

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

Ryszard Konieczny¹, Piotr Daniszewski²

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

Received: 2013.06.26

Accepted: 2013.09.06

Published: 2013.10.10

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 Krapiel 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 m³,
- 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).

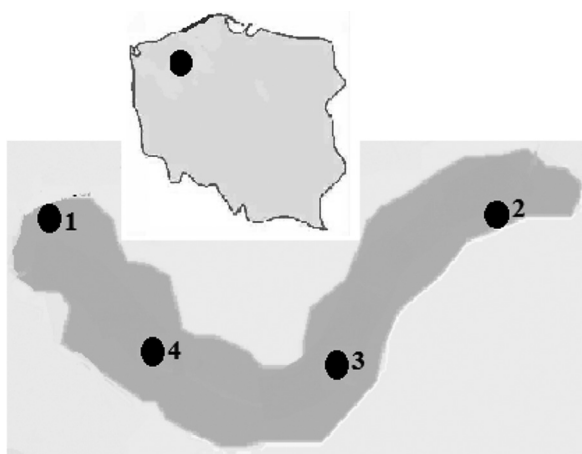


Fig. 1. Location of the measuring point in Starzyc lake. Source: Google maps 2012/own elaboration/

Benthic material (sediments) along with benthic fauna was collected with Ekman-Brige grab sampler (surface of 225 cm²). 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 m² 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 m² 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 Niedbała (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 – littoral, 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}/m² (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 interstitial 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 tanatocenzowy. seashell scrap (Dreissena)	3.5	7.19
4	Hamlets tanatocenzowy. 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					
	<i>Piscicola</i> sp.	25	-	+	-	-
	<i>Helobdella stagnalis</i> L.	25	-	+	-	-
3.	Isopoda – <i>Asellus aquaticus</i> Racov.	25	+	-	-	-
4.	Ephemeroptera larvae					
	<i>Leptophlebia</i> sp.	25	-	+	-	-
	<i>Ephemera</i> sp.	25	-	+	-	-
	<i>Caenis macrura</i> (Stephens)	25	+	-	-	-
5.	Trichoptera larvae					
	Limnephilidae	25	-	+	-	-
	<i>Cyrnus</i> sp.	25	+	-	-	-
	Leptoceridae	25	-	+	-	-
6.	Diptera larvae					
	<i>Chironomus f.l. plumosus</i> L.	100	+	+	+	+
	<i>Chaoborus</i> sp.	25	-	-	+	-
	<i>Procladius</i> sp.	50	+	+	-	-
7.	Bivalvia – <i>Dreissena polymorpha</i> Pall.	25	-	+	-	-
8.	Megaloptera larvae – <i>Sialis lutaria</i> 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.·m⁻², whereas average biomass – 7.3 g_{mm}/m² (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 accessory 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 Tischler's 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					
	<i>Piscicola</i> sp.	25	–	+	–	–
	<i>Helobdella stagnalis</i> L.	25	–	+	–	–
3.	Isopoda – <i>Asellus aquaticus</i> Racov.	50	+	+	–	–
4.	Ephemeroptera larvae					
	<i>Leptophlebia</i> sp.	25	–	+	–	–
	<i>Ephemera</i> sp.	25	+	–	–	–
	<i>Caenis macrura</i> (Stephens)	25	+	–	–	–
5.	Trichoptera larvae					
	Limnephilidae	25	–	+	–	–
	<i>Cyrnus</i> sp.	25	+	–	–	–
	Leptoceridae	25	–	+	–	–
6.	Diptera larvae					
	<i>Chironomus f.l. plumosus</i> L.	100	+	+	+	+
	<i>Chaoborus</i> sp.	25	–	–	+	–
	<i>Procladius</i> sp.	50	+	+	–	–
7.	Bivalvia – <i>Dreissena polymorpha</i> Pall.	25	–	+	–	–
8.	Megaloptera larvae – <i>Sialis lutaria</i> 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
	<i>Piscicola</i> sp.	0	0	1.6	0.3	0	0	0	0
	<i>Helobdella stagnalis</i> L.	0	0	1.1	0.2	0	0	0	0
3.	Isopoda – <i>Asellus aquaticus</i> 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
	<i>Leptophlebia</i> sp.	0	0	0.4	0.17	0	0	0	0
	<i>Ephemera</i> sp.	0	0	0.2	0.07	0	0	0	0
	<i>Caenis macrura</i> (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
	<i>Cyrnus</i> 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
	<i>Chironomus f.l. plumosus</i> L.	0.9	1.2	0.5	1.1	0.4	0.8	0.7	1.9
	<i>Chaoborus</i> sp.	0	0	0	0	1.3	2.8	0	0
	<i>Procladius</i> sp.	1.6	1.1	2.8	1.8	0	0	0	0
7.	Bivalvia – <i>Dreissena polymorpha</i> Pall.	0	0	0.1	0.7	0	0	0	0
8.	Megaloptera larvae – <i>Sialis lutaria</i> 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
	<i>Piscicola</i> sp.	0	0	0.9	0.3	0	0	0	0
	<i>Helobdella stagnalis</i> L.	0	0	0.6	0.1	0	0	0	0
3.	Isopoda – <i>Asellus aquaticus</i> 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
	<i>Leptophlebia</i> sp.	0	0	0.4	0.1	0	0	0	0
	<i>Ephemera</i> sp.	0.3	0.08	0	0	0	0	0	0
	<i>Caenis macrura</i> (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
	<i>Cyrmus</i> 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
	<i>Chironomus f.l. plumosus</i> L.	0.9	1.4	0.5	0.7	1.6	2.1	1.9	3.5
	<i>Chaoborus</i> sp.	0	0	0	0	0.3	0.8	0	0
	<i>Procladius</i> sp.	0.5	0.1	0.8	0.3	0	0	0	0
7.	Bivalvia – <i>Dreissena polymorpha</i> Pall.	0	0	0.7	2.3	0	0	0	0
8.	Megaloptera larvae – <i>Sialis lutaria</i> 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 – <i>Asellus aquaticus</i> Racov.	15	19	17
4.	Ephemeroptera larvae	18	20	19
5.	Trichoptera larvae	19	24	22
6.	Diptera larvae	193	158	176
7.	Bivalvia – <i>Dreissena polymorpha</i> Pall.	8	30	19
8.	Megaloptera larvae – <i>Sialis lutaria</i> 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 <i>Sialis lutaria</i>	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
<i>Bivalvia</i> – <i>Dreissena polymorpha</i>	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 accessory 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.

REFERENCES

1. Bajkiewicz-Grabowska E. 1985. Struktura fizyczno-geograficzne zlewni jako podstawa oceny dostawy materii biogennej do jezior. Pr. Stud. Geogr., 7: 65-89.
2. Bajkiewicz-Grabowska E. 1987. Ocena naturalnej podatności jezior na degradację i rola zlewni w tym procesie. Wiad. Ekol., 33(3): 279-289.
3. Bajkiewicz-Grabowska E. 1990. Stopień naturalnej podatności jezior na eutrofizację na przykładzie wybranych jezior Polski. Gospod. Wod., 12: 270-272.
4. Bécares E. 2006. Limnology of natural systems for wastewater treatment. Ten years of periences at the Experimental Field for Low-Cost Sanitation in Mansilla de las Mulás (León, Spain). Limnetica, 25: 143-154.
5. Cyraniak E., Daniszewski P., Draszawka-Bołzan B. 2012. Characteristics of selected quality parameters of the swimming pools port in Świnoujście. International Letters of Chemistry, Physics and Astronomy, 5, 88-95.
6. Cyraniak E., Daniszewski P., Draszawka-Bołzan B. 2012. Characteristics of selected quality parameters of the swimming pools port in Szczecin. International Letters of Chemistry, Physics and Astronomy, 5, 96-103.
7. Cyraniak E., Daniszewski P., Draszawka-Bołzan B. 2013. Characteristics of the physical and chemical parameters of water in pools of port in Szczecin in 2009. International Letters of Chemistry, Physics and Astronomy, 1, 70-77.
8. Cyraniak E., Daniszewski P., Draszawka-Bołzan B. 2013. Characteristics of the physical and chemical parameters of water in pools of port in Świnoujście in 2009. International Letters of Chemistry, Physics and Astronomy, 1, 78-84.
9. Daniszewski P. 2012. Activity of total alkaline phosphatase in water of the Barlinek lake International Letters of Chemistry, Physics and Astronomy, 1, 13-16.
10. Daniszewski P. 2012. Water quality of the surfaces waters of the Barlinek Lake of the during stagnation time of 2008. International Letters of Chemistry, Physics and Astronomy, 2, 35-41.
11. Daniszewski P. 2012. Activity of total alkaline phosphatase in water of the Barlinek Lake of the during stagnation time of 2008. International Letters of Chemistry, Physics and Astronomy, 2, 42-45.
12. Daniszewski P. 2012. The C:N ratio of the analyzed of bottom sediments of the Barlinek Lake (spring, summer and autumn of 2008). International Letters of Chemistry, Physics and Astronomy, 2, 46-52.
13. Daniszewski P., Draszawka-Bołzan B. 2012. Influence of waste disposal sites on the environment in Miedzyzdoje of 2005–2007. International Letters of Chemistry, Physics and Astronomy, 3, 73-79.
14. Daniszewski P., Draszawka-Bołzan B. 2012. Water quality of the surfaces waters of the swimming pools port in Swinoujście. International Letters of Chemistry, Physics and Astronomy, 4, 96-102.
15. Daniszewski P., Konieczny R. 2013. Evaluation of chemical and physico-chemical indicators of water and bottom macrofauna the Resko Lake on the basis of the European Union Water Framework Directive. International Letters of Chemistry, Physics and Astronomy, 5, 86-96.
16. Daniszewski P., Konieczny R. 2013. Heavy Metal Content in Water of Resko Lake (North-West Poland) International Letters of Chemistry, Physics and Astronomy, 8(3), 279-287.
17. DIRECTIVE 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy. 2000. Off. J. Eur. Commun. L 327, 22 December.
18. Domagała J., Kubiak J., Tadjewski A., Trzebiatowski R. 1982. Możliwości chowu pstrąga tęczowego w eutroficznych wodach estuariowych. Zesz. Nauk. AR Szczec. Ser. Ryb. Mor. Technol. Żywn., 93(12): 81-103.
19. Eaton A.D., Clesceri L.S., Greenberg A.E., (Eds) 1995. Standard Methods for the Examination of Water and Wastewater. Ed. American Public Health Assoc., Washington.
20. Ejsmont-Karabin J. 1995. Rotifer occurrence in relation to age, depth and trophic state of quarry lakes. Hydrobiologia, 313/314, 21-28.
21. Fleituch T., Soszka H., Kudelska D., Kownacki A. 2002. Large Rivers, vol. 13, Arch. Hydrobiol. Suppl., 141/3, No 3-4, 225-239
22. Garcia-Criado F., Tomé A., Vega F.J., Antolin C. 1999. Hydrobiologia, Kluwer Academic Publishers, Leon, 394, 209-217.
23. Gostomeczyk J. 2005. Makrozoobentosu characteristics of wypłyconego reservoir dam Krzynia. Master's thesis, PAP Słupsk.
24. Jańczak J. 1996. Atlas jezior Polski. T. 1. Bogucki Wydawnictwo Naukowe, Poznań.
25. Kajak Z. 1979. Eutrofizacja jezior. PWN, Warszawa: 1-233.
26. Kajak Z. 1980. Influence of phosphorus loads and of some limnological processes on the purity of lake water. Hydrobiologia, 72: 43-50.
27. Kalff J. 2002. Limnology. Prentice Hall Ltd., New Jersey: 1-592.
28. Kasprzak K., Niedbała W. 1981. The methods used in soil zoology. PWN, Warszawa.
29. Kownacki A., Soszka H. 2004. Guidelines for the evaluation of the status of rivers on the basis of

- macroinvertebrates and for intakes of macro-invertebrate samples in lakes, Warsaw, 51.
30. Kubiak J. 1983. Nitrogen, Phosphorus and Primary Production in the Pomeranian Bay. *Acta Hydrochim. Hydrobiol.*, 11: 439-447.
 31. Kubiak J. 2001. Hydrochemistry of Wolin Island Lakes. *Folia Univ. Agric. Stettin. Piscaria*, 218(28): 63-76.
 32. Kudelska D., Cydzik D., Soszka H. 1994. Wytyczne monitoringu podstawowego jezior. *PIOŚ*, Warszawa: 1-42.
 33. Lampert W., Sommer U. 2001. Ecology of inland waters. Scientific Publishing PWN, Warsaw, 415.
 34. Leopold M., Bnińska M., Nowak W. 1986. Commercial fish catches as an index of lake eutrophication. *Arch. Hydrobiol.*, 106: 513-524.
 35. Macioszczyk A. 1987. Hydrochemistry. Ed. Geology, Warsaw 475.
 36. Mudroch A., Azcue J. M., Mudroch P. (Eds) 1997. Influence of the use of a drainage basin on physical and chemical properties of bottom sediments of lakes. Lewis publishers Boca Raton, New York, London, Tokyo.
 37. Nemerow N.L. 1985. Stream, Lake, Estuary, and Ocean Pollution. Van Nostrand Reinhold Company, New York.
 38. Obolewski K. 2006. Characteristic of periphyton inhabiting reed, *Phragmites australis* and artificial substrate in the Lubowidzkie Lake. *Arch. Envir. Protec.*, 32(3): 67-82.
 39. Pejler B., Berzinš B. 1989. *Hydrobiologia*, 186/187: 137-144.
 40. Piór-Zasada A. 1997. Makrobentos przymorskich Lakes: Jamna, Gardna Wielka and Łebska with special consideration of *Oligochaeta*. Master's thesis. PAP Słupsk.
 41. Stumm W., Morgan J., 1996. Aquatic chemistry. Chemical equilibrium and rates in natural waters. John Wiley and Sons, Inc. New York: 1-1022.
 42. Szczerbowski J.A. 1993. Rybactwo śródlądowe. *IRŚ*, Olsztyn: 1-569.
 43. Sládeček V. 1973. *Arch. Hydrobiol. Beih./Ergebn. Limnol.*, 7: 1-218.
 44. Sládeček V. 1983. *Hydrobiologia*, 100: 169-201.
 45. Tiwana N.S., Jerath N., Singh G., Ravleen (Eds.), 2005. Heavy metal pollution in Punja Rivers, in Newsletter Environmental Information System (ENVIS). Punjab State Council for Science and Technology, India, 3(1), 3.
 46. Tórz A., Kubiak J., Nędzarek A. 2000. Naturalna podatność na degradację jezior Koprowo, Liwia, Łuża i Resko Przymorskie [In: Naturalne i antropogeniczne przemiany jezior]. *Materiały 4. Konferencji Limnologicznej, Zalesie 18-20 września 2000*. *UMW*, Olsztyn: 161-173.
 47. Van Urk G., de Vaate B. 1990. *Limnologie Aktuell*, 1, 131-145.
 48. Vollenweider R.A. 1968. Scientific fundamentals of the eutrophication of lakes and flowing waters, with particular reference to nitrogen and phosphorus as factors in eutrophication. *DAS/CSIO/68.27*, OECD, Paris, 192.
 49. Wright J.F., Moss D., Armitage P.D., Furse M.T. 1984. *Freshwat. Biol.*, 14, 221-256.
 50. Zdanowski B. 1983. *Ekol. Pol.*, 31, 287-308, 333-352.