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REMARKS ON THE CAUSES OF THE SCARCITY OF BENTHOS IN LAKE LISUNIE*

Three years of investigation of the benthos in Lake Lisunie revealed that its numbers are very small. Organic fertilization and other field experiments proved that the scantiness of benthos is due to the trophic situation. The considerable amount of organic substance in the bottom sediments is probably inaccessible to the benthos, despite the high concentration of oxygen at the bottom. It was found that percentage of predatory invertebrates was higher in worse environmental conditions accompanied by poorer condition of non-predatory larvae.

The aim of this study is to throw some light on the causes of the scarcity of benthos in Lake Lisunie. This lake, situated in the Mazurian Lakeland in the north of Poland, is a small body of water 13 ha in area, with a maximum depth of about 8 m (Kondracki and Mikulski 1958). The lake is polymictic, not as a whole exhibiting stratification, the water of which has a slightly alkaline pH (pH — 7–8); the bottom sediments are very light, jelly-like, with a high (62%) organic substance content (data on the physicochemistry of the lake obtained from Dr. Szczepański).

The benthos material was collected over the period from 1959–1961, from April to October inclusively, a total of 125 samples being obtained by means of an Ekman dredge with a 225 cm^2 collecting area. In 1959 the material was collected chiefly at maximum depth in two depressions, and in the following years in one depression only. Three series only were taken at lesser depths

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for purposes of orientation. In addition field experiments were made consisting in:

1) separating off sections of the habitat by means of cages measuring 30 × 30 × 30 cm, made of fine 0.5 × 0.5 mm mesh gauze (for details of method see Kajak 1964);

Numbers per 1 m² and frequency of occurrence of benthos in Lake Lisunie (data from 1959–1961). Dominating species of *Tendipedidae* are underlined

Tab. I

Taxonomic groups	Mean numbers	Maximum numbers observed	Frequency of occurrence in percentages*
Oligochaeta	16.3	61.6	61.9
Chaoborus crystallinus Degeer	115.7	440.0	85.7
Heleidae	0.4	8.8	4.8
Tendipedidae	28.2	96.8	85.7
Tanytarsus gregarius Kieff.	3.1	33.0	19.1
Cryptochironomus viridulus (Fabr.)	0.9	8.8	4.8
Tendipes anthracinus Zett.	18.0	66.0	52.4
Tendipes plumosus L.	0.4	8.8	4.8
Tendipes salinarius Kieff.	0.4	8.8	4.8
Paratendipes albimanus (Meig.)	0.4	11.0	4.8
Polypedilum scalaenum (Schr.)	0.4	11.0	4.8
Endochironomus tendens (Fabr.)	0.4	8.8	4.8
Procladius Skuze	3.5	13.2	33.3
Ablabesmyia monilis (L.)	0.9	17.6	4.8

*Percentage of series in which the given species occurred, out of a total number of 21 series

2) enrichment of the food resources of a section of the habitat by means of a quickly decaying organic substance, in the form of cooked mashed potatoes;

3) the introduction of certain species of *Tendipedidae* from other lakes (using experimental cages).

A glance at the numerical data on the benthos in the lake is sufficient to show that numbers of individuals were low, while the number of species was relatively large (Tab. I). Only the following species occur frequently and relatively abundantly: *Tendipes anthracinus*, *Tanytarsus gregarius* and *Procladius*; the remaining species are encountered only sporadically. Fluctuations in numbers were relatively small – the maximum numbers of *Tendipedidae* (and also of *Oligochaeta*) were below 100 individuals per 1 m^2. Only *Chaoborus* was found to occur in slightly larger numbers.

With such small numbers of *Tendipedidae* and *Oligochaeta* it was difficult to speak of regularities in variations in abundance over the course of a year, and it was therefore necessary to restrict findings to establishing that the level of abundance was very low.

The age structure of the dominants was on the whole varied – both young and old individuals constantly occurred. This would appear to be evidence that there is a certain constant influx of eggs and young forms. There is, however, a constantly occurring intensive reduction in numbers which makes abundant appearance of benthos impossible.

Changes in number of *Chaoborus* larvae were found to be very normal and regular – large numbers in the spring, then a decrease in abundance due to emergence during the turning point between July and August, followed by another increase in numbers, not however reaching the spring level, in the autumn.

Comparison of numbers of benthos per 1 m^2 in two depressions of the lake and in different study years (for period June – October)

Tab. II

Taxonomic groups	Year, depression			
	1959		1960	1961
	I	II	I	I
Tendipedidae	21	26	15	54
Oligochaeta	17	31	18	10
Chaoborus crystallinus	113	180	57	49

No distinct differences in numbers or in the species composition were found in the two depressions examined in the lake.

Comparison of the mean numbers in different years showed that 1961 (in which *Tendipes anthracinus* occurred almost exclusively from among species of *Tendipedidae*) is distinguished by the relative abundance of *Tendipedidae* and 1959 by that of *Chaoborus* (Tab. II). Fluctuations in numbers in the groups of organisms mentioned do not exceed more than 3–4 times between the study years.

The benthos biomass (not including *Chaoborus*) did not exceed 0.2 g/m², except for 1961, when it reached the figure of 0.5 g/m². Biomass including *Chaoborus* did not in general exceed 1 g/m².

In field experiments on Lake Śniardwy numbers of benthos far greater than in the neighbourhood of the cages were obtained by using experimental cages (Kajak 1964). The use of similar cages containing mud together with fauna from Lake Lisunie resulted in a considerable increase in numbers similar to that found in the benthos of Lake Śniardwy, although numbers continued fairly low (Tab. III), and whereas the number of species in Lake Śniardwy increased several times over in the cages in relation to their surroundings, in Lake Lisunie this number remained unaltered (Tab. III). As was the case in Lake Śniardwy, more young forms occurred in the cages, which may afford evidence of their greater capacity for survival; whereas in the neighbourhood of the cages young specimens (⩽ 7 mm) of *Tendipes anthracinus* formed 26%, in the cages this figure was as high as 53%, the numbers of older larvae not being smaller in the cages than in the lake. It is also remarkable that while in the experiments in Lake Śniardwy the numbers of *Oligochaeta* in the cages remained on an average the same as in the neighbourhood of the cages (Kajak 1963), in Lake Lisunie *Oligochaeta* exhibited a very considerable increase in numbers. The transfer of mud together with fauna from Lake Śniardwy on to the bottom of Lake Lisunie resulted in a certain reduction in total abundance and reduction in the numbers of different species of *Tendipedidae*. An exception to this is formed by a species common to both lakes and dominating in Lake Lisunie – *Tendipes anthracinus*, which attained distinctly greater numbers (Tab. IV). This points to the fact that the abundance of benthos in Lake Lisunie depends not only on the character of the mud, but also on the more general properties of the habitat in this lake. In Lake Śniardwy at this time not only was there no decrease but there was even an increase in numbers, although certain species such as, for instance, *Einfeldia carbonaria*, disappeared completely as the result of emergence.

The capacity for survival of larvae in the bottom habitat of Lake Lisunie in mud from Lake Śniardwy was, however, far greater than that of larvae from Lake Śniardwy placed in a cage with mud from Lake Lisunie. Whereas in the cage with mud from Lake Śniardwy the numbers of *Tendipes plumosus* larvae decreased 1,5 times, in the cage with mud from Lake Lisunie they decreased more than 4 times.

It is interesting to note that in laboratory experiments the larvae of *Tendipes plumosus* and *Tendipes anthracinus* kept in mud from lakes of different limnological types (including mud from Lake Lisunie) and fed on powdered milk and yeasts, exhibited a similar survival rate.

Comparison of state of benthos in experimental cages and their neighbourhood. Duration of experiment 36 days (July 1st – August 5th 1961)

Tab. III

Fauna	Neighbourhood of cages		Cages
	initial state	final state	final state (mean of two and differenciation)
	number of individuals per 1 m²		
Tendipedidae	80	28	170 (140–200)
Oligochaeta	0	6	165 (60–210)
	number of species		
Tendipedidae	3	2	2.5 (2–3)

Comparison of changes in state of benthos in the cage with mud and fauna from Lake Śniardwy and in the neighbourhood of this cage in Lake Lisunie. Duration of experiment 36 days (July 1st – August 5th 1961). Number of specimens per 1 m²

Tab. IV

Fauna	Neighbourhood of cages		Cages	
	initial state	final state	initial state	final state
Tendipedidae	80	28	360	244
Tendipes plumosus	0	0	120	89
Tendipes anthracinus	54	22	80	144
Einfeldia carbonaria	0	0	100	0
Cryptochironomus conjugens	0	0	40	0
Procladius	0	6	20	11
Ablabesmyia monilis	18	0	0	0
Cryptochironomus viridulus	8	0	0	0

In order to discover how the trophic situation in Lake Lisunie affects the benthos, about 5 kg of boiled, mashed potatoes were scattered on a selected site in the lake, following the method used in the study by Lastočkin (1949). Starting with the time at which the potatoes were thrown into the lake, series of samples of benthos were taken over the course of one month on the site itself and also from a place situated less than 100 m away from it. The organic fertilization caused a considerable increase in the numbers of *Tendipedidae* and *Oligochaeta* (Tab. V). Fertilization in addition induced acceleration o.

the growth of larvae; at first the age structure in the fertilized and control habitats was similar, but after a certain time the numbers of the older larvae in the fertilized habitat increased considerably (*Tendipes anthracinus* occurred almost exclusively in both habitats) (Tab. VI).

Comparison of numbers of benthos on the site fertilized by cooked potatoes and in the neighbourhood of the site. Lake Lisunie 1961. Number of specimens per 1 m²

Tab. V

Fauna	Habitat	
	fertilized	control
*Tendipedidae**	83	29
Oligochaeta	37	7
Chaoborus	12	18

*Almost exclusively *Tendipes anthracinus*.

Age structure (in percentages) of *Tendipes anthracinus* and variations in time on the fertilized site and its neighbourhood

Tab. VI

Period	Habitat			
	control		fertilized	
	percentage of larvae measuring:			
	0–10 mm	> 10 mm	0–10 mm	> 10 mm
13.VII. – – 29.VII.	80	20	71	29
30.VII. – – 15.VIII.	89	11	53	47
Mean values for entire period of the experiment	83	17	62	38

In order to obtain a more complete analysis of the state of benthos in Lake Lisunie comparison was made of the participation of invertebrate predators in three variants of the experimental cages (Tab. VII).

In the cage with mud and fauna from Lake Lisunie the participation of predators was more or less the same as that on the bottom of the lake throughout the whole study period. In the cage with mud and fauna from Lake Lisunie, into which larvae of *Tendipes plumosus* from Lake Śniardwy had been introduced, the percentage of predators was initially low, but increased considerably during

Comparison of ratio (in percentage) of numbers of predatory *Tendipedidae** to the total numbers of *Tendipedidae* in different variants of experimental cages and in their neighbourhood

Tab. VII

Neighbourhood of cages		Variants of experimental cages					
		I		*II*		*III*	
B	*E*	*B*	*E*	*B*	*E*	*B*	*E*
22.2	21.4	5.4	4.5	15.0	14.3	4.4	15.1

**Procladius* and *Ablabesmyia monilis*.
I – mud with fauna from Lake Śniardwy,
II – mud with fauna from Lake Lisunie,
III – mud with fauna from Lake Lisunie + 30 specimens of *Tendipes plumosus* from Lake Śniardwy.
B – beginning of experiment, *E* – end of experiment.

the course of the experiment. It may therefore be concluded that the conditions, unfavourable to *Tendipes plumosus*, in the habitat composed of mud from Lake Lisunie, rendered the larvae easily accessible to predators and caused the immigration of predators into the cage. In addition to the predatory *Tendipedidae*, *Hydracarina* (which are known to be predatory) were found in numbers up to 50 specimens/1 m^2 in this cage. In the cage with mud and fauna from Lake Śniardwy, where living conditions were better, the percentage of predators was small throughout the whole period (Tab. VII).

The increase in the percentage of predatory larvae when habitat conditions or the condition of the larvae were poorer, is confirmed by data given by several other authors (Morduchaj-Boltovskoj 1955, Jarošenko and Nabereżnyj 1959, Kajak 1963 and others).

SUMMARY OF RESULTS AND DISCUSSION

Lake Lisunie belongs to the category of lakes in which the amount of benthos fauna is very low, despite the considerable content of organic substance in the bottom sediments, and the accompanying high degree of oxygen content in the water at the bottom. The high oxygen content of the water enables the young stages of *Tendipedidae* to appear throughout a large part of the growing season, yet the numbers of both young and older larvae are very small. It would seem that the intensive reduction in numbers begins at the very early larval stages. Moreover, the introduction of large larvae of *Tendipes plumosus* from Lake Śniardwy resulted in a high mortality rate among them, being greater in the mud from Lake Lisunie than in the mud from Lake Śniardwy. It must therefore be concluded that the living conditions in Lake Lisunie are difficult not only for the young, but also for the older larvae.

It is an interesting fact here that the number of species is relatively high for a bottom habitat, but the majority of them only occur sporadically.

Variations in numbers in space – in two sections of the lake, and in time – over the period of the three study years, are relatively negligible; at no time was the amount of benthos large.

Increase in the numbers of benthos was obtained in two ways – by means or organic fertilization, and by placing local mud together with fauna into cages made of fine gauze. The numbers of mainly young larvae increased in the cages (probably as the result of the higher survival rate), while in the fertilized habitat the numbers of all the larval stages increased, development rate being far more rapid (and as a result the percent of young larvae decreased after a certain time). The results of the experiment with organic fertilization show that the food supply for the benthos is scanty. The increase in the number of larvae in the cages may also be interpreted in the same way (cf. Kajak 1964). These data point to food as the factor limiting the numbers of benthos in Lake Lisunie, despite the fact that the amount of organic substance in the muds is very considerable and oxygen conditions very good. With such an interpretation the relatively large number of species, with simultaneous scanty numbers of individuals, is also easy to understand – there are probably the individuals with better condition, or individuals which accidentally encountered locally better habitat, which survive. As a result of the poor condition of the majority of the larvae due to unfavourable food conditions, they form an easy prey for predators, which probably play a significant part in determining the numbers of benthos in Lake Lisunie.

A question which remains to be considered is the reason for the unfavourable trophic conditions and lack of suitable food. An increasingly large number of papers has appeared recently which draw attention to the important role of bacteria as food for benthos and demonstrate the correlation between abundance of bacteria and zoobenthos (Kusnecov 1959, Rodina 1949, 1961, 1962, Sorokin 1959).

Observations of the condition of dead *Tendipedidae* larvae provide evidence of the weak development of bacteria in Lake Lisunie – contrary to other eutrophic lakes, where the larvae decomposed very rapidly, undecomposed bodies of larvae were observed for a long time in the bottom habitat. Probably some substances occur in the mud and water at the bottom which inhibit the development of bacteria. This would be in agreement with the fact that the numbers of benthos in mud from Lake Śniardwy decrease after standing for a month on the bottom of Lake Lisunie, whereas a considerable increase in numbers occurred at this time in the habitat from which material was taken in Lake Śniardwy. On the other hand the trophic conditions of the mud from Lake Śniardwy placed in the bottom habitat of Lake Lisunie probably deteriorated and the amount of bacteria decreased.

The numerical level attained in the experiments with benthos in Lake Lisunie. although several times greater in comparison with the natural relations,

was not very high. The reason for this may be found in the habitat conditions referred to above, or in the fact that when the numbers of larvae are small the number of imagines and eggs are in consequence also small; it was not possible with the small experimental section of the lake and the comparatively short duration (one month) of the experiment to attain considerably higher numbers.

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UWAGI O PRZYCZYNACH NISKIEJ LICZEBNOŚCI BENTOSU W JEZIORZE LISUNIE

Streszczenie

Prace przeprowadzono na terenie polymiktycznego jeziora Lisunie o powierzchni 13 ha i głębokości maksymalnej około 8 m, odznaczającego się niskimi liczebnościami bentosu.

Liczebność w ciągu roku zmieniała się nieznacznie (w oparciu o materiały pobierane chwytaczem Ekmana w latach 1959–1961; maksymalne liczebności *Tendipedidae* jak również *Oligochaeta* nie dochodziły do 100 osobników na 1 m², *Chaoborus* okresowo osiągał liczebności do kilkuset osobników na 1 m²).

Stwierdzono występowanie na maksymalnej głębokości 10 gatunków *Tendipedidae*, przy czym dominowały: *Tendipes anthracinus*, *Tanytarsus gregarius* i *Procladius*.

Oprócz analizy składu gatunkowego i liczebności przeprowadzono eksperymenty terenowe, polegające na:

1) odgradzaniu wycinków środowiska w klatkach o rozmiarach 30 × 30 × 30 cm, z gazy młyńskiej o oczkach 0,5 × 0,5 mm (szczegóły metodyki – Kajak 1963),

2) wzbogacaniu troficznym wycinka środowiska gotowanymi tłuczonymi kartoflami,

3) introdukcji niektórych gatunków *Tendipedidae* z innego jeziora, o liczniejszym bentosie.

W klatkach eksperymentalnych uzyskano liczebności *Tendipedidae* kilkakrotnie wyższe, dzięki większej przeżywalności młodych larw. Także liczebności *Oligochaeta* były wyższe.

Również nawożenie organiczne spowodowało kilkakrotne zwiększenie liczebności *Tendipedidae* i *Oligochaeta* oraz przyspieszenie tempa wzrostu.

U *Tendipedidae* introdukowanych z jeziora Śniardwy, obserwowano spadek liczebności. Spadek ten był silniejszy przy umieszczeniu ich w mule z jeziora Lisunie niż w mule z jeziora Śniardwy.

Fakty te, w zestawieniu z omówioną niską liczebnością bentosu w jeziorze Lisunie, świadczą o niekorzystnych warunkach środowiskowych dla bentosu w środowisku dennym jeziora Lisunie, mimo znacznej ilości (62%) substancji organicznej i nasycenia tlenem wody przydennej.

Wzrost liczebności bentosu w efekcie nawożenia organicznego, jak również w klatkach eksperymentalnych (gdzie prawdopodobnie była wyższa liczebność flory bakteryjnej) świadczy o tym, że głównym czynnikiem ograniczającym liczebność bentosu w jeziorze jest sytuacja troficzna. Duże ilości substancji organicznej nagromadzone na dnie jeziora są prawdopodobnie niedostępne dla bentosu, na skutek istnienia warunków ograniczających rozwój mikroflory bakteryjnej. Stwierdzono, że udział procentowy drapieżnych bezkręgowców był tym większy, im gorsze były warunki środowiskowe, a w konsekwencji również kondycja larw niedrapieżnych.

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