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THE ABUNDANCE AND DISTRIBUTION OF THE MUSSEL *DREISSENA POLYMORPHA* (PALL.) IN HEATED LAKES NEAR KONIN (POLAND) *

ABSTRACT: The occurrence of planktonic larvae *D. polymorpha* was analysed in six Konin lakes varying as to the degree of heated-water discharge. Larvae occurred for a long time (from March to the end of September) in the plankton. No differences were observed in the abundance of planktonic larvae in stronger and less heated lakes. Despite the high production of larvae in heated lakes, the density of adult *D. polymorpha* was not greater than in unheated lakes.

KEY WORDS: Heated lakes, mussels *Dreissena polymorpha*, planktonic larvae.

1. INTRODUCTION

The complex of Konin lakes is a unique one in Poland. It is a group of lakes to the north of Konin in the Warta-Gopło Canal system. All lakes are naturally linked or by canals.

Konin lakes are a system of heated lakes, twice included to the power plant cooling system (when starting up the power plant "Konin" and then "Pątnów"), and changes in water temperature are accompanied by changes of through-flow. H i l l b r i c h t-I l k o w s k a and Z d a n o w s k i (1988) give a detailed description of functioning of lakes as a cooling system and of their retention changes. Lakes of Konin system differ among themselves by the degree of heating depending on the distance from the discharge of heated waters. Thus they have different environmental conditions (mainly thermal) which affect organisms living in these lakes.

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Biological studies were conducted from the moment the lakes joined the cooling system. They were conducted all the time and concerned environmental conditions, plankton, benthos, etc. (e.g., K o r y c k a and Z d a n o w s k i 1976, W r ó b l e w s k i 1977, H i l l b r i c h t-I l k o w s k a and Z d a n o w s k i 1978, S p o d n i e w s k a 1984 and others).

There are not many publications on molluscs. The faunistic work of B e r g e r and D z i ę c z k o w s k i (1977) in the volume on the benthos of Konin lakes is of basic significance. It shows that malacofauna composition in heated lakes does not differ much from that in other meso- and eutrophic lakes of central and northern Poland. Similarly as in those lakes, *Dreissena polymorpha* is the dominant species. There separate publications deal with this species (S t a ń c z y k o w s k a 1976, K o r n o b i s 1977, L e w a n d o w s k i and E j s m o n t-K a r a b i n 1983).

The occurrence of *Dreissena polymorpha* in lakes of this system is important not only for the ecosystem functioning (main benthic filter animals) but also because these molluscs occupy the hydrotechnical devices, decreasing the inside diameter of hydrotechnical conduits, etc., which disturbs the proper functioning of two power plants and Aluminium Plant connected with Konin lakes (S z a r f e n b e r g 1972).

The aïm here was to compare the conditions of reproduction and population dynamics of *D. polymorpha* in Konin lakes and in unheated Maśurian lakes. The question was, whether the length and character of reproduction affect the population dynamics of adult individuals.

2. AREA AND METHODS

The investigations have been carried out in 6 lakes to the north of Konin, in the Warta-Gopło Canal system (Table 1, Fig. 1). These lakes have been for many years a part of cooling systems of "Konin" power plant (since 1958) and "Pątnów" power plant (since 1970) and therefore the water in these lakes is warmer than in unheated natural lakes. Lake Licheńskie is the most heated one, in summer the temperatures reach 30°C, and in winter they do not drop below 6°C. A canal conducts the water from Lake

Table 1. Data on Konin lakes

Lake	Surface (ha)	Depth	
		maximal (m)	mean (m)
Licheńskie	154	13.3	4.9
Ślesińskie	148	25.7	7.5
Wąsosko-Mikorzyńskie	245	38.0	11.9
Pątnowskie	307	5.4	2.6
Gosławskie	379	3.0	1.3

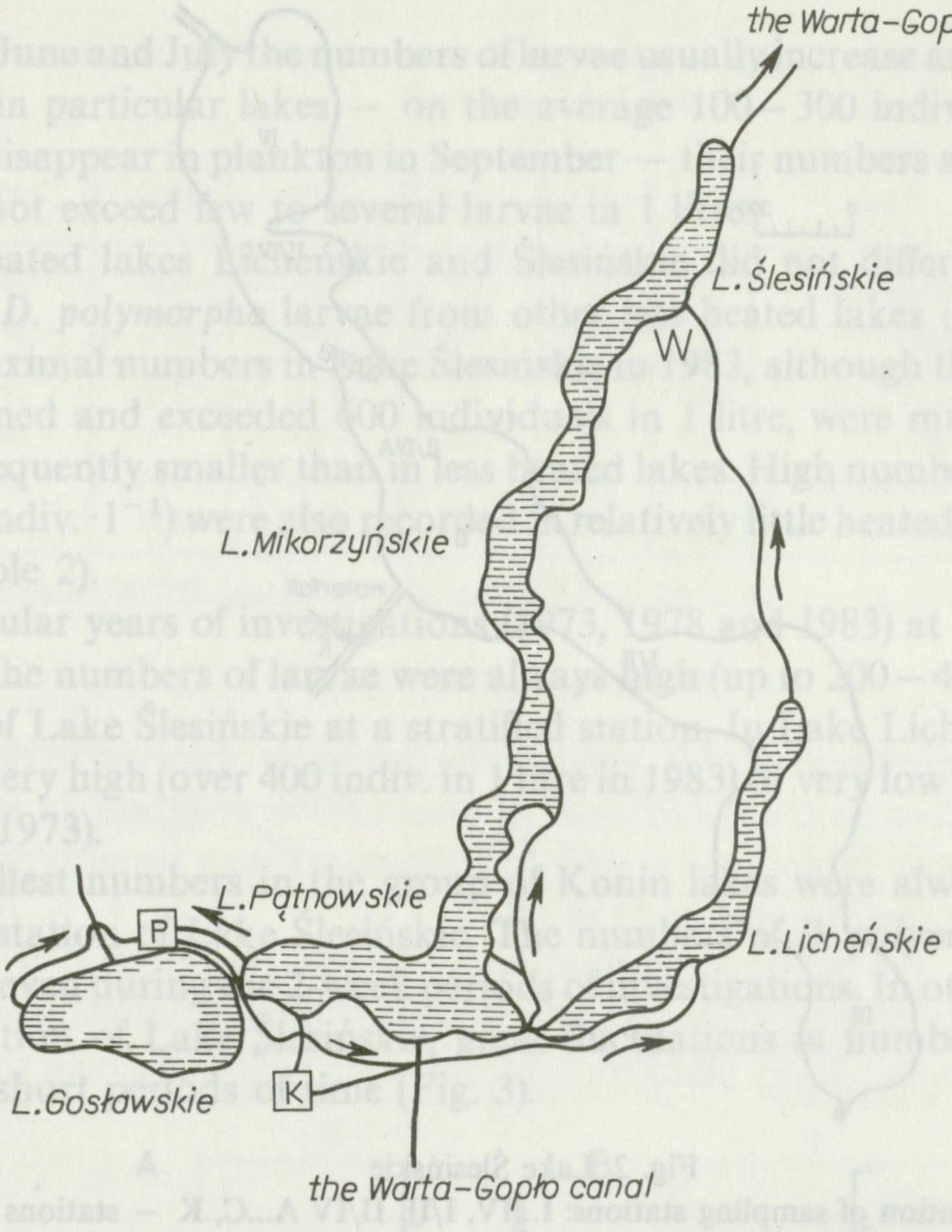

Fig. 1. Diagram of the Konin lake complex
P – Pątnów power plant, K – Konin power plant, W – waterfall

Licheńskie to the last lake in the system – Lake Ślesińskie, which as a result is also strongly heated. The canal outlet is a waterfall and thus apart from heating the water, thermal and oxygen stratification is totally disturbed (Z d a n o w s k i and K o r y c k a 1976). In other lakes of this system: Gosławskie, Wąsosko-Mikorzyńskie and Pątnowskie the temperatures are slightly lower (Z d a n o w s k i and K o r y c k a 1976). All these lakes are strongly through-flow ones (H i l l b r i c h t-I l k o w s k a and Z d a n o w s k i 1978).

Dynamics of occurrence of *D. polymorpha* larvae in the plankton of Konin lakes (monthly samples from early spring till late autumn) were investigated in the years 1970–1974, 1978 and 1983.

Samples were taken in the lake pelagial at 1–3 stations. In three lakes: Licheńskie, Mikorzyńskie and Ślesińskie samples were also taken every 2 days during a fortnight of the summer stagnation (at the turn of July) in 1973, 1978 and 1983. In Lake Ślesińskie samples were taken at two quite different stations – one at the waterfall discharge of heated water at disturbed thermal stratification, the other – far from it, under conditions similar to other stations.

The occurrence of zooplankton was analysed in detail in Lake Ślesińskie in 1983: in

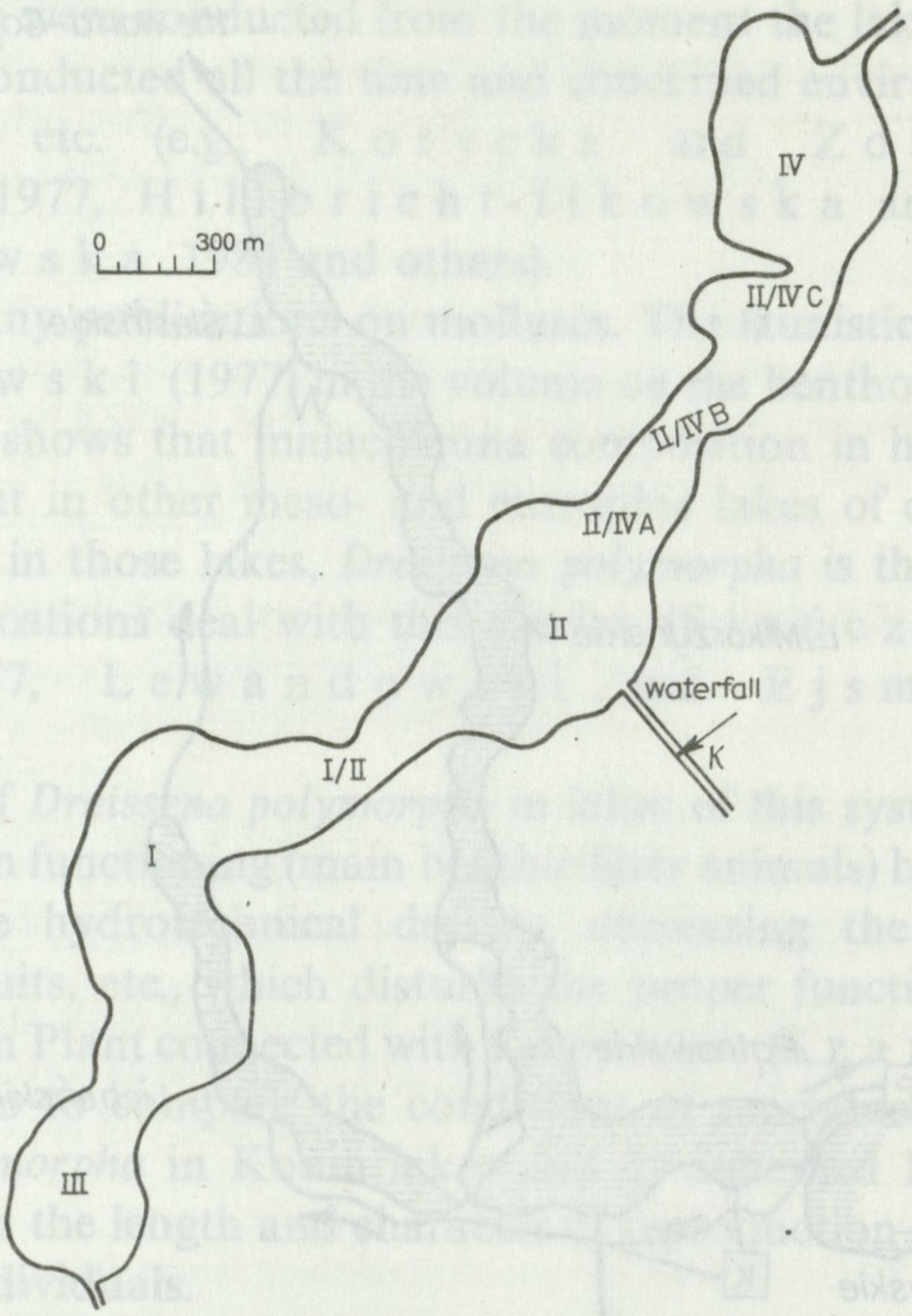

Fig. 2. Lake Ślesińskie
Distribution of sampling stations: I...IV, I/II, II/IV A...C, K – stations

May and July samples were taken at four stations every 2 m from the surface to the bottom and additionally at the depth of 2 m at 5 other stations (Fig. 2).

Samples were taken using 5-litre Bernatowicz sampler, concentrated by means of plankton net and fixed with Utermohl fluid and 4% formalin solution.

All *D. polymorpha* larvae were counted under the microscope in a sample part equivalent to 1 litre of lake water, distinguishing dead larvae from live ones at the moment of sampling.

Larvae were measured using the microscope eyepiece (exact to 5 μm). Usually 100 larvae from each sample were measured and a smaller number at a very low abundance of larvae (never less than 20 individuals).

3. RESULTS

3.1. NUMBER DYNAMICS OF LARVAE IN THE PLANKTON

D. polymorpha larvae occur in the Konin lakes for about 6 months. They begin to appear in the plankton usually in April, at first in small numbers (less than 10 indiv. $\cdot l^{-1}$). Sometimes they appear earlier, as for example, in shallow Lake Gosławskie – in the middle of March in 1978.

In May, June and July the numbers of larvae usually increase and in July are usually the highest in particular lakes – on the average 100–300 indiv. $\cdot l^{-1}$.

Larvae disappear in plankton in September – their numbers are then minimal and usually do not exceed few to several larvae in 1 litre.

More heated lakes Licheńskie and Ślesińskie did not differ significantly in the numbers of *D. polymorpha* larvae from other less heated lakes of this complex. For example, maximal numbers in Lake Ślesińskie in 1983, although the highest among all lakes examined and exceeded 600 individuals in 1 litre, were much smaller in other years and frequently smaller than in less heated lakes. High numbers of *D. polymorpha* larvae (580 indiv. $\cdot l^{-1}$) were also recorded in relatively little heated Lake Mikorzyńskie in 1970 (Table 2).

In particular years of investigations (1973, 1978 and 1983) at the peak of summer stagnation, the numbers of larvae were always high (up to 200–400 indiv. $\cdot l^{-1}$) in the epilimnion of Lake Ślesińskie at a stratified station. In Lake Licheńskie the numbers were either very high (over 400 indiv. in 1 litre in 1983) or very low (less than 100 indiv. in 1 litre in 1973).

The smallest numbers in the group of Konin lakes were always recorded at the unstratified station of Lake Ślesińskie. The numbers of *D. polymorpha* larvae at this station were even during the 2-week periods of investigations. In other lakes, and at the stratified station of Lake Ślesińskie, great fluctuations in numbers were sometimes recorded in short periods of time (Fig. 3).

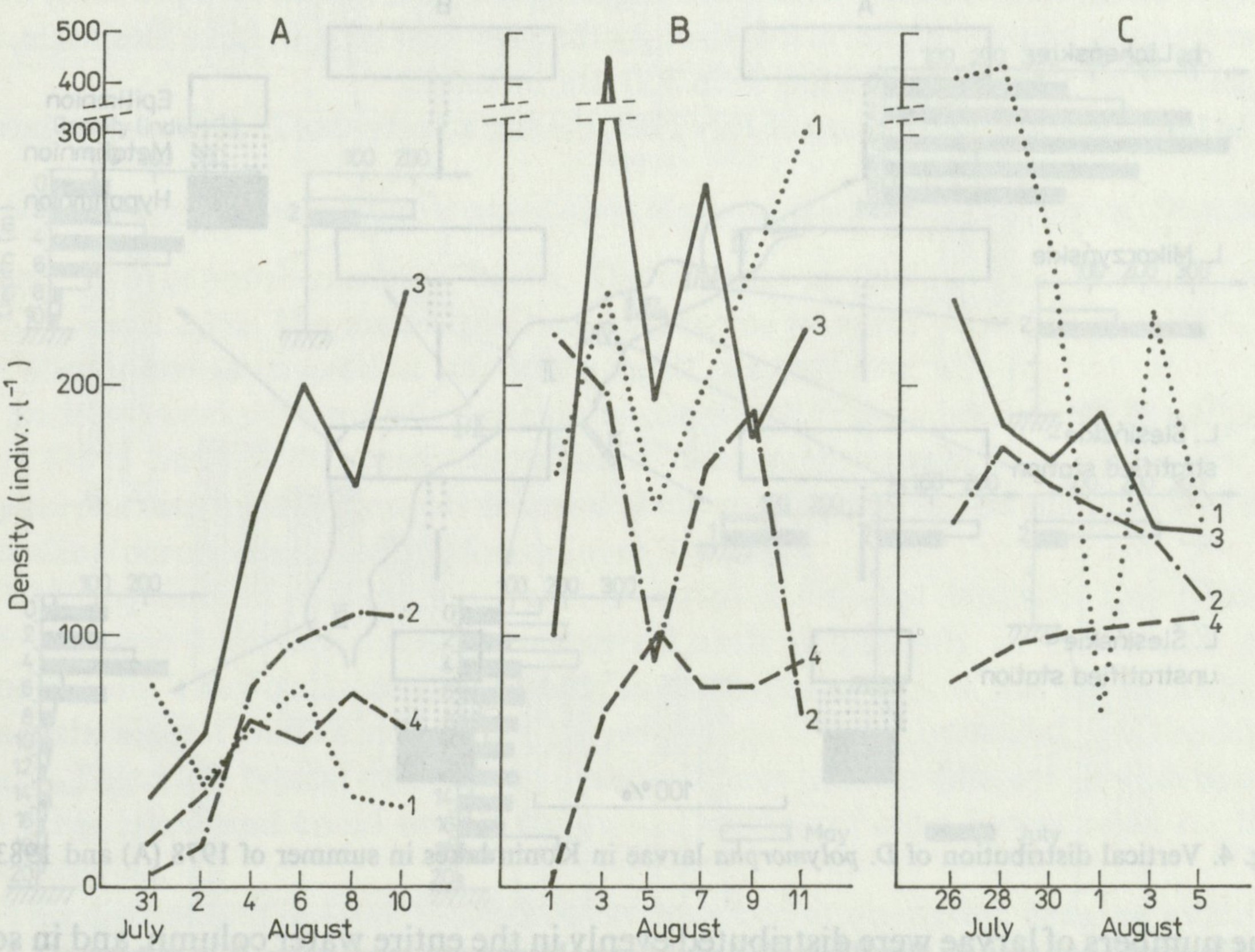

Fig. 3. Number dynamics of *D. polymorpha* larvae during summer stagnation in 1973 (A), 1978 (B) and 1983 (C) in the epilimnion of lakes: 1 – Licheńskie, 2 – Mikorzyńskie, 3 – Ślesińskie – stratified station, 4 – Ślesińskie – unstratified station

Table 2. Maximal numbers (indiv. $\cdot l^{-1}$) of *D. polymorpha* larvae in the plankton of Konin lakes in different years (nd – no data)

Degree of heating	Lake	1970	1971	1972	1973	1974	1978	1983
Strongly heated	Licheńskie	134	45	27	85	424	292	436
	Ślesińskie	246	34	34	238	352	443	666
Poorly heated	Mikorzyńskie	580	27	97	153	375	219	175
	Wąsoskie	209	68	203	53	158	nd	nd
	Pątnowskie	211	51	57	27	274	nd	nd
	Gosławskie	220	nd	70	466	348	45	nd

3.2. VERTICAL DISTRIBUTION

Typical vertical distribution of *D. polymorpha* larvae, as observed in the majority of Konin lakes and other, is the occurrence of about 90% of larvae in surface layers (epilimnion). In deeper layers (meta- and hypolimnion) they usually occur in small numbers and sometimes do not occur at all.

An exception is the vertical distribution of larvae observed at a station near waterfall discharge of heated water in Lake Ślesińskie (non-stratified station) (Fig. 4). Despite the great depth (20 m), planktonic larvae were recorded down to the bottom.

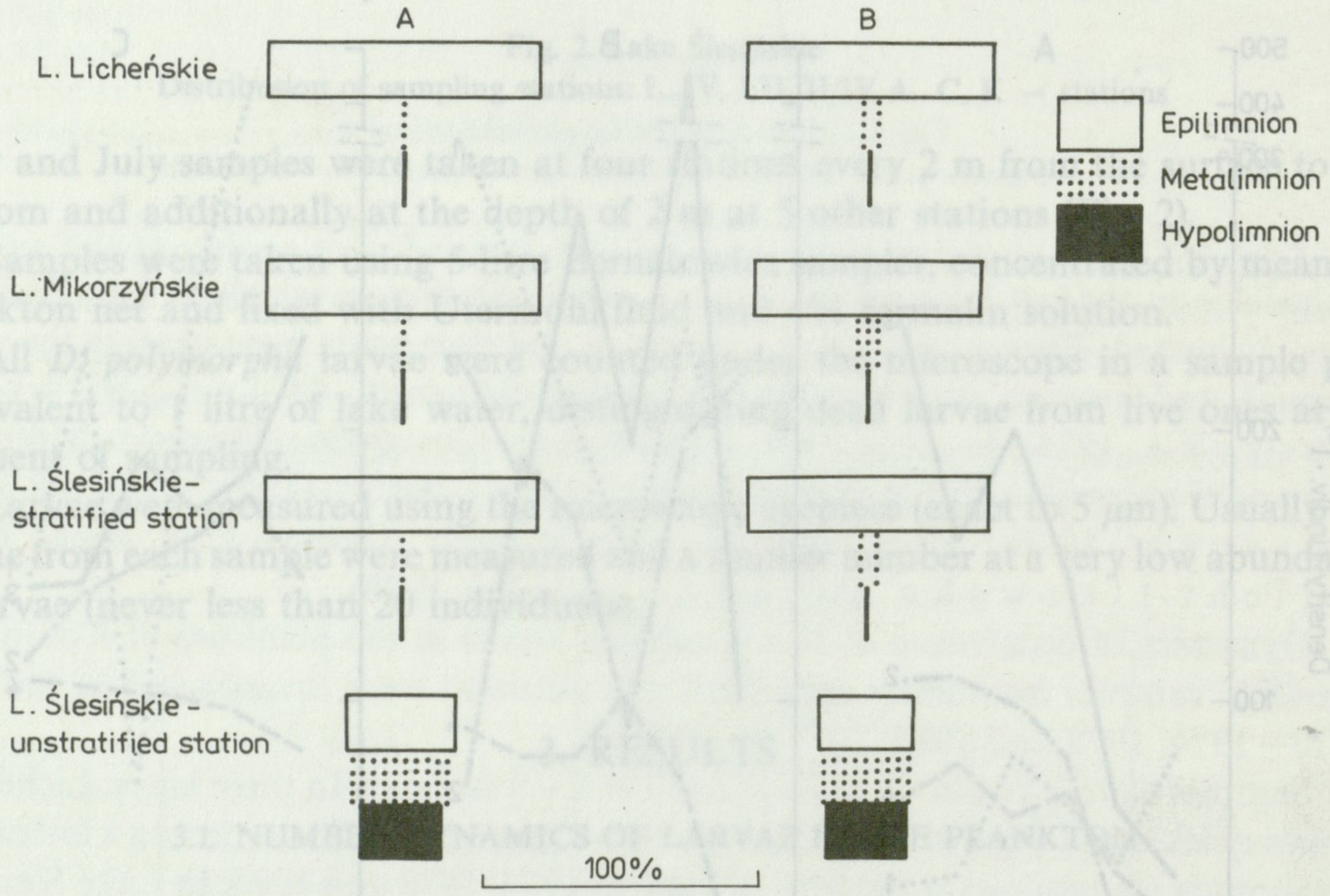

Fig. 4. Vertical distribution of *D. polymorpha* larvae in Konin lakes in summer of 1978 (A) and 1983 (B)

The numbers of larvae were distributed evenly in the entire water column, and in some periods (e.g., in autumn) were even higher in the hypolimnion than in epilimnion.

This system was very stable for longer periods of time (Fig. 5).

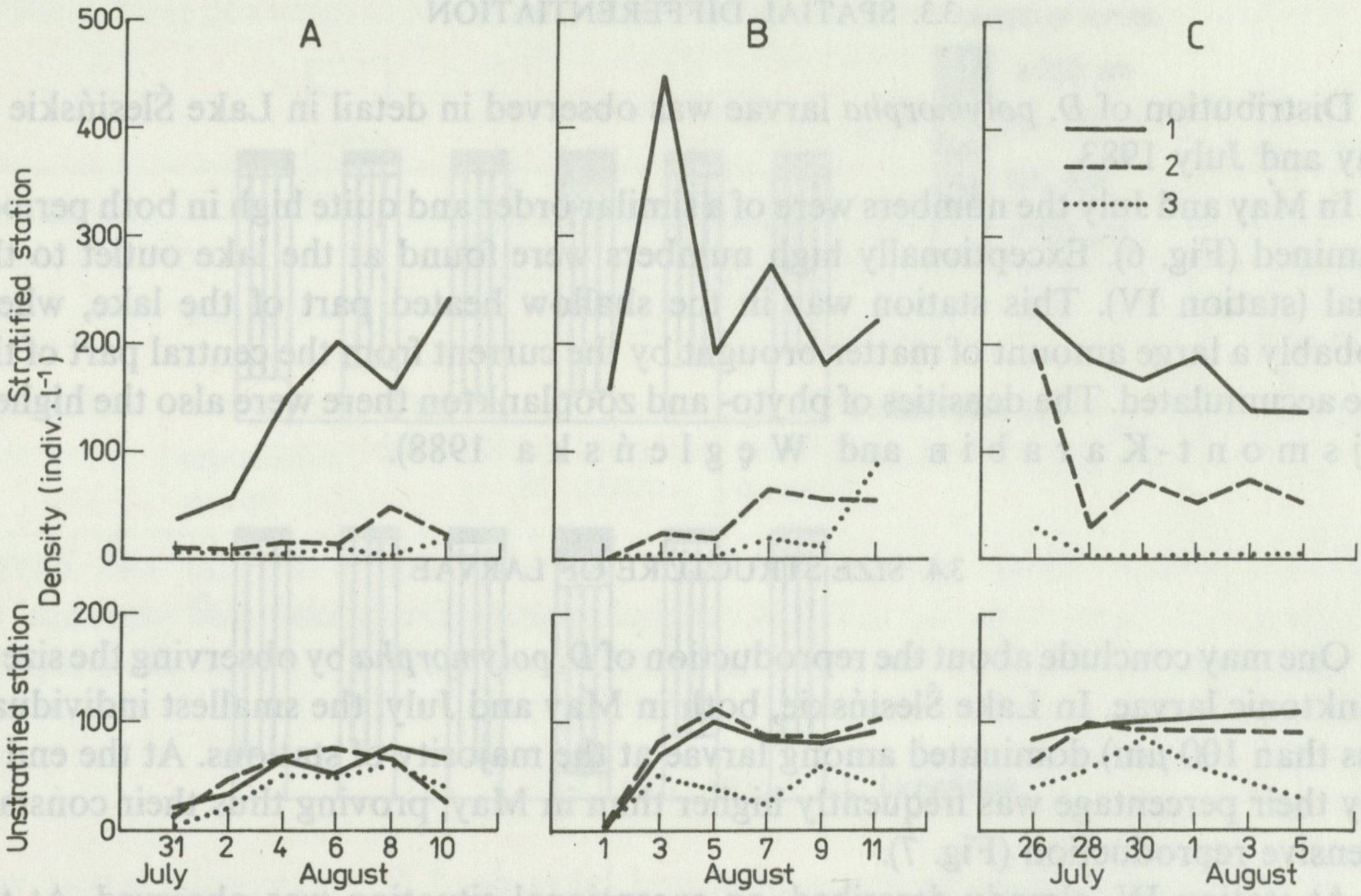

Fig. 5. Number dynamics of *D. polymorpha* larvae at various depths of Lake Ślesińskie during summer stagnation in 1973 (A), 1978 (B) and 1983 (C)
1 – epilimnion, 2 – metalimnion, 3 – hypolimnion

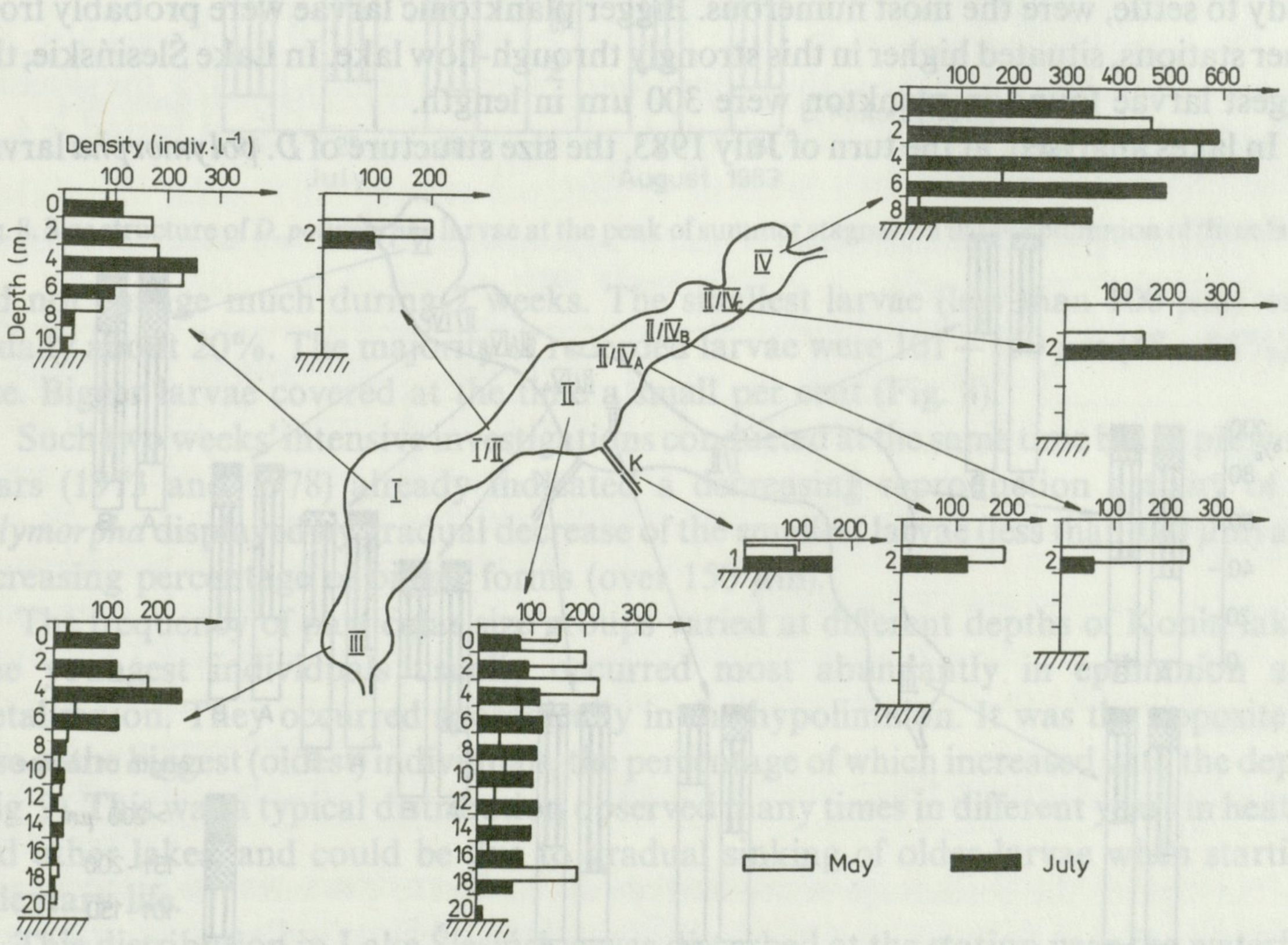

Fig. 6. Occurrence of *D. polymorpha* larvae in May and July 1983 at different stations and depths of Lake Ślesińskie

3.3. SPATIAL DIFFERENTIATION

Distribution of *D. polymorpha* larvae was observed in detail in Lake Ślesińskie in May and July 1983.

In May and July the numbers were of a similar order and quite high in both periods examined (Fig. 6). Exceptionally high numbers were found at the lake outlet to the canal (station IV). This station was in the shallow heated part of the lake, where probably a large amount of matter brought by the current from the central part of the lake accumulated. The densities of phyto- and zooplankton there were also the highest (Ejsmont-Karabin and Węgleńska 1988).

3.4. SIZE STRUCTURE OF LARVAE

One may conclude about the reproduction of *D. polymorpha* by observing the size of planktonic larvae. In Lake Ślesińskie, both in May and July, the smallest individuals (less than 100 μm) dominated among larvae at the majority of stations. At the end of July their percentage was frequently higher than in May, proving thus their constant intensive reproduction (Fig. 7).

At station IV, already described, an exceptional situation was observed. At the outlet to the canal, the percentage of young larvae was the smallest, larvae of an average size prevailed; as compared with other stations larvae over 200 μm in size, i.e., those ready to settle, were the most numerous. Bigger planktonic larvae were probably from other stations, situated higher in this strongly through-flow lake. In Lake Ślesińskie, the biggest larvae found in plankton were 300 μm in length.

In lakes analysed, at the turn of July 1983, the size structure of *D. polymorpha* larvae

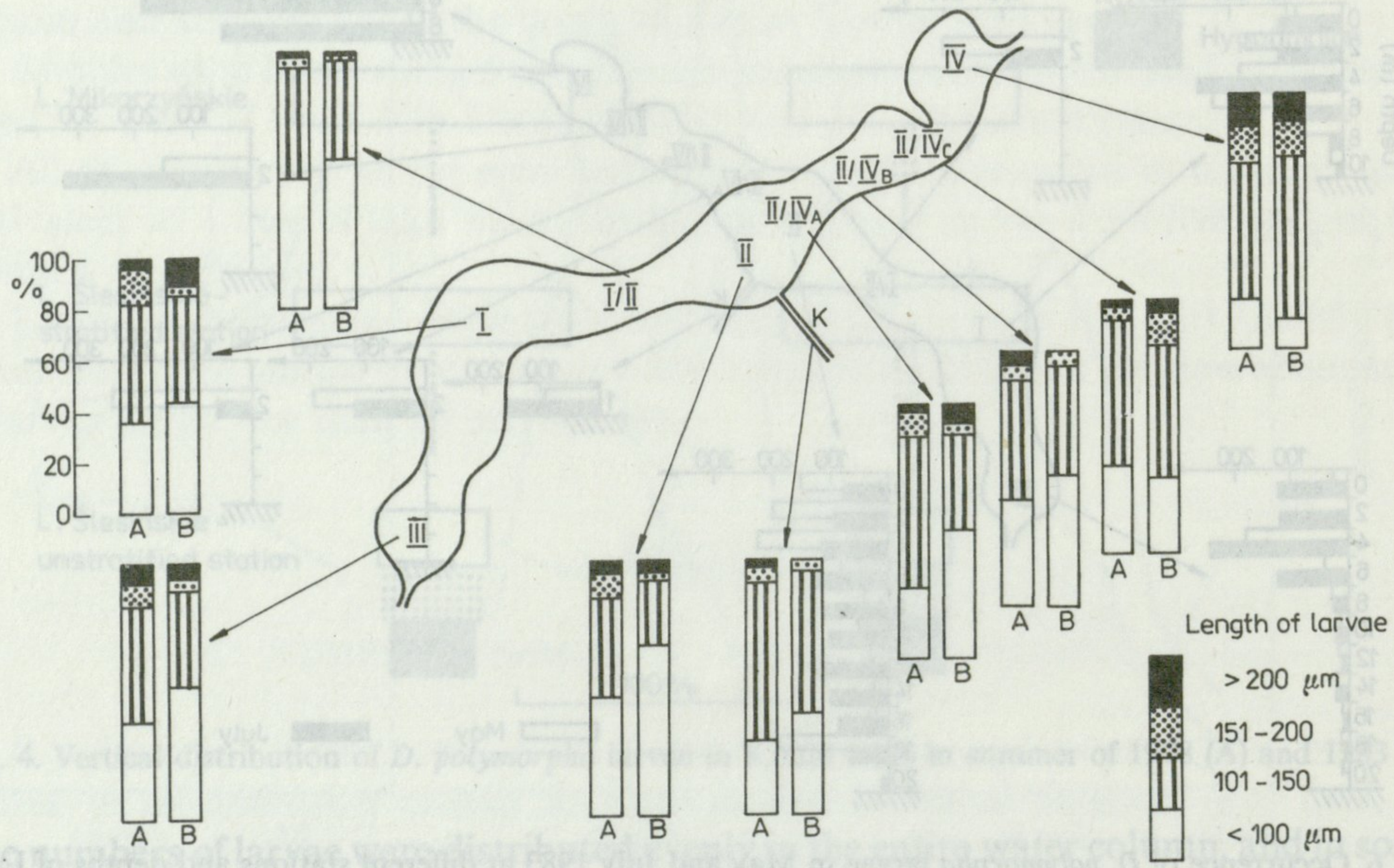

Fig. 7. Size structure of *D. polymorpha* larvae in May (A) and July (B) 1983 in Lake Ślesińskie

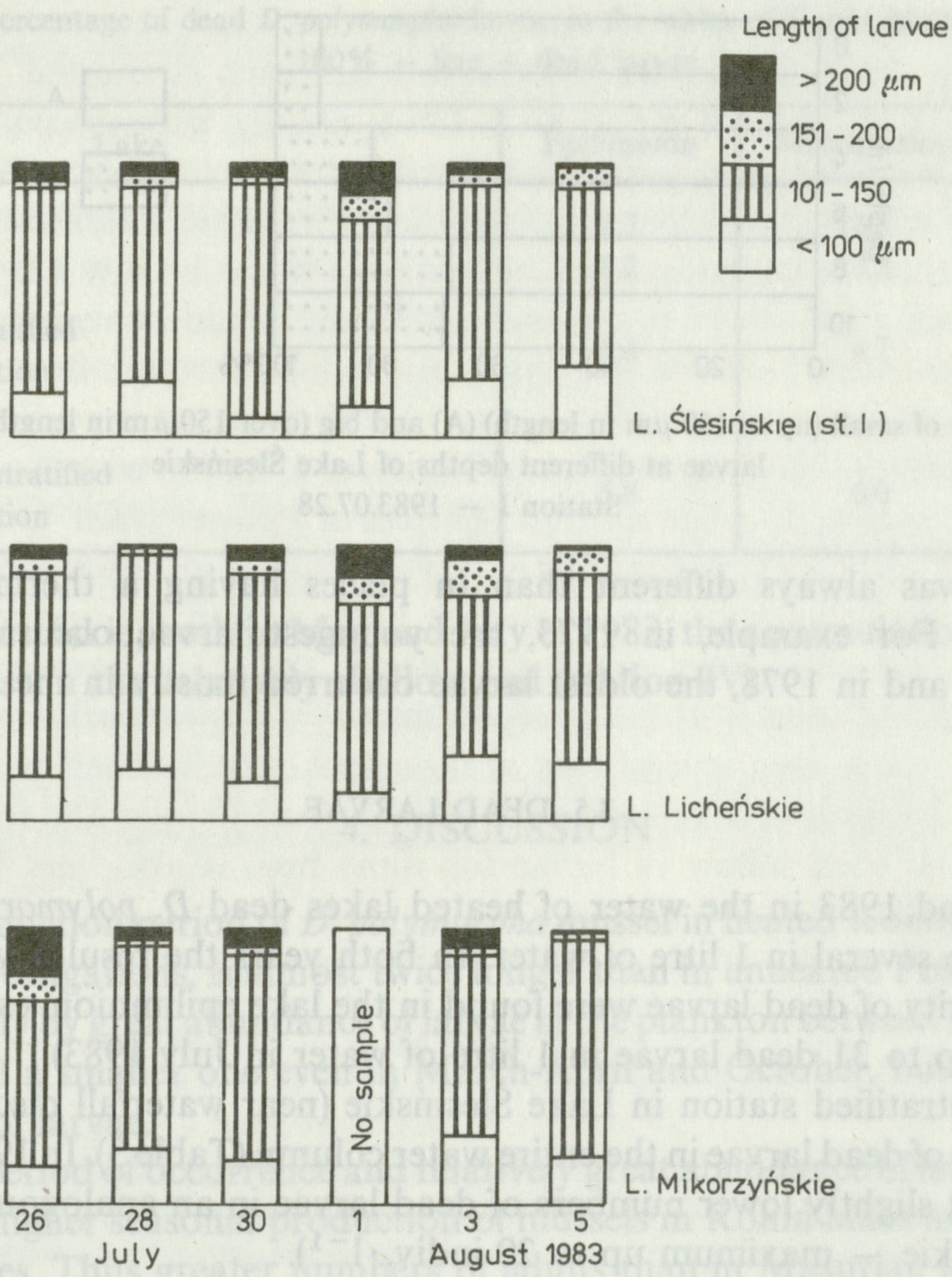

Fig. 8. Size structure of *D. polymorpha* larvae at the peak of summer stagnation in the epilimnion of three lakes

did not change much during 2 weeks. The smallest larvae (less than 100 µm) were usually about 20%. The majority of recorded larvae were 101 – 150 µm (58 – 86%) in size. Bigger larvae covered at the time a small per cent (Fig. 8).

Such two weeks' intensive investigations conducted at the same time but in previous years (1973 and 1978) already indicated a decreasing reproduction activity of *D. polymorpha* displayed by gradual decrease of the smallest larvae (less than 100 µm) and increasing percentage of bigger forms (over 150 µm).

The frequency of particular size groups varied at different depths of Konin lakes. The youngest individuals usually occurred most abundantly in epilimnion and metalimnion. They occurred sporadically in the hypolimnion. It was the opposite in case of the biggest (oldest) individuals, the percentage of which increased with the depth (Fig. 9). This was a typical distribution observed many times in different years in heated and other lakes, and could be due to gradual sinking of older larvae when starting sedentary life.

This distribution in Lake Ślesińskie was disturbed at the station near the waterfall discharge of heated water. Usually there was an even distribution of small and big larvae in the entire water column. Sometimes there were deviations, but the

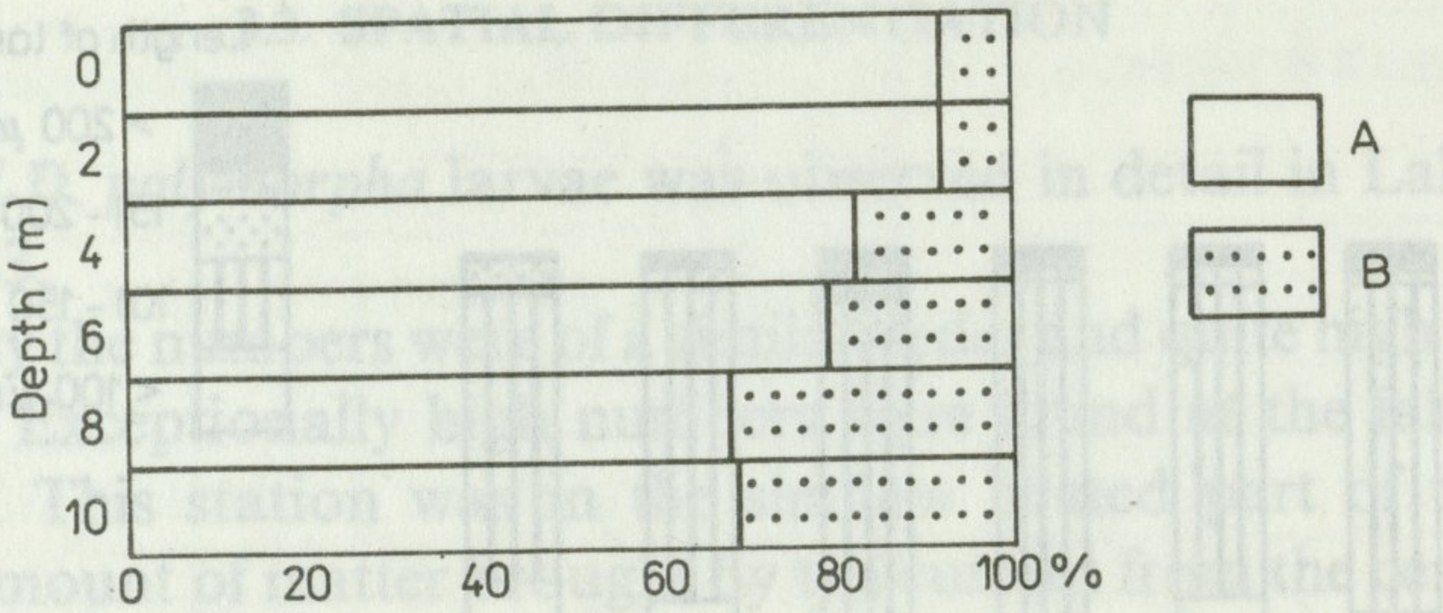

Fig. 9. Frequency of small (up to 150 μm in length) (A) and big (over 150 μm in length) (B) *D. polymorpha* larvae at different depths of Lake Ślesińskie
Station I – 1983.07.28

distribution was always different than in places having a thermal and oxygen stratification. For example, in 1973, the youngest larvae occurred only in the hypolimnion, and in 1978, the oldest larvae occurred mostly in the shallow layers.

3.5. DEAD LARVAE

In 1978 and 1983 in the water of heated lakes dead *D. polymorpha* larvae were usually few to several in 1 litre of water. In both years the results were similar.

The majority of dead larvae were found in the lake epilimnion, especially in Lake Licheńskie (up to 31 dead larvae in 1 litre of water in July 1983).

The non-stratified station in Lake Ślesińskie (near waterfall discharge) also had even numbers of dead larvae in the entire water column (Table 3). In 1978, the situation was similar at slightly lower numbers of dead larvae in an analogous period (e.g., in Lake Licheńskie – maximum up to 20 indiv. $\cdot l^{-1}$).

Table 3. Numbers (mean and range) of dead *D. polymorpha* larvae in Konin lakes (indiv. $\cdot l^{-1}$) (July-August 1983)

Lake	Epilimnion	Metalimnion	Hypolimnion
Licheńskie	12.8 (3–31)	8.0 (3–21)	5.8 (0–20)
Mikorzyńskie	13.2 (5–26)	4.2 (0–8)	2.5 (1–5)
Ślesińskie stratified station	10.0 (2–16)	4.2 (0–14)	3.5 (2–5)
Ślesińskie unstratified station	6.0 (1–12)	5.5 (1–13)	5.8 (1–12)

As regards the percentage of dead larvae in relation to live ones the highest values were recorded in the hypolimnion of lakes examined, whereas in Lake Ślesińskie at the waterfall (non-stratified station) differences between particular water layers were small (Table 4).

Table 4. Mean percentage of dead *D. polymorpha* larvae in the water of Konin lakes (July-August 1983)
100% – live + dead larvae

Lake	Epilimnion	Metalimnion	Hypolimnion
Licheńskie	4.7	10.5	48.3
Mikorzyńskie	8.2	7.3	40.5
Ślesińskie stratified station	5.3	4.7	31.3
Ślesińskie unstratified station	5.8	6.0	9.8

In Lake Ślesińskie, both in May and July of 1983, the accumulation of dead larvae was the highest in the relatively shallow end (station IV).

4. DISCUSSION

The reproduction period of *D. polymorpha* mussel in heated Konin lakes, as shown by present investigations, is almost twice longer than in unheated Polish lakes. This is proved not only by great abundance of larvae in the plankton between May and the end of August and a smaller one even in March-April and October, but also by the size composition of larvae.

The long period of occurrence and relatively great abundance of larvae indicate the almost twice higher seasonal production of mussels in Konin lakes as compared with Masurian lakes. Thus greater numbers of adults than in Masurian lakes could have been expected.

The studies conducted in the Konin lakes in the nineteen-seventies show (S t a ń c z y k o w s k a 1976) that the density of mussels in the zone of their occurrence (littoral zone several cm to few m depth) fluctuate between 300 and 900 indiv. $\cdot m^{-2}$, remaining thus within the mean range or even below the numbers recorded for Masurian lakes.

K o r n o b i s (1977) in his detailed analysis has found also a similar order of numbers in the Konin lakes. He did not find basic differences in numbers between the densities of adult *D. polymorpha* in particular lakes of the Konin system. For example, in Lake Licheńskie heated since 1958 the numbers were of a similar order as in other lakes. There were no differences in numbers at both stations of Lake Ślesińskie differing by environmental conditions.

These data may indicate that the larvae distribute rather evenly in the whole Konin lake system.

Relatively low numbers of adult *D. polymorpha* at high larval production may indicate that mortality in the stage of seettling larvae is even greater in Konin lakes than in the unheated ones. In the latter, according to calculations of W i k t o r (1969), S t a ń c z y k o w s k a (1977) and L e w a n d o w s k i (1982), number reduc-

tion at the larval stage is about 20%, and in the settling stage, i.e., postveliger stage it is as much as 99%. Such high number reduction has been connected (S t a ń c z y k o w s k a 1977, L e w a n d o w s k i 1982) mainly with difficulties in finding suitable place for settlement, i.e., lack of hard substrate (stones, macrophytes, etc.), bad conditions, especially oxygen ones in the hypolimnion, rapid water movements in the littoral. The data on the conditions in Konin lakes (W r ó b l e w s k i 1977) do not show that the lack of place for postveliger settlement could be responsible for small numbers. It seems more probable that this is due to high through-flow of lakes which, on one hand, allow for quite even distribution of settling larvae in particular lakes, and on the other hand, for carrying away great numbers of larvae with the water current. Many larvae die passing through technical devices of a power plant (J a r o š e n k o and N a b e r e ž n y j 1971), similarly as phytoplankton in dam reservoirs (Z. Kajak – unpublished data), whereas those ready to settle stop in the power plant cooling system, where they find very good conditions. As it is known (S z a r f e n b e r g 1972 among others), *D. polymorpha* density on hydrotechnical power plant equipment may reach even several tens of thousand of individuals per 1 m^2. This is connected both with suitable substrate conditions, good oxygen and food conditions. The constant and even inflow of larvae for some time is also very helpful for the formation of so abundant colonies.

5. SUMMARY

Several years of investigations on *Dreissena polymorpha* and especially on the occurrence of planktonic larvae in heated Konin lakes (Fig. 1) do not show differences between the occurrence of larvae in less and more heated lakes (Table 2). This allows to assume that the larvae are carried by the water current from one lake to another.

The period of *D. polymorpha* larvae occurrence in plankton, lasting sometimes from March till the end of September, is almost twice longer than in other Polish lakes.

The numbers of larvae in the lake epilimnion (Fig. 3) are of a similar order or slightly higher than in unheated lakes.

Long reproduction time and high larval production are not accompanied by a greater density of adult *D. polymorpha* than in unheated Masurian lakes. This may be due to high through-flow of Konin lakes, transporting considerable numbers of larvae to power or aluminium plant cooling systems. Great numbers of young larvae may die, but some numbers of older larvae ready to settle may colonize suitable hard substrates.

6. POLISH SUMMARY

Na podstawie wieloletnich badań *Dreissena polymorpha*, a zwłaszcza występowania larw planktonowych, w podgrzanych jeziorach konińskich (rys. 1) nie stwierdzono różnic w występowaniu larw między jeziorami słabiej i silniej podgrzanymi (tab. 2). Pozwala to sądzić, że larwy przenoszone są z prądem wody z jednego jeziora do drugiego.

Okres występowania larw *D. polymorpha* w planktonie, trwający czasami od marca do końca września, jest przeszło dwukrotnie dłuższy niż w innych jeziorach Polski.

Liczebności larw w epilimnionie jezior (rys. 3) są podobnego rzędu lub nieznacznie większe niż w jeziorach nie podgrzewanych.

Długiemu czasowi rozrodu i dużej produkcji larw nie towarzyszy większe niż w nie podgrzewanych jeziorach mazurskich zagęszczenie dorosłych *D. polymorpha*. Można to wiązać z dużą przepływowością jezior konińskich, powodującą przenoszenie znacznych liczebności larw do systemów chłodzących elektrowni i huty aluminium. W systemach tych znaczne liczby młodych larw mogą ginąć, natomiast pewne liczby starszych larw, zdolnych już do osadzania się, mogą pozostawać i osiedlać się na dogodnych twardych podłożach.

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