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Comparison of offshore macrozoobenthos of the eutrophic Lake Gardzień and the alloiotrophic Lake Stęgwica

Porównanie makrozoobentosu pozalitoralowego eutroficznego jeziora Gardzień i alloiotroficznego jeziora Stęgwica

SUMMARY

The aim of the present paper was to compare offshore macrozoobenthos and selected abiotic parameters of water and bottom sediments of two shallow lakes: Lake Gardzień, a "typical" eutrophic lake, and the polyhumic, alloiotrophic Lake Stęgwica. As both lakes are located very close to each other and have a similar morphometry and trophy level, it is highly probable that the observed differences may be the effect of a different humic substance content.

It was found that the presence of humic substances did not significantly affect the taxonomic composition and the biodiversity of the bottom fauna. In contrast to the similar taxonomic composition, the density of zoobenthos in the polyhumic Lake Stęgwica was over 10 times greater than in Lake Gardzień, which was the consequence of the more numerous occurrence of all groups of bottom fauna, particularly Oligochaeta and *Chaoborus* larvae.

A distinct increase in the abundance of bottom fauna in the polyhumic lake may be the consequence of an improvement in the nutritional conditions in the sediments (an increase in the calorific value, development of microorganisms), as well as a decrease in the negative effect of any toxic substances.

STRESZCZENIE

Celem niniejszej pracy jest porównanie makrozoobentosu pozalitoralowego oraz wybranych parametrów abiotycznych wody i osadów dennych dwóch płytkich jezior: „typowego" eutroficznego jeziora Gardzień i polihumusowego, alloiotroficznego jeziora Stęgwica. Jako że oba jeziora są położone bardzo blisko siebie, mają podobną morfometrię i poziom trofii, jest wysoce prawdopodobne, że obserwowane różnice mogą być efektem różnej zawartości substancji humusowych.

Stwierdzono, że obecność substancji humusowych nie wpływa w sposób znaczący na skład taksonomiczny i bioróżnorodność fauny dennej. W przeciwieństwie do podobnego składu taksonomicznego zagęszczenie zoobentosu w polihumusowym jeziorze Stęgwica było ponad 10 razy większe niż w jeziorze Gardzień, co było konsekwencją liczniejszego występowania wszystkich grup fauny dennej, a zwłaszcza Oligochaeta i larw *Chaoborus*.

Wyraźny wzrost obfitości fauny dennej w jeziorze polihumusowym może być konsekwencją poprawy warunków pokarmowych w osadach (wzrost kaloryczności, rozwój mikroorganizmów), jak również zmniejszenia negatywnego oddziaływania ewentualnych substancji toksycznych.

Key words: macrozoobenthos, abiotic parameters, shallow lakes, humic substances

INTRODUCTION

Humic compounds (HC) have a significant impact on the functioning of aquatic ecosystems. Some of these features, such as acidity, buffering properties and high calorific value have a considerable impact on the formation of physical and chemical features of water, tripton or bottom deposits, and thus also the nutritional conditions for hydrobionts (Górniak 1996). Dissolved HC reduce the range of the photic zone (Wojciechowski 1987), with a simultaneous change in the spectrum reaching individual layers of water, and in the case of shallow lakes the bottom sediments as well. These compounds also have the ability to bind heavy metals and aromatic hydrocarbons, whereby they decrease their negative effect on aquatic organisms (Rav-Acha & Rebhun 1992). Moreover, the increase in the concentration of HC stimulates the development of some groups of microorganisms, and can also change the proportion in organic matter of individual fractions of varying proneness to decomposition by microorganisms (Górniak 1996).

Water bodies with a raised level of HC, in other words polyhumic (Mikulski 1982), are divided into two groups. The first includes lakes characterized by very low pH levels, high water transparency caused by a paucity of available biogens and low productivity (Hillbricht-Ilkowska et al. 1998). They are deceptively similar to oligotrophic lakes. The second group consists of lakes in which the inflow of humus is balanced by the inflow of lime – as in Lake Stęgwica. These are alloiotrophic lakes. They differ from the first group in their neutral or alkaline pH and the high concentration of biogens. In fact they are aquifers whose productivity is typical of eutrophic lakes (Górniak 1996). This author's contention that humic acids stimulate the production of phytoplankton in alloiotrophic lakes and also deactivate toxic compounds naturally secreted by some algae is worthy of attention.

Taking the above information into account, the main aim of this paper is the comparison of the taxonomic composition and abundance of bottom fauna inhabiting the offshore zone of two shallow water bodies: the eutrophic Lake Gardzień and the alloiotrophic Lake Stęgwica. In order to determine more precisely the mutual dependencies between the composition and abundance of macrozoobenthos and the habitat conditions, parallel measurements of certain physical and chemical parameters of the water and bottom sediments were carried out. The results obtained may increase the amount of information concerning the effect of various environmental factors on bottom fauna.

MATERIAL AND METHODS

Site description

The research was undertaken in two relatively small, shallow eutrophic lakes. They are located in the Iława Lake District in the same glacial rough, very close to each other (about 1 km), with identical orientation. As mentioned before, Lake Stęgwica is an alloiotrophic water body classified as a non-harmonic lake due to its considerable content of humic substances. Its characteristic feature is the strong brown colour of the water and sediments caused by the presence of humic substances reaching the lake with water running off a peat bog nearby. In contrast, Lake Gardzień (belonging to the harmonic lake group) is characterized by the greenish colour of the water and sediments, which suggests the development of phytobenthos. The basic morphometric data of the lakes under discussion are presented below:

	Gardzień	Stęgwica
Surface area (ha)	85.5	39.7
Maximum depth (m)	1.1	1.2
Average depth (m)	0.9	1.0
Maximum length (m)	4200	1900
Maximum width (m)	350	290

Sampling procedure

Bottom fauna

We selected 3 sampling stations in the offshore zone of each lake. The samples were taken from 24th September 1999 to 17th August 2000. We used an Ekman-Birge grab (catching area: 225 cm^2), 2–4 replicate subsamples depending on the abundance of zoobenthos. In each lake we collected 8 series of samples, generally at monthly intervals. Only in winter was sampling less frequent, as the ice cover was sometimes too thin for walking and too thick for using a boat. The samples were rinsed using a 0.5 mm sieve and preserved in 4% formaldehyde.

Abiotic parameters

Simultaneously with collecting the benthic samples, we monitored several physical and chemical parameters of water and bottom sediments. Water transparency was measured by means of a Secchi-disc. To assess the light conditions we used a Slandi LX204 luxometer. We calculated the vertical attenuation coefficient of light under water (E) (Scheffer, 1998:22,Eq.2.). Furthermore, to estimate the amount of light reaching the bottom, we multiplied the E value by the lake depth (D). This index (ED) is related to the shade level at the lake bottom – the higher the ED value, the less light reaches the bottom (Scheffer 1998). Moreover, we calculated euphotic depth (Scheffer, 1998:25, Eq.7). This is the depth beyond which the light level falls below 1% of the surface irradiation and is considered too low to maintain a positive net photosynthesis of algae.

We measured temperature, conductivity and oxygen concentration of the very surface and near-bottom water layer with a core sampler and a MultiLine P4 (WTW) Universal Pocket Sized Meter.

The bottom sediments (0–5 cm top layer) were collected with the core sampler and their water content measured (by oven-drying sediments to a constant weight at 104^{o}C), as well as their organic matter content (dried sediments were heated at 550^{o}C for 2 h). We also estimated sediment oxygen demand (SOD) by adding 300 ml of tap water oxygenated up to 100% to a special dish containing 20 cm^3 of fresh sediments. The diameter of an oxygen sensor matched tightly the outlet of the dish, which prevented oxygen exchange with the outside. Our preliminary trials showed that the oxygen concentration did not change ca. 15 min. after the end of the oxygenated process, so we assumed that oxygen losses in the pure tap water would be negligible. The oxygen uptake was measured over 1 h, at 20^{o}C. The sediments were kept in permanent resuspension by means of a magnetic stirrer, to sustain the water flow around the membrane of the oxygen sensor. For determination of bottom sediment particle-size composition fresh sediments (100 cm^3, 3 replicate subsamples) were washed through a series of sieves of 480, 280, 120, 60, and 20 µm mesh size. The volume of different fractions was measured and the results were given as a percentage of volume.

RESULTS

Abiotic environment

As seen from the data presented in Table 1, almost all (exception pH – lower in Lake Stęgwica) of the measured physical and chemical parameters of the water displayed similar values in both lakes. In contrast, the situation was quite different in the bottom sediments zone. Somewhat less light reached the bottom of

Table 1. Selected parameters of water and bottom sediments – average values

Water			
		Gardzień	Stęgwica
Secchi depth (m)		0.6	0.7
E		3.3	3.3
Euphotic depth (m)		1.4	1.4
Temperature (^{0}C)	surface	13.2	13.3
	bottom	13.0	13.2
Oxygen ($mg \cdot l^{-1}$)	s	12.6	11.0
	b	10.9	10.1
Conductivity ($\mu S \cdot cm^{-1}$)	s	177	203
	b	189	204
pH	s	9.9	6.8
	b	9.3	6.9
Bottom sediments (0–5 cm)			
Light conditions	ED	3.0	3.3
at the bottom	lux	5121	3681
Water content (%)		97.8	95.9
Organic matter content	(%)	68.3	57.2
	(mg)	122	238
SOD ($mg\ O_2 \cdot h^{-1}$)		2.3	4.2
Particle size	> 480 µm	2	2
	280–480	2	3
(% of volume)	120–280	19	20
	60–120	22	18
	20–60	34	29
	< 20	21	28

E – vertical attenuation coefficient of light under water
ED – a product of the vertical attenuation coefficient of light under water and lake depth
mg – organic matter content in mg of dry weight per 10 cm^3 of fresh sediments
SOD – sediment oxygen demand

Lake Stęgwica, the sediments were less hydrated, they differed in their organic matter content, they used a little more oxygen, and also had a higher proportion of the finest fraction.

Bottom fauna

In both of the examined lakes, offshore macrozoobenthos had representatives from only four taxonomic groups: insect larvae – Chironomidae, Chaoboridae, Ceratopogonidae and Oligochaeta, although the quantitative proportion between them varied (Tab. 2).

Table 2. Bottom fauna of lakes under study – average values

A – number of taxa (L), biodiversity (H), density (N, ind.$\cdot$m^{-2})

Bottom fauna	Gardzień	Stęgwica
Procladius sp. Skuse	36	117
Chironomus sp. (Meigen)	35	42
Tanytarsus sp. (u.d. Wulp)	29	-
Cladopelma lateralis (Goetghebuer)	6	1
Einfeldia dissidens (Walker)	2	19
Microchironomus tener (Kieffer)	2	69
Tanypus sp. (Meigen)	-	1
Polypedilum nubeculosum (Meigen)	-	1
Chironomidae non det.	14	5
Chironomidae – pupae	2	1
CHIRONOMIDAE – total	124	255
Potamothrix hammoniensis (Michaelsen)	3	528
Stylaria lacustris (Linnaeus)	1	-
Dero sp. Oken	-	4
Naididae	-	2
OLIGOCHAETA – total	4	534
CHAOBORIDAE	71	1533
CERATOPOGONIDAE	16	169
ZOOBENTHOS – total L	10	12
H	2.50	1.71
N	215	2492

B – biomass (g$\cdot$m^{-2})

Bottom fauna	Gardzień	Stęgwica
Procladius sp.	0.08	0.27
Chironomus sp.	1.30	1.31
Tanytarsus sp.	0.02	-
Cladopelma lateralis	< 0.01	< 0.01
Einfeldia dissidens	< 0.01	0.01
Microchironomus tener	< 0.01	0.03
Tanypus sp.	-	< 0.01
Polypedilum nubeculosum	-	< 0.01
Chironomidae non det.	0.07	0.01
Chironomidae – pupae	0.02	< 0.01
CHIRONOMIDAE – total	1.49	1.64
OLIGOCHAETA	0.01	0.85
CHAOBORIDAE	0.24	4.74
CERATOPOGONIDAE	0.07	0.25
ZOOBENTHOS – total	1.81	7.48

The biodiversity of the macrozoobenthos as a whole, calculated on the basis of the Shannon-Weaver coefficient, was greater in Lake Gardzień. On the other hand, the number of taxons was similar in both lakes. Among chironomids, larvae from the *Procladius* sp. *Skuse*, and *Chironomus* sp. (Meigen) genera were dominant in both lakes; moreover, in Lake Gardzień larvae of *Tanytarsus* sp. were also relatively numerous, while in Lake Stęgwica – *Microchironomus tener* (Kieffer). In each lake these forms constituted as much as over 90% of the total number of chironomids larvae. Oligochaeta were practically exclusively represented by individuals from the *Potamothrix hammoniensis* (Michaelsen) species.

The number of macrozoobenthos altogether was more than 10 times greater in Lake Stęgwica (almost 2.5 thousand ind./m^{-2}) than in Lake Gardzień (215 ind./m^{-2}). In the former, chaoborids larvae (62% of the total benthos density) and Oligochaeta (21%) were decidedly the most numerous, while in Lake Gardzień, Chironomidae (58%) and Chaoboridae (33%) larvae were clearly dominant.

Bottom fauna biomass was also greater – although not as distinctly as the number – in Lake Stęgwica (almost 7.5 g m^{-2}) compared to Lake Gardzień (1.81 g m^{-2}). In the former in this respect, Chaoboridae (4.74 g m^{-2}) and Chironomidae (1.64 g m^{-2}) larvae were dominant, whereas in Lake Gardzień a decided predominance of chironomids (1.49 g·m^{-2}) was recorded, which represented over 80% of the total macrozoobenthos biomass in this lake.

Summing up, we should state that the taxonomic composition of the bottom fauna in the examined lakes was similar, but in the alloiotrophic Lake Stęgwica the abundance, and particularly density, of macrozoobenthos was considerably greater.

DISCUSSION

Bottom fauna of the middle-lake zone of the examined lakes displays little diversity as regards quality, which may be the consequence of the homogeneity of the habitat (lack of macrophytes), as well as of the effect of certain constraining factors which allow only a few, most tolerant species to exist. The results obtained give us the reason to believe that the amount of oxygen does not have a limiting effect on macrozoobenthos, although in order to exclude completely the limiting impact of oxygen deficits, changes would have to be measured in the concentration of oxygen in interstitial water with increasing penetration into the sediments (Sweerts 1990).

It seems that the presence of humic substances does not significantly affect the taxonomic composition of bottom fauna. In both of the examined lakes a similar number of taxons was recorded, but the lower value of the Shannon-Weaver coefficient of biodiversity in the alloiotrophic lake Stęgwica is the consequence of the marked quantitative predominance of *Chaoborus* larvae and *Potamothrix hammoniensis*. Both among chironomids and oligochets, the most numerous are eurytopic forms, characteristic of strongly eutrophic waters, commonly occurring also in other water bodies of various types (Giziński & Żbikowski 1992). The only exception is the relatively high proportion of *Microchironomus tener* larvae in the polyhumic Lake Stęgwica. In analogous zones of other, equally shallow and eutrophic (but non-humic) lakes in the vicinity of Iława this taxon does not occur at all (Żbikowski, unpubl.) or – as in Lake Gardzień – its presence can be deemed symbolic. However, on the basis of research to date it is difficult to state categorically whether the increased proportion of the larvae mentioned is the consequence of greater concentrations of humic substances, especially as their density was not high.

In contrast to the similar taxonomic composition, the density of the bottom fauna in the polyhumic Lake Stęgwica was over 10 times that of Lake Gardzień, which was the result of the more numerous occurrence of all of the groups of macrozoobenthos, particularly the dominant one among Oligochaeta – *P. hammoniensis* – and *Chaoborus* larvae. The numerous occurrence of Oligochaeta deserves attention, its density in the polyhumic lake being about twice as high as Chironomidae larvae and over 130 times as high as in Lake Gardzień. This is rather surprising as Żbikowski (unpubl.) always recorded the opposite situation in similar, though non-humic lakes situated very close by, i.e. the quantitative predominance of chironomids larvae over oligochets. Similarly Jonasson (1975, 1978) says that Chironomidae larvae are more numerous in shallow lakes than Oligochaeta. It is possible that such a numerous occurrence of Oligochaeta is linked with the presence of humic substances in sediments. In this specific aspect, their high calorific value deserves attention (Górniak 1996), because it may visibly improve nutritional conditions of the zoobenthos. This is significant in so far as in shallow, polymictic lakes, silty, strongly hydrated bottom sediments very often undergo resuspension, and thus also mineralisation, which decreases their calorific value (Jonasson & Lindegard 1979). According to the cited authors the calorific value of the sediment is about twice as low as that of seston, which suggests that organisms that filter the suspension from the water feed on food that is more calorific than the food of typical silt-eating animals. This may explain the quantitative predominance of Chironomidae larvae over Oligochaeta in non-humic lakes since, according to Wolnomiejski et al. (2000), the main food of chironomids larvae is mostly newly sedimenting phytoplankton, and not detritus in bottom sediments. On the other hand, the decidedly greater density of a typical silt-eater, a representative of Oligochaeta – *P. hammoniensis* – in Lake Stęgwica may be the result of an improvement in nutritional conditions resulting from the presence of humic substances. Confirmation of this hypothesis may be the organic matter content, which is almost twice as high in the bottom sediments of this lake expressed in milligrams dry mass of organic matter contained in 10 cm^3 of fresh sediment. Moreover, it is not without importance that an increase in the concentration of humic compounds stimulates the development of certain groups of microorganisms (Górniak 1996) playing a very important role in the diet of animals, which may also contribute to the greater availability, absorbability, and also calorific value of the food mainly for compulsory silt-eaters.

The quantitative predominance of *Chaoborus* larvae in Lake Stęgwica is also rather surprising. In very similar (but non-humic) shallow, eutrophic lakes situated nearby Żbikowski (unpubl.) always recorded a distinct predominance of Chironomidae larvae over other elements of macrozoobenthos. It is very possible that such a numerous occurrence of *Chaoborus* may also be the consequence of the presence of humic compounds leading to the characteristic brown colour of the water (Pace & Cole 2002). Next according to Carpenter et al. (1985) in brown-water lakes the pressure of fish on the larvae under discussion is distinctly reduced since they become less visible to the fish, which consequently allows the larvae to attain greater numbers.

Żbikowski & Kobak (2007) found that in shallow, eutrophic lakes the taxonomic composition and the abundance of the bottom fauna were highly dependent on the amount of light reaching the bottom and the degree of absorption of oxygen by the bottom sediments. In the lakes being compared here, the values of these parameters are generally similar, the consequence of which may be the similar taxonomic composition of the bottom fauna. On the other hand, the distinct increase in its abundance in the polyhumic lake may be the result of an improvement in the nutritional conditions in the sediments (an increase in the calorific value, development of microorganisms), and also – as Rav-Acha & Rebhun (1992) and Górniak (1996) demonstrated – a decrease in the negative impact of any toxic substances.

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