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Ecological Status of the Lake Durowskie in Poznan Based on Benthic Macro-invertebrates

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Introduction

Lake Durowkie located Wagroviec has a high ecologic and cultural value in the region. As one of the main income sources of the city of Wagroviec is tourism and recreational activity in this lake, it also has a high economic value.

As result of human activity, Lake Durowskie has a poor ecological condition; this has reduced the ecological services proposed by the lake. For example as a result of algae bloom (mainly of Cyanobacteria) which has happened recently every year around august, some of the recreational activities are stopped in that period. The lake is in a chain of lakes connected by river Struga Gołańska. These river and lakes are at exposure of nutrients and pollutant from agricultural lands and industrial areas. Also in the Wagroviec city although there are not many industrial activities, the lake receives nutrients and also it is polluted by recreational activities which take place in the lake. The eutrophic condition of the lake which has been shown in the previous studies has had a considerable impact on the ecologic condition of the lake.

This situation has been identified by local government of Wagroviec, which under the tuition of scientist has started a restoration plan in the lake in 2009. This plan is planned as two main restoration actions, first, the installation of two aerators and second, bio-manipulation. The idea of the aerators is to increase the oxygen concentration in the lake (mainly in the hypolimnion), the first aerator start to work on the end of April 2009 and is located in the southern part of the lake, the second one start work in July 2009 and is located in the north of the lake. The efficiency of the restoration actions are not assessed yet. Regarding, aerators it is expected that due to the short time passed from its installation the oxygen concentration has not changed significantly.

For assessing the quality of water and ecological condition of the Durowskie Lake chemical analysis and biological survey were done. Beside macrophytes and algae, benthic macro-invertebrates were assessed as indicator of the ecological status of the lake.

By analyzing the composition, abundance, diversity and sensitive taxa of benthos invertebrates we can have an indication of the water quality; nutrient concentration, dissolved oxygen, pH, and so forth in the different areas or levels in the lake (Littoral, sub-littoral and profound).

Freshwater benthic macro-invertebrate communities are composed primarily of insect larvae, mollusks, and worms. They are an essential link in the aquatic food web, providing food for fish and consuming algae and aquatic vegetation. The presence and distribution of macro-invertebrates in streams can vary across geographic locations based on elevation, stream gradient, and substrate. These organisms are sensitive to disturbances in stream chemistry and physical habitat, both in the stream channel and along the riparian zone. Alteration of the physical habitat or water chemistry of the stream can have direct and indirect impacts on their community structure. Because of their relatively long life cycles (approximately 1 year) and limited migration, benthic macro-invertebrates are particularly susceptible to site-specific stressors.

Benthic macro-invertebrates make good indicators of watershed health because they:

1) live in the water for all or most of their life
2) stay in areas suitable for their survival
3) are easy to collect
4) differ in their tolerance to amount and types of pollution
5) are easy to identify in a laboratory
6) often live for more than one year
7) have limited mobility
8) are integrators of environmental condition

They can be used as indicators for enrichment/eutrophication and organic loading/reduced DO:

Enrichment/eutrophication. Wetland invertebrates respond strongly to trophic condition. Abundance generally increases with increased nutrient concentrations and species richness may decrease or increase. Particular species assemblages of invertebrates have commonly been reported to be useful indicators of lake trophic state and may find similar usage in wetlands. These include:

aquatic worms (Oligochaeta) ;
midges (Chironomidae) ;
snails (Gastropoda); and
clams (Sphaeriidae).

In particular, the ratios of (a) tubificid worms to aquatic insects, (b) the chironomid subfamilies Tanypodinae and/or Chironomini to the subfamily Orthocladiinae), and/or (c) cladocerans to rotifers, have been reported to increase with increasingly eutrophic conditions. As species shifts occur with increasing eutrophication, chironomid species richness may decline; however, chironomid biomass and/or abundance increase. Indeed, chironomid emergence was recommended as an efficient indicator of secondary production in lakes.

Organic loading/reduced DO. Excessive organic loading of surface waters is known to alter community composition, usually reduces invertebrate diversity and evenness, and sometimes reduces density and biomass.

Under moderate loading, attached algae may increase and consequently, herbivorous mayflies and midges may dominate the community. However, if turbidity and hydroperiod conditions allow submersed or floating-leaved aquatic plants to out-compete algae, other aquatic invertebrates may become dominant.

Some scientists recently underlined several disadvantages of the existing benthic indices:

1) they represent a static expression of an ecological condition,

2) they are not explicitly links to changes in ecological functions,

3) they may not be specific with respect to different kinds of stressors

4) they are subject to underlying taxonimic changes across estuarine gradients

5) their use can be labor intensive

6) they are not applied consistently across biogeographic provinces

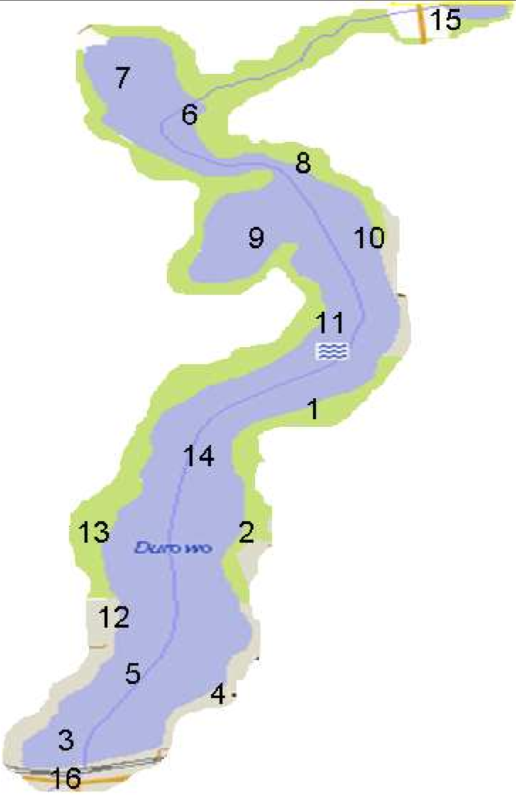
Methods

Sampling methodology

The samples of zoobenthos were collected in 14 different places of the lake and 2 places in the Struga Gołańska River, one the inflow and the other in the outflow. All the samples were collected between 19th and 25th of July 2009.

The 14 sampling points in the lake were assigned into 4 different categories. Four of the sampling points belong to the pelagial, two to the aerator zone (one sample in each aerator), five to littoral zones near forest and three belong to littoral zones near urban area(Table 1 and Figure 1).

In the sampling zones five samples (grabs) were taken from each pelagial, eight samples (grabs) from each littoral zone and ten from each river.



1. Littoral with reed near forest cover,
2. Littoral near urban area,
3. Pelagial near dam,
4. Littoral near urban area,
5. Pelagial (Aerator I)
6. Littoral near Struga Gołaniecka River,
7. Pelagial,
8. Littoral (Bulrush near forest cover),
9. Pelagial,
10. Pelagial (aerator II),
11. Littoral with reed,
12. Littoral near urban area,
13. Littoral with reed near forest cover,
14. Pelagial,
15. Inflow of Struga Gołaniecka River,
16. Outflow of Struga Gołaniecka River

Figure 1: Distribution of the sampling points in lake Durowskie

Table 1: Sampling points

Zone	Point
Littoral Forest	1 – 6 – 8 – 11 - 13
Littoral Urban	2 – 4 – 12
Aerator	5 – 10
Pelagial	3 – 7 – 9 – 14

Two core samplers were used, in order to take the sediment samples with the organisms. The first core sampler called „Czapla” (figure 2) was used to collect samples from shallow waters (littoral part of the lake) with a depth of 2 meters or less. The second sampler called „Kajak” (figure 3) was used to collect samples from deeper parts of the lake including the part with the maximum depth of 14.6 meters.

Samples of zoobenthos from all places were washed on a sieve (figure 4) and then were kept in plastic boxes filled with water. Afterwards organisms longer than 2 mm were separated (figure 5) from the sediment, dried, weighted, and put in a test tube with alcohol (70%), except for Oligochaeta which were put with formaldehyde (4%).

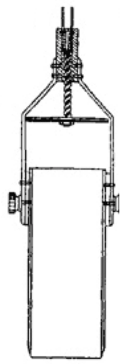
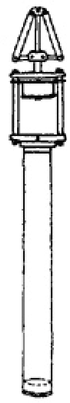
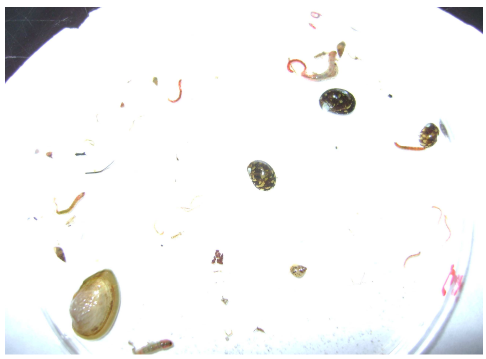
	

Figure 2, core sampler ‘Czapla’	Figure 3, core sampler ‘Kajak’
	
Figure 4: sieve	Figure 5: Zoobenthos selection

In the laboratory a stereoscopic microscope was used for the identification and counting of the different species based on the book “Bezkręgowce wód śródlądowych” (Annex I).

Index description

To analyze the information obtained during the sampling and give answers of the state of the water quality, EPT index, Shannon-Wiener index and BMWP-PL (Biological Working Party Score) were calculated, how to obtain these indexes is explained bellow.

EPT index: an index of water quality based on the abundance of three pollution-sensitive orders of macroinvertebrates relative to the abundance of a hardy species of macroinvertebrate. It is calculated as the sum of the number of Ephemeroptera, Plecoptera, and Trichoptera divided by the total number of midges (Diptera: Chironomid).

$$\frac{\text{Ephemeroptera + Plecoptera + Trichoptera}}{\text{Chironomids}}$$

Shannon-Wiener index: is one of several diversity indices used to measure diversity in categorical data. It is simply the information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness.

$$H_S = -\sum_{i=1}^{S} p_i \bullet \ln p_i$$

1. *ni:* The number of individuals in species i; the abundance of species i.
2. *S:* The number of species. Also called species richness.
3. *N:* The total number of all individuals
4. *pi:* The relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community:

According to Water Framework Directive, the relationship between the indices and ecological level is as following:

High status: bigger than 4 bits / individual
Good status: 4 -3 bits / individual
Moderate status: 3-2 bits/ individual
Poor status: 2-1 bits/individual
Bad status: 1-0 bits/individual

BMWP-PL (Biological Monitoring Working Party index adopted to polish conditions)

The BMWP method provides a score for each macro-invertebrate family that is primarily dependent on its sensitivity to organic pollution. This method is intended to be applied in Poland, operating with a modified BMWP discrimination table.

This index has 2 components:

1) One common taxa list (annex II), the following categorization is developed based on the scoring to different taxa:

I Class BMWP-PL over 100

II Class BMWP-PL 70 – 99

III Class BMWP-PL 40 – 69

IV Class BMWP-PL 10 – 39

2) Calculating biodiversity by diversity index (d)

$$d = s/\log N$$

d : the index of biodiversity

s : the amount of families of invertebrates on a certain station

logN : average condensation of families per m2

A 5-scale water quality index is the following:

Class I > 5,50

Class II 4,00 – 5,49

Class III 2,50 – 3,99

Class IV 1,00 – 2,49

Class V < 1

Results

Abundance of species and individuals in different sampling points is shown in the map (figure 6 and annex III). Littoral zones have more species and individuals than pelagial zones. Considering the lake, station 2 (littoral-urban) and station 4 (littoral-urban) had the highest number of species: 15 and 11 species respectively. Also in the same stations the species were more abundant: 94 and 60 individuals respectively. In pelagial zones, in station 5 (aerator I), station 9 (aerator II) and station 14 (middle of the lake) there were not much difference in the number of species; there were no species found in the station 3 and 7. About the rivers, there were 6 species (211 individuals) in station 15 (inflow river) and 8 species (268 individuals) in station 16 (outflow river). Overall, in the northern half of the lake there is less species and individuals than the southern part.

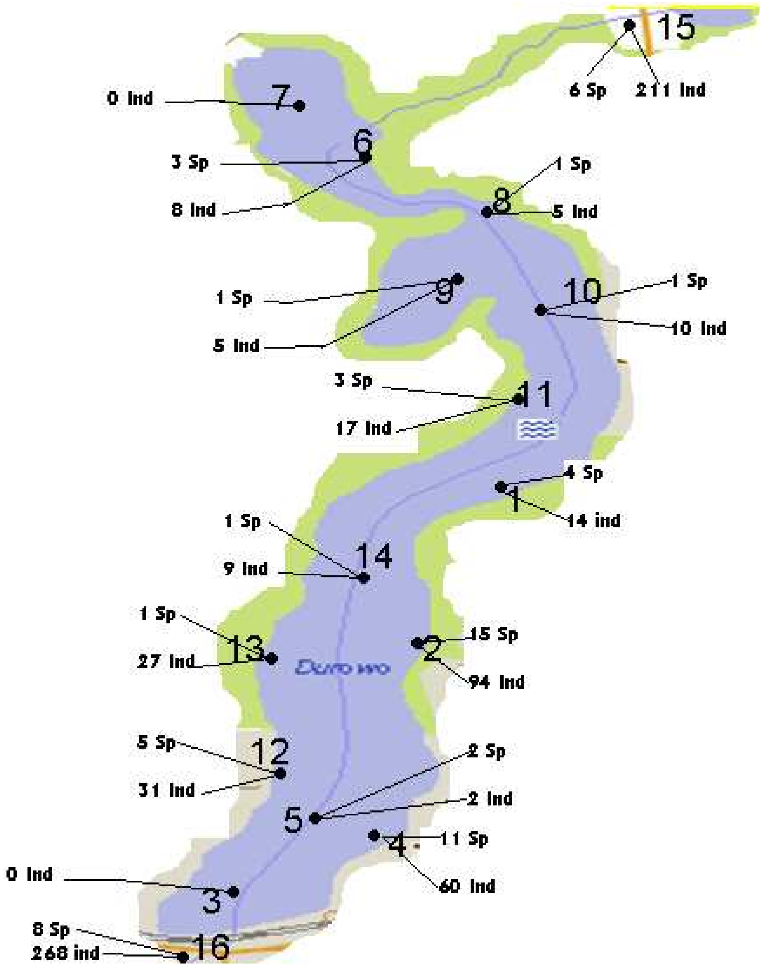


Figure 6: Distribution of abundance of species in the lake, (Sp. Species, Ind., individuals).

Looking at macro-invertebrates in the lake, it is seen that that the Chironomidae family (Chironamidae and Chaobarus) and Gastropoda class are the most abundant ones per area (per m²) (figure 7). Considering biomass, Chironamidae, Gastropoda and Trichoptera are the ones that have the highest biomass per area (mg/m²) (figure 8). In comparison, the abundance and biomass of others benthic macro-invertebrates is much lower.

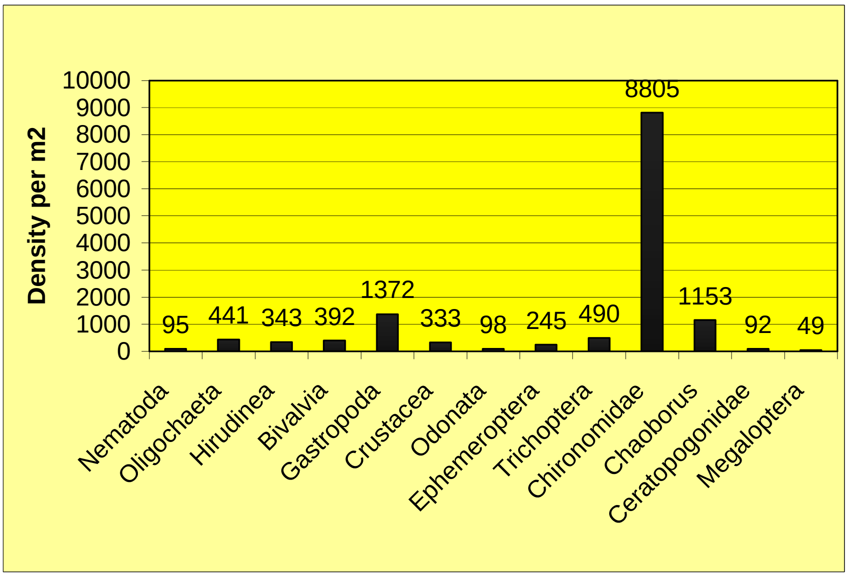


Figure 7: Density of benthic macro-zoobenthos in the lake Durowskie (per m2)

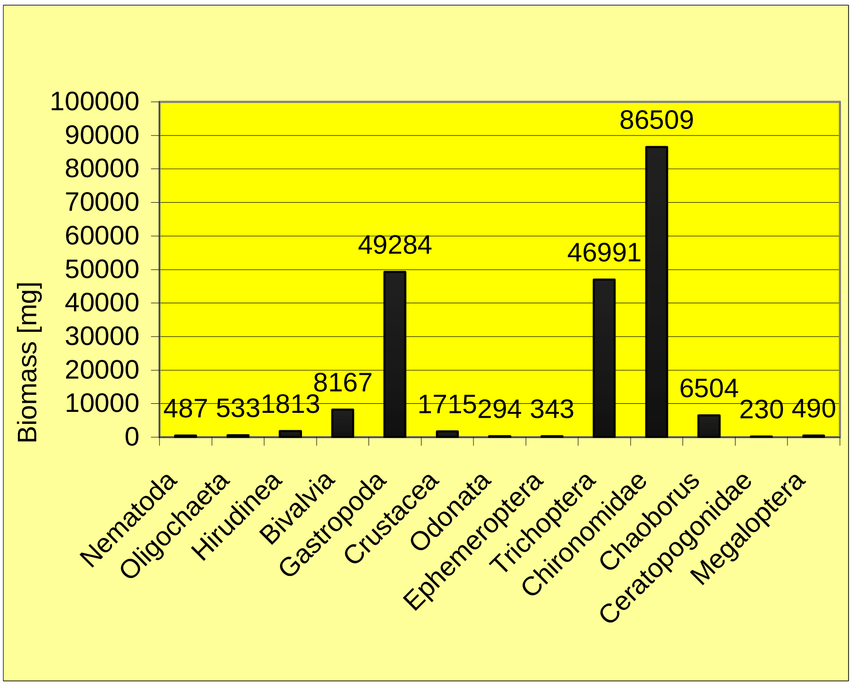


Figure 8: Biomass of benthic macro-zoobenthos in the lake Durowskie (mg/m2)

Considering average species diversity in different zones of the lake, littoral zones of the lake have higher species diversity. In littoral zones near urban areas the species are more diverse than the littoral zones near forest areas. Between the pelagial zones near aerator and the pelagial zones elsewhere there is only a small difference in the species diversity, even thought near the aerators the diversity is higher (figure 9).

In Figure 10 that average number of individuals of benthos macro-invertebrates in different zones of the lake is shown. The same pattern as diversity of species is observed here; in littoral-urban zones the macro-invertebrates are more abundant than littoral-forest. And in pelagial zones near aerators there are more individuals of macro-invertebrates than in other pelagial areas, but the difference is small.

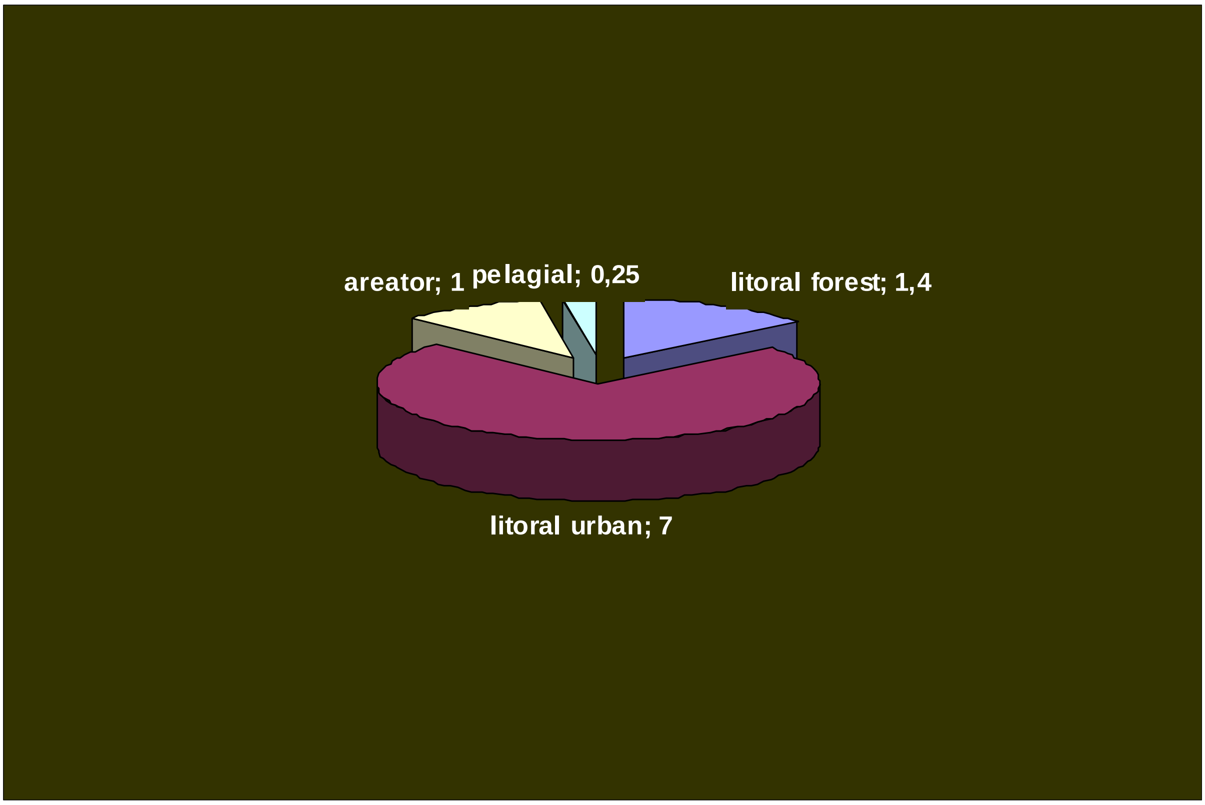


Figure 9: Species types (average) in different zones of the lake Durowskie

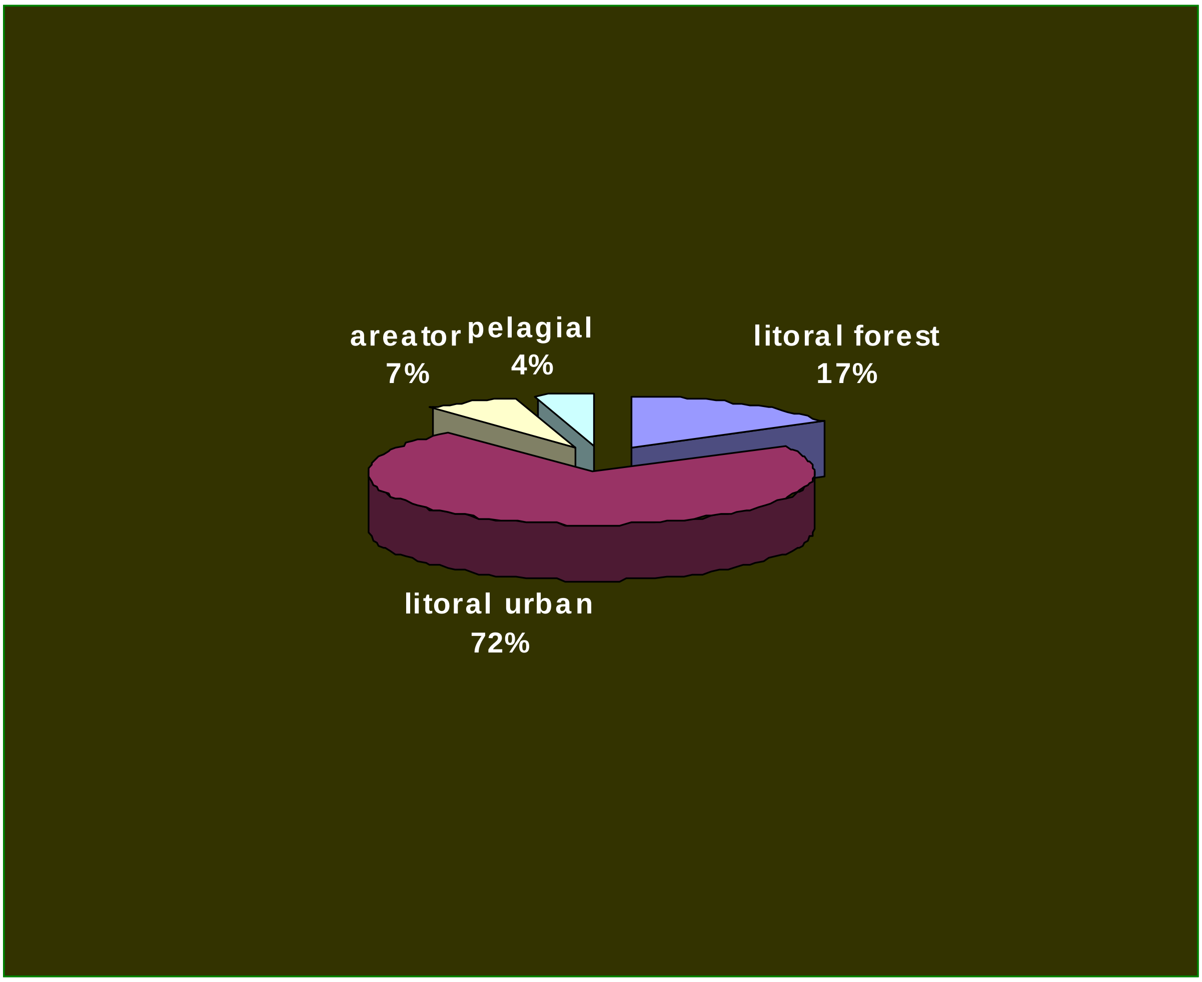


Figure 10: Individual species Counts (average) in different zones of the lake Durowskie

EPT index for all the stations in the lake:

EPT index is calculated for all the stations separately. As there were no Ephemeroptera, Plecoptera and Trichoptera in most of the sampling points, so the EPT index for most of them was zero. Station 4 which is a littoral-urban station in southern part of the lake had the highest EPT index, after that station 2 (which is a littoral-urban station near boats) and station 1 (littoral-forest station with reed) had the highest EPT index. These stations are at the east and southern east part of the lake.

EPT index in river outflow is higher than river inflow, but the difference is small.

Table 2: EPT index for all the stations in the lake Durowskie

Sampling station	EPT index
1 Littoral with reed near forest cover	**0.09**
2 Littoral urban near boats	**0.125**
4 Littoral urban south-east	**0.176**
15 River inflow	**0.017**
16 River outflow	**0.03**
3,5,6,7,… All other stations	**0**

Shannon-Wiener index for 4 zones of the lake:

Shannon-Wiener index is calculated for 4 zones of the lake (Table 3).According to categorization of water quality by Shannon index done by Water Framework Directive, water quality in the 4 zones of the lake is categorized as poor status (index, 1 to 2) and bad status (index, 0 to 1).

According to Shannon index, biodiversity in littoral-urban zone is higher than littoral-forest. Also pelagial areas near aerators have higher Shannon index than other pelagial zones, but the difference is very small. According to categorization of water quality by Shannon index done by Water Framework Directive littoral-urban zone have poor status (index, 1 to 2) and other zones have a worse condition: bad status (index, 0 to 1).

Table 3: Shannon-Wiener index in the different zones of the lake Durowskie

Zone	H'
Littoral forest	0,506
Littoral Urban	1,62
Pelagial	0
Aerator	0,28

BMWP-PL index

This index was calculated for the inflow and outflow rivers (Struga Gołaniecka River). By the two component separately (BMWP-PL and d index) and also overall, the water of inflow and outflow rivers is categorized as water with poor quality (table 4).

Table 4. BMWP index for inflow and outflow rivers

Sampling station	BMWP-PL	Categoty by BMWP-PL	d index	Category by d index	Category overall
15 river inflow	21	IV (poor)	1.53	IV (poor)	IV (poor)
16 river outflow	20	IV (poor)	1.25	IV (poor)	IV (poor)

Conclusions

Overall the benthic macro-invertebrate biodiversity in the lake and rivers is very low, and the species that are sensitive to the polluted status as Trichoptera, Ephemeroptera, Pleotera are rarely found in the lake and the river, and the most common are the Chironomidae and Oligochaeta which are tolerant to pollution.

According to benthic macro-invertebrates indices which are calculated here (Shannon-Weaver, EPT and BMWP-PL index) the ecological level in the lake and in the rivers is poor. This is supported by other biological indices (macrophytes, algeas) and chemical indices (O2, PH, Chl a, NH4…), that all show that the lake has a eutrophic or even hypertrophic condition. For example the amount of oxygen is very low after 4 meters of depth in the lake.

The littoral-urban zones have an overall better ecological level than littoral-forest zone of the lake according to Shannon and EPT indices. Probably this difference is because in the littoral urban areas the predators of zoobenthos have no place to hide (low coverage of macrophytes and more recreational activities in urban zones), therefore they don't hunt in those areas, this makes a more suitable environment for zoobenthos.

Pelagial-zones near aerator have the same water quality as pelagial zone elsewhere, according to Shannon and EPT indices; this may indicate that the aerator is not effectively oxygenating water which can be because of the lack of enough wind power necessary for its function. Overall the Shannon and EPT index is very low for pelagial zones. It should be mentioned that pelagial zones have lower species diversity and abundance even in oligotrophic lakes but here also the lack of oxygen cause lower biodiversity. Further monitoring is needed to assess the efficacy of the restoration plans; to find the main sources of pollution, and to find more effective way to control the pollution and to restore the lake.

Applicability of the indices:

Some scientists believe that, Shannon Index shows the abundance and species richness. But the high Shannon Index doesn't mean the better water quality. It has two factors which haven't been considered in Shannon Index. One is the abiotic factor. Due to the oxygen depletion, the deeper lake layer is harder for the benthic life. The littoral zone's Shannon index is higher than the Pelagial zone. It is mainly because of the site condition. Another factor is the species uniqueness is not considered either. There are two types of species. One is pollution sensitive and another one is pollution tolerant.

BMWP-PL index takes species uniqueness into account and it is also adapted to the Polish conditions. But it is only applied to river and there is no scientific support for the application to the lake ecosystem.

The indices based on benthic macro-invertebrates are not commonly used in EU; the methodology is not consistent across EU. Also there is not enough information available for comparison to reference. Their use is at early stage of development, and their applicability to lake is moderate.

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