ECOLOGICAL STATUS OF DUROWSKIE LAKE: CURRENT STATE OF MACROPHYTE COVER OF LAKE DUROWSKIE AND THEIR INDICATIONS FOR THE LAKE'S ECOLOGICAL STATE

[1]Lucian Eugen Bolboacă, [2]Marcin Dziuba, [3]Claas Faber, [2]Magdalena Litwin

[1]Alexandru Ioan Cuza University Iasi, Romania

[2]Adam Mickiewicza University in Poznan, Poland

[3]Christian Albrechts University zu Kiel, Germany

Abstract

In this report, the macrophyte associations of Lake Durowskie near Wągrowiec, Poland is studied. After severe algal bloom events in recent years, a lake restoration program was started in 2009. The research is focused on the present macrophyte situation in the lake. A map of macrophyte cover is derived from field studies. Ecological indices (ESRI, MIR) are calculated. The results are compared to the results of former studies in the years 2009 and 2010.

Keywords: Lake Durowskie, ESMI, MIR, Water Framework Directive, Lake Ecology

1. Introduction

Aquatic habitats are some of the most affected habitats due to human activities. Currently, the European Water Framework Directive (European Commission, 2000) is the main operating tool for water protection in European countries. According to this, all the members are forced to asses ecological status of water bodies exceeding a surface of 0,5 km^2.

Macrophytes represent the group of organism of a high importance for the health of ecosystem. First of all, compared with algae or bacteria that are affected almost immediately after the occurrence of a changing factor, macrophytes need long period to respond to this. So, they are important long-term bioindicators of the ecosystems condition. On the other hand, dominating plants represent one of the most important elements that form a characteristic habitat. Some of them works like filters for different particles from water, or have different affinities towards some chemical elements, in which case they are again good bioindicators. In some condition, plants work as a buffer for erosion by stopping the water waves from reaching the shore.

The following study concentrates on macrophytes assessment in the Durowskie Lake.

Lake Durowskie is situated in the Polish Chodzieskie Lakeland (Fig. 2), at the northern edge of the town of Wągrowiec (Fig.1), in the region called Wielkopolska. It makes part of a chain of several lakes situated on the Struga Gołaniecka River. The surface of the lake is 143.7 ha, and the deepest point exceeds 14 meters. As it is a post glacial lake, the shores of the lake have a steep slope, influencing the macrophytes distribution and abundance.

Figure 2 The position of Durowskie Lake on the map of Poland

The stratification of water offers good condition for cyanobacteria development, which led in the past to a low water quality, influencing in a negative way the tourism which is a big part in local economy of the region.

To prevent this, several measures were taken starting in 2009. There are currently two large aerators that provide oxygen in the lower layer of water. Bio-manipulation was also used to control phytoplankton abundance.

This is the third consecutive year that the assessment of ecological condition of Durowskie Lake was taken in order to observe the changes due to restoration measures.

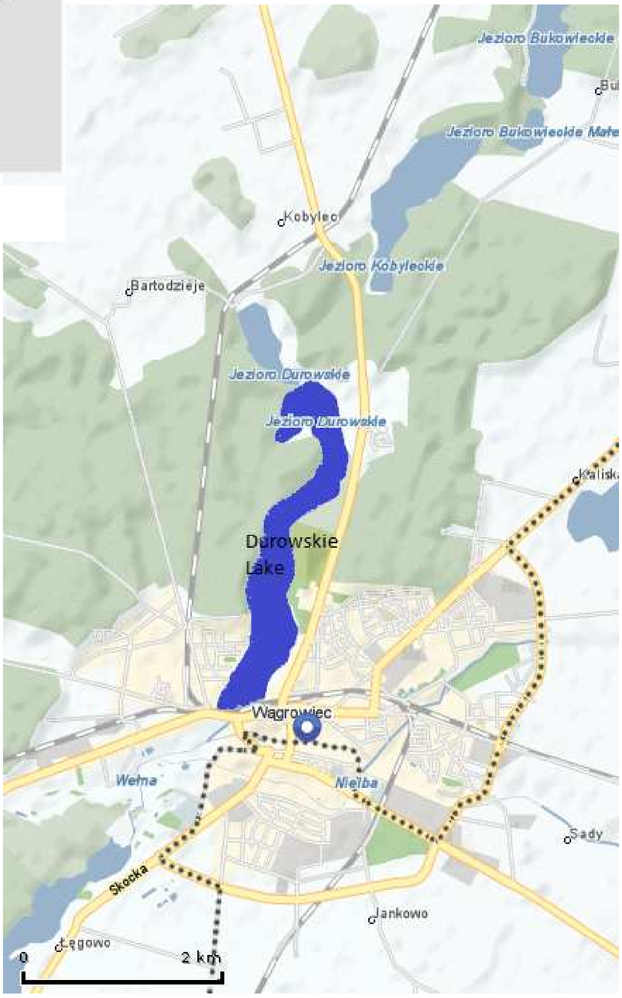

Figure 1 Map of Durowskie Lake compared with the town of Wagrowiec

This study focus on the evaluation of the water ecosystem conditions by evaluating the distribution, structure and biodiversity of the macrophytes. For a better picture concerning the dynamics of the ecosystem quality, we are comparing the data form this year with the previous two years.

,

2. **Methods**

Study sites

Lake Durowskie is situated in Great Poland Voivodeship, in Wagrowiec County, Poland. Its geographical coordinates are E 17˚12’1” and N 52˚49’6”. The origins of the lake are glacial. The topography of the lake is topical for the ones formed in deep valleys, so the banks are deep slopes, with a narrow littoral zone.

The Durowskie Lake has an inflow and an outflow, so the macrophyte assessment method used are Ecological State Macrophyte Index (ESMI, see for example Ciecierska et al., 2010) and Macrophyte River Index (MIR, see for example Goldyn et al., 2009). According to European Directive, there are five status classes used for ecological evaluation of the lake: high, good, moderate, poor and bad.

Sampling

In 4^{th} – 9^{th} of July period, the field data was collected, using the following protocol: There were taken some transects covering the all shoreline in order to map the different macrophyte association, classified after Podbielkowski & Tomaszewicz (1996). We noted the association’s plant abundance using 1 to 5 Braun-Blanquet scale (Braun-Blanquet, 1928). Another parameter taken into account was the surface area of the macrophyte patch, calculated using length and width of it, as well as the depth and geographical position. Each patch was located using GPS points.

For submerged macrophyte, we used a special anchor on which we could collect samples as it scratches the lake bottom.

For a better understanding of the associations distribution we download the GPS points into a computer and, using Google Earth (www.earth.google.com), we mapped the patches of macrophyte.

The ESMI was calculated in order to estimate the ecological state of the lake.

$$ESMI = 1 - \exp\left[-\frac{H}{H_{\max}} * Z * \exp\left(\frac{N}{P}\right)\right]$$

H represents Shannon – Wiener Index, and it can be calculated using the following equation:

$$H = \frac{ni}{N} * ln\left(\frac{ni}{N}\right),$$

where ni is the plant coverage area of an association and N is the total area covered by plants.

H_{max} represents the natural logarithm of the number of association encountered (m)

$$H_{max} = \ln(m)$$

Z is an index that shows the percent of the area that is covered by macrophytes compared with the surface that has the potential to be covered. For this it is assumed that macrophytes can grow on the area A of a lake that is not deeper than 2.5m (Rejweski, 1981).

$$Z = \frac{N}{A}$$

P is the value of the total surface of water.

MIR could also be calculated because the lake has an inflow and an outflow. For this, the following equation is used:

$$MIR = \frac{\Sigma\, Li * Wi * Pi}{\Sigma\, Wi * Pi} * 10$$

L_i represent a factor specific for each species, adjusted for every country.

P_i is the coverage for each species, on a scale from 1 to 9:

Table 1 Coverage classes for the MIR (after Instytut Ochrony Srodwiska, 2006)

Coverage class	% coverage
1	< 0.1%;
2	0.1-1%
3	1- 2.5%
4	2.5-5%
5	5-10%
6	10-25%
7	25-50%
8	50-75%
9	75-100%;

3. Results and discussions

Macrophyte composition

We were able to identify 15 different plant species. As Table 2 shows, the dominating associations are *Phragmitetum communis*, *Typhetum angustifoliae*, *Nuphaeo- nupharetum* and *Potametum perfoliati*.

Table 2 Macrophyte Association of Lake Durowskie in 2011

Association	Surface Area [m²]	Coverage [%]
Phragmitetum communis	39504	58.8
Typhetum angustifoliae	21987	32.7
Nymphaeo- nupharetum	1872	2.8
Potametum perfoliati	1667.5	2.5
Myriophylletum spicati	833	1.2
Acoretum calami	651	1
Spharganietum erecti	228	0.3
Carex riparia	191.5	0.3
Butometum umbellati	67.5	0.1
Caricetum acutiformis	58	0.1
Scirpetum lacustris	57	0.1
Potamogetum pectinati	49	0.1
Eleocharitetum palustre	34	0.1
Typhetum latifoliae	12	0
Glicerium maximum	2	0
Total:	**67213.5**	

Spatial distribution

Figure Figure 3 and Figure 4 show the spatial distribution of the dominant macrophytes.

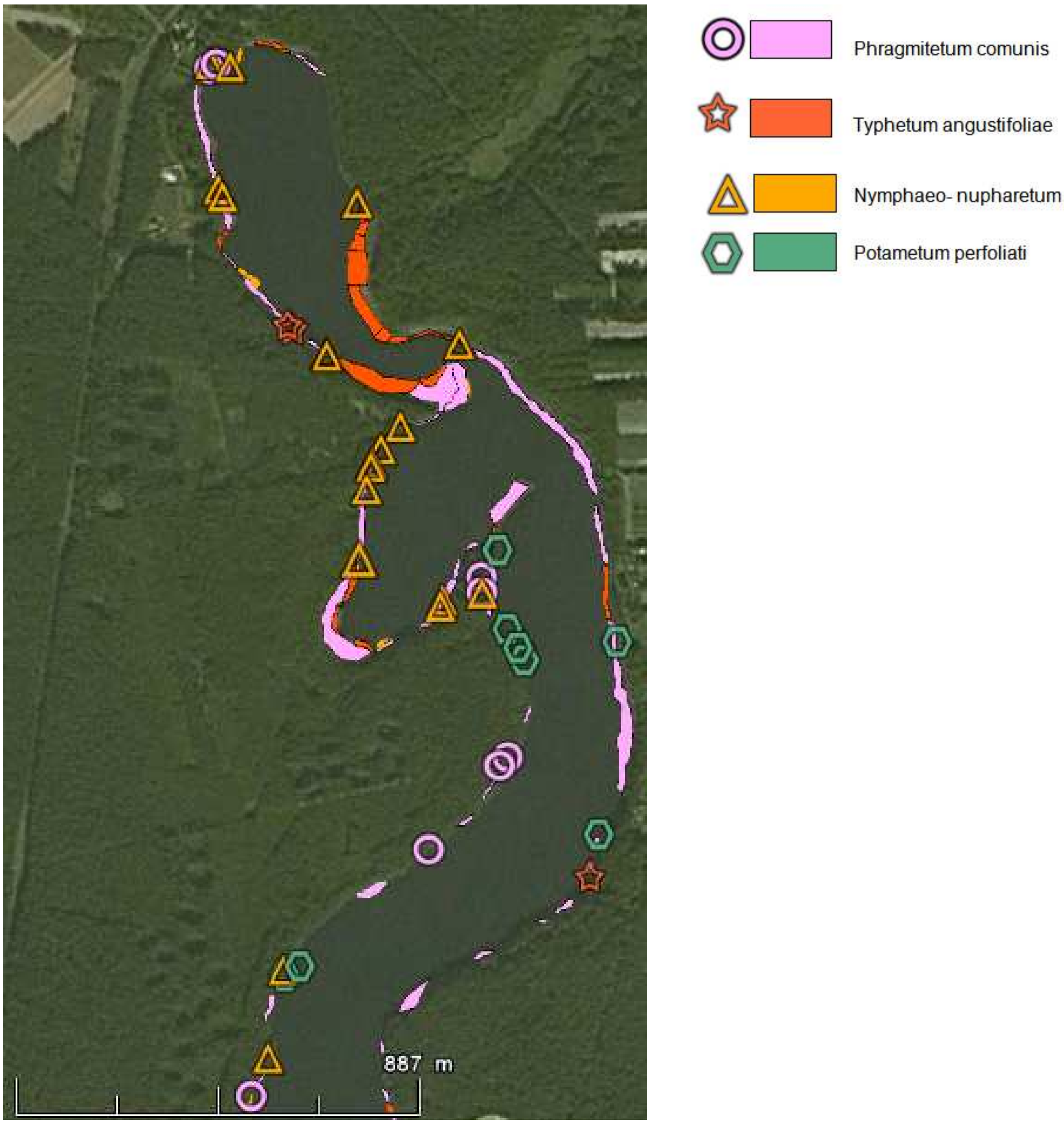

Figure 3 Spatial distribution of dominant macrophytes on northern part of Lake Durowskie

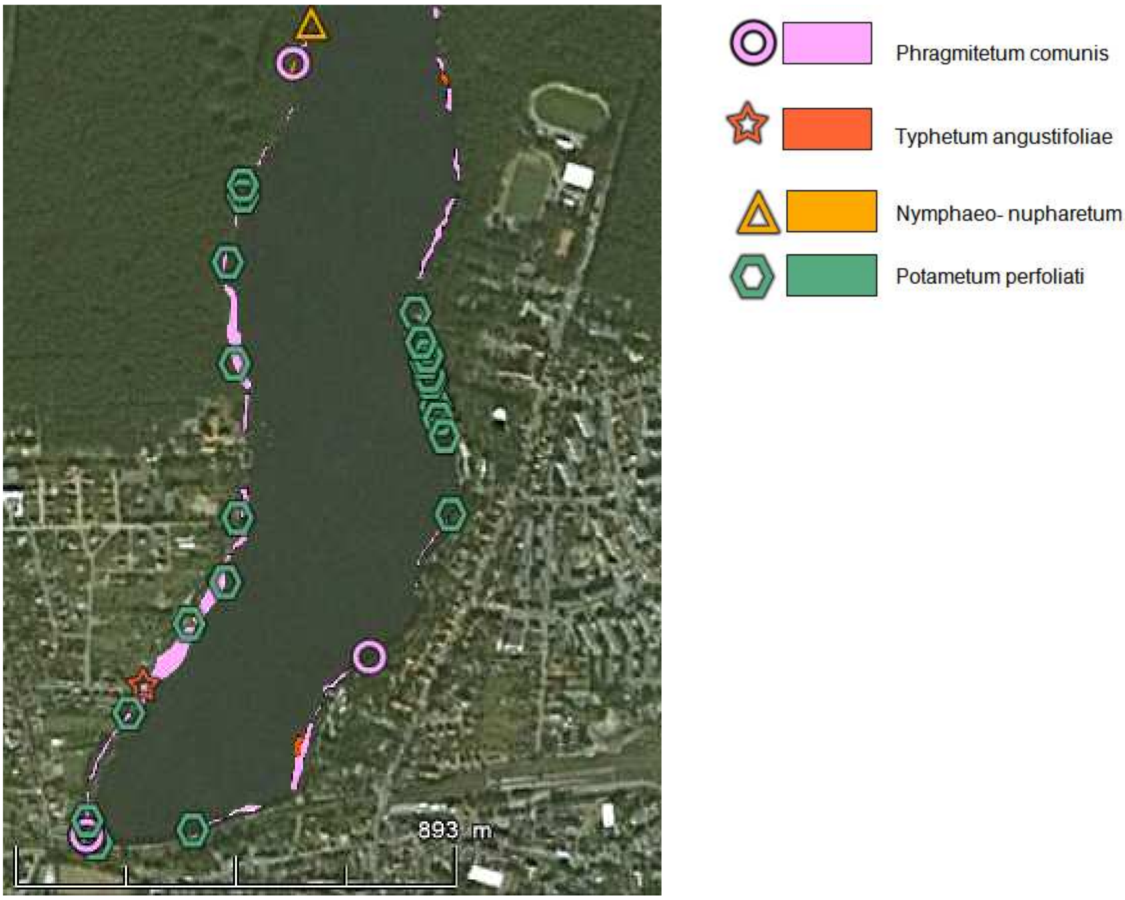

Figure 4 Spatial distribution of dominant macrophytes on southern part of Lake Durowskie

While *Phragmitetum communis* is present in the whole lake, we can observe clear north-south gradient for *Nymphaeo- nupharetum* (high abundance in northern part near inflow) and to a lesser degree also for *Typhetum angustifoliae* (slightly higher abundance north) and (not appearing in very northern part near inflow). The maps also indicate a higher density of *Potametum perfoliati* patches on the Easter shore near the main bathing facilities.

Indices

Although the ESMI of 0.118 is close to the moderate threshold, it still indicates poor water quality (Table 3). The MIR index of 29.8 indicates moderate water quality (Table 4). A comparison of the MIR parameters for the years 2009 till 2011 is given in Table 5.

Table 3 ESMI of 0.118 indicates poor water quality

Stan ekologiczny (Ecological Status)	ESMI Index
Bardzo dobry (Very good)	0.680-1.000>
Dobry (Good)	0.340-0.679>
Umiarkowany (Moderate)	0.172-0.339>
Słaby (Poor)	**0.090-0.169>**
Zły (Bad)	<0.090

Table 4 MRI of 29.8 indicates moderate water quality

Stan ekologiczny (Ecological Status)	MIR Index
Bardzo dobry (Very good)	≥44.5
Dobry (Good)	44.5-35.0>
Umiarkowany (Moderate)	**35.0-25.4>**
Słaby (Poor)	25.4-15.8>
Zły (Bad)	<15.8

Comparison with former years

Although we can see some changes in the parameters of the MRI (Table 5) the overall changes for the indices shown in Table 6 show no clear results. There seems to be a small upward trend for the lake state indicated by ESRI, and a slight downward trend for the state of the outflow given by MIR.

Table 5 Comparison of MIR parameters for the years 2009-2011

Species Name	P			L	W
	2009	2010	2011		
Potemogeton pectinatus	7	8	7	1	1
Butamos umbellatus	6	6	7	5	2
Acorus calamus	3	2	5		
Phaladis arundinacella	2	1	2	2	1
Scrophularia alata			1	4	1
Stachis palustris	1	-	1	1	1
Mentha aquatica	-	-	1	1	1

Table 6 Comparison of ESRI and MIR values for 2009-2011

	2009	2010	2011
ESRI	0.109	0.103	0.118
MIR	30.6	31.7	29.8

The indices alone do not provide a conclusive picture of the ecological state. For this reason, the assembled data needs to be addresses in more detail. Table 7 shows the summary of our results in terms of absolute and relative surface cover as well as a comparison with the former studies from 2009 and 2010.

Table 7 Summary of results and comparison with years 2009 and 2010

Association	Surface [m²]			Difference [m²]	Coverage share [%]			
	2009	2010	2011	2010-2011	2009	2010	2011	2010-2011
Phragmitetum communis	59448	36691	39504	-2813	66.11	62.48	66.18	-3.70
Typhetum angustifoliae	24910	16001	21987	-5986	27.70	27.25	27.73	-0.48
Nymphaeo- nupharetum	3969	2300	1872	428	4.41	3.92	4.42	-0.50
Myriophylletum spicati	124	1520	833	687	0.14	2.59	0.14	2.45
Acoretum calami	528	871	651	220	0.59	1.48	0.59	0.89
Ceratophylletum demersi	15	570	0	570	0.02	0.97	0.02	0.95
Potametum perfoliati	26	387	1668	-1281	0.03	0.66	0.03	0.63
Sparganietum erecti	460	102	228	-126	0.49	0.17	0.51	-0.34
Eleocharitetum palustre	84	70	34	36	0.09	0.12	0.09	0.03
Caricetum acutiformis	94	38	58	-20	0.10	0.06	0.10	-0.04
Glycerietum maximae	55	36	2	34	0.06	0.06	0.06	0.00
Potametum pectinati	0	30	49	-19	0.00	0.05	0.00	0.05
Caricetum riparie	92	27	192	-165	0.10	0.05	0.10	-0.05
Butometum umbellati	0	24	68	-44	0.00	0.04	0.00	0.04
Polygonetum natantis	0	1	0	1	0.00	0.00	0.00	0.00
Typhetum latifoliae	8	4	12	-8	0.01	0.01	0.01	0.00
Najadetum marinae	20	0	0	0	0.02	0.00	0.02	-0.02
Scirpetum lacustri	0	0	57	-57	0.00	0.00	0.00	0.00
Total:	**89833**	**58672**	**67214**					

In order to get a clearer picture of the changes, changes in the total area covered as well as area covered by submerged macrophytes is presented in Figure 5 and Figure 6 respectively.

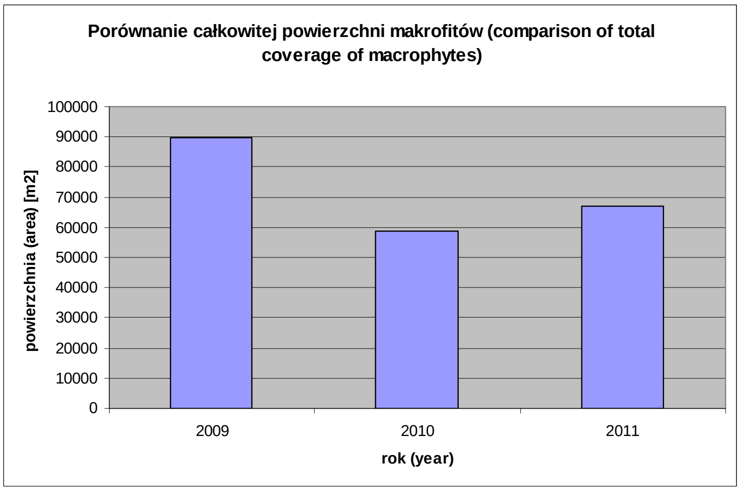

Figure 5 Comparison of total macrophyte cover for the years 209-2011

Figure 5 shows a slight increase in cover for 2011 compared with 2010. This might be indicative of improved conditions in the littoral zone. The low amount of cover for 2010 and 2011 when compared with 2011 can likely be attributed to the relatively harsh winters of those years.

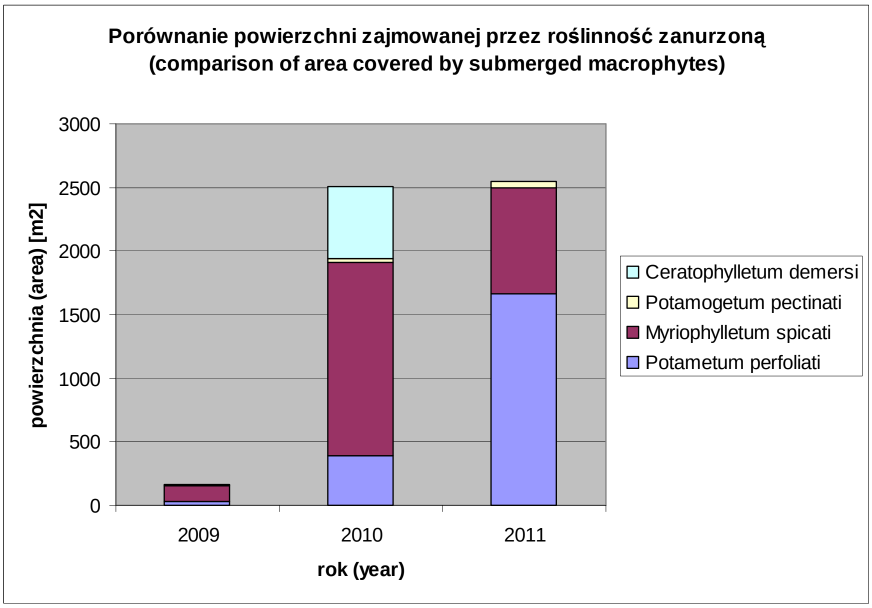

Figure 6 Comparison of area covered by submerged macrophytes for the years 2009-2011

Figure 6 shows not only the area covered by submerged macrophytes, but also the macrophyte composition for the respective years. We see a strong increase from 2009 to 2010 (probably an effect of restoration effort which increased Secchi depth), but no strong increase from 2010 to 2011. What did change, however, was the species composition between 2010 and 2011. We see a decline in *Myriophylettum spicati* in favour of *Potametum perfolati*. This can be taken as sign of improvement in water quality, as *Myriophylettum spicati* is stronger associated with eutrophic water than *Potametum perfolati.* The disappearance of the associations of *Ceratophyllum demersum*, which are characteristic for low quality waters, can also be considered as indicative of better water quality.

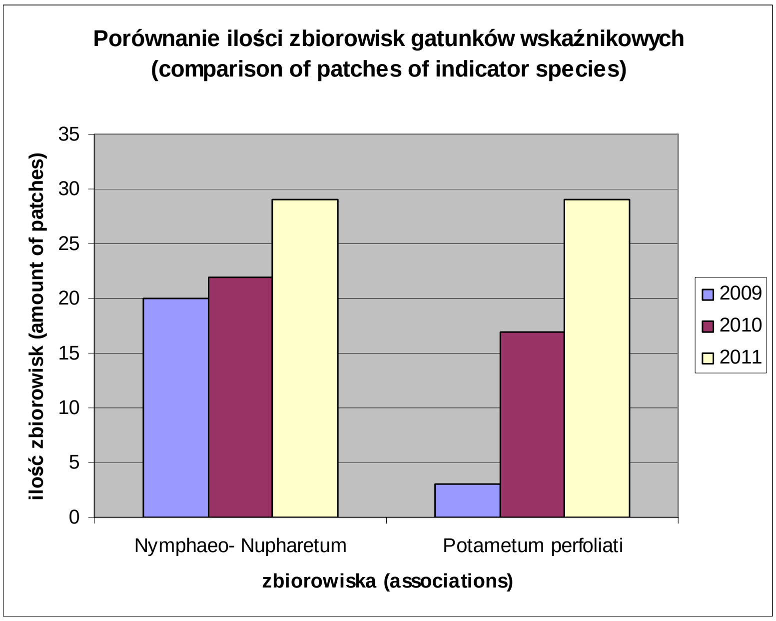

Figure 7 Comparison of number of patches for indicator species from 2009-2011

Figure 7 shows that the amount of patches of macrophyte associations appearing in clean waters (*Potametum perfoliati* and *Nymphaeo- nupharetum*) increased. Although the total area covered by *Nymphaeo- nupharetum* decreased slightly (see Table 7), the appearance of new patches together with an increase of *Potametum perfoliati* indicates overall improvement of water transparency.

4. Conclusions

The study of macrophytes as indicator for the ecological state of a lake shows mostly long term effects. For this reason, the lack of strong changes was expected and is not surprising. The study could however identify some trends.

We can see obvious difference in composition of associations growing in littoral zones of northern parts of the lake surrounded by forests and southern, urban parts placed in Wągrowiec. It is an evidence of different state of water in these two parts. Macrophytes of southern part of the lake has better growing conditions, despite worst catchment area conditions.

Macrophyte belts growing parallel to the shoreline has very low width, which is caused by the lakes morphometry. The steep slope of the banks is limiting the growth of macrophytes which are more dependent of water quality, especially transparency. However, we can observe a slight increase in the areas occupied by macrophytes, comparing to last year. This indicates an improving quality of litoral zone of the lake.

This improvement is also shown by the disappearance of the associations of *Ceratophyllum demersum*, which are characteristic for low quality waters. The amount of patches of macrophyte associations which appear mainly in clean waters (like *Potametum perfoliati* and *Nymphaeo-nupharetum*) have instead increased. We can observe an overall increasing amount of submerged macrophytes, especially *Potametum perfoliati,* which indicates better water transparency.

The ESMI index still shows poor ecological state of the lake. The result is slightly higher than the one from previous years, which could be a positive effects of restoration treatments

MIR index, used for estimation of river state is a little lower comparing to previous years. showing the poor state of water outflow from Durowskie Lake. This might be explained by the big influence of rainwater inflow from the catchment area. The Struga Gołaniecka is influenced by these inflows which bring high loads of pollutants. The treatment systems for these inflows are often neglected, which explains their low efficiency.

The maintenance of the water treatment systems already in place should be an immediate measure for the improvement of the state of macrophytes of Durowskie Lake. Another measure with long term effects could be the introduction of other species (i.e. Characeae, freshwater *Ulva*) from different lakes located in neighbourhood. As we have observed from the spatial distribution of the macrophytes, the management of the inflow into Lake Durowski is needed to sustainably improve water quality. One measure for this could be the re-establishment of *Characeae* plants in the Lake Kobleckie situated immediately before Lake Durowski. This lake used to have *Characeae* which could be used for phyto-remediation (harvesting of lake biomass in order to improve trophic state). The *Characeae* colonies dissappeared due to toxic effects of Cyanobacteria. Management of Cyanobacteria could be attempted by the means of introducing barley straw as decribed for example by Berret et al. (1996). *Characeae* are cold resistant and can fulfil their filtering function even in spring when nutrient inflow is usually highest.

Another plant that might be introduced into Lake Kobleckie and the northern part of Lake Durowskie with beneficial results is freshwater *Ulva*. This plant has extremely high biomass production and is well suited for phyto-remediation as it can be harvested easily. The biomass harvested from *Ulva* and *Characeae* could possibly be used for biogas production, providing another socio-economic incentive for the region.

5. References

- Barret, P.R.F., Curnow, J.C.. The control of diatom and cyanobacterial blooms in reservoirs using barley straw, Hydrobiologica 340, pp. 307-311, 1996

- Braun-Blanquet, J.. Pflanzensoziologie-Grundzuege der Vegetationskunde. Berlin, Germany: Springer Verlag, 1928.

- Ciecierska, H., Kolada, A., Soszka, H., Gołub, M. 2010. A Method for Macrophyte-Based Assessment of the Ecological Status of Lakes, Developed and Implemented for the Purpose of Environmental Protection in Poland. BALWOIS 2010 - Ohrid, Republic of Macedonia - 25, 2010.

- Gołdyn, H., E. Arczyńska-Chudy, P.Pańskwar, M. Jezierska-Madziar. Transformation of flora versus the ecological status of the Wyskoć Watercourse in the last thirty years. Botanika-Steciana, 13: 103-108. 2009

- Podbielkowski, Z. and Tomaszewicz, H. Zarys hydrobotaniki. Warszawa, Poland: Wydawnictwo Naukowe PWN. 1996

- Rejewski, M. Lake vegetation in the Laski region in the Tuchola Forest. Nicolaus Copernicus University in Toruń (in Polish). 1981

- Instytut ochrony środowiska. Opracowanie metodyki badań terenowych makrolitów na potrzeby rutynowego monitoringu wód oraz metoda oceny i klasyfikacji stanu ekologicznego wód na podstawie makrofitów. Tom I – Rzeki. Instytut ochrony środowiska. . 2006