Macrophytes as indicators of the ecological status of Durowskie Lake

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Abstract

The Lake Durowskie with 7km long and maximum depth of 14.6m in Wagrowiec, Poland is a eutrophic lake and experiences algal blooms every year around August which made recreational activities stop at that period. Therefore a restoration program was carried out by the local government in 2009. The research is focused on the present status of Lake Durowskie and the improvement after the restoration problem, using macrophytes as indicator. We found 17 associations of macrophytes with Phragmitetum communis, Typhetum angustifoliae and Nupharo-Nymphaeetum albae as dominant associations. According to the Ecological status Macrophyte index (ESMI) and Macrophyte River Index (MRI), we get the conclusion that from 2009 to 2010, there is no big change of ecological status of Durowskie, as the macrophytes show only the long-term development.

Keywords*:* Durowskie Lake, ESMI, MRI, Association, Ecological Status

1. Introduction

According to European Water Framework Directive (European Commission, 2000) all European Union countries are obliged to assess, improve and report on the ecological status of all water bodies in lakes exceeding a surface area 0.5 km^2 before 2015. In addition to the biological quality elements of phytoplankton, benthic invertebrate fauna and fish, this status shall be determined by macrophytes which are the element that has been taken into consideration in aquatic ecosystems classification.

Aquatic macrophytes in the littoral zones of lakes have three basic features which make them attractive as limnological indicators. Firstly, their taxonomy is relatively easy (Maggioni et al., 2009). Secondly, in contrast to bacteria and micro-algae, they react to changes in environmental condition very slowly and progressively over several years (Melzer, 1999) due to their mobility limitation and annual and pluriannual lifecycle (Maggioni et al., 2009). Macrophytes therefore function as integrators of environmental conditions and can be used as long-term indicators with high spatial resolution. Thirdly, the littoral zone is subject to pattern of nutrient (and pollutant) concentrations (Dave, 1992; Drake & Heaney, 1987) by which aquatic macrophytes can be affected and reflect the nutrient status of their immediate habitat by their presence, absence and abundance and thus can be effectively used as biological indicators (Suominen, 1968; Uotila, 1971).

In 2002 Poland adopted this Water Framework Directive in order to improve aquatic ecosystems which face the threat from urbanization, industrial developments and agricultural intensification (UAM, 2010). To assess the ecological state of polish lakes and rivers, a macrophyte-based method has been developed namely Ecological State Macrophyte Index (ESMI) (Ciecierska et al. 2006, Ciecierska, 2008) and Macrophyte River Index (MRI) (Szoszkiewicz et al., 2006) respectively. The former method has to account for the lake's taxonomic composition and macrophyte abundance and five status classes (high, good, moderate, poor, bad) have to be defined following normative definitions in the directive.

In the present study, the ecological state of Lake Durowskie would be examined according to the requirements of the Water Framework Directive. Lake Durowskie is located in Wągrowiec, Poland in which the restoration program has been carried out in 2009 following the severe algal blooms (Goldyn & Messyasz, 2008). The restoration use water oxygenation method in the hypolimnion layer. Two big aerators are utilized in the deepest part of the lake allowing the oxygenated water move towards surface, providing oxygen to the water without destroying the summer thermal stratification of the lake. The restoration also used bio-manipulation method to control the phytoplankton abundance. The objective of this study is to evaluate the water ecosystem of the lake after the restoration programs through evaluation of structure, distribution and biodiversity of macrophytes. Since Lake Durowskie has an inflow and outflow, both ESMI and MRI indexes are possible to be implemented. Furthermore comparison study with macrophytes associations found in 1994 and previous assessment in 2009 would also be performed to investigate the improvement of water quality and the dynamic of the vegetations.

2. Methods

2.1 Study site

Lake Durowskie is located in Wagrowiec municipality, province of Greater Poland Voivodeship, Poland with geographical coordinates of E 17°12'1" and N 52°49'6" (Figure 1). This lake has glacial origin and can be classified as deep-stratified and tunnel-valley lake with steep shore and very narrow littoral zone. Detail of the bathymetric map and basic morphometric data are shown in Figure 1 and Table 1 respectively. Lake Durowskie has ecological and cultural as well as economical values in the region, as it is one of the main destinations for tourism and recreational activities.

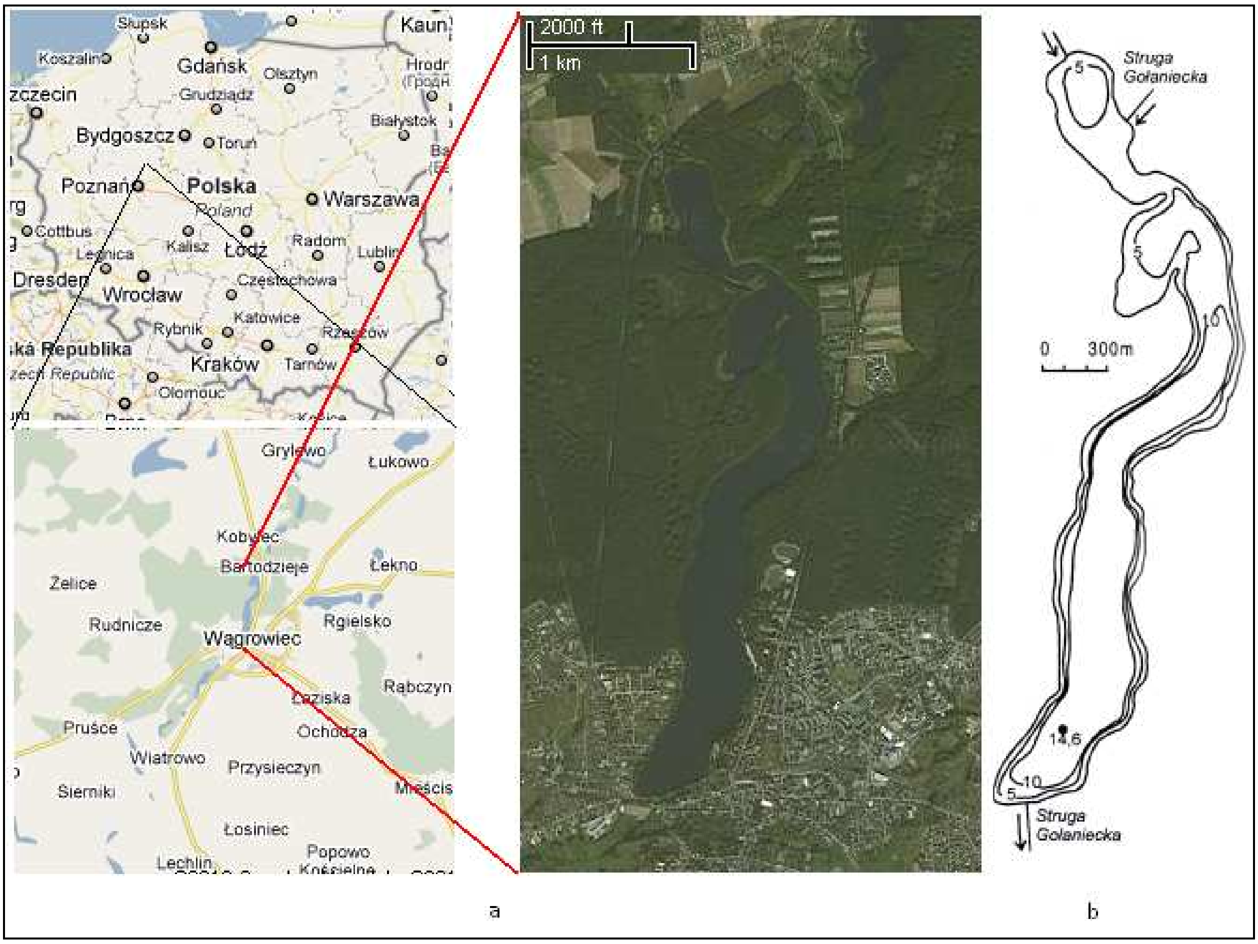

Figure1. Location (a) and bathymetric map (b) of Lake Durowskie (figure from maps.google.com and Goldyn & Messyasz (2008))

The lake often experiences algal blooms every year around August which stops recreational activities at that period. This situation enforced the local government of Wagrowiec to carry out the restoration program in 2009. These restorations include the installation of two aerators and bio-manipulation through introduction of predatory fish into the lake. The first aerator is located in the southern part of the lake and started to work at the end of April 2009. The second one started to work in July 2009 and is located in the northern part of the lake.

Table 1 Basic morphometric data of Lake Durowskie (from Goldyn & Messyasz, 2008)

Morphometric	Unit	Morphometric	Unit
Water surface area	143.7 ha	Immediate catchment area	1 581.3 ha (Messyasz, 1999)
Volume of the lake	11 322.9 m^3	Farming land	58.26% (Messyasz, 1999)
Maximum depth	14.6 m	Forest	33.52 % (Messyasz, 1999)
Average depth	7.9 m	Building compact	8.25 % (Messyasz, 1999)
Total catchment area	236.1 km^2	The Nature of catchment area	North: Agriculture South: Forest-Urban

2.2 Sampling design and GIS mapping

On 5-10th July 2010 macrophytes along the shoreline of Lake Durowskie as well as at outflow were surveyed. The encountered vegetation patches were classified to certain types of plant association following the classification of Podbielkowski & Tomaszewicz (1996). For each plant association, the name of present species and its abundances were estimated using Braun-Blanquet scale (Braun-Blanquet, 1928). In addition, the information of surface area (length and width) of the association, maximum depth and geographical position of the beginning and the end point of the patch were also gathered. The last information was used to measure later the length when the patch is too long that on-site estimation would be difficult to be performed.

To get clear depiction of macrophytes distribution along the shoreline, the geographical positions taken from the field were input into Google Earth (www.earth.google.com). The position of each patch of associations was depicted and length was measured.

2.3 Ecological status Macrophyte indexe (ESMI)

Base on the gathered data, the Ecological Status Macrophyte Index (ESMI) was calculated to assess the ecological state of the lake. The ESMI index meets all requirements of the Water Framework Directive imposed on quality indicators for assessing the ecological state of a water body. It is calculated based on the following formula:

$$ESMI = 1 – \exp [- H/H_{max} \times Z \times \exp (N/P)]$$

ESMI is based on the Shannon-Weaver diversity index (H) (Rejewski, 1981), which was adopted as an indicator of taxonomic composition.

$$H = -\sum n_i/N \times \ln (n_i/N)$$

where:
H - Shannon-Weaver diversity index
n_i -Area covered by given plant association expressed as a percentage of total phytolittoral surface area
N-Total surface area of plant association (100%)

The structural simplification of plant systems due to anthropological pressure is measured by the ratio of actual Shannon-Weaver diversity (H) to the theoretically possible maximum diversity (H_{max}), calculated based on the following formula:

$$H_{max} = \ln S$$

where:
H_{max} - Index of theoretical maximum Shannon-Weaver diversity;

S - Number of plant association in the phytolittoral

The colonization index (Z) is the ratio of the actual surface area occupied by macrophytes to the surface area potentially available to plants. In Polish methodology, for a lake to represent at least a good ecological state, the phytolittoral surface area should not be less than the area limited by the 2.5 isobath (Rejewski, 1981; Ciecierska, 2008), which corresponds to a maximum plant depth of 2.5 m. The colonization index is calculated based on the following formula:

$$Z = N / 2.5\ isob$$

where:
Z – Colonization index
N - Total phytolittoral surface area (ha);
2.5 isob. – Phytolittoral surface area limited by the 2.5 isobath (in Poland, all lakes with the area of > 20 ha share the same data) (ha)

The index takes on values within the range of 0 to 1, where the maximum value indicates a reference state and it decreases with deterioration in ecosystem quality. Moreover, these values are interpreted to the ecological state of lake, as shown in Table 2.

Table 2 Ranges of ESMI for deep-stratified lake types and ecological status classes (from Ciecierska et al., 2010)

Ecological status	Range of ESMI values
High (very good)	0.680 – 1
Good	0.340 - 0.679
Moderate	0.170 - 0.339
Poor	0.090 - 0.169
Bad	<0.090

2.4 Macrophyte River Index (MRI)

The MRI that is necessary to estimate the ecological status according to the European Water Framework Directive was calculated using the formula:

$$MRI = [\sum(Li \times Wi \times Pi) / \sum(Wi \times Pi)] \times 10$$

where:
Li – Indicator value of the species,

Wi – Weight coefficient of the species,

Pi – Cover coefficient of the species, according to the gradual scale (Table 3).

Table 3 Coverage classes for the calculation of MIR (from Instytut Ochrony Srodowiska, 2006)

Coverage class	Percent of 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%

The value of the MIR index may vary between 10 (the most degraded rivers) and 100 (the best water quality) (Szoszkiewicz et al., 2006), as shown in Table 4.

Table 4 Range of Macrophyte River Index (MIR) for the class of the ecological status (according to Szoszkiewicz et al., 2006)

Class of the ecological status	MIR
I - Very good	≥44.5
II - Good	44.5 - 35
III - Moderate	35.0 - 25.4
IV - Sufficient	25.4 - 15.8
V - Bad	<15.8

3. Results and discussion

3.1 Macrophyte associations

As the phytosociological on various phytocoenoses of macrophytes association shows their respond to environmental changes by modifying their taxonomic composition as well as increase or decrease of plant abundance (Schaumburg et al., 2004), it can be used as indicators in water ecosystem evaluation. The following table shows the macrophyte associations found in Lake Durowskie in 2010.

Table 5 Phytosociological associations of Lake Durowskie in 2010

Association	Surface(m2)	Percentage of Coverage (%)
Phragmitetum communis	36691	62.5

Typhetum angustifoliae	16001	27.2
Nupharo-Nymphaeetum albae	2300	3.9
Myriophylletum spicati	1520	2.6
Acoretum calami	871	1.5
Ceratophylletum demersi	570	1.0
Potametum perfoliati	387	0.7
Sparganietum erecti	102	0.2
Eleocharitetum palustre	70	0.1
Scirpetum lacustris	54	0.1
Caricetum acutiformis	38	0.1
Glycerietum maximae	35.5	0.1
Potametum pectinati	30	0.1
Caricetum ripariae	27	0.0
Butometum umbellate	24	0.0
Polygotynetum natantis	1	0.0
Typhetum latifoliae	4	0.0
Total	58725	100.0

As it's shown on the Table 5 totally 17 associations were found in Durowskie Lake. The most dominating association is Phragmitetum communis. They grow compacted near the shoreline and Typha angustifolia was often observed to be within this association. This association is one of the communities with the greatest productivity on our planet (Masing, 1992) and is commonly found in the water bodies which experience eutropication (Tiina, 2010). They show a distinct linkage with the trophic state of lake, as well as sulphates, chlorides, soluble silica, sodium, magnesium, of wide amplitudes of the organic matter content, total nitrogen, calcium, potassium and total phosphates (Pełechaty,1999).

The second dominating association is Typhetum angustifoliae, which is typical for eutrophic and mesotrophic lakes (Sender, 2003). This association is often observed together with Phragmitetum communis association. T. angustifolia is tolerant to saline environments (Grace & Harisson,1986; Hansen et al., 1988) and where T.angustifolia and T. latifolia occur together, T. angustifolia usually colonizes the deeper waters (80 cm or more) (Grace & Wetzel, 1982). After establishment, it can tolerate fluctuating water levels including periods of drought and deep flooding. It height growth is best in hot temperatures but does not seem to be adversely affected by extreme cold (Beule, 1979).

Nupharo-Nymphaeetum albae, Myriophylletum spicati, Acoretum calami and Ceratophylletum demersi are the next association found in the lake. They usually occur in lakes with following characteristic (Piotrowicz et al., 2006): (i) low water transparency, which limits growth and eliminates their competitive pressure, (ii) the presence of fertile organic-mineral sediments near the place where the river flows into the lake and near the place where it flows out, (iii) gentle slopes of the lake basin in the phytolittoral zone and (iv) the presence of inlets sheltered from wind.

The next association is Potametum perfoliati. Potamogeton is a genus of aquatic, mostly freshwater, plants of the family Potamogetonaceae. Potamogeton species are found worldwide in many aquatic ecosystems. It is one of the most important taxa in the aquatic environment, especially as food or habitat for aquatic animals as well as in stabilizing substrates and removing particulate matter from the water column (Haynes, 1975).

The next one is Sparganietum erecti which are often observed with Phragmitetum communis and Typhetum angustifoliae association. CAPM (2004) described that this association grows best in water between 10 and 20 cm deep in silty mud. It is easily uprooted and therefore does not grow well by fast-flowing streams. It is restricted to the shallow margins and cannot withstand prolonged emersion. It is found in relatively nutrient rich waters.

Eleocharietum palustris association are observed in the littoral zone near the outflow of the lake as well as in the east shoreline and outflow near to urban area. This usually can be found in habitats with the following ecological conditions: (i) areas with considerable oscillations of the water level, (ii) a depth of water up to 50 cm and (iii) a soil rich in nutrients and calcium carbonate (Balatova-tulakova et al., 1993; Philippi, 1998; Mertz, 2002). The study by Berelson (1996) found out that the main species of this association, *Eleocharietum palustris*, has an ability to filter Cu (Copper) and Pb (Lead) from sewage treatment plants, mine effluent and agricultural effluent.

Scirpetum lacustris is only found in small patch in the east part of the lake. This association has wide range of ecological condition as it can be found in oligomesotrophic, mesotrophic, eutrophic and dystrophic lakes (Balevičienė & Balevičius, 2006). The study by Sender (2008) in lake Moszne, Poland found that this association exist in that lake from 1960s to 2008 regardless the abiotic conditions changes caused by climatic, economic and recreational activity, as well as on hydro-technical factors.

The rest associations only constitute the small coverage of the lake. Caricetum acutiformis grows on wet areas and covers shores of lakes. Its main species Carex acutiformis forms close belts near the shore. Glycerietum maximae grows in shallow seasonally dry stagnant or running waters near to Caricetum ripariae or Caricetum acutiformis. Potametum perfoliati, an association of submerged plants, grows in stagnant or running waters. Furthermore, there are very few patches of Caricetum ripariae, Butometum umbellate, Polygotynetum natantis and Typhetum latifoliae found in the Durowskie Lake.

3.2 Distribution of macrophyte associations

As it shows in Figure 2 that Phragmitetum communis has an average distribution all over the lake. Typhetum angustifoliae, in the north part, also shows up averagely. But in the south part of the lake, it focuses at the outflow. Nupharo-Nymphaeetum albae mostly distributes at the northwest, but still some small parts in the south and east. Above are three of most dominant associations in Durowskie Lake.

When we focus on the east-west distribution, many submerged associations, such as Myriophylletum spicati, Ceratophylletum demersi, Potametum perfoliati, mainly show up on the east shoreline. Moreover, the new associations in 2010, Potametum pectinati and Polygotynetum natantis, respectively submerged and floating, concentrate on the east side too. Scirpetum lacustris(emergent) distributes only on the east shoreline. Sparganietum erecti, emergent association, was mainly found out on the west shoreline. Caricetum acutiformis(emergent) and Glycerietum maximae(emergent) only show up in the west.

As the north-south distribution was taken into consideration, Potametum perfoliati and Myriophylletum spicati, submerged associations, were found mostly in the south part of the lake. Potametum pectinati (submerged), Glycerietum maximae (emergent) were only found in the south. The third dominant association in Durowskie Lake, Nupharo-Nymphaeetum albae (emergent) shows a north dominating distribution. Caricetum ripariae(emergent) and Ceratophylletum demersi (submerged) only show at some points in the north.

3.3 Comparison of macrophyte associations in different years

3.3.1 Coverage of association

According to Canfield et al. (1985) the relationship between Secchi-disc transparency and colonization of macrophytes has not been quantified for a large number of lakes. The maximum depth, to which aquatic macrophytes can colonize, however, is determined to a large degree by water transparency. When we compare the data of associations between 1994 and 2009, the Secchi-disc transparency decreased from 2.5m in 1994 to 1m in 2009. A strong decrease in submerged macrophytes within the last 15 years was found in Durowskie Lake. Polygonetum natantis, Parvopotamo-Zannichellietum and Myriophylletum spicati disappeared completely. No big difference was observed from the emergent macrophytes between 1994 and 2009. Phragmitetum communis and Typhaetum angustifoliae were still the main cover plants. There was a slight increase of Nupharo-Nymphaeetum albae.

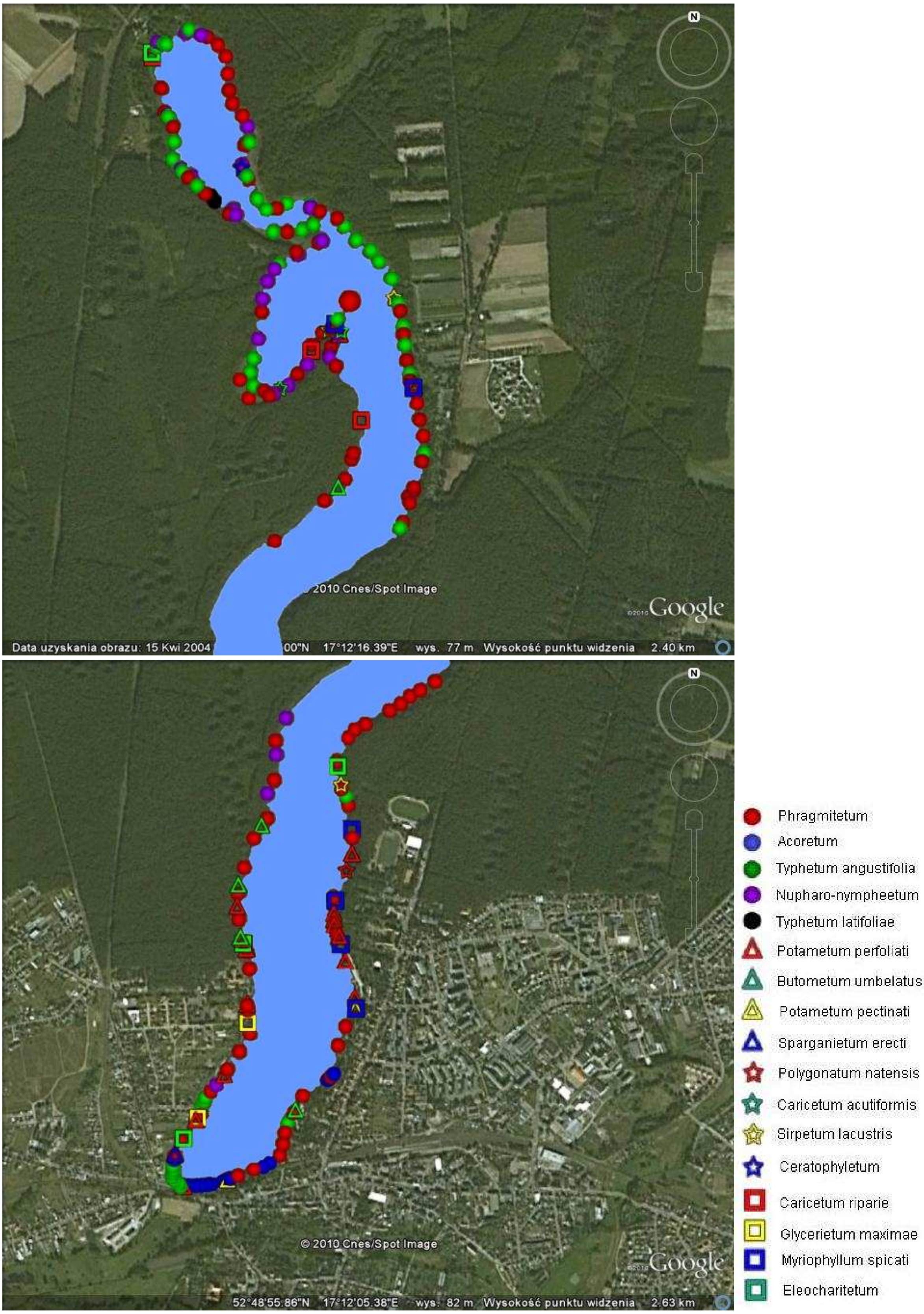

Figure 2. Distribution map of macrophytes association in Durowskie Lake in 2010

Table 6 Phytosociological associations of Lake Durowskie in 2009 and 2010

Association	Surface (m^2)		Difference (m2)	Coverage share (%)		Difference (%)
	2009	2010		2009	2010	
Phragmitetum communis	59448	36691	22757	66.11	62.48	3.63
Typhetum angustifoliae	24910	16001	8910	27.7	27.25	0.45
Nupharo-Nymphaeetum albae	3969	2300	1669	4.41	3.92	0.49
Myriophylletum spicati	124	1520	-1396	0.14	2.59	-2.45
Acoretum calami	528	871	-343	0.59	1.48	-0.89
Ceratophylletum demersi	15	570	-555	0.02	0.97	-0.95
Potametum perfoliati	26	387	-361	0.03	0.66	-0.63
Sparganietum erecti	460	102	358	0.49	0.17	0.32
Eleocharitetum palustre	84	70	14	0.09	0.12	-0.03
Caricetum acutiformis	94	38	56	0.1	0.06	0.04
Glycerietum maximae	55	35.5	20	0.06	0.06	0
Potametum pectinati	0	30	-30	0	0.05	-0.05
Caricetum ripariae	92	27	65	0.1	0.05	0.05
Butometum umbellati	0	24	-24	0	0.04	-0.04
Polygonetum natantis	0	1	-1	0	0	0
Typhetum latifoliae	8	4	4	0.01	0.01	0
Najadetum marinae	20	0	20	0.02	0	0.02

As it's shown on Table 6 that the biggest change shows in Phragmitetum communis and Myriophylletum spicati, respectively 3.6% of decreasing and 2.4% of increasing in percentage of surface. Typhetum angustifoliae, Nupharo-Nymphaeetum albae and Sparganietum erecti show a slight decrease at 0.45%, 0.49% and 0.32%, while Acoretum calami, Ceratophylletum demersi and Potametum perfoliati increase at 0.89%, 0.95% and 0.63%. The other associations almost stay at the same level.

Three new associations were found this year including Potametum pectinati, Butometum umbellate, and Polygonetum natantis. Potametum pectinati is submerged and Polygonetum natantis is floating association. Submerged association Najadetum marinae is not observed this year.

For the emergent species as Typhetum angustifoliae, Nupharo-Nymphaeetum albae, Sparganietum erecti and Acoretum calami, the first three kinds decrease slightly. However the Acoretum calami increases at 0.89%. Most of the submerged as Ceratophylletum demersi and Potametum perfoliati increased, and Myriophylletum spicati has a big increase at 2.45%.

3.3.2 Ecological state of the lake

ESMI accounts the specific geographic features and water typology of Poland. It has been verified by an international intercalibration study and meets all requirements of the Water Framework Directive imposed on quality indicators for assessing the ecological state of a water body (Ciecierska et al., 2010). The ESMI value for Lake Durowskie in the present study is 0.103, which indicates the poor ecological state of the lake. This value is slightly lower than of in 2009 (0.109), yet they still indicates the same ecological state. The ESMI results shows that macrophytes have small respond to restoration program carried out in the lake, although some parameters of water quality have improved. For example Secchi disk visibility in this year is 1.507 m, much higher than of in 2009 when the value is only 1 m.

Apart from its advantages, classification with aquatic macrophytes is restricted to sites with sufficient macrophyte cover and therefore may fail to indicate extreme eutrophication leading to depopulation of submerged macrophytes. If natural reasons for low macrophyte abundance can not be excluded, a classification based on macrophytes may not possible to be performed (Schaumburg et al., 2004).

3.3.3 Ecological state of outflow of the lake

In the outflow of the lake, nine macrophyte species were found (Table 7). *Potamogeton pectimatus* and *Butomus umbellatus* are two species with the highest coverage. This result is similar to the result of 2009 with slightly decrese of *P. pectinatus* coverage. The former species is typical for fair chemical water quality (Triest et al., 2001) while the later one indicates relatively base-rich water, which can be found commonly in the UK and Polish rivers (Raven et al., 2008). The number of species observed in this year is less than last year, when 13 species were found. Glyceria maxima, Iris pseudacorus, Lysimachia thyrsiflora, Rorippa amphibian, Sparganium ramosum and Stachys palustris were the species which were not observed in 2010. However there are two new species that observed in this area: Hildebrandia rivularis and Polygonum amphibium.

Table 7 Outflow species of the lake in 2009 and 2010

Name of species	P		L	W
	2009	2010		
Acorus calamus	3	2	2	3
Butomus umbellatus	6	6	5	2
Cladophora glomerata	4	2	1	2
Glyceria maxima	1	-	3	1
Hildebrandia rivularis	-	3	6	1
Iris pseudacorus	1	-	2	1
Lysimachia thyrsiflora	1	-	3	1
Myriophyllum spicatum	4	2	3	2

Phalaris arundinacea	2	1	2	1
Polygonum amphibium	-	1	4	1
Potamogeton pectimatus	7	8	1	1
Potamogeton perforiatus	2	2	4	2
Rorippa amphibia	4	-	1	4
Sparganium ramosum	1	-	1	1
Stachys palustris	1	-	1	1

The MIR of 2010 is 31.7 which is slightly higher than in 2009 (30.6). Both values, however, indicate the same moderate class of ecological status. Similar to ESMI results, It seems that the restoration programs applied in the lake have small effect to the macrophyte species diversity, composition and abundance in the outflow of the lake. This is understandable since macrophytes are long term indicator where it responds to the changes of environmental condition very slowly (Melzer, 1999). The study by Goldyn et al. (2009) in the Wyskoć Watercourse, Poland showed that macrophytes responded in very long time to the increase of eutrophication level. They found that MIR value only changed from 42.7 to 38 in 30 years, which indicates that based on macrophyte index the ecological status of the river was still in good state.

4. Conclusion

From the data of 2009 and 2010, we can find out that three new associations show up, including Butometum umbellate (emergent association), Potametum pectinati (submerged association) and Polygonetum natantis (floating association). And Najadetum marinae disappeared this year.

The distribution of association shows that many emergent associations focus on the outflow corner. And more submerged associations are on the south and west shoreline, which somehow indicates the good effect of restoration program in the lake.

From the ESMI and MRI data, we see that the ecological status of the lake is in the class IV (poor) and the outflow status is in the moderate. There is no obvious change between 2009 and 2010.

References

Balatova - tulakova, E., L. Mucina, T. Ellmauer & S. Wallanofer. 1993. *Phragmiti - Magnocaricetea*. In: Grabherr, G. & L. Mucina (eds.), Die Pflanzengesellschaften Österreichs. Teil II. Natürliche waldfreie Vegetation. Gustav Fischer Verlag, Jena-Stuttgart-New York, p.79–130.

Balevičienė, J. & A. Balevičius. 2006. Qualitative and quantitative parameters of

phytocenoses in Lithuanian lakes of different trophic state. EKOLOGIJA, 2: 34–43.
Berelson, W.L.1996. Exploring the Use of *Eleocharis palustris* and *Phleum pretense* to Filter Out Cu and Pb In Stormwater Runoff Entering the Laramie River. Conference Proceedings of the American Water Resources Association Wyoming State Section 9th Annual Meeting, Nov. 14-15,1996
Beule, J. D. 1979. Control and management of cattails in southeastern Wisconsin wetlands. Tech. Bull No. 112. Madison, WI: Department of Natural Resources. 40 p.
Braun-Blanquet, J. 1928. Pflanzensoziologie-Grundzuege der Vegetationskunde. Berlin, Germany: Springer Verlag.
Canfield, D. E., Jr., K. A. Langeland, S. B. Linda, & W. T. Haller, 1985. Relations between water transparency and maximum depth of macrophyte colonization in lakes. J. Aquat. Plant Manage. 23:25–28.
CAPM. 2004. Information Sheet *Sparganium Erectum* Branched Bur-Reed. Centre for Ecology & Hydrology, Wallingford, Crowmarsh Gifford, Wallingford, Oxon. http://www.nerc-wallingford.ac.uk/research/capm/pdf%20files/20%20sparganium%20erectum.pdf downloaded at 17 July 2010
Ciecierska H., 2008: Macrophytes as indicators of the ecological status of lakes. Monographs and Dissertations, 139, University of Warmia and Mazury in Olsztyn (in Polish).
Ciecierska, H., Kolada, A., Soszka, H., Gołub, M. 2006. Methodological improvements in the macrophyte-based biological monitoring of surface waters-a pilot study of waters representing selected categories and types. Stage II. Methods for field investigations of macrophytes for the purpose of routine water monitoring, and macrophyte-based assessment and classification of the ecological status of waters. Institute of Environmental Protection, Warszawa (in Polish)
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, 29 May 2010.
Dave, G. 1992. Sediment toxicity and heavy metals in eleven lime reference lakes of Sweden. Wat. Air Soil Pollut., 63:187–200.
Drake, J.C. & S.I. Heaney, 1987. Occurence of phosphorus and its potential remobilization in the littoral sediments of a productive English lake. Freshwat. Biol., 17:513–523.
European Commission. 2000. Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy. Official Journal of the European Communities, L 327 Vol. 43.
Grace, J. B. & Wetzel, R. G.. 1982. Niche differentiation between two rhizomatous plant species: Typha latifolia and Typha angustifolia. Canadian Journal of Botany. 60: 46-57.
Grace, J. B. & Harrison, J. S. 1986. The biology of Canadian weeds.73. Typha latifolia

L., Typha angustifolia L. and Typha xglauca Godr. Canadian Journal of Plant Science. 66: 361-379

Goldyn, R. & B. Messyasz. 2008. Stan jakosci wod I mozilowosci rekultywacji Jeziora Durowskiego. Wydzial Biologii, Uniwersytet im. Adama Mickiewicza w Poznaniu, ul. Umultowska 89, 61-614 Poznan.

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

Hansen, P. L., Chadde, S. W., Pfister, R. D. 1988. Riparian dominance types of Montana. Misc. Publ. No. 49. Missoula, MT: University of Montana, School of Forestry, Montana Forest and Conservation Experiment Station. 411 p.

Instytut ochrony środowiska. 2006. 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.

Maggioni, L.A., D. Fontaneto, S. Bocchi, S. Gomaraska. 2009. Evaluation of water quality and ecological system conditions through macrophytes. Desalination, 246:190–201

Melzer, A. 1999. Aquatic macrophytes as tools for lake management. Hydrobiologia, 395/396:181–190.

Messyasz, B. 1999. Zależności między fitoplanktonem a elementami fizyczno-chemicznymi sześciu jezior Strugi Gołanieckiej. PhD thesis. Department of Hydrobiology, A. Mickiewicz University, Poznań.

Mertz, P., 2002. Pflanzenwelt Mitteleuropas und der Alpen. Nikol Verlagsgesellschaft, Hamburg.

Pełechaty, M. 1999. The phytosociological characteristic and habitat requirements of the Phragmitetum communis (Gams, 1927) Schmale 1939 phytocoenoses in the lakes of the Wielkopolski National Park. Hydrobiologia 408/409: 327–334.

Philippi, G., 1998: 15. Ges.: *Eleocharis palustris*-Gesellschaft Schennikov 19. In: Oberdorfer, E. (ed.), Süddeutsche Pflanzengesellschaften. Teil I. Fels- und Mauergesellschaften, alpine Fluren, Wasser-, Verlandungs- und Moorgeselschaften. Ed. 4. Gustav Fischer Verlag, Jena-Stuttgart-Lübeck-Ulm, p. 156.

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

Raven, P., N. Holmes, P. Scarlett, K. Szoszkiewicz, A. Lawniczak & H. Dawson. 2008. River habitat and macrophytes survey in Poland: Result from 2003 and 2007. River Habitat Survey (RHS), UK.

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

Schaumburg, J., C. Schranz, G. Hofmann, D. Stelzer, S. Schneider, U. Schmedtje. 2004. Macrophytes and phytobenthos as indicators of ecological status in German lakes – a contribution to the implementation of the Water Framework

Directive. Limnologica 34: 302–314.
Suominen, J. 1968. Changes in the aquatic macroflora of the polluted Lake Rautavesi, SW-Finland. Ann. Bot. Fenn., 5:65–81.
Szoskiewicz K., Zbierska J., Jusik S., Zgola, T. 2006. Opracowanie podstaw metodycznych dla monitoringu biologicznego wód powierzchniowych w zakresie makrofitów i pilotowe ich zastosowanie dla części wód reprezentujących wybrane kategorie i typy. Typescript. Instytut Ochrony Środowiska, Warszawa, Akademia Rolnicza im. A. Cieszkowskiego w Poznaniu, Uniwersytet Warmińsko-Mazurski, Olsztyn.
Triest, L., P. Kaur, S. Heylen&N. De Pauw. 2001. Comparative monitoring of diatoms, macroinvertebrates and macrophytes in the Woluwe River (Brussels, Belgium). Aquatic Ecology 35: 183–194
UAM. 2010. Lake ecosystem changes due to restoration measures. Uniwersytet im. Adama Mickiewicza w Poznaniu. http://www.amu.edu.pl/en/about-us/conferences-and-events/summerschools/lake-ecosystem-changes-due-to-restoration-measures-wgrowiecpozna,-july-2010 downloaded at 13 July 2010.
Uotila, P., 1971. Distribution and ecological features of hydrophytes in the polluted Lake Vanajavesi, S-Finland. Ann. Bot. Fenn., 8:257–295.