Ecological state of the lake during restoration measures using macroinvertebrates.

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1. Introduction

The lakes in the Pałuki region in western Poland are facing the consequences of various human activities. Changes in land use and increasing leisure activity are continuous threats to the ecosystem. Eutrophication decreases the water quality by changing the content of oxygen and nutrients. Furthermore, toxic chemicals and habitat changes affect the species composition in lakes. In the end, a degraded ecosystem will also affect the economic and social use of the lake and will reduce the benefits humans obtain from nature. Hence, regular monitoring is of high importance.

Assessing the status of a lake, macroinvertebrates can serve as biological indicators. According to the U.S. Environmental Protection Agency (EPA, 2012) and Muralidharan et al. (2010), macroinvertebrates can be used as indicators because of the following characteristics:

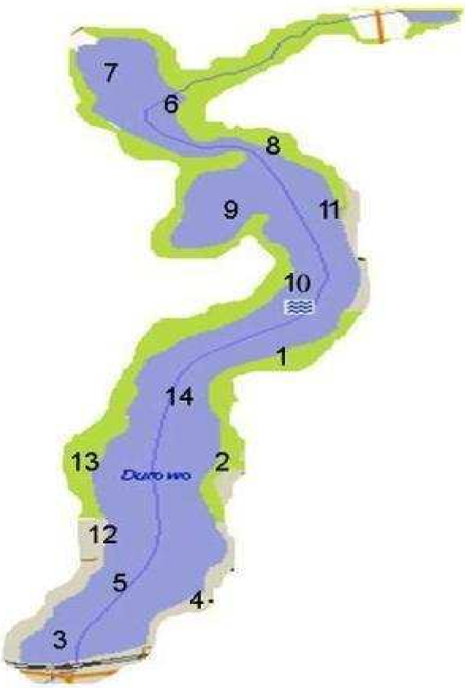
- They live in water for all or most of their life.
- They stay in areas suitable for their survival.
- They are easy to collect.
- They differ in their tolerance to amount and types of pollution.
- They are easy to identify in a laboratory.
- They often live for more than one year.
- They have limited mobility.
- They are integrators of environmental condition.
- They can recover rapidly.
- There is a high variety of species.

The Water Framework Directive (WFD, 2000) determines the goals for the protection of aquatic ecosystems in Europe. Within this framework, macroinvertebrates function as one aspect to classify a lake. According to the WFD, lakes can be distinguished into different status': high status, good status and moderate status. Lakes of high status are close to pristine conditions and are inhabited by disturbance-sensitive species. In contrast, lakes of moderate status show species indicating pollution. Disturbance-sensitive species are missing. Lakes of good status provide habitats for most sensitive species.

The aim of the study is to investigate the current ecological status of Lake Durowskie referring to different species of macroinvertebrates and their abundance. Hence, different sampling sites are compared with each other. Due to studies carried out in previous years, a comparison of the results to detect a long term trend is possible. This study seeks to give recommendation for the improvement of the ongoing lake management.

2. Methodology

Fig. 1. Sites of sampling



Number of sites	Sites description
1	Littoral with reeds near forest cover
2	Littoral near urban area
3	Pelagial near dam
4	Littoral near urban area
5	Pelagial (aerator 1)
6	Littoral near Struga Golaniecka River
7	Pelagial
8	Littoral (bulrush near forest cover)
9	Pelagial
10	Pelagial (aerator 2)
11	Littoral with reeds
12	Littoral near urban area
13	Littoral with reeds near forest cover
14	Pelagial

- We took samples from 14 sites along the lake from 2nd to 7th of July, 2012. The 14 sampling of the lakes were assigned to 6 different categories:

    1. Pelagial : 4 sampling sites
    2. Aerator I & II zones: 1 sampling sites each
    3. Littoral (forest): 5 sampling sites
    4. Littoral (urban): 3 sampling sites

1. Steps of taking samples and investigating

a. Fieldwork:

- Collecting samples from deeper parts of the lake using Kajak sampler:

10 samples were taken at each site

- Collecting samples from shallow water using Czapla sampler

Czapla sampler was used to take samples near the littoral sites with the depth not bigger than 2m. 17 samples were taken from littoral zones.

- Washing samples: using a sieve

Samples from different sites were washed separately and stored in different plastic boxes filled with water.

b. Lab analysis:
- Sorting out microinvertebrates:

Microinvertebrates were taken out from samples by tweezers

- Identifying species:

The macroinvertebrates were identified to the species level using the key (Jan Igor Rybak, 2000; Adrzej Kołodziejczyk and Paweł Koperski, 2000; Chiriac and Udrescu, 1965)

- Calculating: number of individuals and biomass

Number of individuals was multiplied by 23 in order to find the density per square meter

Biomass was multiplied by 23 in order to find total biomass of each species per square meter

c. Data analysis:

The Shannon-Wiener Index, Eveness and diversity indices were used to measure diversity for macroinvertebrates according to Shaw (2003). The Shannon-Wiener Index is calculated from the abundances of each species (abundance of the species/total abundances)

$$H' = -\sum_{i=1}^{S} p_i \ln p_i$$

Where S is the total number of species and p_i is the frequency of the *i*th species (the probability that any given individual belongs to the species, hence p).

Equitability (E) or eveness index is calculated as:

$$E = \frac{H'}{H_{max}} = \frac{-\sum p_i \ x \log(p \ )}{\log(S)}$$

where E is equitability (Eveness) and S is the number of species or lower taxonomic level used.

Margalef Index - a measure of species diversity

It is calculated from the total number of species present and the abundance or total number of individuals. The higher the index the greater the diversity

Da = (S-1)/log to base e N

where

Da = Margalef Index

S = the number of species

N= the total number of individuals

The EPT Index is named for three orders of aquatic insects that are common in the benthic macroinvertebrate community: Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera(caddisflies).

The EPT Index is based on the premise that high-quality streams usually have the greatest species *richness.* Many aquatic insect species are intolerant of pollutants and will not be found in polluted waters. The greater the pollution, the lower the species richness expected, as only a few species are pollutant tolerant.

Ratio of EPT and Chironomidae: The EPT/Chironomidae Index is calculated by dividing the sum of the total number of individuals classified as *Ephemeoptera, Plecoptera,* and *Trichoptera* by the total number of individuals classified as *Chironomidae.*

The biological monitoring working party (BMWP) is a procedure for measuring water quality using species of macroinvertebrates as biological indicators.

The method is based on the principle that different aquatic invertebrates have different tolerances to pollutants

Table 1. The five classes of water quality according to BMWP score and diversity index

Class	BMWP score	Range	Diversity Index
I	> 100	1	> 5,5
II	70-99	2	4,0-5,4
III	40-69	3	2,5-3,9
IV	10-39	4	1-2,4
V	< 10	5	< 1

A numerical value has been attributed to each taxon based on its tolerance to organic pollution, one being tolerant and ten being intolerant. The BMWP score for a site is the sum of the values for each taxon present in a sample. The score is based on the presence of each taxon, regardless of the number of representatives of the taxon in the sample. The values assigned for each family are given in Annex 1.

The WFD classification scheme for water quality includes five status classes: high, good, moderate, poor and bad.

'High status' is defined as the biological, chemical and morphological conditions associated with **no** or **very low** human pressure. This is also called the 'reference condition' as it is the best status achievable - the benchmark. These reference conditions are type-specific, so they are different for different types of rivers, lakes or coastal waters so as to take into account the broad diversity of ecological regions in Europe.

Table 2. The ecological status according to the water framework directive classification

Ecological Status	Class
Very Good	I
Good	II
Moderate	III
Poor	IV
Bad	V

Simpson Index

Simpson's diversity index (also known as species diversity index) is one of a number of diversity indices, used to measure diversity. In ecology, it is often used to quantify the biodiversity of a habitat. It takes into account the number of species present, as well as the relative abundance of each species. The Simpson index represents the probability that two randomly selected individuals in the habitat will not belong to the same species. The simplicity of Simpson's Diversity Index has led it to be used frequently.

$$D = \frac{\sum_{i=1}^{S} n_i(n_i - 1)}{N(N-1)}$$

Where n_i is the number of individuals of species *i* which are counted, and N is the total number of all *individuals* counted. The value of **D** ranges between 0 and 1. With this index, 0 represents infinite diversity and 1, no diversity. That is, the bigger the value of D, the lower the diversity.

3. Results and discussion

In 2012, species of the following classes and orders were found: Nematoda, Oligochaeta, Hirudinea, Gastropoda, Bivalvia, Isopoda, Megaloptera, Ephemeroptera, Trichoptera, Diptera and Hydracarina (Table 3)

Table 3. Frequence of macroinvertebrates community in Durowskie lake from July 2-7.2012

Taxon	**s**													
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Nematoda			+											
Oligochaeta				+	+						+	+		
Hirudinea:														
Erpobdella octooculata (L.)			+								+			
Glossiphonia complanata (L.)		+												
Helobdella stagnalis (L.)			+					+				+		
Hemiclepsis marginata (O.F. Müller)											+			
Piscicola geometra (L.)		+									+			
Gastropoda:														
Anisus spirorbis (L.)	+	+					+	+			+	+	+	
Bitynia tentaculata (L.)							+	+			+	+		
Potamopyrgus antipodarum (E.A. Smith)	+	+		+				+				+	+	
Theodoxus fluviatilis (L.)							+							
Valvata piscinalis (O.F. Müller)				+										
Viviparus contectus (Millet)				+										
Bivalvia:														
Anodonta anatina (L.)				+			+	+			+			
Anodonta cygnea (L.)		+												
Dreissena polymorpha (Pallas)	+													
Unio pictorum (L.)		+		+				+			+	+	+	
Unio tumidus (L.)				+										
Isopoda:														
Asselus aquaticus (L.)				+										
Megaloptera:														
Sialis fuliginosa Pictet		+		+			+	+						
Ephemeroptera:														
Caenis sp.	+			+			+	+				+	+	
Trichoptera														
Trichoptera sp.	+	+		+			+				+			
Mollana sp.		+					+	+						
Diptera:														
Ceratopogonidae							+							
Chaoborus flavicans (Meig.)						+				+				+
Chironomidae Larvae	+	+		+			+	+				+	+	
Chironomidae Pupae				+			+							
Hydracarina							+							

Number of macroinvertebrates collected from the sampling stations in Lake Durowskie is presented in table 4, and their biomass in table 5.

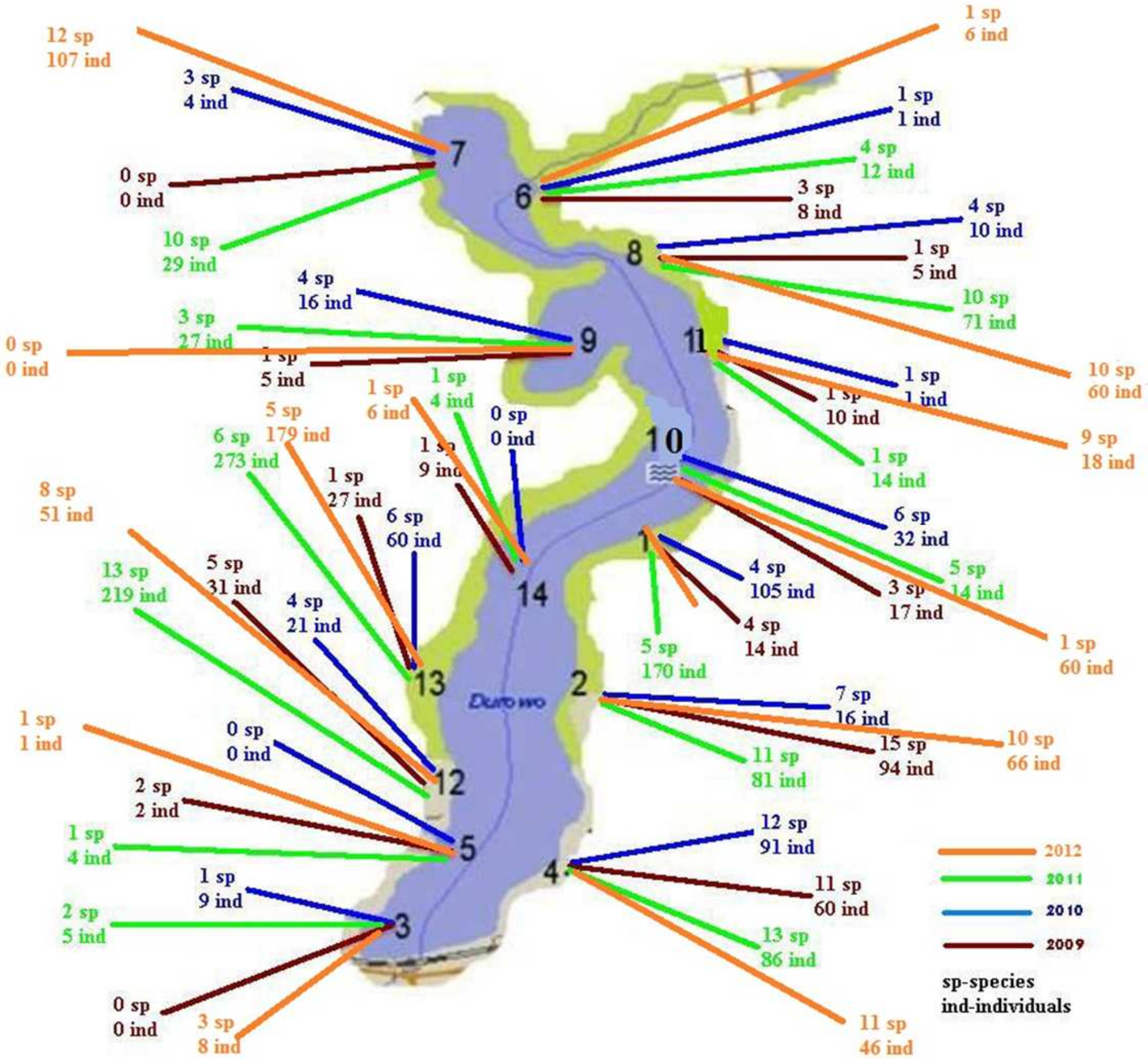
Table 4. Number of macroinvertebrates collected from the sampling stations in Lake Durowskie ($1m^2$)

		S													
N	**Taxon:**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	**Nematoda**			115											
2	**Oligochaeta**			92	23	23						23	230		
	Hirudinea:														
3	*Erpobdella octooculata* (L.)			23								23			
4	Glossiphonia complanata (L.)		23												
5	*Helobdella stagnalis* (L.)			46					23				23		
6	*Hemiclepsis marginata* (O.F. Müller)											23			
7	*Piscicola geometra* (L.)		23									23			
	Gastropoda:														
8	*Anisus spirorbis* (L.)	92	46					23	184			92	115	943	
9	*Bitynia tentaculata* (L.)							23	207			92	92		
10	*Potamopyrgus antipodarum* (E.A. Smith)	69	115		437				23				23	46	
11	*Theodoxus fluviatilis* (L.)							23							
12	*Valvata piscinalis* (O.F. Müller)				23										
13	*Viviparus contectus* (Millet)														
	Bivalvia:														
14	*Anodonta anatina* (L.)				23			92	23			23			
15	*Anodonta cygnea* (L.)		23												
16	*Dreissena polymorpha* (Pallas)	23													
17	*Unio pictorum* (L.)		23		46				69			69	69	46	
18	*Unio tumidus* (L.)														
	Isopoda:														
19	*Asselus aquaticus* (L.)				69										
	Megaloptera:														
20	*Sialis fuliginosa* Pictet		23		23			23	23						
	Ephemeroptera:														
21	*Caenis* sp.	23			46			92	46				23	23	
	Trichoptera														
22	*Trichoptera* sp.	276	46		164			92				46			
23	*Mollana* sp.		69					69	161						
	Diptera:														
24	*Ceratopogonidae*							23							
25	*Chaoborus flavicans* (Meig.)						138				1380				138
26	*Chironomidae larvae*	2530	1127		2346			1794	437				1035	3059	
27	*Chironomidae pupae*				115			92							
28	**Hydracarina**							115							
Total		3013	1518	276	3315	23	138	2461	1196	0	1380	414	1610	4117	138

Table 5. Biomass of macroinvertebrates calculated for the sampling stations in lake Durowskie (mg/m²)

	S													
Taxon	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
Nematoda			230											
Oligochaeta				322	46						23	207		
Hirudinea:														
Erpobdella octooculata (L.)			2116								2277			
Glossiphonia complanata (L.)		368												
Helobdella stagnalis (L.)			184					115				299		
Hemiclepsis marginata (O.F. Müller)											115			
Piscicola geometra (L.)		23									46			
Gastropoda:														
Anisus spirorbis (L.)											399			
Bitynia tentaculata (L.)	5428	1955					115	1840			690	1186	9200	
Potamopyrgus antipodarum (E.A. Smith)							138	1081			368	598		
Theodoxus fluviatilis (L.)	9164	14421		57592				552				690	6118	
Valvata piscinalis (O.F. Müller)							1012							
Viviparus contectus (Millet)				19642										
Bivalvia:														
Anodonta anatina (L.)				236440			235727	180550			193200			
Anodonta cygnea (L.)								77050			76590			
Dreissena polymorpha (Pallas)		506												
Unio pictorum (L.)	2507													
Unio tumidus (L.)		117070		171810				133860			135700	105984	280600	
Isopoda:														
Asselus aquaticus (L.)				207										
Megaloptera:														
Sialis fuliginosa Pictet		230		874			759	207						
Ephemeroptera:														
Caenis sp.	46			69			161	69				69	69	
Trichoptera														
Trichoptera sp.	16997	345		2783			437				138			
Mollana sp.		638					5152	6348						
Diptera:														
Ceratopogonidae							23							
Chaoborus flavicans (Meig.)						736				5405				506
Chironomidae larvae	1058	7567		16997			10304	3703				2898	7061	
Chironomidae pupae				1265			805							
Hydracarina							414							
Total	35200	143123	2530	508001	46	736	255047	405375	0	5405	409546	111931	303048	506

Fig. 2. Total number of species and individuals identified in 2009, 2010, 2011 and 2012 sampling season in Lake Durowskie



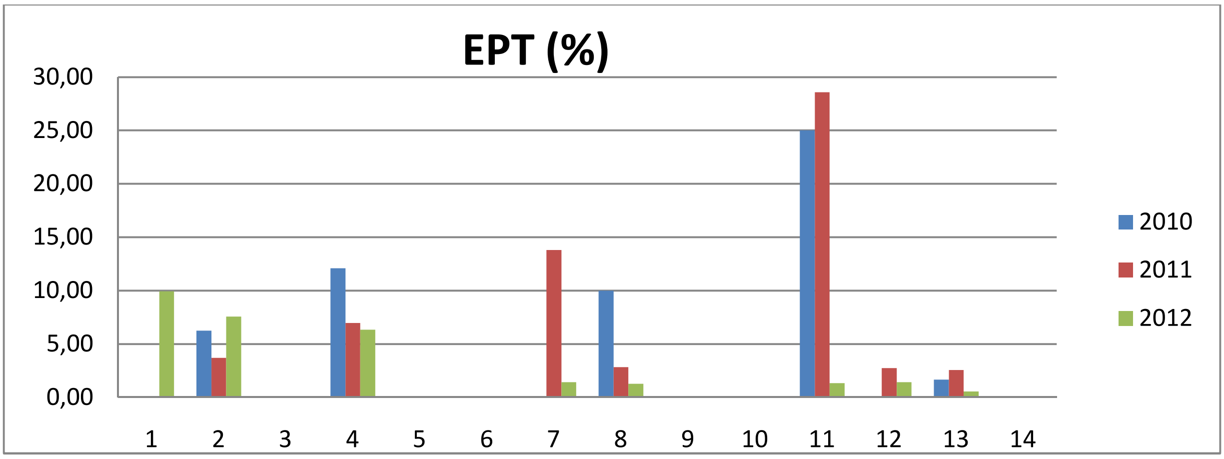
In the study of macroinvertebrates from Lake Durowskie in July 2011 a total of 26 taxa were identified from the all the 14 stations and except the taxa of Nematoda, Oligochaeta, Trichoptera, Chironomidae and Hydracarina all remaining taxa were identified to the species level.

According to the map (Fig. 2) we can see higher richness in species diversity between 2012 and the other three years in the sampling zones number 8, 1, 3, 5, 14, 7. In zones number 10, 4, 13, 12, 9 the diversity richness is lower.

Table 6. Indices and BMWP score of sampling sites of Lake Durowskie ($1m^2$)

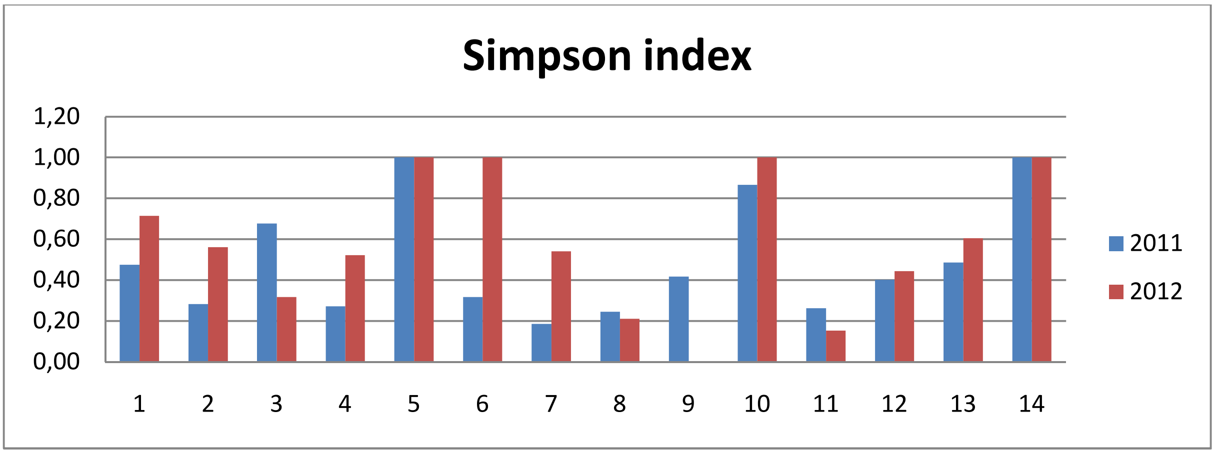
Indices	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Simpson index	2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	0,4758	0,2830	0,6772	0,2714	1,0000	0,3170	0,1855	0,2453	0,4174	0,8669	0,2630	0,4021	0,4859	1,0000
	2012	0,7150	0,5617	0,3170	0,5227	1,0000	1,0000	0,5402	0,2109	0,0000	1,0000	0,1523	0,4441	0,6047	1,0000
Shannon	2010	0,3400	0,7200	0,0000	0,7100	0,0000	0,0000	0,4500	0,5200	0,4500	0,0000	0,5900	0,2500	0,2500	0,0000
	2011	0,8866	1,7280	0,5004	1,8359	0,0000	1,2367	1,9519	1,6861	0,9526	0,2573	1,4328	1,2291	0,9217	0,0000
	2012	0,6331	1,0215	0,8705	1,8936	0,0000	0,0000	1,1836	1,8232	0,0000	0,0000	2,0165	1,2312	0,6877	0,0000
Species evennes	2010	0,5600	0,8600	0,0000	0,6600	0,0000	0,0000	0,9500	0,8600	0,7500	0,0000	0,7600	0,4100	0,3200	0,0000
	2011	0,5509	0,7206	0,7219	0,7157	0,0000	0,8921	0,8477	0,7323	0,8671	0,3712	0,8902	0,4792	0,5144	0,0000
	2012	0,3533	0,4436	0,7923	0,4647	0,0000	0,0000	0,4763	0,7918	0,0000	0,0000	0,9178	0,5921	0,4273	0,0000
Margalef	2010	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	2011	0,6045	1,4608	0,4215	1,7128	0,2212	0,7117	1,5378	1,3517	0,4665	0,3463	0,8659	1,5250	0,6861	0,2212
	2012	0,6242	1,2286	0,3835	1,2336	0,0000	0,0000	1,4088	1,2700	0,0000	0,0000	1,3276	0,9480	0,4806	0,0000
EPT %	2010	0,0000	6,2500	0,0000	12,0879	0,0000	0,0000	0,0000	10,0000	0,0000	0,0000	25,0000	0,0000	1,6666	0,0000
	2011	0,0000	3,7037	0,0000	6,9767	0,0000	0,0000	13,7931	2,8169	0,0000	0,0000	28,5714	2,7397	2,5641	0,0000
	2012	9,9240	7,5760	0,0000	6,3350	0,0000	0,0000	1,4090	1,2700	0,0000	0,0000	1,3280	1,4290	0,5590	0,0000
EPT Chironomidae	2010	0,0000	0,1700	0,0000	0,2200	0,0000	0,0000	0,0000	0,2500	0,0000	0,0000	0,5000	0,0000	0,0200	0,0000
	2011	0,0000	0,0040	0,0000	0,0072	0,0000	0,0000	0,0600	0,0045	0,0000	0,0000	0,2484	0,0010	0,0013	0,0000
	2012	0,1182	0,1020	0,0000	0,0853	0,0000	0,0000	0,0488	0,1579	0,0000	0,0000	0,0000	0,0222	0,0075	0,0000
BMWP	2010	12	28	0	50	0	0	4	12	5	0	26	15	15	0
class	2010	IV	IV	V	III	V	V	V	IV	V	V	IV	IV	IV	V
BMWP	2011	24	36	0	30	0	0	32	26	0	0	19	54	27	0
class	2011	IV	IV	V	IV	V	V	IV	IV	V	V	IV	III	IV	V
BMWP	2012	26	48	6	42	0	0	53	55	0	0	36	35	26	0
class	2012	IV	III	V	III	V	V	III	III	V	v	IV	IV	IV	V

Fig. 3. Comparison of the EPT-index for the 14 stations assessed in 2010, 2011 and 2012.



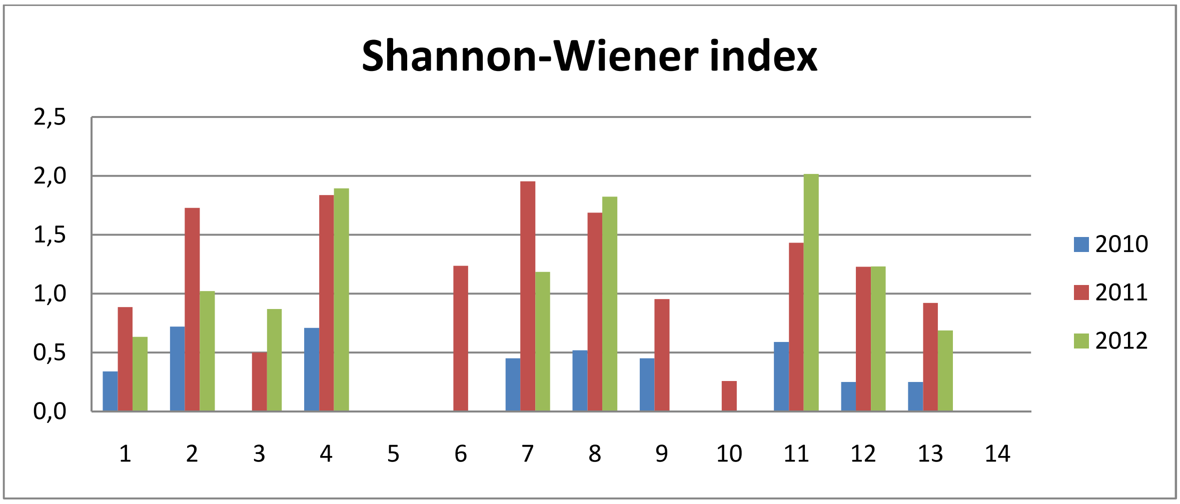
Station 1, 2 and 4 show high values in 2012 while there are low or no values for the other stations. In comparison to 2010 and 2011, the values for station 1 and 2 increased. For the stations 4, 7, and 11 lower values were derived.

Fig. 4. The Simpson index for the stations 1 – 14 in comparison of 2011 and 2012.



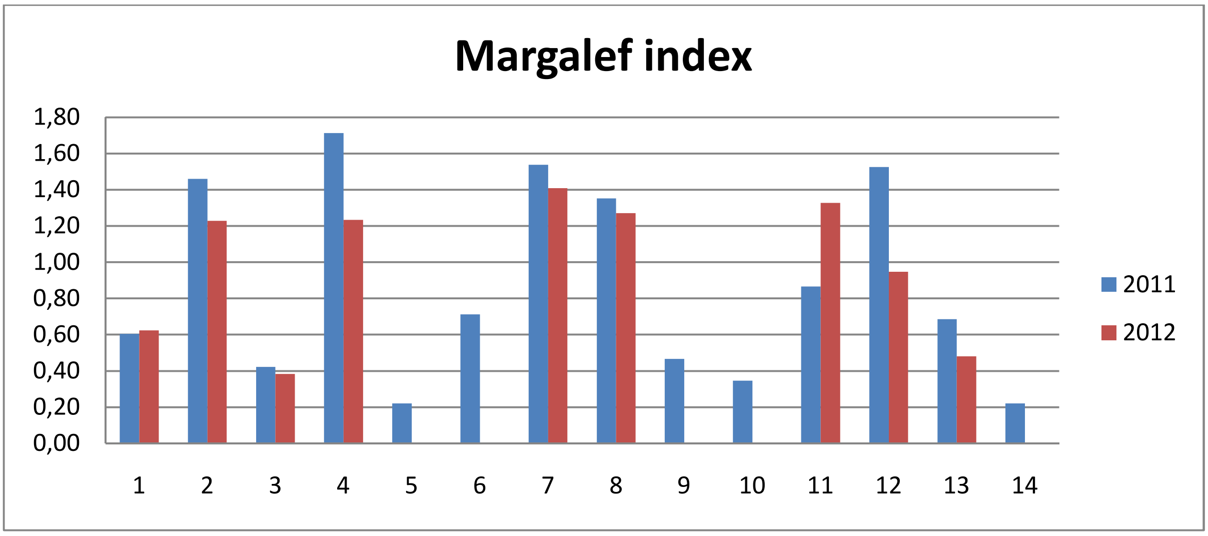
In 2012, the stations 8, 9 and 11 show lower values. The data from the stations 1, 2, 4, 7, 12 and 13 provide medium values. For the stations 5, 6, 10 and 14 higher values were calculated. Compared to the results of 2011, station 3, 8, 9 and 11 show lower values in 2012. For the stations 1, 2, 4, 6, 7, 12 and 13 higher values were calculated while 5, 10 and 14 show similar values.

Fig. 5. The Shannon-Wiener index for stations 1 – 14 in 2010, 2011 and 2012.



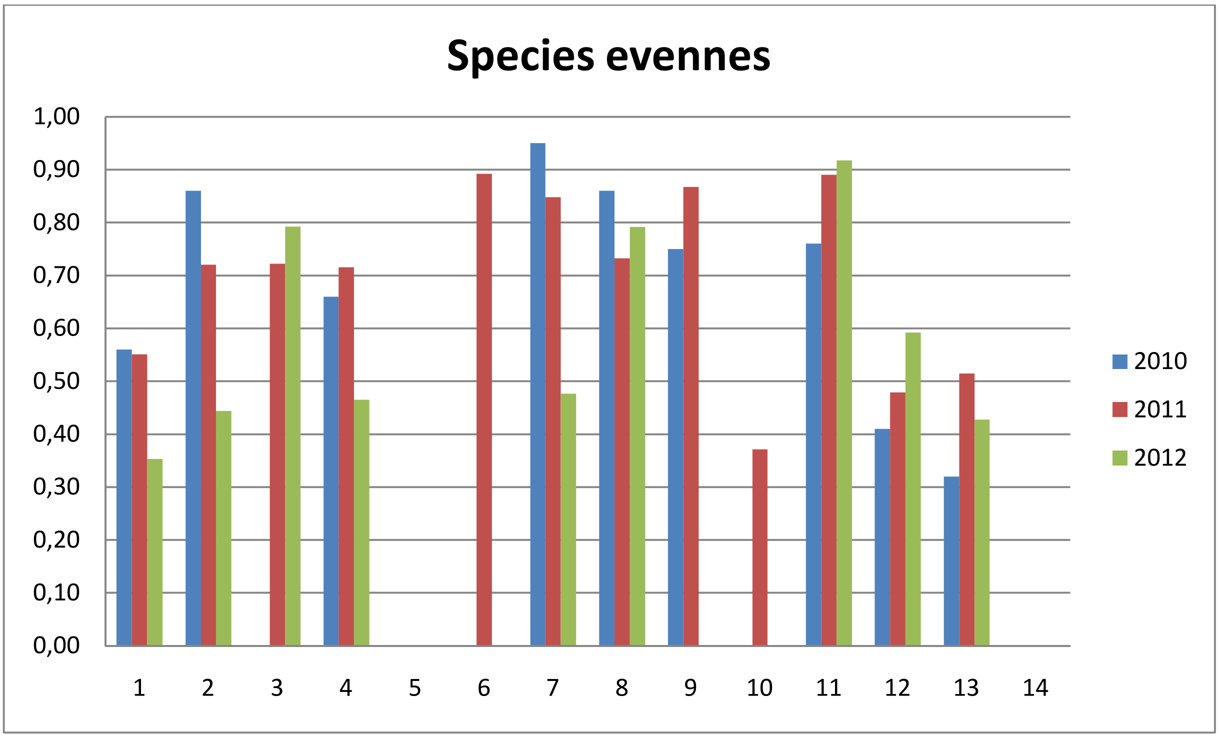
The calculation of the Shannon-Wiener index reveals high values for station 4, 8 and 11. Station 1, 2, 3, 7, 12 and 13 show lower values. For the stations 5, 6, 9, 10 and 14 there do not exist values. Compared to the results of 2010 and 2011, higher or equal values could be derived for the stations 4, 8, 11 and 12 in 2012. Lower values were calculated for station 1, 2, 6, 7, 9, 10 and 13.

Fig. 6. The values of the Margalef index for the stations 1 – 14 in 2011 and 2012.



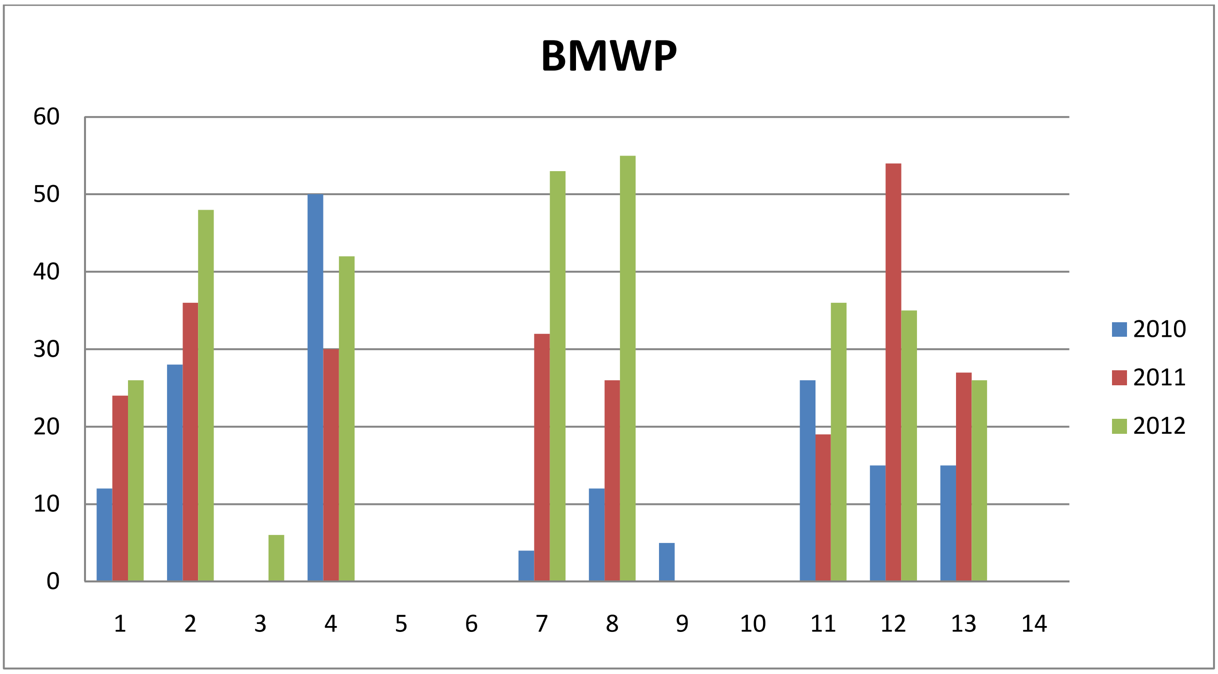
There are high values for the stations 2, 4, 7, 8, 11 and 12. There are no values for the stations 5, 6, 9, 10 and 14. Low values were calculated for station 1, 3 and 13. Station 1 and 11 show higher values in 2012 compared to 2011. All other stations show lower or no values in 2012.

Fig. 7. Species evenness for the stations 1 – 14 in comparison for the years 2010, 2011 and 2012.



Stations 3, 8 and 11 show high values. The results for station 1, 2, 4, 7, 12 and 13 are low values. There is no data for the stations 5, 6, 9, 10 and 14. Over the last three years, the values for the stations 3, 8, 11 and 12 increased, for the stations 1, 2, 4, 7, 10 and 13 the values decreased.

Fig. 8. Scores of the BMWP index (y-axis) for the stations 1 – 14 in comparison for the years 2010, 2011 and 2012.



According to the score, the stations 2, 4, 7 and 8 can be assigned to class III. Station 1 and 13 belong to class IV. Station 3 can be assigned to class V. There is no data for the stations 5, 6, 9, 10 and 14. In comparison to previous years, an increase can be detected at station 1, 2, 3, 4, 7, 8 and 11. The results for station 12 and 13 show a decrease.

Discussion

<u>Species</u>

The classes *Hirudinea* and *Oligochaeta* are both pollution tolerant benthos. Species of *Hirudinea* indicate very poor water quality. *Oligochaeta* can be found in soft mud bottoms indicate in high numbers very poor water quality. Species of the class *Bivalvia* are considered to be sensitive benthos, reacting to siltation and low dissolved oxygen. The class *Gastropoda* can indicate nutrient enriched conditions and poor water quality. *Nematoda* can indicate bad water quality. Species of the order *Isopoda* are moderately tolerant benthos. They often indicate poorer water quality. Species of the order of *Megaloptera* are intolerant to pollution while species of *Trichoptera* show a large range of pollution tolerance. Organisms of the order Ephemeroptera vary in their varied tolerance to pollution, but are generally living in cleaner water. Species of the order *Diptera* indicate moderately clean water (EPA, 2012).

EPT

The stations 1, 2 and 4 show better water quality than at the other stations in 2012. Generally, there is a trend of decrease in water quality visible.

Simpson index

In 2012, station 8, 9 and 11 are richer in species. For the stations 1, 2, 4, 7, 12 and 13 there is an average diversity indicated. The stations 5, 6, 10 and 14 have low species diversity. Species richness is higher at the stations 3, 8, 9 and 11 in 2012 compared to 2011. Station 1, 2, 4, 6, 7, 12, 13 have a lower species richness in 2012 than in 2011 while the stations 5, 10, 14 show the same species richness as in the previous year.

Shannon-Wiener index

The results indicate high biodiversity for the stations 4, 8 and 11 while station 1, 2, 3, 7, 12 and 13 show lower biodiversity. For the stations 5, 6, 9, 10 and 14 there cannot be made a statement. Compared to the results of 2010 and 2011, stations 4, 8, 11 and 12 show higher or equal biodiversity in 2012. Station 1, 2, 6, 7, 9, 10 and 13 have lower biodiversity.

Margalef index

Species diversity is high at the stations 2, 4, 7, 8, 11 and 12. Station 1, 3 and 13 have low diversity. Station 1 and 11 show a higher diversity in 2012 compared to 2011. For all other stations there is lower diversity or no data.

Species evenness

There is a high species evenness found at the stations 3, 8 and 11. Station 1, 2, 4, 7, 12 and 13 show low species evenness. Over the years, species evenness increased at the stations 3, 8, 11 and 12. At the stations 1, 2, 4, 7, 10 and 13 species evenness decreased.

BMWP -PL

In combination with the classification of the Water Framework Directive, the following conclusion from the values can be drawn:

- The result of the stations 2, 4, 7 and 8 indicate a moderate ecological status of the lake.
- The data from the stations 1 and 13 show the lake in a poor condition.
- The values from station 3 indicate bad ecological condition of the lake.

There is a trend visible for the improvement of the lake in several stations over the last three years (1, 2, 3, 4, 7, 8, 11). In comparison to previous years, station 12 and 13 degrade.

4. Conclusions

The biodiversity has increased from 26 taxa in 2011 to 28 taxa in 2012.

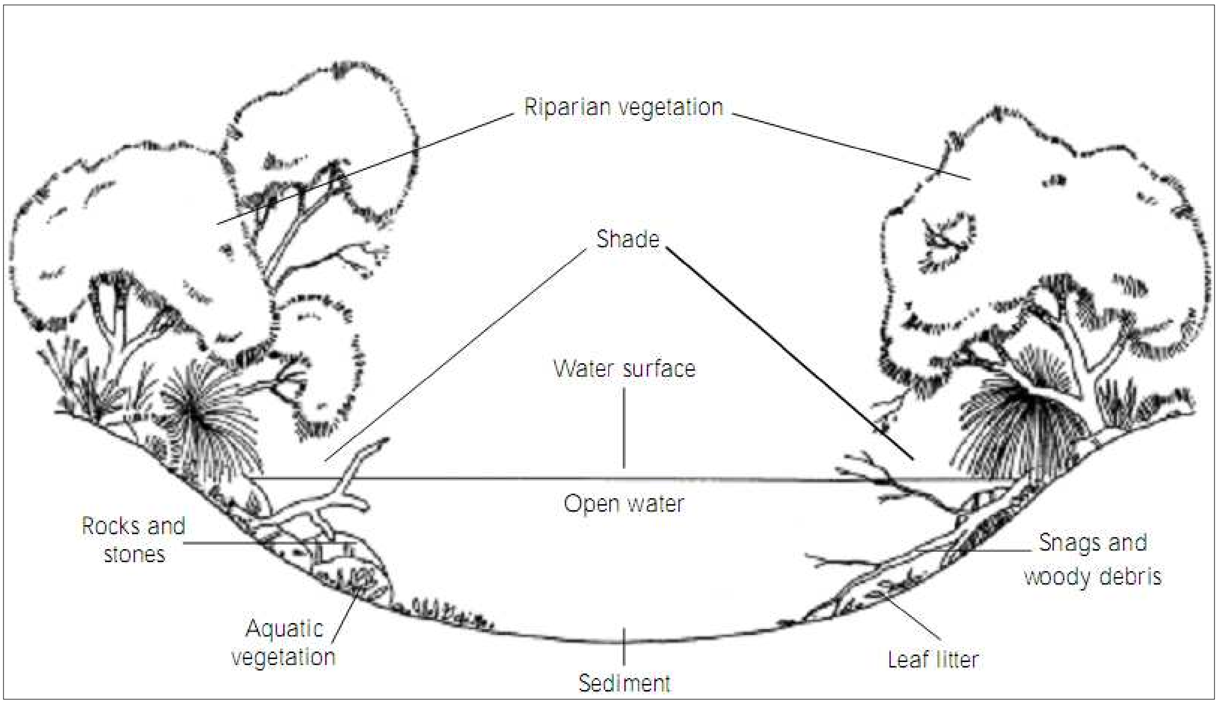
In comparison to previous years there is less *Theodoxus fluviatilis* which is important indicator of clean water. However for the first time another very important indicator of clean water appeared – *Mollana* sp.

There are difficulties in the application of macroinvertebrates as ecological indicators. This can be problems with sampling and sorting methodology and taxonomy. (Busch & Sly, 1992). Nevertheless, macroinvertebrates are commonly and successfully used to determine the ecological status of lakes.

According to Muralidharan et al. (2010), macroinvertebrates are sensitive to pollution, low oxygen contents and sedimention of fine materials. Problems can also be caused by thermal and radioactive pollution.

Best living conditions are provided in lakes with pristine conditions. An undisturbed transition zone provides suitable habitats for many different species of macroinvertebrates (Figure XXX). Macrophytes are of special importance in this context, since they regulate the “water flow, light availability and temperature around them” (WRC, 2001: 3).

Fig. 9. Habitats for macroinvertebrates in an undisturbed aquatic environment.



For Lake Dorowskie, several recommendations can be made:

- Planting and broadening of the macrophyte belt at the southern shoreline with restricted access to the waterline.
- The jetties should be placed in front of the macrophyte belt to protect the vegetation, the accesses should be as small as possible.
- Pollutants should be reduced.
- The use of motorboats should be restricted to minimize the wave impact on the lake banks
- Regular monitoring to assess the status of macroinvertebrates should be applied.

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6. Appendix

Annex 1. Standard table of BMWP- PL (Kownacki, Soszka 2004)

	Rodziny	Punktacja
Ephemeroptera	Ameletidae	10
Trichoptera	Glossosomatidae, Molannidae, Beraeidae, Odontoceridae, Leptoceridae	
Diptera	Blephariceridae, Thaumaleidae	
Ephemeroptera	Behningiidae	9
Plecoptera	Taeniopterygidae	
Odonata	Cordulegastridae	
Trichoptera	Goeridae, Lepidostomatidae	
Crustacea	Astacidae	8
Ephemeroptera	Oligoneuriidae, Heptageniidae (rodzaje Epeorus, Rhithrogena)	
Plecoptera	Capniidae, Perlidae, Chloroperlidae	
Trichoptera	Philopotamiidae	
Diptera	Athericidae	
Ephemeroptera	Siphlonuridae, Leptophlebiidae, Potamanthidae, Ephemerellidae, Ephemeridae, Caenidae,	7
Plecoptera	Perlodidae, Leuctridae	
Odonata	Calopterygidae, Gomphidae,	
Trichoptera	Rhyacophilidae, Brachycentridae, Sericostomatidae, Limnephilidae	
Coleoptera	Elmidae	
Heteroptera	Aphelocheiridae	
Gastropoda	Viviparidae	
Bivalvia	Unionidae, Dreissenidae	
Hirudinea	Piscicolidae	6
Crustacea	Gammaridae, Corophiidae	
Ephemeroptera)	Baetidae, Heptageniidae (z wyjątkiem rodzajów Epeorus i Rhitrogena)	
Plecoptera	Nemouridae	
Odonata	Platycnemididae, Coenagrionidae	
Trichoptera	Hydroptilidae, Polycentropodidae, Ecnomidae	
Diptera	Limoniidae, Simuliidae, Empididae	
Gastropoda	Neritidae, Bithyniidae	
Crustacea	Cambaridae	5
Trichoptera	Hydropsychidae, Psychomyidae	
Coleoptera	Gyrinidae, Dytiscidae, Haliplidae, Hydrophilidae	
Heteropera	Mesoveliidae, Veliidae, Nepidae, Naucoridae, Notonectidae, Pleidae, Corixidae	
Diptera	Tipuliidae	
Gastropoda	Hydrobiidae	
Diptera	Ceratopogonidae	4
Gastropoda	Valvatidae, Planorbidae	
Bivalvia	Sphaeriidae	
Hirudinea	Glossiphonidae, Erpobdellidae, Hirudinidae	3
Crustacea	Asellidae	
Megaloptera	Sialidae	
Diptera	Chironomidae	
Gastropoda	Ancylidae, Physidae, Lymnaeidae	
Oligochaeta	wszystkie Oligochaeta	2
Diptera	Culicidae	
Diptera	Syrphidae, Psychodidae	1