KOMITET EKOLOGICZNY - POLSKA AKADEMIA NAUK

EKOLOGIA POLSKA — SERIA A

Tom XVI Warszawa 1968 Nr 41

DEPARTMENT OF HYDROBIOLOGY, INSTITUTE OF ECOLOGY, WARSZAWA

Head: Dr. Z. Kajak

Zdzisław KAJAK

BENTHOS OF OXBOW LAKES SITUATED IN THE AREA OF THE ZEGRZYŃSKI RESERVOIR BEFORE ITS FILLING UP WITH WATER

Analysis of the benthos from 5 oxbow lakes, made over the period from July to November, provided a basis for arranging these habitats in evolutionary order depending on their progressive isolation from the influences of the river, increase of oxygen deficit and degree to which they are overgrown by macrophytes. As evolutionary advance of the lake proceeded the qualitative richeness and abundance of benthos, as well as frequency of appearances and abundance of the juvenile instars of *Chironomidae* decreased, while the sharply defined domination and percentage of predatory forms increased (*Procladius* sp. and *Heleidae*).

The objective of the study was to compare benthos from 4 oxbow lakes differing as to their degree of contact with the river, and in their area and depth (Fig. 1, Tab. I). The order given in the table corresponds to the increasing evolutionary advance of the lakes, the following criteria being accepted: distance and degree of isolation from the river, degree to which they were overgrown by macrophytes and the occurrence of shallow and marshy parts of the lakes. Where influence of the river is strong the lake is maintained in a relatively unchanged evolutionary state, but lakes more isolated from the river undergo more rapid evolution in the sense used by Lindeman (1942). This is confirmed by the data given by Zimina (1954). Confirmation of the correctness of the evolutionary order in which the lakes were arranged is supplied by the

organic substance contents in the bottom sediments (Tab. I). It is possible to distinguish: 1) lakes with lower organic substance content (younger from the point of view of evolution) – Popowo I, a habitat least advanced evolutionally and Wierzbica; 2) lakes with higher organic substance content – Serock and Białobrzegi (more advanced in evolution). Popowo II seems to have "mixed" character in the evolutionar order. It is young according to the sediments (Tab. I) and old according to the development of macrophytes.

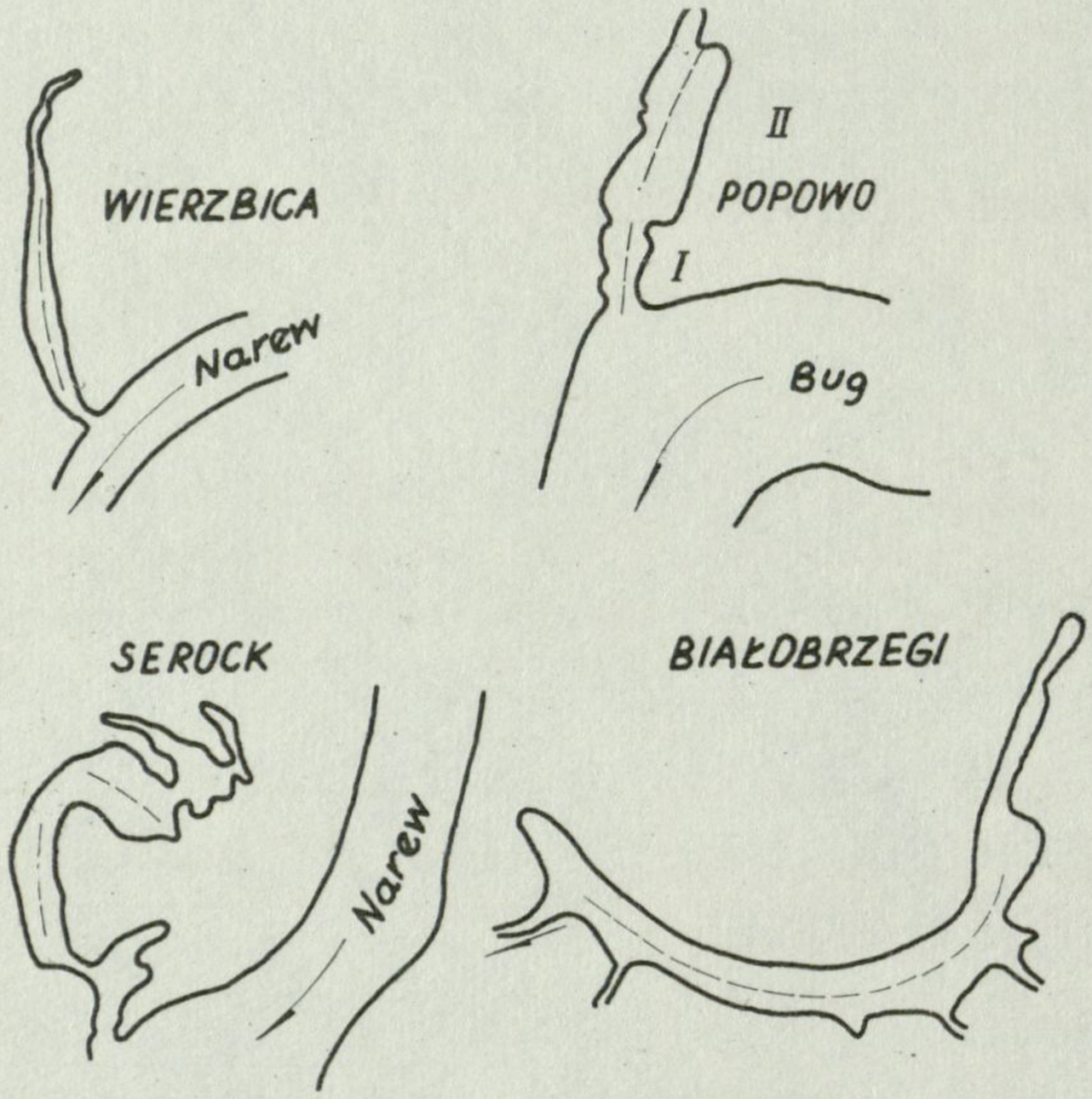

Fig. 1. Oxbow lakes of the rivers Bug and Narew which were investigated before being flooded by the water of Zegrzyńskie Reservoir
Line of dashes indicates the benthos sampling stations

Selected characteristics of the habitats examined

Tab. I

Body of water	Area (ha)	Maximum depth (m)	Organic substance contents in bottom sediments (%)
Wierzbica	1.3	1.9	9.1
Popowo I	0.5	1.0	5.8
Popowo II	2.5	2.0	8.9
Serock	2.6	3.0	14.2
Białobrzegi	8.5	5.0	15.3

Attention must be drawn to the fact that the organic substance content is very low in all the lakes and comes within the limits of the values characteristic of oligotrophic lakes (Olszewski 1948, Rybak in press).

Greater oxygen deficits (about 5% of oxygen at the bottom – Sept. 6th)

were observed only in lakes more advanced in evolution – Białobrzegi and Popowo II[1].

Investigations were carried out from July 28th to November 16th 1961. 5–7 benthic samples were taken five times during the study period along the main axis of each lake, always in the same places, with the 225 cm² Ekman grab. The samples were sieved through a 0.4 × 0.4 mm mesh sieve. The material was preserved in a 4% formalin solution.

QUALITATIVE COMPOSITION OF BENTHOS

The largest number of species of *Chironomidae* (taking the whole study period into consideration) was found in Wierzbica, the smallest – in Białobrzegi lake (Tab. II). The same applies in fact to the remaining fauna – it is more heterogeneous in the three first water bodies given in Table I than in the others (Tab. II).

Mean numbers of basic groups of fauna per 1 m² (range of variations in each series is given in brackets) and number of species of *Chironomidae* during the study period

In addition to the groups mentioned in the table the following were sporadically encountered: *Trichoptera, Ephemeroptera, Odonata, Hirudinea, Heteroptera, Hydracarina*

Tab. II

Groups of fauna	Popowo I	Wierzbica	Serock	Popowo II	Białobrzegi
Oligochaeta	8,870 (5,200–15,680)	666 (300–1,100)	938 (131–1,690)	2,696 (1,610–4,220)	384 (120–740)
Chironomidae	1,790 (930–3,460)	594 (80–1,130)	302 (100–580)	358 (210–720)	50 (0–110)
Mollusca	96 (0–250)	14 (10–20)	6 (0–10)	–	–
Nematoda	80 (30–180)	40 (0–170)	–	–	–
Chaoborus sp.	36 (0–130)	26 (0–50)	90 (0–250)	52 (0–120)	1,066 (370–1,670)
Heleidae	236 (90–390)	188 (30–340)	380 (100–600)	240 (90–520)	52 (0–100)
Asellus aquaticus L.	–	68 (0–310)	–	–	–
Sialis lutaria L.	–	30 (10–70)	–	–	–
Total number of species of *Chironomidae*	15	17	14	9	5

[1]All data describing the habitat were taken from J. Paschalski's unpublished material.

The fauna in Wierzbica and Popowo I, the water bodies most closely connected with the river is the richest. The development of vegetation is very poor here in comparison with Popowo II and Serock. The sediments are of river origin. Owing to this, and possibly also to the inconsiderable depth of these water bodies (about 1.5 m), very varied fauna can survive in them. In oxbow lakes more advanced in evolution the fauna is less varied.

The difference in the number of species of *Chironomidae* in lakes similar in respect of the degree to which they are overgrown by plants is remarkable (Popowo II and Serock). Their greater number in the latter (Tab. II) results probably from the better oxygen conditions in Serock, due to its greater area and consequently better circulation of the water.

Distinct differences were observed in the oxbow lakes examined in respect of the number of species of *Chironomidae* over the course of the season: at Popowo I the number of species was constantly high, but in all other water bodies there was a distinct decrease in the number of species in the summer in relation to the spring state, and remarkable increase in autumn.

QUANTITATIVE RELATIONS

In the majority of habitats *Oligochaeta* and *Chironomidae* predominate numerically, *Heleidae* are also numerous. The last occur least numerously in Białobrzegi lake, where *Chaoborus* sp. is the distinct dominant (Tab. II, Fig. 2)

With regard to the quantitative relations of *Oligochaeta* and *Chironomidae*, it is only in Wierzbica (which, as mentioned above, is the youngest evolutionally), in which the abundance of the two groups is similar; in all the others *Oligochaeta* markedly predominate over *Chironomidae*. This is probably due to the greater resistance of the former to poor oxygen conditions (Alsterberg 1922). In Popowo I, however, where the total abundance of the fauna is far greater than in the other water bodies, the quantitative predominance of *Oligochaeta* over *Chironomidae* is caused by other factors; the oxygen conditions, on account of the constant connection with the river, are undoubtedly good in this case.

Within the *Chironomidae* family (Tab. III) distinct monospecies dominance is observed in the Białobrzegi lake, where, as already mentioned, the differentiation of the fauna is lesser. The only dominant among *Chironomidae* here is *Chironomus plumosus*.

The second water body from the point of view of differentiation and variations in domination of *Chironomidae* is Wierzbica. At the beginning of the season one species, namely *Pelopia kraatzi*, dominates, later the following species join it in this respect or take over the position of dominants: *Polypedilum nubeculosum*, *Microtendipes chloris* and *Pelopia villipennis*.

The least distinct and most variable domination is observed in Popowo I. At the beginning of the season *Chironomus plumosus* and *Pelopia kraatzi* dominate here, then other species are joining or taking over the domination:

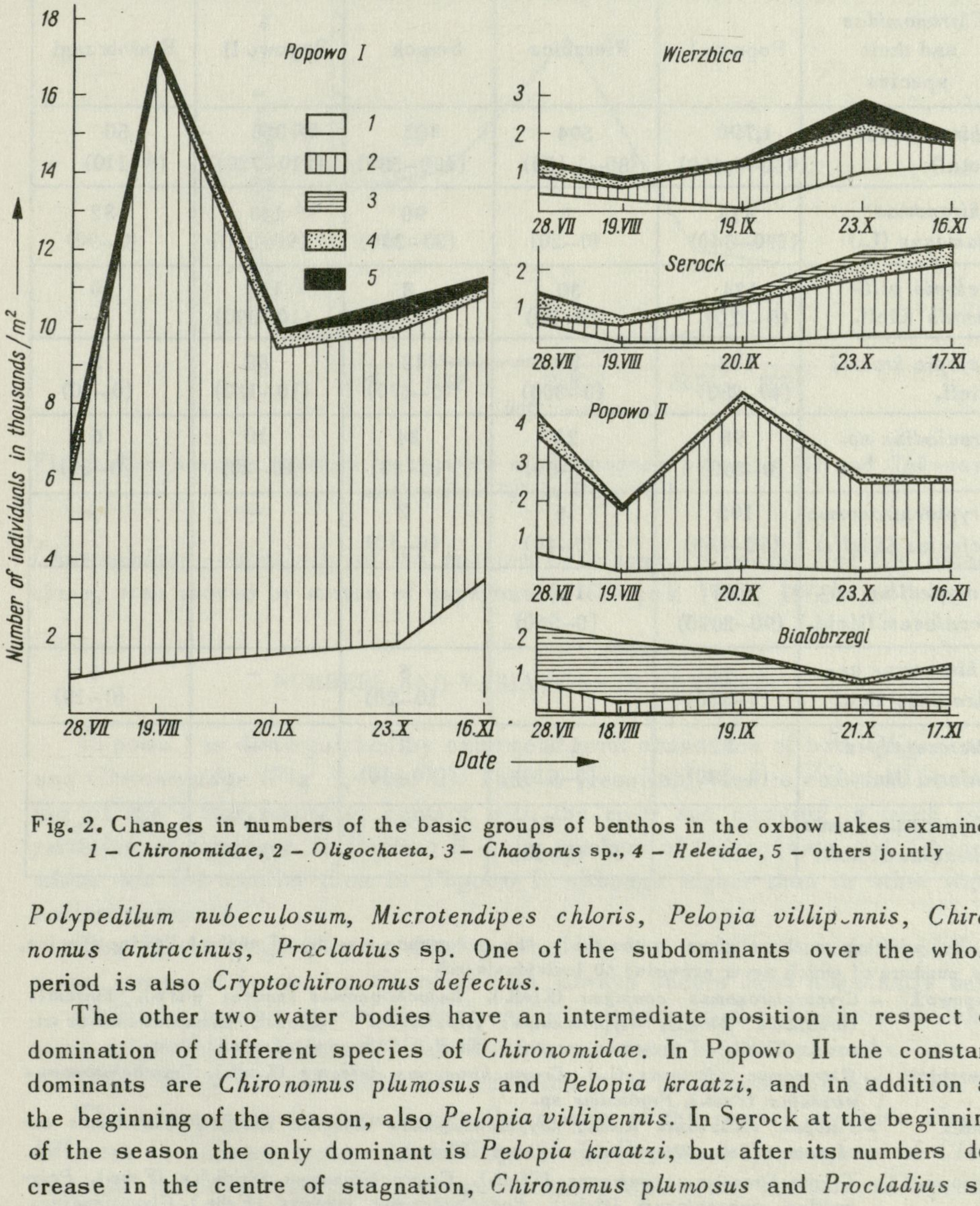

Fig. 2. Changes in numbers of the basic groups of benthos in the oxbow lakes examined
1 – Chironomidae, 2 – Oligochaeta, 3 – Chaoborus sp., *4 – Heleidae, 5* – others jointly

Polypedilum nubeculosum, Microtendipes chloris, Pelopia villipennis, Chironomus antracinus, Procladius sp. One of the subdominants over the whole period is also *Cryptochironomus defectus.*

The other two water bodies have an intermediate position in respect of domination of different species of *Chironomidae.* In Popowo II the constant dominants are *Chironomus plumosus* and *Pelopia kraatzi*, and in addition at the beginning of the season, also *Pelopia villipennis.* In Serock at the beginning of the season the only dominant is *Pelopia kraatzi*, but after its numbers decrease in the centre of stagnation, *Chironomus plumosus* and *Procladius* sp. become the dominants.

In several cases we found exchange of species during the season, characteristic for competition relations, namely replacement in time of two species

Mean numbers of *Chironomidae* per 1 m² during study period (range of variations in each series is given in brackets)

Tab. III

Chironomidae and their species	Popowo I	Wierzbica	Serock	Popowo II	Białobrzegi
Chironomidae (total)	1,790 (930–3,460)	594 (80–1,130)	302 (100–580)	358 (210–720)	50 (0–110)
Chironomus plumosus (L.)	474 (270–840)	8 (0–20)	90 (30–200)	140 (90–180)	32 (0–90)
Pelopia villipennis Kieff.	124 (0–270)	30 (0–90)	8 (0–30)	116 (10–390)	0 –
Pelopia kraatzi Kieff.	132 (40–280)	88 (0–300)	112 (0–470)	68 (10–130)	2 (0–10)
Procladius sp.	98 (0–360)	22 (0–50)	34 (0–80)	10 (0–20)	6 (0–20)
Cryptochironomus defectus (Kieff.)	102 (60–160)	16 (0–40)	2 (0–10)	–	–
Polypedilum nubeculosum (Meig.)	644 (90–2090)	182 (0–560)	–	–	–
Chironomus anthracinus Zett.	46 (0–130)	–	6 (0–20)	–	4 (0–10)
Microtendipes chloris (Meig.)	72 (0–180)	138 (0–610)	2 (0–10)	–	–
Cryptochironomus viridulus (Fabr.)	–	2 (0–10)	–	4 (0–20)	–

In addition to those given in the table, the occurrence was found of the following species, the numbers of which never exceeded 50 individuals/m²:

Popowo I – *Cryptochironomus conjuges* (Kieff.), *Endochironomus tendens* (Fabr.), *Einfeldia carbonaria* (Meig.), *Glyptotendipes gripekoveni* (Kieff.), *Limnochironomus tritomus* (Kieff.), *Tanytarsus gregarius* (Kieff.), *Chironomus dorsalis* Meig.

Wierzbica – *Chironomus plumosus* (L.), *Cryptochironomus defectus* (Kieff.), *Cryptochironomus viridulus* (Fabr.), *Procladius* sp.

Serock – *Pelopia villipennis* Kieff., *Cryptochironomus defectus* (Kieff.), *Chironomus anthracinus* Zett., *Microtendipes chloris* (Meig.).

Popowo II – *Cryptochironomus conjugens* (Kieff.), *Cryptochironomus viridulus* (Fabr.), *Polypedilum nubeculosum* (Meig.), *Endochironomus tendens* (Fabr.), *Glyptotendipes gripekoveni* Kieff., *Procladius* sp.

Białobrzegi – (numbers below 20 individuals/m²) – *Pelopia kraatzi* Kieff., *Procladius* sp., *Chironomus anthracinus* Zett.

of the same genus; in Popowo I *Chironomus plumosus* was replaced by *Ch. anthracinus* (Fig. 3) and *Pelopia kraatzi* by *P. villipennis*, in Wierzbica – also *P. kraatzi* by *P. villipennis*. The strong competitive interaction of benthic

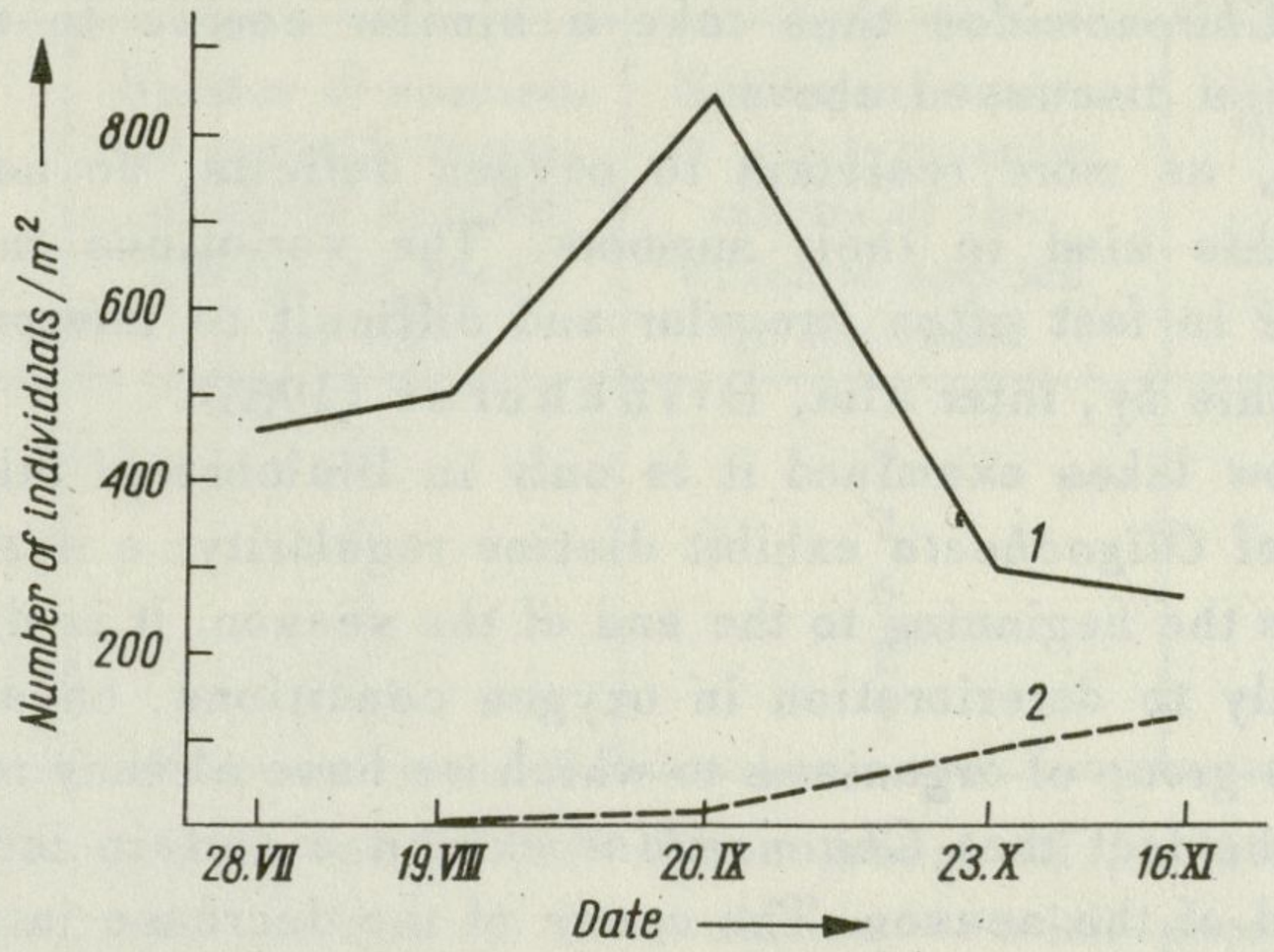

Fig. 3. The adverse changes in numbers of *Chironomus plumosus* (*1*) and *Chironomus anthracinus* (*2*) in Popowo I

Chironomidae, especially of the species *Chironomus plumosus* and *Ch. anthracinus*, was proved by means of experiments (Kajak 1963, 1968).

NUMBERS AND VARIATIONS IN NUMBERS

Popowo I is distinguished by extremely great abundance of both *Oligochaeta* and *Chironomidae* (Fig. 2, Tab. II). This is presumably due to constant freshening of the water owing to contact with the river and carrying in fresh food particles by the river. In Popowo II – the numbers of *Oligochaeta* and *Chironomidae* are far smaller than in Popowo I, although higher than in other water bodies examined.

The Białobrzegi lake is distinguished by the smallest numbers of both these groups of fauna, but *Chaoborus* sp. always occurs most abundantly here.

Mollusca exhibit a marked decrease in numbers in the direction of lakes more advanced evolutionally, but there is no such regularity in the case of *Heleidae*, these are distinctly less numerous only in Białobrzegi lake (Tab. II).

The changes is numbers during the course of the season are also clearly different in different oxbow lakes (Fig. 2). In Popowo I the numbers of *Chironomidae* increase with the passage of time, while the numbers of species dominating at the beginning of the season – *Chironomus plumosus* and *Pelopia kraatzi* decrease, and the abundance of *Polypedilum nubeculosum* and *Procladius* sp. gradually increase. In all the other water bodies the decrease of the numbers

of *Chironomidae* occurs in the centre of stagnation (in Białobrzegi lake this took place as early as in July), followed by increase again in the autumn. It is only Pópowo II which does not distinctly exhibit this regularity: the decrease during summer stagnation is not very great here. Variations in the abundance of *Chironomidae* thus take a similar course to the variations in number of species discussed above.

Oligochaeta, as more resistant to oxygen deficits, do not exhibit distinc variations of this kind in their numbers. The variations in the numbers of *Oligochaeta* are in fact often irregular and difficult to interpret; attention has been drawn to this by, inter alia, Brinkhurst (1965).

Of the oxbow lakes examined it is only in Białobrzegi lake that variations in the number of *Oligochaeta* exhibit distinc regularity: a systematic decrease in numbers from the beginning to the end of the season. It is difficult to explain this as due only to deterioration in oxygen conditions, on account of the resistance of this group of organisms to which we have already referred, especially in view of the fact that *Chironomidae* exhibit a certain increase in numbers towards the end of the season. The cause of the decrease in numbers of *Oligochaeta* in this lake is perhaps their being eaten by *Chaoborus* sp. The possibility of *Tubificidae* being consumed by *Chaoborus* sp. has been pointed out by Jonasson (1964). The decreased activity of *Oligochaeta* due to poor oxygen conditions and protrusion of the greater part of the body above the surface of sediments may result in their intensive elimination by *Chaoborus* sp. in the Białobrzegi lake.

Variations in total abundance of benthos in the oxbow lakes examined are relatively small (Fig. 2).

APPEARANCES OF YOUNG *CHIRONOMIDAE* LARVAE

Among the water bodies examined Wierzbica and Popowo I are distinguished by greater numbers of young *Chironomidae* larvae and by their occurrence at different periods of the year (Tab. IV). In the other lakes young larvae probably occurred in spring only.

These facts confirm the view that appearances of the juvenile instars depend far more on habitat conditions than on the phenology and mass emergence of imagines, which is proved in other studies (Kajak 1964, 1968).

QUANTITATIVE PARTICIPATION OF PREDATORY FORMS

The percentage of the common benthic predator *Procladius* sp. was not very high – it did not exceed 20%, and usually was far less. This form is very numerous and dominating in many habitats (Kajak 1966). *Heleidae*, which must also be treated as predatory (Pčelkina 1950, Weerekoon 1953) were

Comparison of occurrence of juvenile *Chironomidae* instars in the water bodies examined

The following dominating species were taken into consideration: *Chironomus plumosus* (below 10 mm), *Microtendipes chloris*, *Cryptochironomus defectus*, *Polypedilum nubeculosum*, *Procladius* sp., *Pelopia kraatzi* (all below 5 mm)

Tab. IV

Body of water	Number of species, the juvenile instars of which occurred during the study period	Number of series in which juvenile instars of the different species were found	Mean numbers of juvenile instars (individuals/m²)
Popowo I	5	9	106.0
Wierzbica	5	7	24.0
Serock	3	6	11.0
Popowo II	2	2	3.0
Białobrzegi	1	1	0.5

also numerous. The percentage of both these groups of predators was clearly greater in habitats more advanced in evolution – with poorer benthos and worse oxygen conditions (Białobrzegi, Serock, Popowo II), but smaller in evolutionally younger habitats with richer benthos and better oxygen conditions (Wierzbica, Popowo I) (Tab. V). This may be treated as an argument confirming the hypothesis that under poorer habitat conditions the accessibility of food to predators increases, which enables a shift to take place in the quantitative relations of predatory and non-predatory forms in favour of the former (Kajak 1965, 1968).

Relation (in percentages) of the numbers of *Heleidae* and *Procladius* sp. to the total numbers of *Chironomidae*

Mean value for the whole study period

Tab. V

	Percentage of *Procladius* sp.	Percentage of *Heleidae*
Popowo I	5.5	13.2
Wierzbica	3.7	31.6
Popowo II	2.8	67.0
Białobrzegi	12.0	104.0
Serock	19.4	125.8

SUMMARY

A description is given of the benthos fauna of 5 oxbow lakes situated in the area of Zegrzyński Reservoir before its filling up with the water. *Oligo-*

chaeta and *Chironomidae* occurred most numerously in all these water bodies. In Białobrzegi lake *Chaoborus* sp. was numerous too. The greatest abundance of benthos was found in Popowo I – *Oligochaeta* up to 15,500 individuals/1 m², *Chironomidae* up to 3,500 individuals/1 m². In the remaining water bodies the numbers of *Oligochaeta* did not generally exceed 1,000 individuals/1 m², *Chironomidae* – several hundreds individuals/1 m². (Tab. II and III, Fig. 2). These numbers are of the same order as in the majority of the stagnant habitats within and by the Vistula (Kajak 1959), but are far lower than in the particularly rich Konfederatka lake. The abundance of benthos in this last, may result from the fact that being still the subject to the fertilizing effect of Warsaw wastes, is not overloaded with them (Kajak 1958).

Greater abundance of *Chironomidae* was observed at the beginning of the season and in autumn in the majority of the oxbow lakes examined, but lower in the centre of stagnation. An exception to this is formed by Popowo I, where the abundance of benthos was always high and increased towards the end of the season. *Oligochaeta* did not exhibit any regular variations in numbers (Fig. 2).

The qualitatively richer benthos was found in the "evolutionally younger" habitats – Popowo I and Wierzbica; the poorest – in lake Białobrzegi, which was of a slightly different character (Tab. II).

In lakes with qualitatively richest benthos the variability of domination relations in time was the greatest; in lake Białobrzegi, with the qualitatively poorest benthos domination was most stable (*Chaoborus* sp. always dominated).

In the evolutionally younger oxbow lakes (Popowo I and Wierzbica) appearances of the young instars of *Chironomidae* were found in different periods, whereas in the evolutionally older lakes such appearances took place in spring only, the mean numbers of the young forms being far higher in the first group of lakes (Tab. IV).

In several cases we found the exchange in time of related species (*Chironomus plumosus* – *Ch. anthracinus* (Fig. 3) and *Pelopia kraatzi* – *P. villipennis*), characteristic of competitive relations.

The percentage of predatory forms – *Procladius* sp. and *Heleidae* – increases as the evolutionary advance of the lake, and the detorioration in oxygen conditions connected with this, develops. (Tab. V); this confirms the view that the percentage of predatory forms in benthos depends on the accessibility of victims (Kajak 1965, 1968).

To recapitulate it may be said that as the evolutionary advance of oxbow lakes proceeds the qualitative and quantitative richness of the fauna are reduced, the frequency of appearances and the abundance of the juvenile instars of *Chironomidae* decrease, while domination becomes more distinct and the percentage of predatory forms increases.

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BENTOS ZBIORNIKÓW PRZYRZECZNYCH POŁOŻONYCH NA TERENIE JEZIORA ZEGRZYŃSKIEGO PRZED JEGO ZALEWEM

Streszczenie

Scharakteryzowano faunę bentosową 5 środowisk przyrzecznych położonych na terenie Jeziora Zegrzyńskiego przed jego zalewem. We wszystkich tych zbiornikach najliczniej występowały *Oligochaeta* i *Chironomidae*, w zbiorniku Białobrzegi – poza tym *Chaoborus* sp. Najwyższą liczebność stwierdzono w bliższej rzeki części zbior-

nika Popowo – *Oligochaeta* do 15500 osobn./1 m², *Chironomidae* do 3500 osobn./1 m²; w pozostałych zbiornikach liczebność *Oligochaeta* na ogół nie przekraczała 1000 osobn./1 m², *Chironomidae* – kilkuset osobn./1 m² (tab. II i III, fig. 2). Liczebności te są tego rzędu co w większości środowisk śród- i przyrzecznych Wisły (Kajak 1959), jednak znacznie niższe niż w szczególnie bogatym zbiorniku Konfederatka, być może podlegającym jeszcze użyźniającemu wpływowi ścieków Warszawy, a nie przeciążonym nimi (Kajak 1958).

W większości zbiorników obserwowano wyższe liczebności *Chironomidae* na początku sezonu i jesienią, niższe w szczycie stagnacji; wyjątkiem jest tu bliższa rzeki część zbiornika Popowo, gdzie obfitość bentosu była zawsze wysoka i rosła ku końcowi sezonu. *Oligochaeta* nie wykazywały na ogół prawidłowych zmian liczebności (fig. 2).

Największe zróżnicowanie jakościowe bentosu stwierdzono w środowiskach „młodszych ewolucyjnie" – bliższej rzeki części zbiornika Popowo (Popowo I) oraz zbiorniku Wierzbica; najmniejsze – w zbiorniku Białobrzegi o nieco odmiennym charakterze (tab. II).

W zbiornikach o największym zróżnicowaniu fauny bentosowej największa była też zmienność stosunków dominacji w czasie; w zbiorniku Białobrzegi, o najmniejszym zróżnicowaniu składu bentosu – dominacja była najbardziej stała (zawsze dominował *Chaoborus* sp.).

W zbiornikach młodszych ewolucyjnie (Popowo I i Wierzbica) stwierdzono pojawy młodych stadiów *Chironomidae* w różnych okresach, podczas gdy w zbiornikach starszych ewolucyjnie pojawy te zachodziły tylko wiosną; przy tym średnia liczebność form młodych była znacznie wyższa w pierwszej grupie zbiorników (tab. IV).

W kilku wypadkach stwierdzono wymianę w czasie pokrewnych gatunków, *Chironomus plumosus* – *Ch. anthracinus* (fig. 3) i *Pelopia kraatzi* – *P. villipennis*, charakterystyczną dla stosunków konkurencyjnych.

Udział form drapieżnych – *Procladius* sp. i *Heleidae* – wzrasta zgodnie ze wzrastającym zaawansowaniem ewolucyjnym zbiorników oraz związanym z tym pogarszaniem się warunków tlenowych (tab. V); potwierdza to tezę, że udział form drapieżnych w bentosie jest uwarunkowany dostępnością ofiar (Kajak 1965, 1968).

Reasumując można stwierdzić, że ze wzrostem zaawansowania ewolucyjnego zbiorników przyrzecznych maleje zróżnicowanie i liczebność fauny, zmniejsza się częstość pojawów, jak również liczebność młodocianych stadiów *Chironomidae*, rośnie zaś ostrość dominacji oraz udział form drapieżnych.

AUTHOR'S ADDRESS:
Doc. dr Zdzisław Kajak
Instytut Ekologii PAN
Warszawa, Nowy Świat 72
Poland