Macroinvertebrate Survey

The Ecological state of the Lake Durowskie during restoration measures

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1. Introduction

The deterioration of the environmental state forces governments to undertake various measures to go against this development. One of the most affected parts within the landscapes that suffers most due to human activities, are water bodies within the urban catchment. The main tool used to protect aquatic habitats in Europe is The European Water Framework Directive (WFD). All European Union member states are prompted to reach a good ecological status of water bodies and therefore improve the water quality by 2015.

Water in general is a vulnerable and limited resource in most parts of the world and should be treated as a natural heritage that has to be protected. Water quality has to be monitored, observed, measured and evaluated in order to achieve the claimed target of the WFD. The adaptation of different plant and animal species to environmental conditions allow their use as indicators of water quality of natural sources. The results of this report refer to the annual research and survey of the water quality status that was derived with the use of macroinvertebrates as biological indicators at Lake Durowskie.

1.1. Lake Durowskie

The Durowskie Lake is located in the community of Wągrowiec, in the south-eastern part of the Wielkopolskie voivodship. It belongs to the Chodzieskie Lakeland, a mezoregion, that again is in Greater Poland, considered a macroregion, which is situated in Southern-Baltic Lakelands subprovince (Kondracki J., 2002). The southern part of the Durowskie Lake is placed in the town of Wągrowiec , and one-fourth of the water body is under the pressure of human impact. The northern region of the catchment area mainly has a forest character. However, the agriculture should also be considered to have an influence on the ecological state of the lake (see fig. 1.).

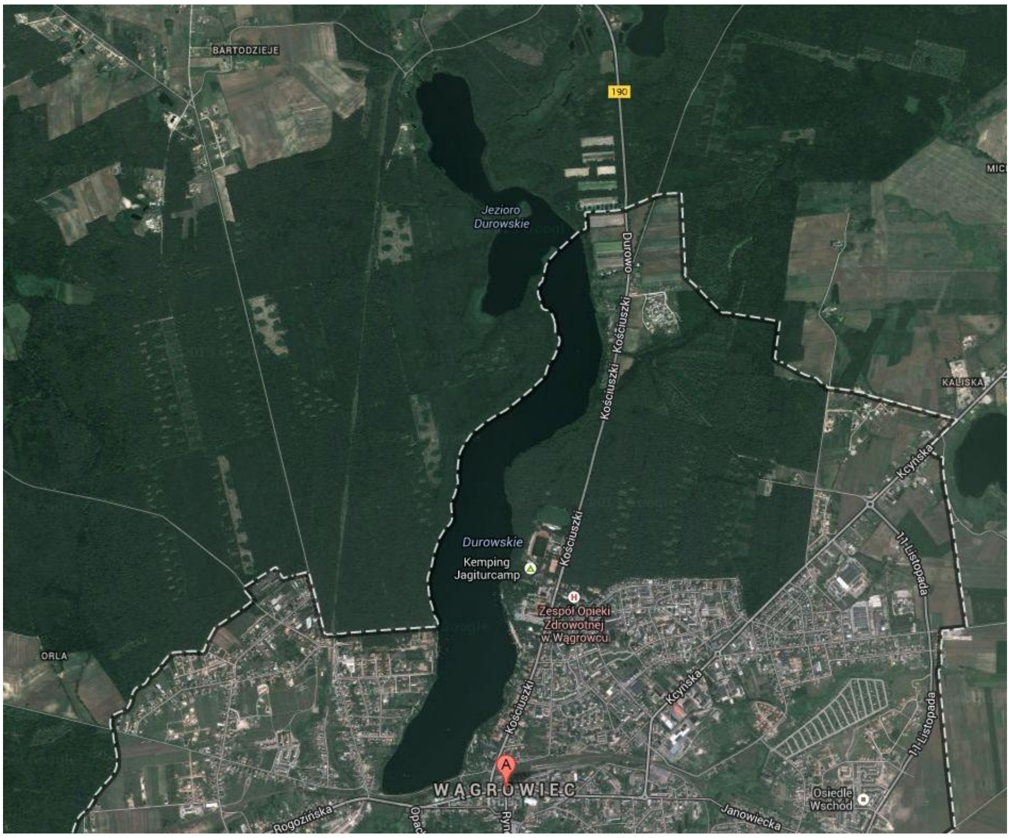


Figure 1.: Satellite picture of Lake Durowskie north of Wągrowiec (source: Google maps, 11/07/2013)

The Durowskie Lake is stratified, chain lake connected with the Kobyleckie Lake through the Struga Gołaniecka River.

Basic morphometrical data:

- water surface 143,7 ha
- volume 11 322,9 thousands of m^3
- maximum depth 14,6 m
- mean depth 7,9 m
- catchment area 236,1 km^2

1.2. European Water Framework Directive

The European Water Framework Directive (WFD) is a framework for the protection of water bodies and presents the legal background for the assessment and improvement of their quality status. The target of the WFD is a 'good ecological quality status' for all water bodies by 2015. This results in a need to identify and to assess pressures and impacts and the risk of failing to achieve the 'good ecological quality status' (European Parliament & Council, 2000).According to the WFD macroinvertebrates, among others, can be used as target organisms to improve the aquatic habitat. The WFD defines five quality classes to evaluate the state of water bodies. Class I indicates a very good ecological status and class V a very bad ecological status (see table 1).

Table 1.: The table shows the five quality classes to evaluate the state of water bodies adjusted according to the WFD

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

1.3. Macroinvertebrates

Macroinvertebrates are organisms without backbones, with a size > 2 mm. This means that they are large enough to be seen with an unaided eye (EPA, 2012). They are inhabiting all types of freshwater e.g. streams, rivers, wetlands and lakes and are sensitive to different chemical and physical conditions (Water and River Commission, 2001).

As a result of their habitat choice, macroinvertebrates are often regarded as "benthos" which refers collectively to organisms which live on, in or near the bottom Davis J., Christidis, F. 1997). Examples of freshwater benthic macroinvertebrates include the immature and adult stages of many different types of invertebrates. A freshwater benthic community may consist of the immature stages of many flies, beetles (adults and immatures), mayflies, caddisflies, stoneflies, dragonflies, aquatic worms, snails, leeches and numerous other organisms that inhabit the benthos. Benthic macroinvertebrates, especially aquatic insects, represent a choice group of organisms for use in biological monitoring programs. Macroinvertebrates within the same system may be residents for several months to multiple years, depending on the lifespan of the particular organism. Macroinvertebrate communities therefore reside in an aquatic system long enough to reflect the chronic effects of pollutants, and yet short enough to respond to relatively acute changes in water quality. Unlike fish, these populations tend to be relatively immobile, and as a result are continuously exposed to the constituents of the surface water they inhabit. Thus, because of the limited mobility of macroinvertebrates and their relative inability to move away from adverse conditions, the location of chronic sources of pollution often can be pinpointed by comparing communities of these organisms. (Lydy, M.J., Crawford, C.G., & Frey, 2000). Macroinvertebrates exhibit varying responses to changes in water chemistry, water quality and physical habitat. Each macroinvertebrate responses to environmental perturbations produces measurable, and often predictable, shifts in abundance and composition at the community level. Benthic macroinvertebrates and Chironomids in particular, are used as bioindicators for environmental stress in aquatic ecosystems at different levels. The sensitivity of macroinvertebrates to changes in environmental quality render them an integral part of any biomonitoring program.

Macroinvertebrates are considered the most appropriate organism group due to the generally good response to a multitude of stressors (Kiesel et al., 2009). Due to this fact and the following characteristics they are adequate to be used as ecological indicators (EPA, 2012).:

- Relatively easy sampling technique
- Generally abundant
- They are a critical part of the lake's food web
- They can't escape pollution and show the effects of short- and long term pollution events
- They are affected by the physical, chemical, and biological conditions of the lake
- They may show the cumulative impacts of pollution
- Diversity indicates local conditions, e.g.: sedimentation, pollution, habitat loss

2. Material and Methods

2.1. Sampling

For the sampling of macroinvertebrates 14 different station were chosen. They are distributed all over the lake (see figure 2) and belong to different lake regions (see table 2). The sampling took place from 01.07.2013 to 06.07.2013 with rowboats. During this fieldwork sediment samples were taken from the deeper parts of the lake with the so called “Kajak” sampler (see figure 3). For the collection of sediments from the shallower parts of the lake the “czapla” sampler was used (see figure 4).

Figure 2.: Location of sampling sites. This map shows the 14 stations in the lake Durowskie where sampling took place from 01.07.2013 to 06.07.2013

Table 2.: Description of the different sampling sites in Lake Durowskie

STATION	DESCRIPTION
1	Littoral with reed near forest cover
2	Littoral near urban area
3	Pelagial near dam
4	Littoral near urban area
5	Pelagial (Areator I)
6	Pelagial near Struga Golaniecka River
7	Littoral near Camping ground
8	Littoral (Bulrush near forest cover)
9	Pelagial
10	Pelagial (Areator II)
11	Littoral with reed
12	Littoral near urban area
13	Littoral with reed near forest cover
14	Pelagial

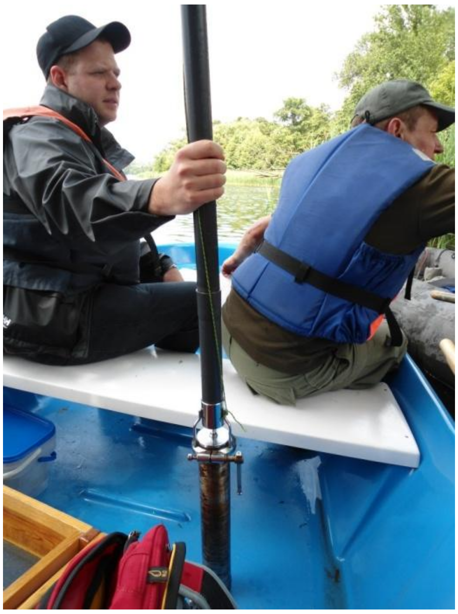


Figure 3.: „Kajak”- sampler for sediment collection in deeper parts of the lake

Figure 4.: „czapla” sampler for the collection of sediments from the shallower parts of the lake

With the “Kajak” sampler ten sediment samples were taken. At the littoral zones with a maximum depth of two meters the “czapla” - sampler was used for 17 samples. The different number of samples results from the different volume of the samplers because one need to get a comparable amount of sediment.

After getting the samples on board sieving of the sediment took place(see figure 5-7).

Figure 5.: Overview over the fieldwork activities

Figure 6.: taking the sediment samples on board

Figure 7.: sieving of the sediments

The washed and sieved samples from the different sites were stored in different plastic boxes. Later in the lab the microinvertebrates were sorted out with tweezers and the species were classified, weighted and determinated. Finally the biomass and number of individuals per square meter was calculated (see figure 8 – 9).

Figure 8.: Sorting out of the macroinvertebrates

Figure 9.: Weighting of the macroinvertebrates

2.2. Data analysis

For the data that was receive from the 14 sample stations distributed all over the lake, as shown in figure 2, four different indices were utilized to create the tables and graphs (see 3. Results) that again were used for the interpretation (see 4. Discussion). The indices were used as follows.

The Shannon-Wiener Index is a diversity index with a quantitative measure that reflects how many different species there are in a dataset, and simultaneously takes into account how evenly the individuals are distributed among the species found.

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

Pi is the proportion of individuals that is derived by dividing the number of individuals of one species found, with the number of all individuals of all species found. The higher the values of H’, the better the conditions of the water body.

Pielou's species evenness refers to how close in numbers each species in an environment is.

$$J' = \frac{H'}{H'_{\max}}$$

J' is constrained in the range between 0 and 1. The less variation in communities between the species the higher J' is. Where H' is the number derived from the Shannon Wiener index. **H'max** is the maximum value of H' which is equal to **ln S**, with **S** as the total number of the species richness. In other words, the higher the value, the less the variation in communities between the species, the better the quality of the water.

The Simpson index is used to measure the degree of concentration when individuals are classified into type.

$$\lambda = \sum_{i=1}^{R} p_i^2$$

Small values in datasets are indicating a high diversity and large values in datasets indicating a low diversity.

The EPT index is an index of water quality based on the abundance of three pollution-sensitive orders of macroinvertebrates. It is calculated as the sum of the number of Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) divided by the total number of Chironomidae. The EPT index (NCDEHNR, 1997) increases with improving water quality.

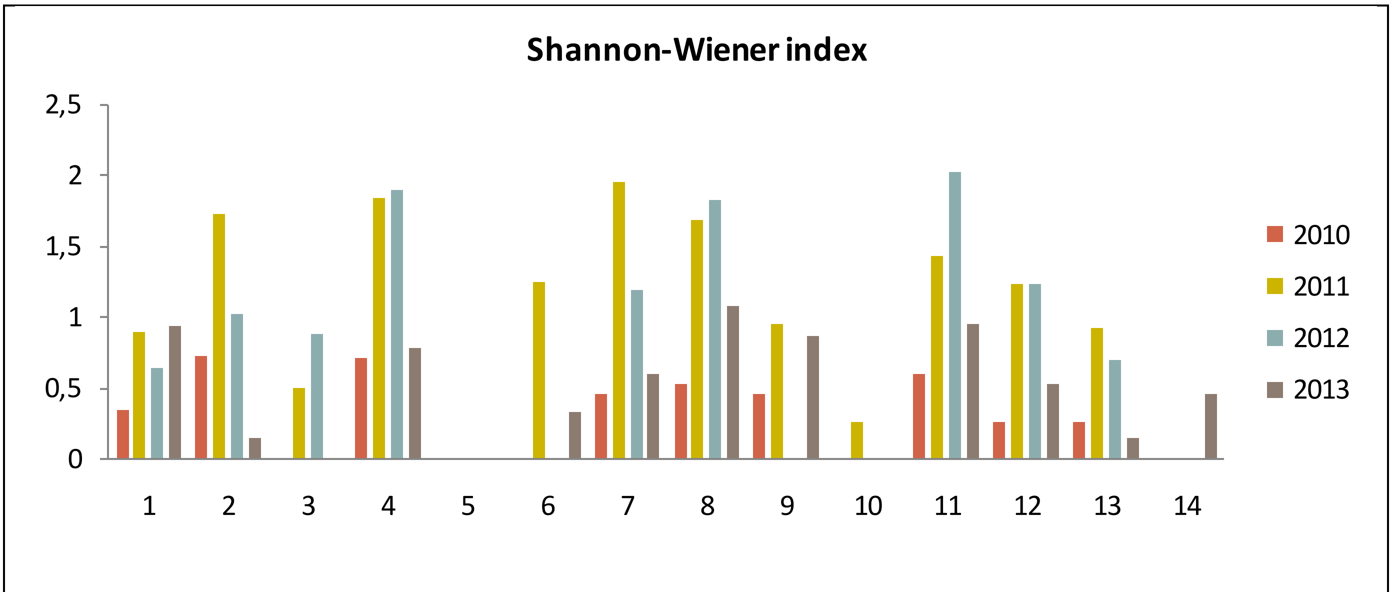
EPT Index = Σ(EPT / Chironomidae)

In other words, the greater the number of taxa from the EPT orders, the higher the value and the better the water quality.

3. Results

The Shannon-Wiener index values decreased in comparison to the previous three years. The only exception is for the station 1 where the results showed higher biodiversity. The lowest values were calculated in stations: 2, 6 ad 13. The lack of results for the sampling sites 5 and 10 is due to the abundance of only one species (see figure 10).

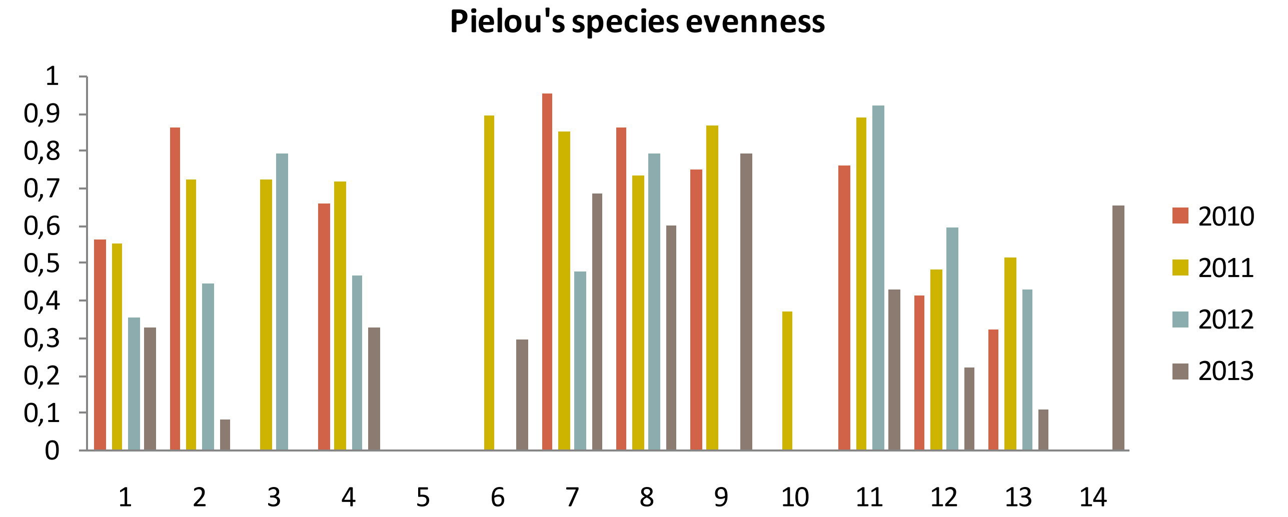
Figure 10.: Results derived by the calculation of the Shannon-Wiener index



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2010	0,34	0,72	one sp.	0,71	no sp.	one sp.	0,45	0,52	0,45	one sp.	0,59	0,25	0,25	no sp.
2011	0,8866	1,728	0,5004	1,8359	one sp.	1,2367	1,9519	1,6861	0,9526	0,2573	1,4328	1,2291	0,9217	one sp.
2012	0,6331	1,0215	0,8705	1,8936	one sp.	one sp.	1,1836	1,8232	no sp.	one sp.	2,0165	1,2312	0,6877	one sp.
2013	**0,9375**	**0,1439**	**one sp.**	**0,7766**	**one sp.**	**0,3245**	**0,5905**	**1,069**	**0,8676**	**one sp.**	**0,9405**	**0,5253**	**0,148**	**0,4506**

The Pielou's species evenness was lower in 2013 than in the years of 2010-2012. The lowest results were calculated for the following sites of sampling: 2, 13 and 12, while the highest have been found for the stations: 9, 7 and 14. Only one taxon each was found on sites 5 and 10 that is reflected in no value for the species evenness (see figure 11).

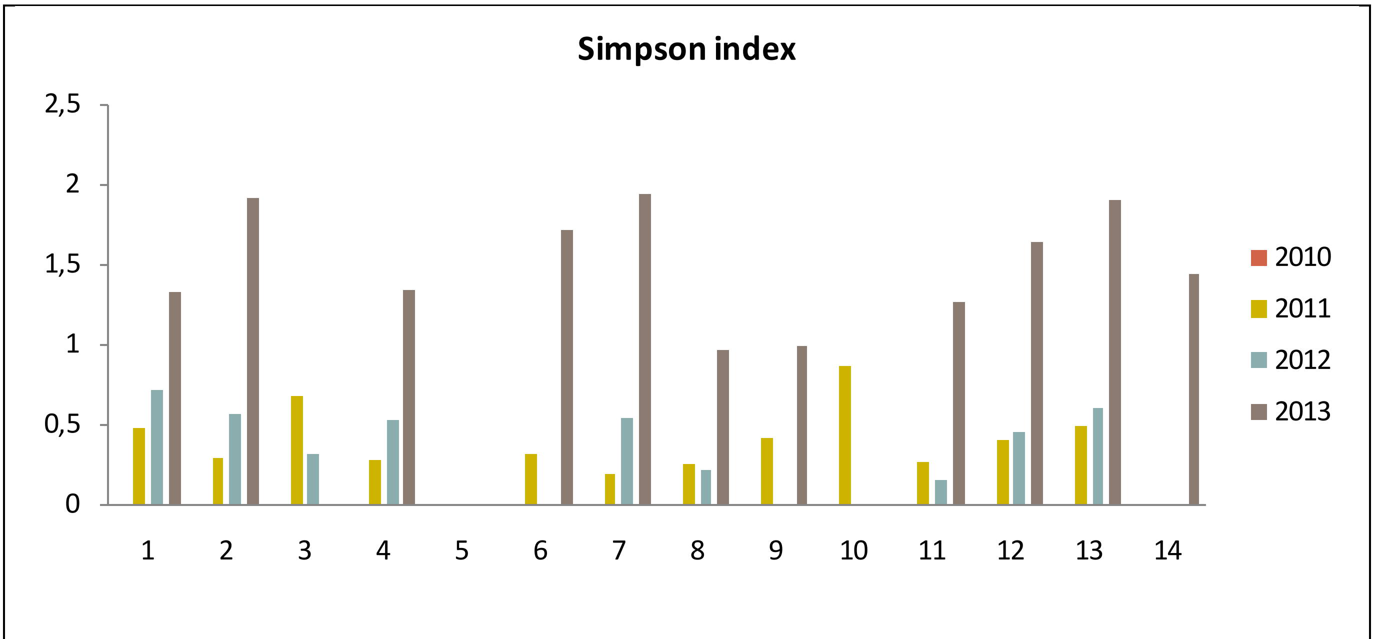
Figure 11.: Results derived by the calculation of the Pielou's species evenness



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2010	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data	no data
2011	0,4758	0,283	0,6772	0,2714	one sp.	0,317	0,1855	0,2453	0,4174	0,8669	0,263	0,4021	0,4859	one sp.
2012	0,715	0,5617	0,317	0,5227	one sp.	one sp.	0,5402	0,2109	no sp.	one sp.	0,1523	0,4441	0,6047	one sp.
2013	**1,324**	**1,911**	**one sp.**	**1,341**	**one sp.**	**1,71**	**1,934**	**0,9604**	**0,9927**	**one sp.**	**1,258**	**1,637**	**1,896**	**1,44**

Because of the fact that no calculations for the Simpson index were done for 2010, the results were juxtaposed only for the years: 2011, 2012 and 2013. The values for each station increased drastically in comparison to previous data (see figure 12).

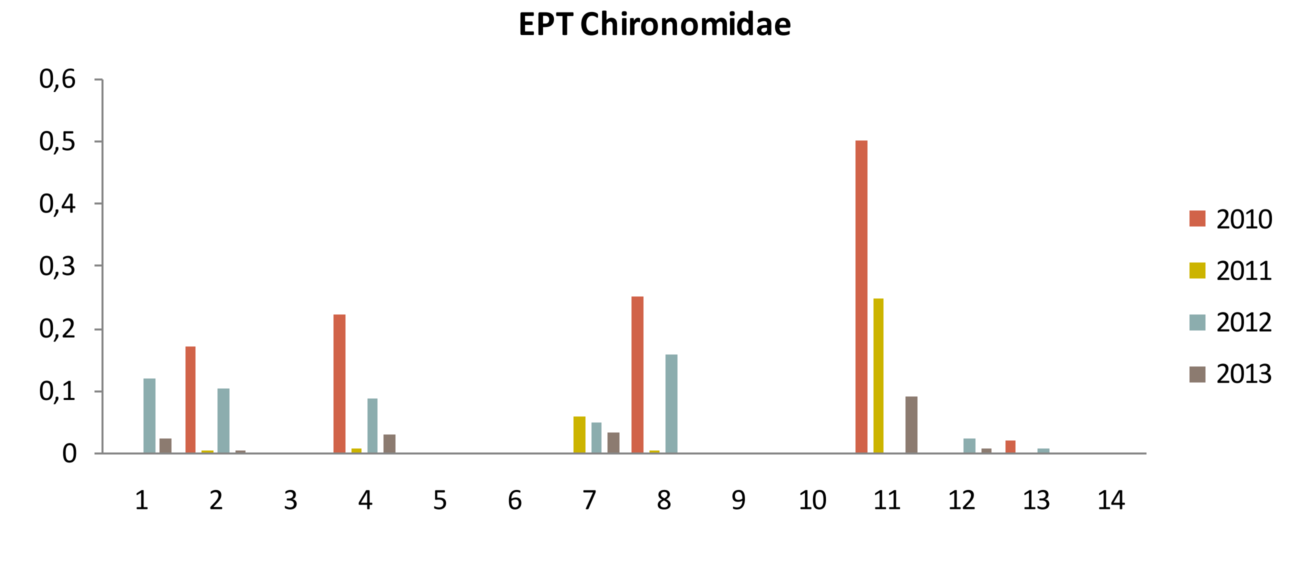
Figure 12.: Results derived by the calculation of the Simpson index



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2010	0,56	0,86	one sp.	0,66	no sp.	one sp.	0,95	0,86	0,75	one sp.	0,76	0,41	0,32	no sp.
2011	0,5509	0,7206	0,7219	0,7157	one sp.	0,8921	0,8477	0,7323	0,8671	0,3712	0,8902	0,4792	0,5144	one sp.
2012	0,3533	0,4436	0,7923	0,4647	one sp.	one sp.	0,4763	0,7918	no sp.	one sp.	0,9178	0,5921	0,4273	one sp.
2013	**0,3244**	**0,0803**	**one sp.**	**0,3239**	**one sp.**	**0,2958**	**0,6825**	**0,5964**	**0,7897**	**one sp.**	**0,428**	**0,2191**	**0,1067**	**0,65**

The EPT index according to Chironomidae shows values that critically decreased at stations 1, 4, 7, 11 and 12. It was impossible to get the results for the other sampling sites, associated with the lack of needed taxa (see figure 13).

Figure 13.: Results derived by the calculation of the EPT Chironomidae



	1	2	3	4	5	6	7	8	9	10	11	12	13	14
2010	0	0,17	0	0,22	0	0	0	0,25	0	0	0,5	0	0,02	0
2011	0	0,004	0	0,0072	0	0	0,06	0,0045	0	0	0,2484	0,001	0,0013	0
2012	0,1182	0,102	0	0,0853	0	0	0,0488	0,1579	no sp.	0	0	0,0222	0,0075	0
2013	**0,0217**	**0,0046**	**0**	**0,0278**	**0**	**0**	**0,0333**	**0**	**0**	**0**	**0,0889**	**0,0066**	**0**	**0**

4. Discussion

The graph of the Shannon Wiener index shows a general downward trend, specially taking the years 2012 and 2013 into account and in comparison. The exception is the station one, where the water quality increased. The samples at station one were taken in the littoral zone with reed cover along the shoreline that contribute to the filtration and cleaning of the water in the surrounding area. At station 5 and 10 only one species was found so that the Shannon Wiener index couldn't be derived. In the benthic zones of station 9 and 14, values have to be considered not as a contribution to an increasing water quality. The species found belong to the order of Diptera, *Chaoborus flavicans,* that was abundant in different states, adults and pupae. This can refer to the latest long and cold winter that is responsible for the postponement of the seasonal development of this species.

Pielou's species evenness, that accesses the number derived with the Shannon Wiener index, shows, that mainly at all stations the variation in communities between the species has increased and therefore the water quality has decreased. The values shown at station 9 and 14 again appear cause of the fact stated above. Stations 3, 5 and 10 couldn't been shown in the graph cause no species have been found in this benthic, anoxic part of the lake. Station 5 and 10 in addition are the stations where the aerators are located. Eventually it can be derived from the fact that no species have been found there, that the aerators are not working as effective as they should.

The Simpson index shows throughout all stations results, that the quality of the water has to be in a worse state than in the former two years, with an remarkable increase of the values, more than the double in some cases.

With the calculation of the EPT index it can be shown as well, that the trend of the water quality is decreasing. Stations with no values are benthic zones of the lake where anoxic conditions in the hypolimnion of course make it impossible to find species of Ephemeroptera (Mayflies), Plecoptera (Stoneflies), and Trichoptera (Caddisflies) and therefore a calculation cannot be made.

5. Conclusions

Altogether the number of identified taxa with wide ecological range continues to increase. This refers mostly to species adapted to more stressful environmental conditions. According to the EPT Index the species that indicate the good water quality are less abundant. Higher biodiversity throughout the lake doesn't indicate a higher quality. Moreover the increase in biodiversity is due to the abundance of species found that are adapted to anoxic condition. Furthermore the species that are indicators for good water quality decrease in numbers of individuals per species or are not found at all, e.g. Plecoptera.

Naturally the abundance of species is higher in the littoral zone than in the benthic zone, mainly based on the different oxygen concentrations. In this regard it has to be stated, that the situation in the shallow parts of the lake is degraded. This applies specially in the southern part where the urban area is located and human impacts increase more and more.

In the deeper parts of the lake aerators are used as restoration measures to improve the oxygen content, but the measurement of the oxygen content, that was carried out by another research group, indicates a low efficiency. To enhance the oxygen situation in the hypolimninon and thereby generally the quality status of the habitat for all species, the use of a new method should be considered. The required advancement could then be indicated by the occurrence of other macroinvertebrate species besides the already present species of Diptera.

At present time the general trend of the used indices indicates, that the quality state of the lake decreases. This results in the need of further management and restoration activities, particularly with regard to the target of the WFD.

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7. Appendices

Table 1.: Number of macroinvertebrates collected from the sampling stations in Lake Durowskie (1m²)

		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
	PLATYHELMINTHES														
1	*Dugesia tigrina* (Girard)							46							
2	**NEMATODA**							23							
3	**OLIGOCHAETA**						23	69					23		
4	**HIRUDINEA**														
5	*Batracobdella paludosa* (Carena)	23			23										
6	*Erpobdella octoculata* (L.)	23			23			23				23			
7	*Glossiphonia complanata* (L.)				23										
8	*Helobdella stagnalis* (L.)	23			46			92				23	69		
9	*Hemiclepsis marginata* (O.F. Müller)							23							
	GASTROPODA														
11	*Bithynia tentaculata* (L.)	46						69	23				46	23	
12	*Lymnaea (Radix) auricularia* (L.)				23										
13	*Potamopyrgus antipodarum* (E.A. Smith)		23										46	69	
14	*Theodoxus fluviatilis* (L.)	299	23					46				46	23		
15	*Valvata piscinalis* (O.F. Müller)							23					23		
16	*Viviparus contectus* (Millet)	69													
	BIVALVIA														
17	*Anodonta anatina* (L.)	46	23		23										
18	*Anodonta cygnea* (L.)				23										
19	*Pisidium* spp. Pfeiffer							23							
20	*Sphaerium corneum* (L.)	23						23							

21	*Unio pictorum* (L.)	23													
22	*Unio tumidus* Philipsson	69	23					23					23	23	
	ISOPODA														
23	*Asellus aquaticus* (L.)	161			529			69							
	MEGALOPTERA														
24	*Sialis fuliginosa* Pictet	23			161			23	138			46			
	EPHEMEROPTERA														
25	*Caenis* sp.	23										23			
	TRICHOPTERA														
26	*Apatania* sp.	23													
27	*Mollana* sp.												23		
28	*Mystacides* sp.	46													
29	Leptoceridae							23							
30	Polycentropodidae											23			
31	Rhyacophilidae											46			
32	*Trichoptera* sp.		23		138										
	DIPTERA														
33	*Chaoborus flavicans* (Meig.)			115		23	552			23	736				115
34	*Chaoborus flavicans* (Meig.) pupae														23
35	Ceratopogonidae									23					
36	Chironomidae larvae	4232	4991		4370			690	644	92		1035	3473	4209	
37	Chironomidae pupae	46					23	23	23			46	69		
	ACARI														
38	*Hydracarina* sp.								115				23		
39	*Hydrachna* sp.	23							23						
	Total	5221	5106	115	5382	23	598	1311	966	138	736	1311	3841	4324	138

Table 2.: Biomass of macroinvertebrates collected from the sampling stations in Lake Durowskie (1m²)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PLATYHELMINTHES														
Dugesia tigrina (Girard)							69							
NEMATODA							69							
OLIGOCHAETA						138						69		
HIRUDINEA														
Batracobdella paludosa (Carena)	69			69										
Erpobdella octoculata (L.)	230			1380			1472				2415			
Glossiphonia complanata (L.)				138										
Helobdella stagnalis (L.)	46			138			92				46	460		
Hemiclepsis marginata (O.F. Müller)							23							
GASTROPODA														
Bithynia tentaculata (L.)	3703						6854	2783				552	437	
Lymnaea (Radix) auricularia (L.)				69										
Potamopyrgus antipodarum (E.A. Smith)		207										184	713	
Theodoxus fluviatilis (L.)	50646	3151					5244				8556	3887		
Valvata piscinalis (O.F. Müller)							1150					460		
Viviparus contectus (Millet)	241730													
BIVALVIA														
Anodonta anatina (L.)	67850	49680		192050										
Anodonta cygnea (L.)				241040										
Pisidium spp. Pfeiffer							5014							
Sphaerium corneum (L.)	4485						10028							
Unio pictorum (L.)	59570													
Unio tumidus Philipsson	63641	238280					7314					12581	190210	
ISOPODA														
Assellus aquaticus (L.)	529			1564			276							

MEGALOPTERA														
Sialis fuliginosa Pictet	322			1748			46	1311			1610			
EPHEMEROPTERA														
Caenis sp.	115										69			
TRICHOPTERA														
Apatania sp.	575													
Mollana sp.												8533		
Mystacides sp.	1150													
Leptoceridae							92							
Polycentropodidae											161			
Rhyacophilidae											391			
Trichoptera sp.		69		1311										
DIPTERA														
Chaoborus flavicans (Meig.)			391		92	2438			115	2714				437
Chaoborus flavicans (Meig.) pupae						92								184
Ceratopogonidae									23					
Chironomidae larvae	15019	10074		52762			4163	2875	2024		16629	9913	8234	
Chironomidae pupae	506						437	92			460	966		
ACARI														
Hydracarina sp.								69				23		
Hydrachna sp.	69							138						

Table 3.: Frequency of macroinvertebrates collected from the sampling stations in Lake Durowskie ($1m^2$)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
PLATYHELMINTHES														
Dugesia tigrina (Girard)							■							
NEMATODA							■							
OLIGOCHAETA						■	■					■		
HIRUDINEA														
Batracobdella paludosa (Carena)	■			■										
Erpobdella octoculata (L.)	■			■			■				■			
Glossiphonia complanata (L.)				■										
Helobdella stagnalis (L.)	■			■			■				■	■		
Hemiclepsis marginata (O.F. Müller)							■							
GASTROPODA														
Bithynia tentaculata (L.)	■						■	■				■	■	
Lymnaea (Radix) auricularia (L.)				■										
Potamopyrgus antipodarum (E.A. Smith)		■										■	■	
Theodoxus fluviatilis (L.)	■	■					■				■	■		
Valvata piscinalis (O.F. Müller)							■					■		
Viviparus contectus (Millet)	■													
BIVALVIA														
Anodonta anatina (L.)	■	■		■										
Anodonta cygnea (L.)				■										
Pisidium spp. Pfeiffer							■							
Sphaerium corneum (L.)	■						■							
Unio pictorum (L.)	■													
Unio tumidus Philipsson	■	■					■					■	■	
ISOPODA														
Asellus aquaticus (L.)	■			■			■							
MEGALOPTERA														
Sialis fuliginosa Pictet	■			■			■	■			■			
EPHEMEROPTERA														
Caenis sp.	■										■			
TRICHOPTERA														
Apatania sp.	■													
Mollana sp.												■		
Mystacides sp.	■													
Leptoceridae							■							
Polycentropodidae											■			
Rhyacophilidae											■			
Trichoptera sp.		■		■										
DIPTERA														

Chaoborus flavicans (Meig.)														
Chaoborus flavicans (Meig.) pupae														
Ceratopogonidae														
Chironomidae larvae														
Chironomidae pupae														
ACARI														
Hydracarina sp.														
Hydrachna sp.														