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Research Article

USING MACROZOOBENTHOS TO ASSESS THE ECOLOGICAL CONDITION OF THE STARZYC LAKE (NORTH-WEST POLAND)

Ryszard Konieczny[1], Piotr Daniszewski[2]

[1] Institute of Technological and Life Sciences Falenty, Branch Poznań, 67 Biskupińska Str., 60-463 Poznań, Poland, e-mail: r.konieczny@itep.edu.pl

[2] Faculty of Biology, Department of Invertebrate Zoology and Limnology, University of Szczecin, 13 Wąska Str., 71-415 Szczecin, Poland, e-mail: daniszewski73@gmail.com

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ABSTRACT
In the summer of 2008–2009 species composition and quantity of macrozoobenthos in deposits samples collected with Ekman gripping device at 4 points of Starzyc Lake was studied. Lake Starzyc also called Chociwel is located in West Pomeranian Voivodeship and is adjacent to the town of Chociwel from South and South East of the city. In the collected material of the analysed lake macrozoobenthos organisms from the following classes were found: Oligochaeta, Hirudinea, Crustacea, Insecta and Bivalvia. The Insecta class was the most numerous one in respect of species found, including larvae of the following orders: Ephemeroptera (*Leptophlebia* sp., *Ephemera* sp., *Caenis macrura* (Stephens)), Trichoptera (Limnephilidae, Leptoceridae, *Cyrnus* sp.) Diptera and Megaloptera (*Sialis lutaria* L.). The density and biomass distribution in the analysed Starzyc Lake demonstrates the occurrence of unfavourable changes which may lead to eutrophication in the shallowest layers of the body reservoir and in the zone at the depth of 4.9 m. The littoral zone of the studied lake features high density and significant benthic fauna biomass with low values of PIE biodiversity index.

Keywords: water, lake, macrozoobenthos, European Union Water Framework Directive.

INTRODUCTION

Urbanization is the cause of many changes which are taking place in the environment, including those found in the catchment [1–6, 9–17, 21–23, 36–40, 48–67].

These alarming changes gave an impetus to taking suitable legal actions for the protection of water resources. European Union issued a series of regulations, the so-called "water directives", yet it recognized the need for introducing a coherent framework regulating the acts of law aimed at conservation of water resources in all EU member states [1–6, 9–17, 21–23, 36–40, 48–53].

Directive 2000/60/EC, the so-called Water Framework Directive (WFD), which entered into force in December 2000, constitutes such an integrated act of law [1–6, 9–17, 21–23, 36–40, 48–53]. The main objective of the WFD is providing access to good quality water to present and future generations as well as enabling the use of water by, inter alia, industry and agriculture, while simultaneously preserving and conserving the natural environment [6–17, 21–23, 36–40, 48–53].

EXPERIMENTAL

Lake Starzyc, also called Chociwel, is located in West Pomeranian Voivodeship and is adjacent to the town of Chociwel from South and South East of the city [28]. Starzyc is the second largest lake in the municipality of Chociwel. Has an area of 59.2 ha, its length is approximately 3000 m and the width of the average 200 m, its depth is 9 m. The Lake is located at 68 m above the sea level. flows through the settlements not Krąpiel River [28].

The Starzyc lake is characterized by the following indicators of morphometric [28]:

- latitude – N 53°27'39",
- longitude – E 15°20'43",
- mirror surface water – 59.2 ha,
- capacity – 1575.8 m^3,
- maximum depth – 6.1 m,
- average depth – 2.7 m,
- maximum length – 1960 m,
- maximum width – 370 m,
- the length of the coastline – 5175 m.

Research was carried out in the years 2008–2009, in the period from July. At the place of sampling pH was determined (Fig. 1).

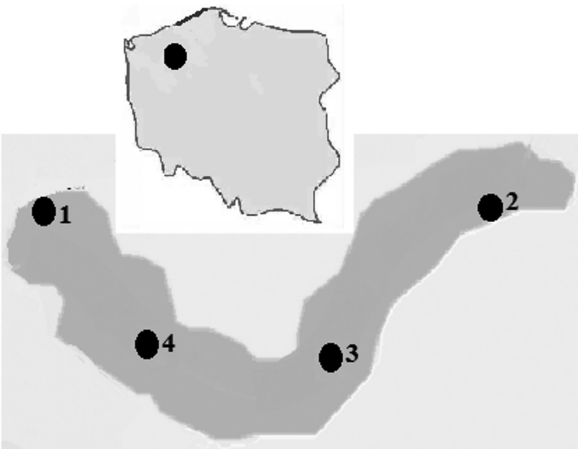

Fig. 1. Location of the measuring point in Starzyc lake. *Source: Google maps 2012/own elaboration/*

Benthic material (sediments) along with benthic fauna was collected with Ekman-Brige grab sampler (surface of 225 cm^2). Following that, the type of sediment and depth of the bottom were determined (Table 1). Benthic fauna was collected during two summer months from 6 sampling stations located in the littoral and profundal zone (altogether 4 samples).

The location of research stations resulted from tributary positions and water reservoir morphometry. At each station 2 sub-samples were collected.

The collected material was rinsed on a sieve with a mesh size of 0.5 mm and it was conserved in 4% formalin solution. Animals were segregated macroscopically and under a stereomicroscope (PZO make) into individual taxa, and their concentration was referenced to 1 m^2 of the surface of the lake bottom. Benthic fauna taxa collected from individual stations were weighted with an accuracy of 0.01 g after having been dried on filter paper. Fauna biomass was presented in grams of wet mass per 1 m^2 of the bottom.

Frequencies (F) were calculated from the following formula:

$$F = \frac{n}{N} \cdot 100\%$$

where: n – number of stations where a given taxon occurred,
N – number of research stations.

Dominance index (D) was calculated from the following formula:

$$D = \frac{S(a)}{S} \cdot 100\%$$

where: $S(a)$ – is a sum of individuals belonging to taxon „a",
S – is a total biomass of individuals of macrozoobenthos in all samples.

The dominance index and frequency values were interpreted in accordance with the criteria specified by Kasprzak and Niedbałe (1981).

PIE biodiversity index was determined through the application of the following formula:

$$PIE = \frac{N}{N+1}(1 - \sum p_i^2) \quad p_i = \frac{n_i}{N}$$

where: N – total number of individuals,
p_i – share of i species in total number of individuals.

At work, particular attention has focused on a comparison of the two zones – litoral, profundal of the Starzyc Lake.

RESULTS AND DISCUSSION

The results of the Starzyc Lake are presented in Tables 1 to 7.

In the collected material of the analysed lake macrozoobenthos organisms from the following classes were found: Oligochaeta, Hirudinea, Crustacea, Insecta and Bivalvia. The Insecta class was the most numerous one with respect to the species found, including larvae of the following orders: Ephemeroptera (*Leptophlebia* sp., *Ephemera* sp., *Caenis macrura* (Stephens)), Trichoptera (Limnephilidae, Leptoceridae, *Cyrnus* sp.) Diptera and Megaloptera (*Sialis lutaria* L.), (details are presented in Tables 2 to 5).

Average concentration of total benthic fauna in the summer of 2008 in Starzyc Lake amounted to 685 ind.·m^{-2}, whereas average biomass – 6.6 g_{mm}/m^2 (Tables 4 and 6). The Oligochaeta, Hirudinea and the Chironomidae larvae were of

Table 1. Type of bottom deposits, depth and pH of interstitial waters in measurement points on Starzyc Lake (July, 2008; July, 2009)

Sampling site no.	Type of bottom deposits	Depth [m]	pH of intersitial waters
1	Fine sand. leftover cane. the remains of shells	1.5	7.09
2	Fine sand. autochthonous detritus. the remains of shells	2.1	7.45
3	Hamlets tanatocenozowy. seashell scrap (Dreissena)	3.5	7.19
4	Hamlets tanatocenozowy. seashell scrap (Dreissena). detritus	4.9	7.37

Table 2. Qualitative amount bottom fauna in the Starzyc Lake in July of 2008

Lp.	Taxa	F [%]	Sampling sites			
			Litoral		Profundal	
			1	2	3	4
1.	Oligochaeta	100	+	+	+	+
2.	Hirudinea					
	Piscicola sp.	25	–	+	–	–
	Helobdella stagnalis L.	25	–	+	–	–
3.	Isopoda – *Asellus aquaticus* Racov.	25	+	–	–	–
4.	Ephemeroptera larvae					
	Leptophlebia sp.	25	–	+	–	–
	Ephemera sp.	25	–	+	–	–
	Caenis macrura (Stephens)	25	+	–	–	–
5.	Trichoptera larvae					
	Limnephilidae	25	–	+	–	–
	Cyrnus sp.	25	+	–	–	–
	Leptoceridae	25	–	+	–	–
6.	Diptera larvae					
	Chironomus f.l. plumosus L.	100	+	+	+	+
	Chaoborus sp.	25	–	–	+	–
	Procladius sp.	50	+	+	–	–
7.	Bivalvia – *Dreissena polymorpha* Pall.	25	–	+	–	–
8.	Megaloptera larvae – *Sialis lutaria* L.	25	+	–	–	–
Number of taxa			7	10	3	2

Explanation: F – Turnou.

the greatest significance in the littoral zone, constituting 92% of benthic fauna density, whereas only representatives of the Oligochaeta and the Chironomidae larvae were found in the profundal zone.

Average concentration of total benthic fauna in the summer of 2009 in Starzyc Lake amounted to 694 ind.$\cdot$m^{-2}, whereas average biomass – 7.3 g_{mm}/m^2 (Tables 5 and 6). The Oligochaeta, Hirudinea and the Chironomidae larvae were of the greatest significance in the littoral zone, constituting 94% of benthic fauna density, whereas only representatives of the Oligochaeta and the Chironomidae larvae were found in the profundal zone.

The study of 2008 in macrofauna frequency related to the benthic zone showed that the sand-eating Oligochaetes and the Chironomidae larvae (F = 100%) were the most commonly found, and they were categorized according to Tischler's classification as dominant species. *Chironomus f.l. plumosus* (F = 100%) were the dominant species among the Chironomidae larvae, while *Procladius* sp. and *Chaoborus* sp. are categorized as accessoric species.

The remaining identified species of benthic fauna were accidental species F = 25%.

In 2009 attendance related macrofauna test bed showed that the most common they were mud-eating and larvae chironomids, oligochaeta (F = 100%), which consisted of Tischlera classification of the species is absolutely solid. Among larvae of Chironomidae the species is absolutely integral

Table 3. Qualitative amount bottom fauna in the Starzyc Lake in July of 2009

Lp.	Taxa	F [%]	Sampling sites			
			Litoral		Profundal	
			1	2	3	4
1.	Oligochaeta	100	+	+	+	+
2.	Hirudinea					
	Piscicola sp.	25	–	+	–	–
	Helobdella stagnalis L.	25	–	+	–	–
3.	Isopoda – *Asellus aquaticus* Racov.	50	+	+	–	–
4.	Ephemeroptera larvae					
	Leptophlebia sp.	25	–	+	–	–
	Ephemera sp.	25	+	–	–	–
	Caenis macrura (Stephens)	25	+	–	–	–
5.	Trichoptera larvae					
	Limnephilidae	25	–	+	–	–
	Cyrnus sp.	25	+	–	–	–
	Leptoceridae	25	–	+	–	–
6.	Diptera larvae					
	Chironomus f.l. plumosus L.	100	+	+	+	+
	Chaoborus sp.	25	–	–	+	–
	Procladius sp.	50	+	+	–	–
7.	Bivalvia – *Dreissena polymorpha* Pall.	25	–	+	–	–
8.	Megaloptera larvae – *Sialis lutaria* L.	25	+	–	–	–
Number of taxa			8	10	3	2

Explanation: F – Turnout.

Table 4. Condensing of macrozoobenthos – C (10^2 individuals per m^{-2}) and wet mass M (g_{mm} m^{-2}) at examined measurement stations on Starzyc Lake (July of 2008)

Lp.	Taxa	Sampling sites							
		Litoral				Profundal			
		1		2		3		4	
		C	M	C	M	C	M	C	M
1.	Oligochaeta	7.5	2.8	9.3	3.7	5.2	1.6	4.6	1.1
2.	Hirudinea	0	0	2.7	0.5	0	0	0	0
	Piscicola sp.	0	0	1.6	0.3	0	0	0	0
	Helobdella stagnalis L.	0	0	1.1	0.2	0	0	0	0
3.	Isopoda – *Asellus aquaticus* Racov.	1.2	0.3	0	0	0	0	0	0
4.	Ephemeroptera larvae	0.8	0.2	0.6	0.24	0	0	0	0
	Leptophlebia sp.	0	0	0.4	0.17	0	0	0	0
	Ephemera sp.	0	0	0.2	0.07	0	0	0	0
	Caenis macrura (Stephens)	0.8	0.2	0	0	0	0	0	0
5.	Trichoptera larvae	1.4	0.9	1.6	0.8	0	0	0	0
	Limnephilidae	0	0	0.9	0.6	0	0	0	0
	Cyrnus sp.	1.4	0.9	0	0	0	0	0	0
	Leptoceridae	0	0	0.7	0.2	0	0	0	0
6.	Diptera larvae	2.5	2.3	3.3	2.9	1.7	3.6	0.7	1.9
	Chironomus f.l. plumosus L.	0.9	1.2	0.5	1.1	0.4	0.8	0.7	1.9
	Chaoborus sp.	0	0	0	0	1.3	2.8	0	0
	Procladius sp.	1.6	1.1	2.8	1.8	0	0	0	0
7.	Bivalvia – *Dreissena polymorpha* Pall.	0	0	0.1	0.7	0	0	0	0
8.	Megaloptera larvae – *Sialis lutaria* L.	0.8	2.9	0	0	0	0	0	0
Σ		14.2	9.4	17.6	8.8	6.9	5.2	5.3	3.0
Biodiversity index PIE		1.084		0.841		0.539		0.716	

Table 5. Condensing of macrozoobenthos – C (10^2 individuals per m^{-2}) and wet mass M (g_{mm} m^{-2}) at examined measurement stations on Starzyc Lake (July of 2009)

Lp.	Taxa	Sampling sites							
		Litoral				Profundal			
		1		2		3		4	
		C	M	C	M	C	M	C	M
1.	Oligochaeta	5.5	2.8	9.5	3.9	6.2	2.7	5.4	2.1
2.	Hirudinea	0	0	1.5	0.4	0	0	0	0
	Piscicola sp.	0	0	0.9	0.3	0	0	0	0
	Helobdella stagnalis L.	0	0	0.6	0.1	0	0	0	0
3.	Isopoda – *Asellus aquaticus* Racov.	0.6	0.1	0.9	0.3	0	0	0	0
4.	Ephemeroptera larvae	1.1	0.38	0.4	0.1	0	0	0	0
	Leptophlebia sp.	0	0	0.4	0.1	0	0	0	0
	Ephemera sp.	0.3	0.08	0	0	0	0	0	0
	Caenis macrura (Stephens)	0.8	0.3	0	0	0	0	0	0
5.	Trichoptera larvae	0.8	0.9	1.2	1.6	0	0	0	0
	Limnephilidae	0	0	0.4	0.5	0	0	0	0
	Cyrnus sp.	0.8	0.9	0	0	0	0	0	0
	Leptoceridae	0	0	0.8	1.1	0	0	0	0
6.	Diptera larvae	1.4	1.5	1.3	1.0	1.9	2.9	1.9	3.5
	Chironomus f.l. plumosus L.	0.9	1.4	0.5	0.7	1.6	2.1	1.9	3.5
	Chaoborus sp.	0	0	0	0	0.3	0.8	0	0
	Procladius sp.	0.5	0.1	0.8	0.3	0	0	0	0
7.	Bivalvia – *Dreissena polymorpha* Pall.	0	0	0.7	2.3	0	0	0	0
8.	Megaloptera larvae – *Sialis lutaria* L.	0.6	2.8	0	0	0	0	0	0
Σ		10.0	8.5	15.5	9.6	8.1	5.6	7.3	5.6
Biodiversity index PIE		1.287		0.847		0.507		0.635	

Table 6. Macrozoobenthos condensing in summer of Starzyc Lake

Lp.	Taxa	Density of macrozoobenthos [indiv.· m^{-2}]		
		2008	2009	average
1.	Oligochaeta	362	384	373
2.	Hirudinea	32	21	27
3.	Isopoda – *Asellus aquaticus* Racov.	15	19	17
4.	Ephemeroptera larvae	18	20	19
5.	Trichoptera larvae	19	24	22
6.	Diptera larvae	193	158	176
7.	Bivalvia – *Dreissena polymorpha* Pall.	8	30	19
8.	Megaloptera larvae – *Sialis lutaria* L.	38	35	37
Σ		685	694	690
Biodiversity index PIE		0.795	0.819	0.807

Table 7. Comparison of macrozoobenthos condensing in summer in some lakes of Western and Northern Polish

Taxa	Density of macrozoobenthos (indiv.· m^{-2})				
	Lakes				
	Jamno (Piór-Zasada 1997)	Gardno (Piór-Zasada 1997)	Krzynia (Gostomczyk 2005)	Lubowidzkie (Obolewski 2006)	Starzyc (by author)
Oligochaeta	272	1669	666	979	373
Hirudinea	0	11	48	99	27
Crustacea	0	0	146	2	0
Ephemeroptera larvae	0	2	22	4	19
Megaloptera *Sialis lutaria*	0	0	28	6	37
Trichoptera larvae	0	0	53	12	22
Diptera larvae	487	2427	674	276	176
Caretopogonidae	0	2	0	0	0
Gastropoda	0	0	7	0	0
Bivalvia – Dreissena polymorpha	0	0	123	4	19
Σ	759	4111	1767	1382	690
Numer of taxa	2	5	9	8	7
Biodiversity index PIE	0.920	0.973	1.990	0.940	0.807

were *Chironomus f.l. plumosus* (F = 100%). However, *Asellus aquaticus* Racov. and *Chaoborus* sp. are categorized as accessoric species.

Comparison of average density of benthic fauna in the studied lake to the studies of benthic fauna of selected lakes in north-western Poland shows substantial changes in the density of the analysed taxa (details are presented in Table 7). Against this background, Starzyc Lake features a significant macrozoobenthos density, since higher values were found only in Lakes Gardno, Lubowidzkie [43] and Krzynia Lake [23] (details are presented in Table 7).

In relation to other lakes, a large number of taxa occur in Starzyc Lake, however, as a result of its non-harmonic distribution, it does not translate into the value of PIE biodiversity index (details are presented in Tables 4 to 7).

On the basis of the summer analyses of macrozoobenthos studies in the lakes of northern and western Poland presented by Piór-Zasada 1997, Gostomczyk 2005, Obolewski 2006 conclusion arises that the Oligochaeta develops with high intensity in Starzyc Lake (details are presented in Tables 6 and 7).

The dominance of the Oligochaeta, the Chironomidae larvae and a high number of *Chaoborus* sp. in north-western Poland lakes demonstrates the eutrophication processes in those water bodies (details are presented in Tables 6 and 7).

The density and biomass distribution in the analysed Starzyc Lake demonstrates the occurrence of unfavourable changes which may lead to eutrophication in the shallowest layers of the body reservoir and in the zone at the depth of 4.9 m (details are presented in Tables 1 to 5). The littoral zone of the studied lake features high density and significant benthic fauna biomass with low values of PIE biodiversity index (details are presented in Tables 4 to 7). These conditions may have been caused by contamination inflow from the farming fields surrounding the lake as well as by intensive tourist traffic. Favourable trophic conditions in Starzyc Lake are found at the depth of 2.1 m, where high macrozoobenthos density and biomass are accompanied by the highest biodiversity index (details are presented in Tables 6 and 7).

CONCLUSION

During the summer stagnation the benthic fauna of Starzyc Lake was qualitatively poor, what constitutes a proof of its significant biological degradation.

The Oligochaeta dominated in the macrozoobenthos of the studied lake in respect of its density, while the Chironomidae larvae dominated in respect of wet mass. It is a situation typically found in eutrophicated water reservoirs.

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