bithynia tentaculata, Valvata piscinalis, Theodoxus fluviatilis and species of the genus Sphaerium.

3.2. Populations of Dreissena polymorpha in lakes examined

3.2.1. Occurrence and number dynamics of larvae

The numbers of larvae in lakes examined ranged from few to below 20 individuals per 1 litre of water. Only in Lake Majcz Wielki the numbers were high; in 1976 and 1978 the density of larvae there was several times higher than in other lakes (Fig. 1).

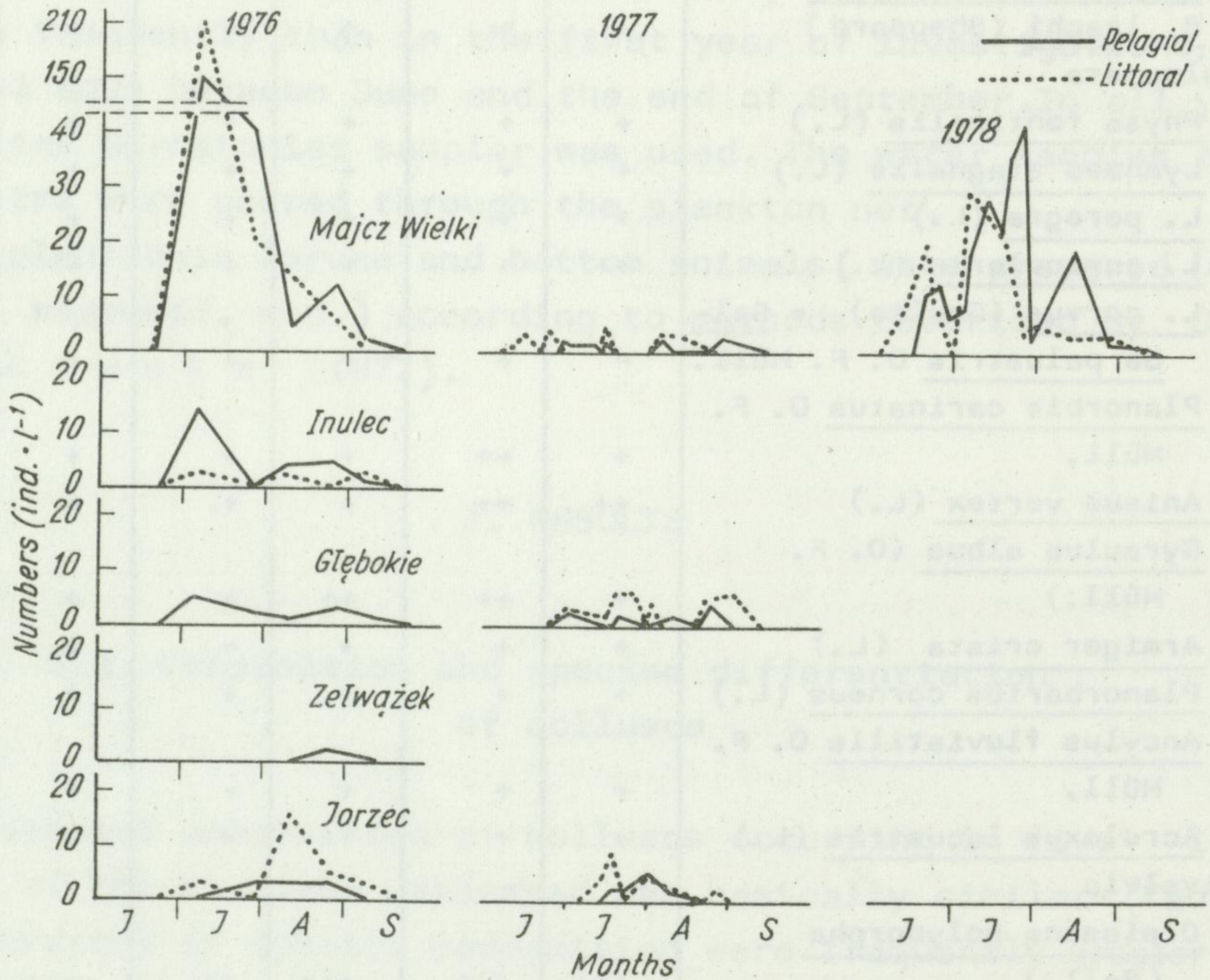


Fig. 1. Number dynamics of larvae of D. polymorpha in the epilimnion of lakes of the r. Jorka watershed

The occurrence of larvae in lakes of the r. Jorka watershed was observed in the pelagic zone (in the epilimnion) and in the littoral. The numbers of larvae in the littoral zone in the water above shoals of adult mussels were usually higher than in the zone of open water. For example, in parallel samples, at maximal numbers of larvae, it was recorded:

in Lake Majcz Wielki:	in the littoral -	210 individuals in 1 l	
	in the pelagial -	150	"
in Głębokie Lake:	in the littoral -	6	"
	in the pelagial -	4	"
in Lake Jorzec:	in the littoral -	15	"
	in the pelagial -	2	"

The larvae in the zone above the shoals were usually younger (smaller) than in the pelagial (Fig. 2). For example, in Lake

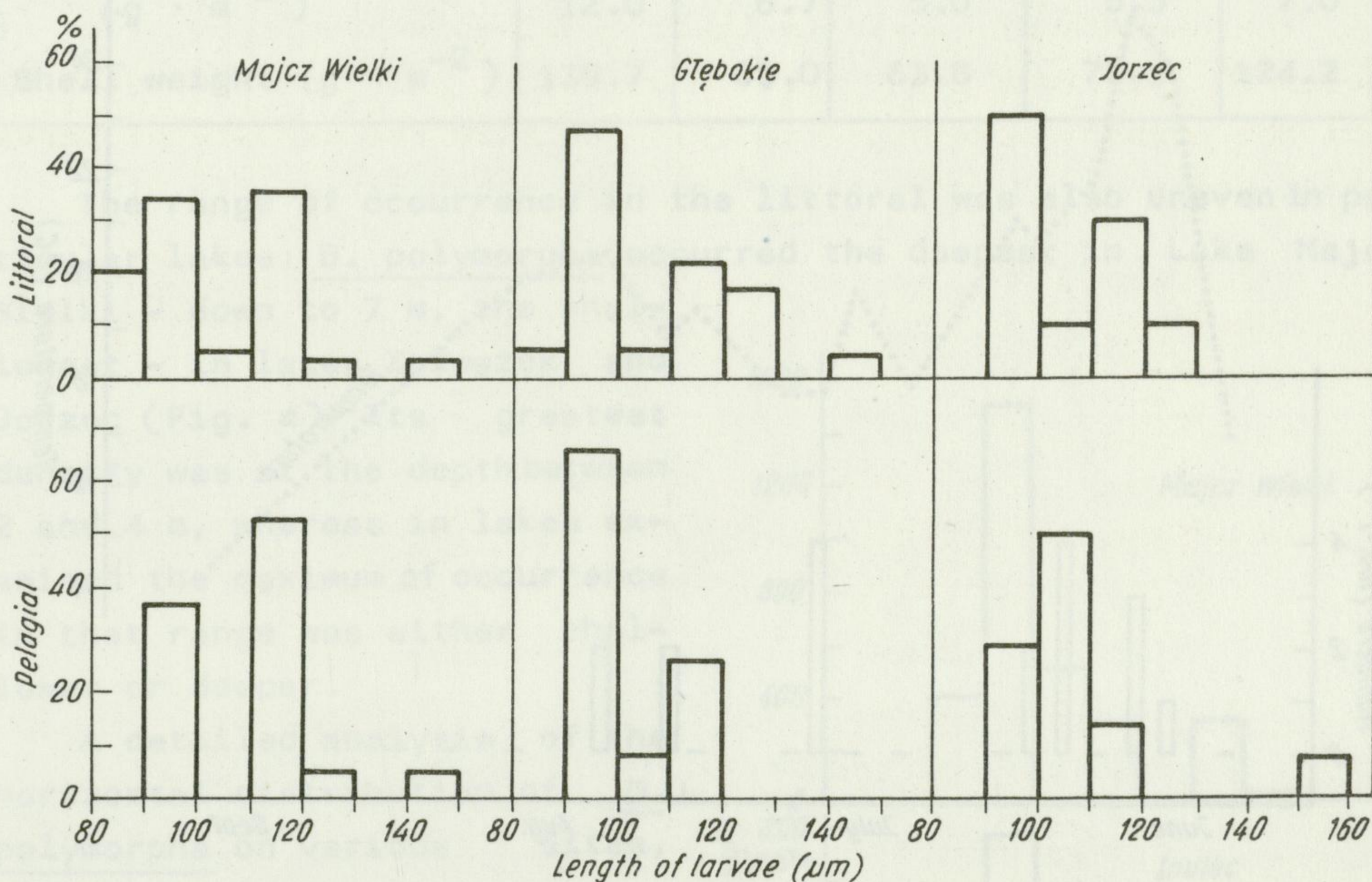


Fig. 2. Size distribution of larvae of *D. polymorpha* in lakes examined (June-August 1977)

Majcz Wielki and in Głębokie Lake larvae 80 μm long were found in the littoral, whereas they did not occur in the pelagial. In the first lake they were even 20% of all larvae. In Lake Jorzec, in both environments, the youngest larvae were similar in size (90 μm), but they were about 50% in the littoral and only 30% of all larvae in the pelagial.

Larvae in lakes examined usually appeared at the end of June and occurred to the first days of September, i.e., they occurred about 2.5 months in the plankton (Fig. 1). The maximal numbers of larvae were recorded usually in July. The appearance of larvae and their number dynamics were due to a great extent to the tempera-

ture of water. The reproduction of D. polymorpha usually begins at water temperature 15°C (Kačanova 1965, Galperina and Lvova - Kačanova 1972, Walz 1973 and others). In lakes examined the temperature rise was usually accompanied by an increase in the numbers of larvae, whereas the temperature drop - by a decrease in the numbers of larvae or their disappearance. In Lake Majcz Wielki successive cohorts of larvae appeared parallelly to changes in water temperature (Fig. 3).

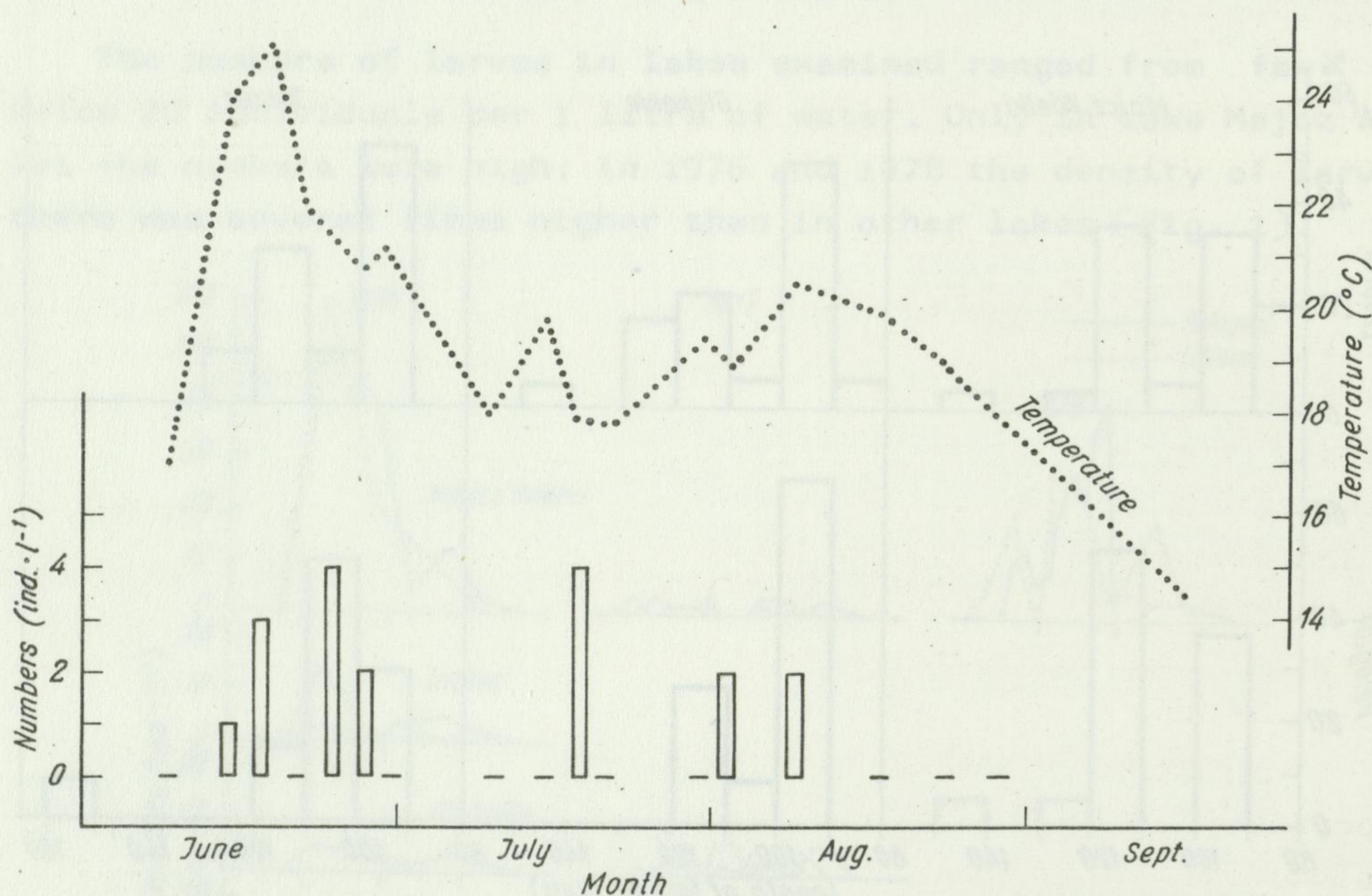


Fig. 3. Occurrence of larvae of D. polymorpha in the littoral of Lake Majcz Wielki depending on water temperature

3.2.2. Occurrence of adult individuals

Average numbers of D. polymorpha in the zone of occurrence in lakes examined were 100-500 ind. per 1 m^2 of bottom surface area (Table II). Only in few cases the maximal numbers reached 15 thous. In Lake Majcz Wielki maximal values were the highest, and in Lake Jorzec - the lowest, i.e., about $800\text{ ind.} \cdot \text{m}^{-2}$. Thus the average and maximal numbers of D. polymorpha decreased gradually in the sequence of lakes examined - being the highest in Lake Majcz Wielki and the lowest in Lake Jorzec.

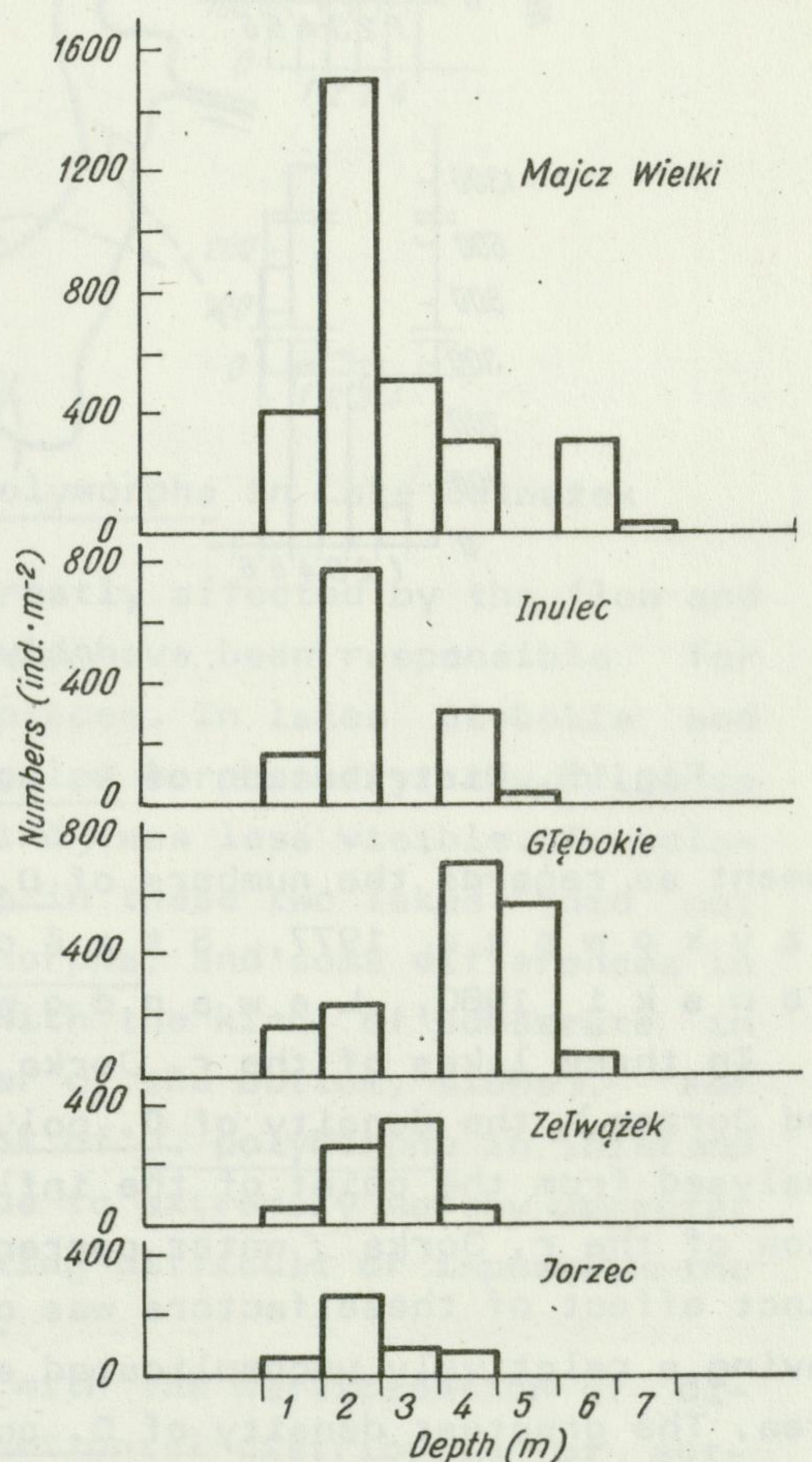
Table II. Mean numbers and biomass (dry body and shell weight) of D. polymorpha in the zone of occurrence in lakes of the r. Jorka watershed

Elements compared	Majcz Wielki	Inulec	Głębokie	Zelwążek	Jorzec
Numbers (ind. · m ⁻²)	510	400	280	175	130
Biomass (dry body wt) (g · m ⁻²)	12.0	6.7	5.0	5.5	7.0
Shell weight (g · m ⁻²)	139.7	85.0	63.8	77.1	124.2

The range of occurrence in the littoral was also uneven in particular lakes; D. polymorpha occurred the deepest in Lake Majcz Wielki - down to 7 m, the shallowest - in lakes Zelwążek and Jorzec (Fig. 4). Its greatest density was at the depth between 2 and 4 m, whereas in lakes examined the maximum of occurrence in that range was either shallower or deeper.

A detailed analysis of the horizontal distribution of D. polymorpha on various sites, within particular lakes, showed a high variability (Figs. 5-7). Differences in the horizontal distribution within particular lakes were connected with the differentiation of environmental conditions in various parts of lakes. Thus it was found that the period when planktonic larvae settle on the permanent substrate was the most significant

Fig. 4. Occurrence of D. polymorpha at various depths in lakes of the r. Jorka watershed



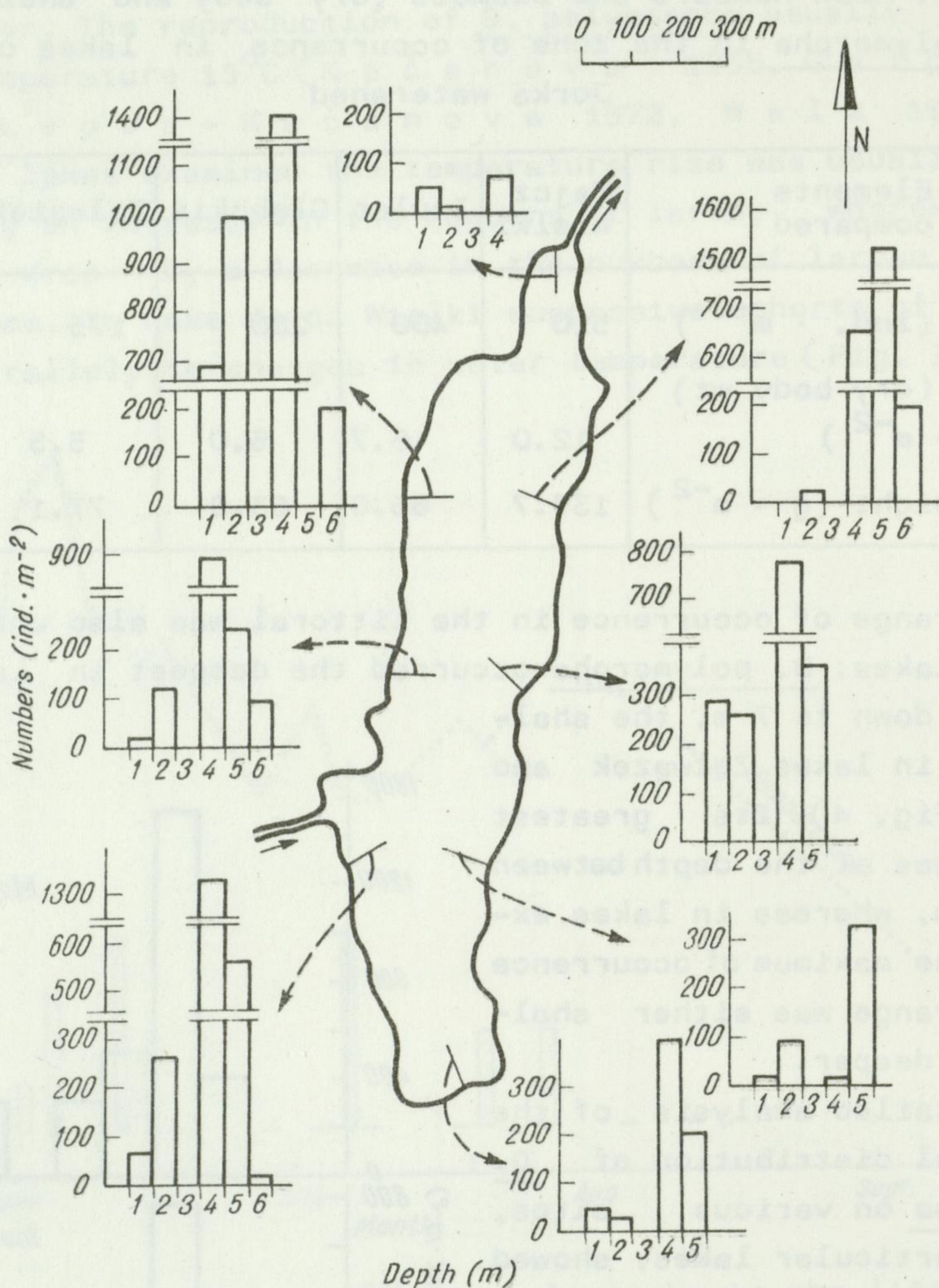


Fig. 5. Distribution of *D. polymorpha* in Głębokie Lake

moment as regards the numbers of *D. polymorpha* population (Stańczykowska 1977, Stańczykowska and Lewandowski 1980, Lewandowski 1982).

In three lakes of the r. Jorka watershed (Głębokie, Żelwążek and Jorzec) the density of *D. polymorpha* on particular sites was analysed from the point of the influence of wind direction and flow of the r. Jorka (water current) through these lakes. A distinct effect of these factors was observed only in Lake Żelwążek having a relatively uncomplicated shore line and a small surface area. The greatest density of *D. polymorpha* was recorded on sites

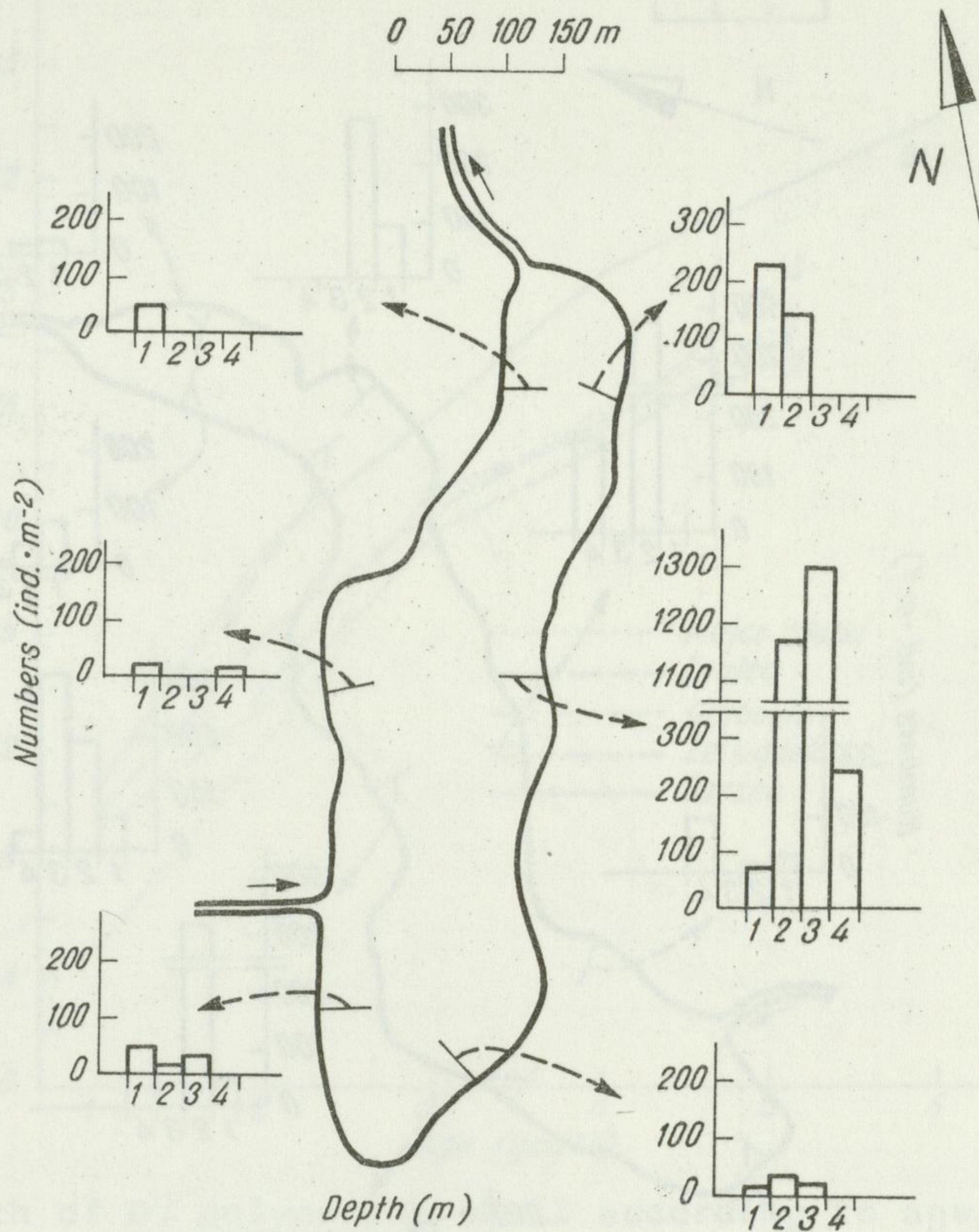


Fig. 6. Distribution of *D. polymorpha* in Lake Zełwążek

on the eastern side of the lake, greatly affected by the flow and prevailing western winds, which could have been responsible for mass transport of larvae to these places. In lakes Głębokie and Jorzec, bigger and having more complex morphometry, the influence of these factors (water current, wind) was less visible. A relatively weak current of the r. Jorka in these two lakes did not affect the distribution of *D. polymorpha*, and some differences in the density were rather connected with the kind of substrate in the littoral (vegetation, character of the bottom, slope). For example, small numbers or total lack of *D. polymorpha* in inlet and outlet parts of Lake Jorzec were due to extremely marshy character or silting of these zones, thus making difficult or impossible the settling of postveligers (Fig. 7).

Such detailed investigations (with the participation of diver) of factors conditioning the horizontal distribution of set-

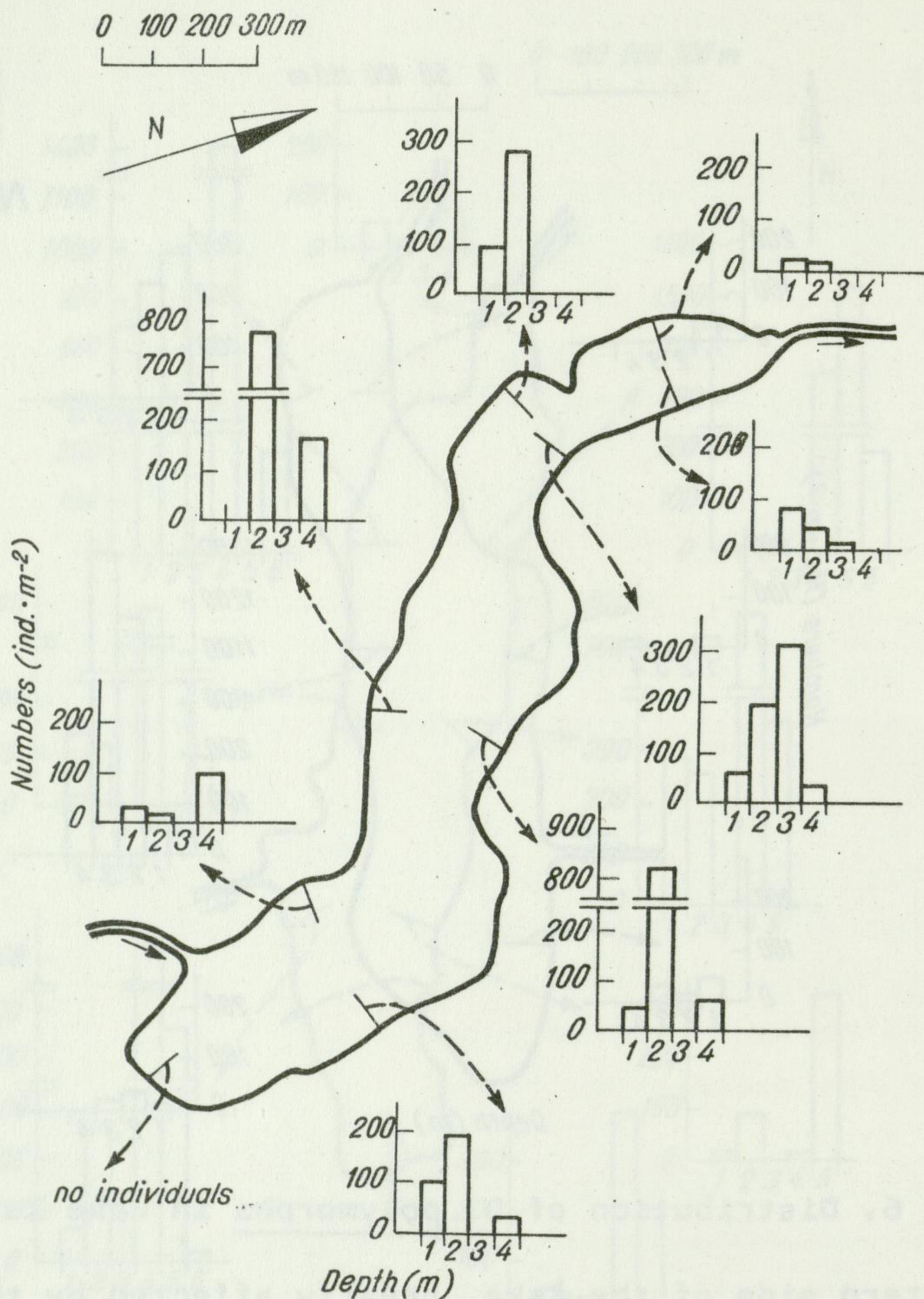


Fig. 7. Distribution of D. polymorpha in Lake Jorzec.

tled D. polymorpha, were not carried out in the two biggest and most differentiated lakes of this system, i.e., in lakes Majcz Wielki and Inulec. This was because a clear picture of correlations was not expected.

The biomass of D. polymorpha as related to surface area unit of the bottom did not always correspond to the differences in numbers among lakes examined. The highest biomass was recorded in Lake Majcz Wielki, where the numbers were the highest, but also high values were recorded in Lake Jorzec at the lowest numbers (Table II).

Comparison of size and the weight of shells and body of D. polymorpha of corresponding age classes in lakes examined showed considerable differences in these values in Lake Jorzec as compar-

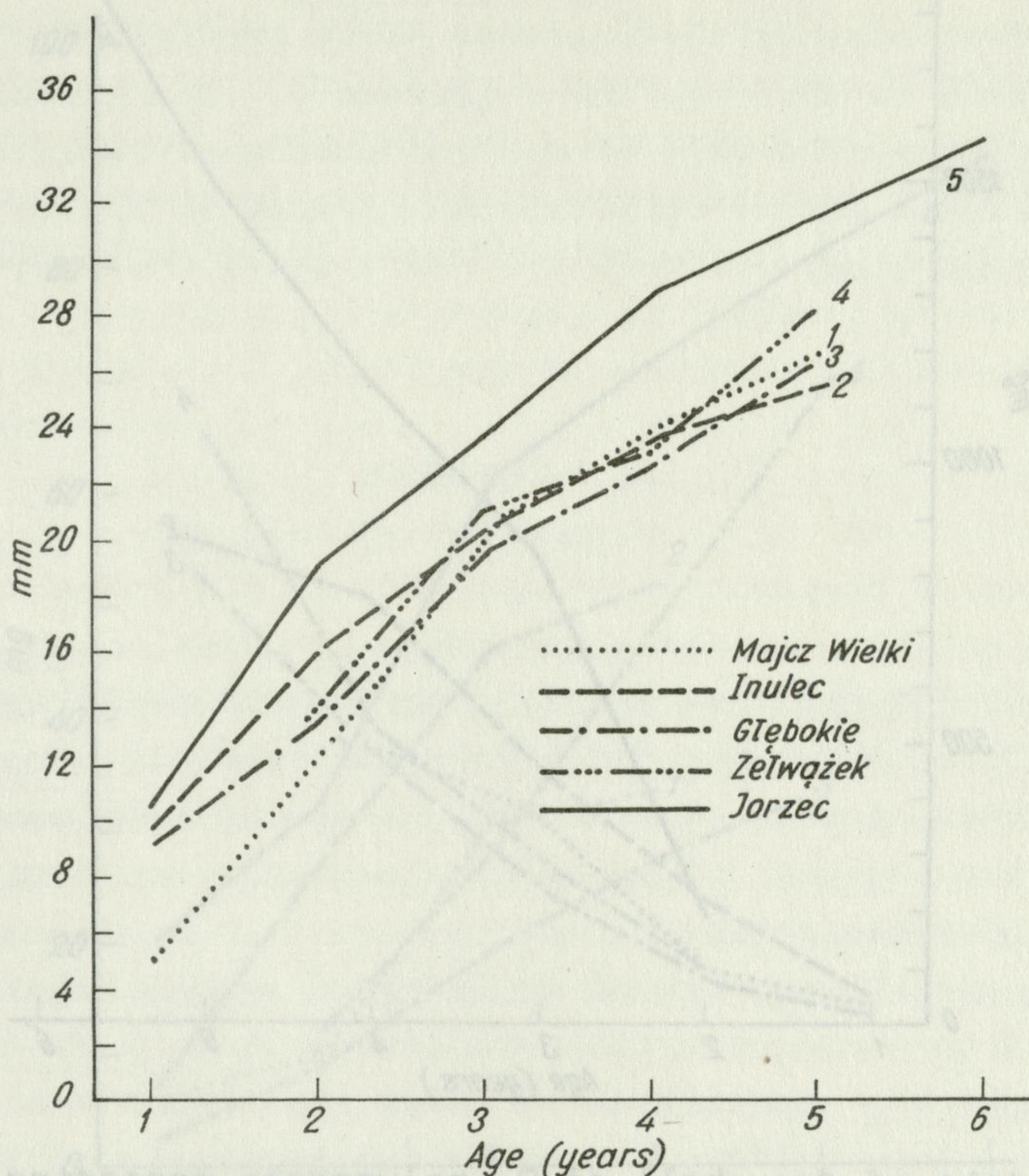


Fig. 8. Length of *D. polymorpha* shell according to age, in lakes of the r. Jorka watershed

ed with other lakes of the r. Jorka watershed (Figs. 8-10). The mussels in Lake Jorzec were much greater and heavier than in remaining lakes. They also had a different rusty-red colour of shells.

Differences in biomass of mussels per surface area unit of bottom in particular lakes were not only due to their different size and weight, but to quite different age structure of *D. polymorpha* in particular lakes (Fig. 11). In 1977, in Lake Majcz Wielki, the population consisted of more than 50% of one year old individuals, which covered hardly few per cent in remaining lakes. At the same time, in Głębokie Lake, most numerous were 3 years old mussels, and in lakes Jorzec and Zełwążek - 4 years old ones.

The above data distinctly point to an individual character of *D. polymorpha* population in each lake examined of the r. Jorka watershed. Because of the morphological differences of these lakes the possibilities of distribution of mussels were different in each lake. In each lake a different per cent of bottom surface was

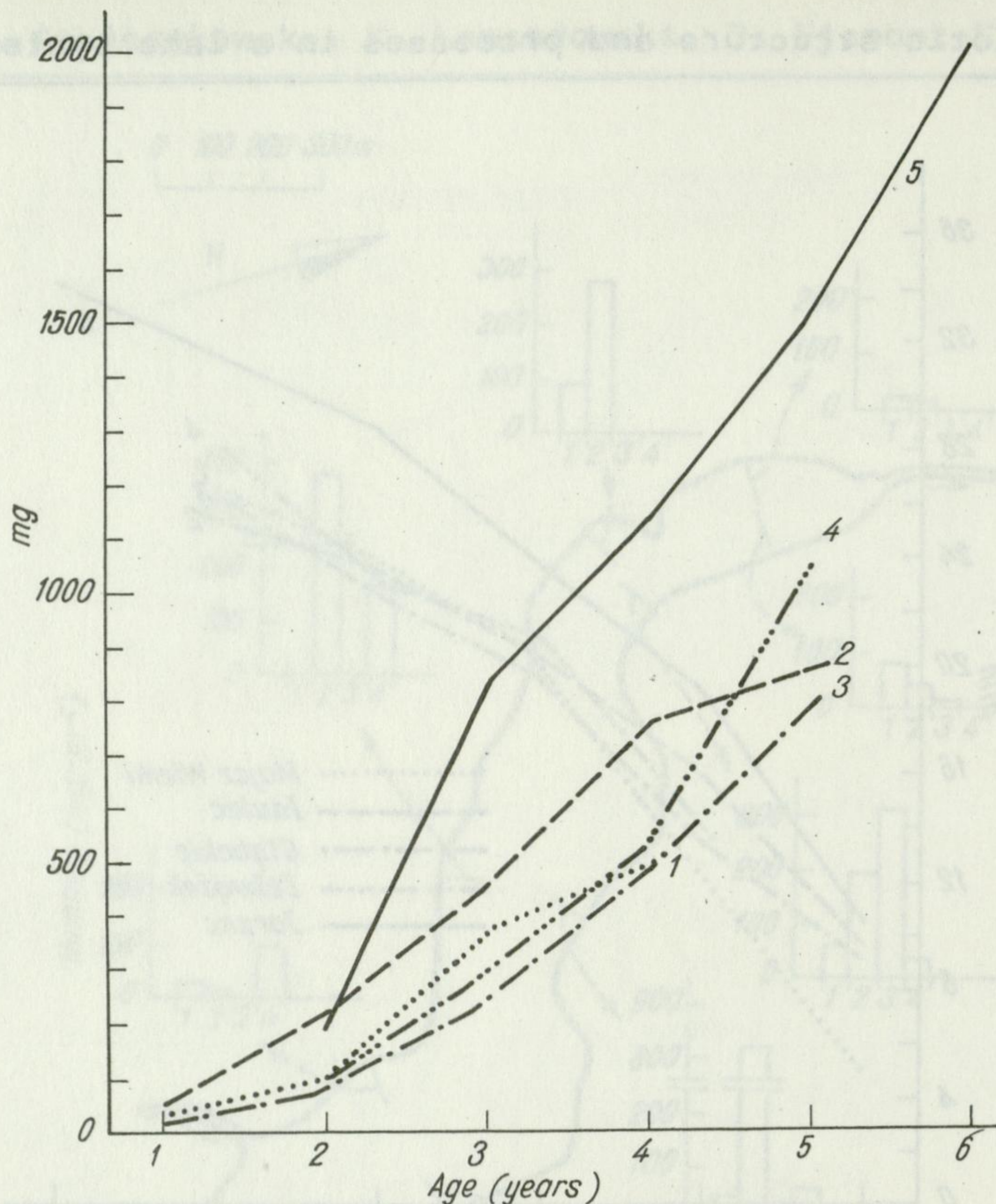


Fig. 9. Weight of dry shell of D. polymorpha according to age, in lakes of the r. Jorka watershed
For explanations see Figure 8

Table III. Comparison of the significance of D. polymorpha population in lakes of the r. Jorka watershed

Elements compared	Majcz Wielki	Inulec	Głębo- kie	Zelwają- zek	Jorzec
Settled area (%)	63	48	21	34	24
(ha)	103	85	10	4	9
Number of individuals (mil- lions)	523	341	28	7	12
Dry biomass (tons)	12.3	5.7	0.5	0.2	0.6
Shell weight (tons)	143	72	6	3	11
Water filtration (million $m^3 \cdot season^{-1}$)	79	52	4	1	2
Seston consumption (tons of d. wt $\cdot season^{-1}$)	245	160	13	3	6
Faeces (tons of d. wt $\cdot season^{-1}$)	151	98	8	2	4

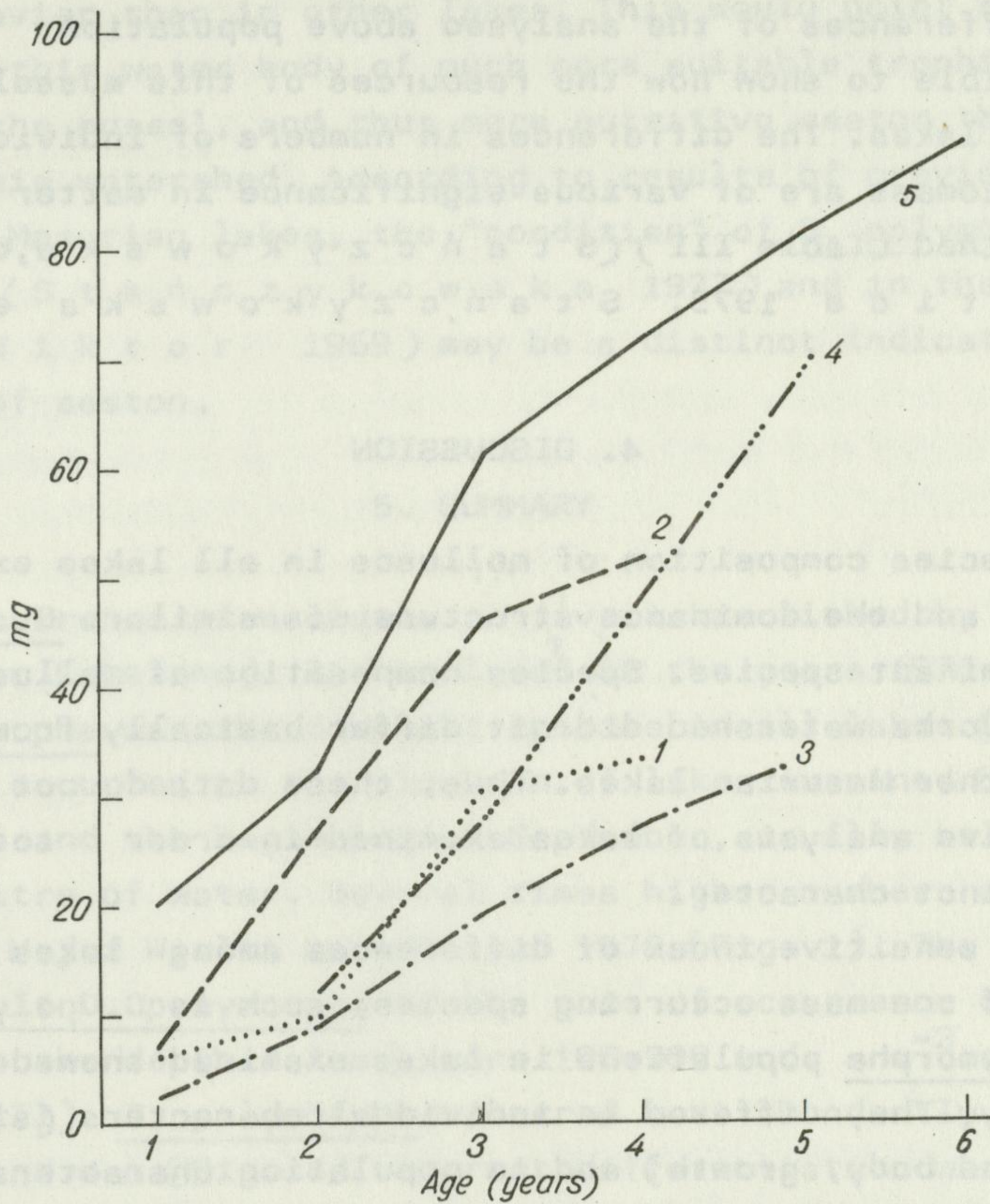


Fig. 10. Dry weight of *D. polymorpha* body according to age, in lakes of the r. Jorka watershed
For explanations see Figure 8

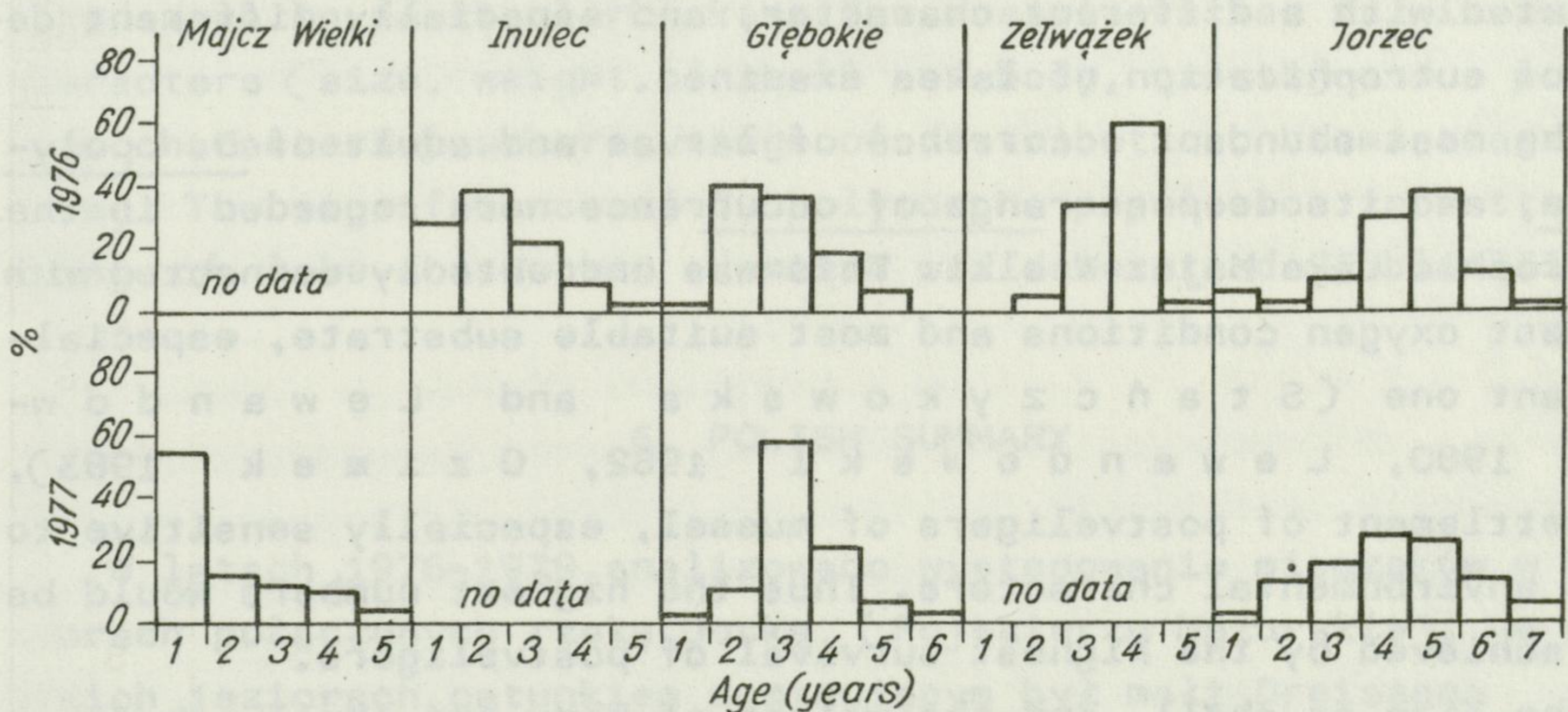


Fig. 11. Age structure of *D. polymorpha* in lakes of the r. Jorka watershed

suitable for colonization by D. polymorpha (Table III). Considering the differences of the analysed above population characters it is possible to show how the resources of this mussel vary in particular lakes. The differences in numbers of individuals and in their biomass are of various significance in matter cycling in lakes examined (Table III) (Stańczykowska, Ławacz and Matyja 1975, Stańczykowska et al. 1976).

4. DISCUSSION

The species composition of molluscs in all lakes examined approximated and the dominance structure was similar. D. polymorpha was the dominant species. Species composition of molluscs in lakes of the r. Jorka watershed did not differ basically from the molluscs of other Masurian lakes. Thus, these data do not allow for a comparative analysis of lakes examined in order to indicate their distinct character.

A more sensitive index of differences among lakes may be an analysis of one mass occurring species, such as D. polymorpha.

D. polymorpha populations in lakes examined showed a great variability. They differed in individual characters (size, weight of shell and body, growth) and in population characters (density, distribution, biomass, age structure). The consequence of above-mentioned differences in mussel population was its different significance in matter cycling in lake ecosystems examined. Some characters of D. polymorpha population in particular lakes could be connected with a different character, and especially different degree of eutrophication of lakes examined.

The most abundant occurrence of larvae and adult of D. polymorpha, and its deepest range of occurrence were recorded in the mesotrophic Lake Majcz Wielki. This was undoubtedly connected with the best oxygen conditions and most suitable substrate, especially plant one (Stańczykowska and Lewandowski 1980, Lewandowski 1982, Ozimek 1983), for settlement of postveligers of mussel, especially sensitive to these environmental characters. Thus the highest numbers would be here achieved by the highest survival of postveligers.

The size of shell, and the weight of body and shell, had a totally different character in Lake Jorzec - the mussels were big-

ger and heavier than in other lakes. This would point to the existence in this water body of much more suitable trophic conditions for the mussel, and thus more nutritive seston than in other lakes of this watershed. According to results of previous investigations on Masurian lakes, the "condition" of D. polymorpha in Lake Balaton (S t a ń c z y k o w s k a 1977) and in the Lagoon of Szczecin (W i k t o r 1969) may be a distinct indicator of trophic values of seston.

5. SUMMARY

The occurrence of molluscs in five lakes linked by the r. Jorka (Masurian Lakeland) was analysed in the years 1976-1979. Dreissena polymorpha was the dominant species in all lakes (Table I). Its larvae occurred in the plankton of lakes examined between the end of June and the beginning of September, usually below 20 larvae in 1 litre of water. Several times higher numbers were recorded in Lake Majcz Wielki in 1976 and 1978 (Fig. 1). The average numbers of adult D. polymorpha in the zone of occurrence of lakes examined (to the depth 4-7 m) were 100-500 ind. · m⁻² of the bottom (Table II). D. polymorpha occurred most abundantly at the depth between 2 and 4 m (Fig. 4). A great differentiation was observed as regards horizontal distribution (Figs. 5-7), but in the small Lake Żelwążek greater numbers of D. polymorpha in the eastern part could be due to the transport of planktonic larvae by the current of river Jorka and to prevailing western winds. D. polymorpha differed much in particular lakes. The mussels varied in individual characters (size, weight of shell and body, growth) and population characters (numbers, range of distribution, biomass, age structure). The significance of D. polymorpha population in matter cycling of lake ecosystems examined was determined (Table III).

6. POLISH SUMMARY

W latach 1976-1979 analizowano występowanie mięczaków w 5 jeziorach połączonych rzeką Jorką (Pojezierze Mazurskie). We wszystkich jeziorach gatunkiem dominującym był małż Dreissena polymorpha (tab. I). Jej larwy w planktonie badanych jezior występowały od końca czerwca do początku września przeważnie w liczebno-

ściach kilka-kilkanaście larw w 1 l wody. Kilkakrotnie większe liczebności stwierdzono w jeziorze Majcz Wielki w 1976 i w 1978 r. (rys. 1). Przeciętne liczebności dorosłych D. polymorpha w strefie występowania badanych jezior (do głębokości 4-7 m) wynosiły 100-500 osobn. · m⁻² dna (tab. II). D. polymorpha występowała najliczniej na głębokości między 2 a 4 m (rys. 4). Stwierdzono duże zróżnicowanie w rozmieszczeniu poziomym (rys. 5-7), przy czym w małym jeziorze Zełwążek większe liczebności D. polymorpha w części wschodniej mogły być wynikiem znoszenia larw planktonowych przez prąd rzeki Jorki i przez przeważające wiatry zachodnie. D. polymorpha wykazywały duże zróżnicowanie między poszczególnymi jeziorami. Różniły się one zarówno cechami osobników (wymiary, ciężar muszli i ciała, wzrost) jak i cechami populacji (liczebność, zasięg występowania, biomasa, struktura wiekowa). Określono znaczenie populacji D. polymorpha w krążeniu materii w badanych ekosystemach jeziornych (tab. III).

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