Hydro-macrophytes as biological indicator for ecological assessment and monitoring of Lake Durowskie.

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Table of content

Index

List of Table

List of the Figure

List of annexes

1. INTRODUCTION

The dynamics of macrophytes are essential in the structure and function of freshwater ecosystem. They function as primary producers which are relevant in mineral transformation and cycling and for the integration of sediment, water and atmospheric conditions and so therefore are important criteria for lakes assessment (Thomaz & Ribeiro da Cunha, 2010).

The Durowskie Lake in Wagrowiec offers a wide range of ecosystem services such as recreation, sport and fishing activities. Prior to this moment, the lake was strongly eutrophic with cyanobacterial bloom (Goldyn, et al, 2013). In a bid to comply with stipulations in the European Union's Water Framework Directive (WFD) on all waters within the EU area, certain restoration measures were applied. The Directive is the EU's collective legislation for managing and protecting water bodies based on geographical and hydrological formation; the main objective of this is to ensure that such waters achieve good ecological and chemical status for the protection of human health, water supply, natural ecosystems and biodiversity (WFD, EU, 2000). The restoration methods applied include oxygenation (use of aerators), immobilization of phosphorus via iron treatment and bio manipulation, which is the introduction of pike fingerlings into the lake; these are then monitored yearly to observe the progress achieved with the restoration measures (Goldyn et al., 2013).

It is important to maintain the quality of this natural resource so that it is continually in a good state for human use to guarantee its continued enjoyment while also generating income for the city government. Lakes have been categorized into three different zones viz: littoral, sublittoral, profundal and pelagic zone. The littoral zone is the shallowest part of a lake, closest to the shore line where there is variation in temperature, abundance of sunlight and concentration of oxygen. In this zone, there are concentrations of classes of macrophytes in associations, as well as young fish and other flora and fauna. The sub littoral zone has poorer fauna quality while the profundial zone is a much deeper zone with no light and much lower temperature; bacteria and zoobenthos are more common here. The pelagic zone however is the open water zone where there are phytoplanktons, zoo planktons, protozoa and many other marine invertebrates (Messyasz & Pikosz, 2017).

Macrophytes are known as good indicators of the quality of ecosystems and vital for the proper functioning of ecosystems (Kozak & Goldyn, 2016). Submerged macrophytes, the most important association of macrophytes perform certain ecosystem functions that assist lakes and rivers to achieve a desired level of water quality. For instance, they provide habitat and breeding area for periphytons, and act as sites of abundant food production for many aquatic animals (Ali et al., 2007). They are also useful for eliminating excess nutrients from lakes and rivers through the process of nutrients absorption using their roots as bio-filters, and equally act as refuge for zoo planktons. However, aside the removal of nutrients from lakes and rivers, macrophytes are also reported to affect the hydrological cycle through evapotranspiration (Lone et al., 2014). In a study about the functions of macrophytes as tools for improving water quality, it was reported that an increase in macrophytes can increase water quality since it assists with heavy nutrient removal; this is called phytoremediation (Lone et al., 2014).

This study reflects part of the monitoring exercises conducted yearly on the lake to investigate the role of macrophytes and the ecological status of the lake. Results from this study are analyzed as part of the long-term monitoring process so that conclusions can be made on the present ecological state of the lake to enable the municipal government make an informed decision on grey areas for improvement.

2. MATERIALS AND METHODS

2.1. Study area

The study was conducted on the Lake Durowskie, Wagrowiec, in the northwestern part of Poland. The Lake lies on coordinates N 52°49'6" and E 17°12'1" (Figure 1). It covers an area of 143.7 ha with a maximum depth of 14.6m (Table 1). It is also connected with four other lakes; Laskowickie, Grylewskie, Bukowieckie, Kobyleckie and all the lakes are linked to the Struga Gołaniecka River. In 2008, the upstream lakes were observed to be highly eutrophic owing to nutrient load from untreated sewage discharge and agricultural uses in surrounding catchments.

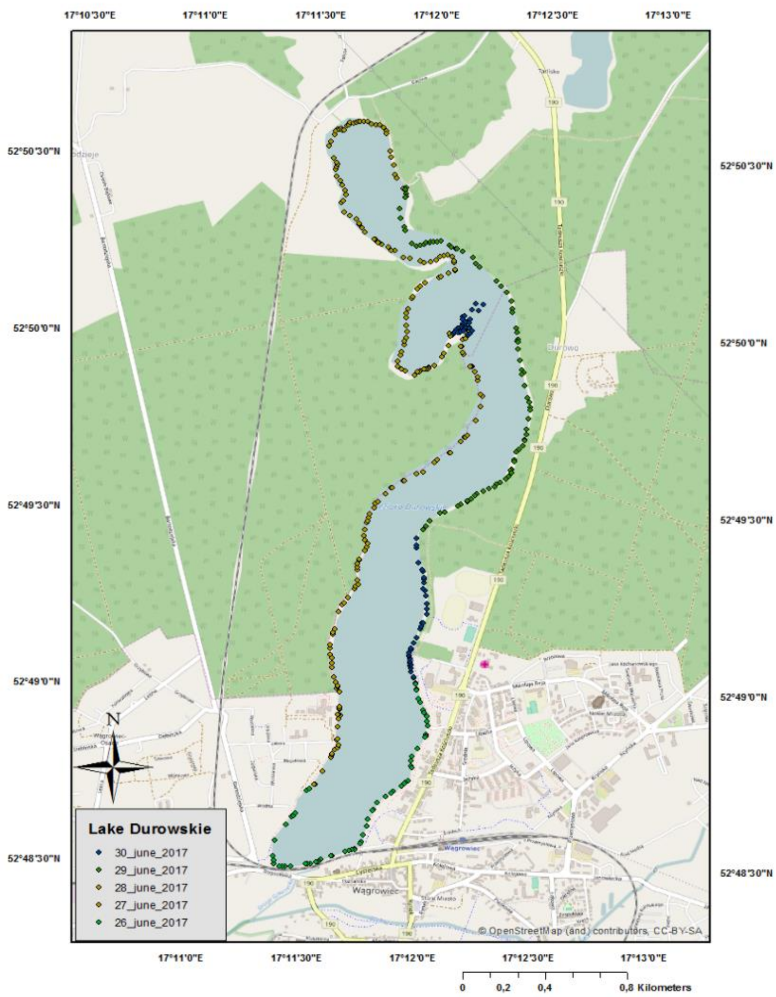

Figure 1. Map of the study area

Table 1: Typical characteristics of Lake Durowskie.

Surface	143.7 ha
Volume	11,322,900 m3
Maximum depth	14.6 m
Average depth	7.9 m
Main tributary	Struga Golaniecka
Surface of the entire sampling area	236.1 km2
Surface in the direct catchment area	1.581 ha
Share of agricultural area	58.26 %
Share of forests	33.52 %
Urban areas	8.25 %

Source: Macrophytes report 2014.

2.2. Data collection

Lake Durowskie has moderately narrow littoral zone due to its very steep bank. However, many species of macrophytes are distributed on the shoreline with different widths from one to ten meters or even more (Macrophytes report 2014). In the summer of each year, effective from 2010 all submerged and emergent macrophytes were sampled to evaluate the success of the ongoing restoration process in the lake. Data for submerged, emergent as well as floating macrophytes were collected from June 26 to July 1, 2017 by boat. Species associations were identified and the number of the patch for each association noted. Patches of every association were classified using Brown-Blanquet phytosociological method (Goldyn et al., 2013). To get information on the spatial areas of respective plant association, GPS coordinates were recorded at the start and end of the patch along with the width of the patch. The presence of submerged macrophytes was examined by using an anchor to pull them up for closer assessment. Simultaneously, the maximum depth where submerged plants occurred was measured and recorded.

In the outflow of the lake to the river, macrophytes of around 25m area were identified on species level. In this case, percentages of coverage were used to determine the dominance of the species. This outflow receives rain water discharge from the Wągrowiec town with diluted concentration of nutrient input owing to the treatment of rain water. The bank of the river has high density of trees coverage which gives shade to the water body. These two factors regulate the presence and abundance of the macrophytes in the shadowed area of this inflow.

2.3. Data analysis

The analysis of data was carried out by importing all GPS co-ordinations to QGIS and saved as an ESRI-Shaped file. ArcGIS 10.5 software was then used to generate the spatial area for the macrophytes. Polygons were drawn for each patch while species of the same association were combined in one patch. Thereafter, with the use of a geometric calculation tool total coverage areas of the macrophytes were calculated. Several maps were produced to illustrate the species composition of macrophytes around the lake.

2.4. Evaluation of the Lake

To assess the ecological state of Lake Durowskie "Ecological State of Macrophyte Index (ESMI)" was used. The ESMI, developed in Poland, evaluates the taxonomic composition and abundance of macrophytes communities. The ESMI fulfills all the requirements set by the Water Framework Directive (WFD) for biological indicators for the assessment and classification of the ecological status of water bodies (Ciecierska & Kolada 2014). ESMI uses the following equation and standards,

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

$$H = -\sum \frac{n_i}{N} \cdot \ln \frac{n_i}{N}$$

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

$$Z = \frac{N}{P_{isob2.5}}$$

Where,

P = Total area of the lake.

n_i = The proportion in percentage of the area inhabited by each plant association .

S = the total number of plant associations in the Phyto littoral.

N (ESMI, Z) = Total Phyto littoral area vegetated in m^{2}.

Pisob2.5 = is the potential Phyto littoral area bounded by the 2.5 meters isobath (area in the lake with a depth inferior to 2.5 meters). In the case of Lake Durowskie, to be consistent with previous years, it is of 20.96 ha (Macrophytes Report 2016).

Table 2: Ecological status from ESMI index

Ecological status	**ESMI Index**
Very good	0.680-1.000
Good	0.340-0.679
Moderate	0.170-0.339
Poor	0.090-0.169
Bad	<0.090

To assess the ecological status of the river, the “Macrophytic Index for River (MIR)” index was calculated. MIR index is used as a biological indicator value, which gives an indication of water quality of running water (Kuhar et al., 2011). It was developed in the UK and compatible with the European Water Framework Directive. This index was calculated using the following equations and standards (Table 3).

$$\text{MIR} = \frac{\sum L_{i*} W_{i*} P_i}{\sum W_{i*} P_i} * 10$$

Where:

L* = indicator value for each species.

P = coverage for each species

W* = weight factor

Ciecierska and Dynowska (2013) were used to have L and W values.

Table 3: Cover coefficient for P

Cover coefficient (P)	Cover species in % (in-situ)
1	<0.1
2	01-1
3	1-2.5
4	2.5-5
5	5-10
6	10-25
7	25-50
8	50-75
9	75-100

Table 4: Ecological status for the MIR index

Ecological status	MIR Index
Very good	≥44.5
Good	(44.5-35.0>
Moderate	(35.0-25.4>
Poor	(25.4-15.8>
Bad	<15.8

3. RESULTS

3.1 Macrophyte associations

As part of the long-term monitoring survey, 19 different associations of the hydro-macrophytes were identified on Lake Durowskie and covers a total area 96,611.8 m^2. *Phalaridetum arundinaceae* re-emerged on this lake five years after it was last seen in 2012. We identified 13 emergent, 5 submerged and 1 floating macrophytes (Table 5).

Table 5. Phytosociology associations of Lake Durowskie in 2017.

Name of the associations	Area in m^2	Area in %
Phragmitetum communis (Garms 1927 , Schmale 1931)	62346,3	64,533
Typhetum angustifoliae (Allorge 1922 , Soo1927)	12804,6	13,254
Myriophylletum spicati (Soo 1927)	11713,3	12,124
Fontinaletum antipyreticae (Kaiser 1936)	4855,0	5,025
Nupharo-Nymphaeetum (Tomaszewicz 1977)	2685,9	2,780
Potametum perfoliati (W, Koch 1926)	817,0	0,846
Acoretum calami (Kobendzz 1948)	368,5	0,381
Caricetum ripariae (Soo 1928)	337,9	0,350
Eleocharitetum palustris (Schennikov 1919)	154,5	0,160
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	136,7	0,141
Typhetum latifoliae (Soo 1927)	115,1	0,119
Sparganietum erecti (Roll 1938)	82,2	0,085
Butometum umbelati (Konczak 1968)	64,7	0,067
Thelypteridi-Phragmitetum (Kuiper 1958)	37,9	0,039
Potametum lucentis (Hueck 1931)	36,0	0,037
Charetum tomentosae (Corillion 1957)	31,7	0,033
Glycerietum maximae (Hueck 1931)	21,4	0,022
Phalaridetum arundinaceae	2,1	0,002
Caricetum acutiformis (Eggler 1933)	1,1	0,001
Total area	**96611,8**	**100**

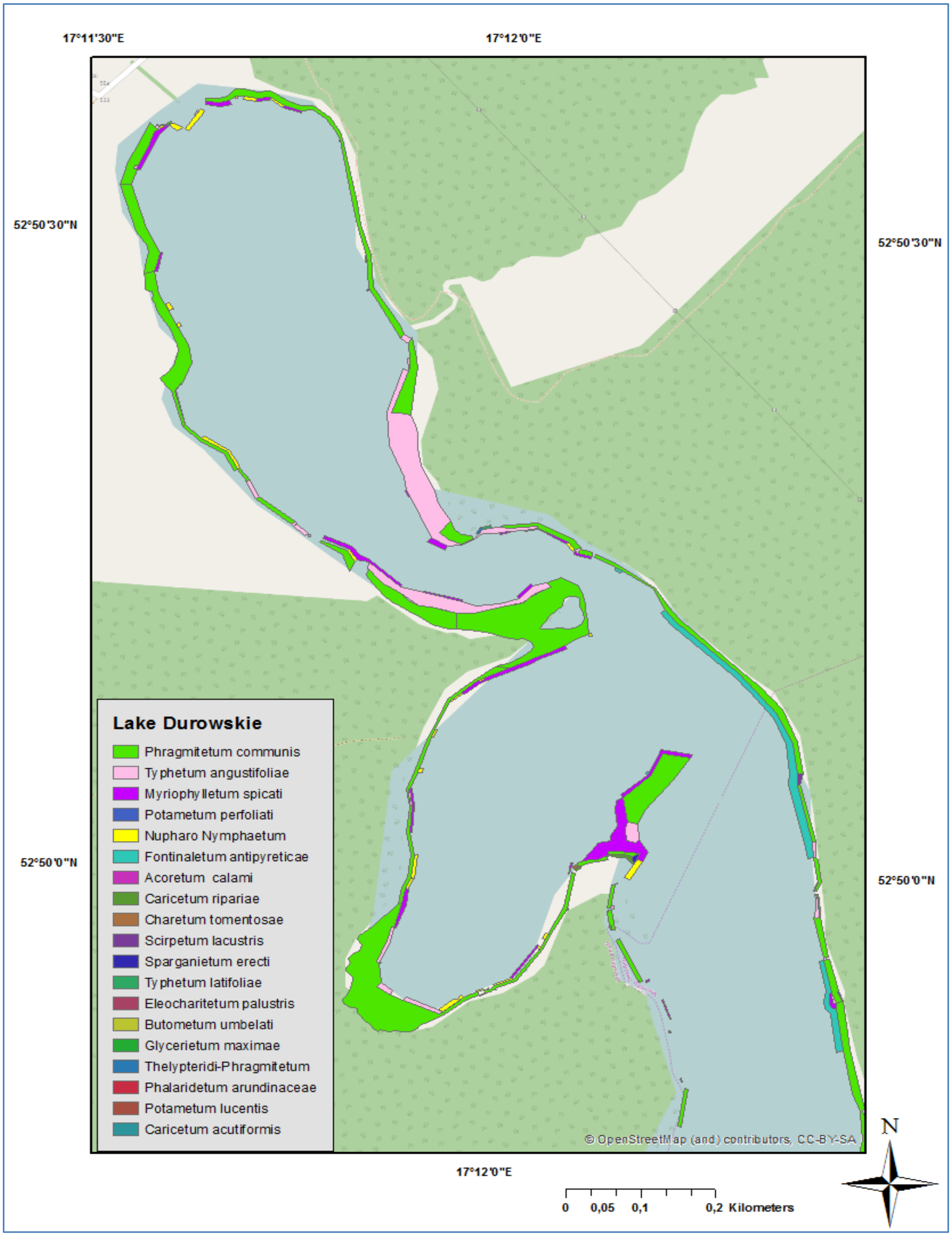

Figure 2: Northern part of the lake

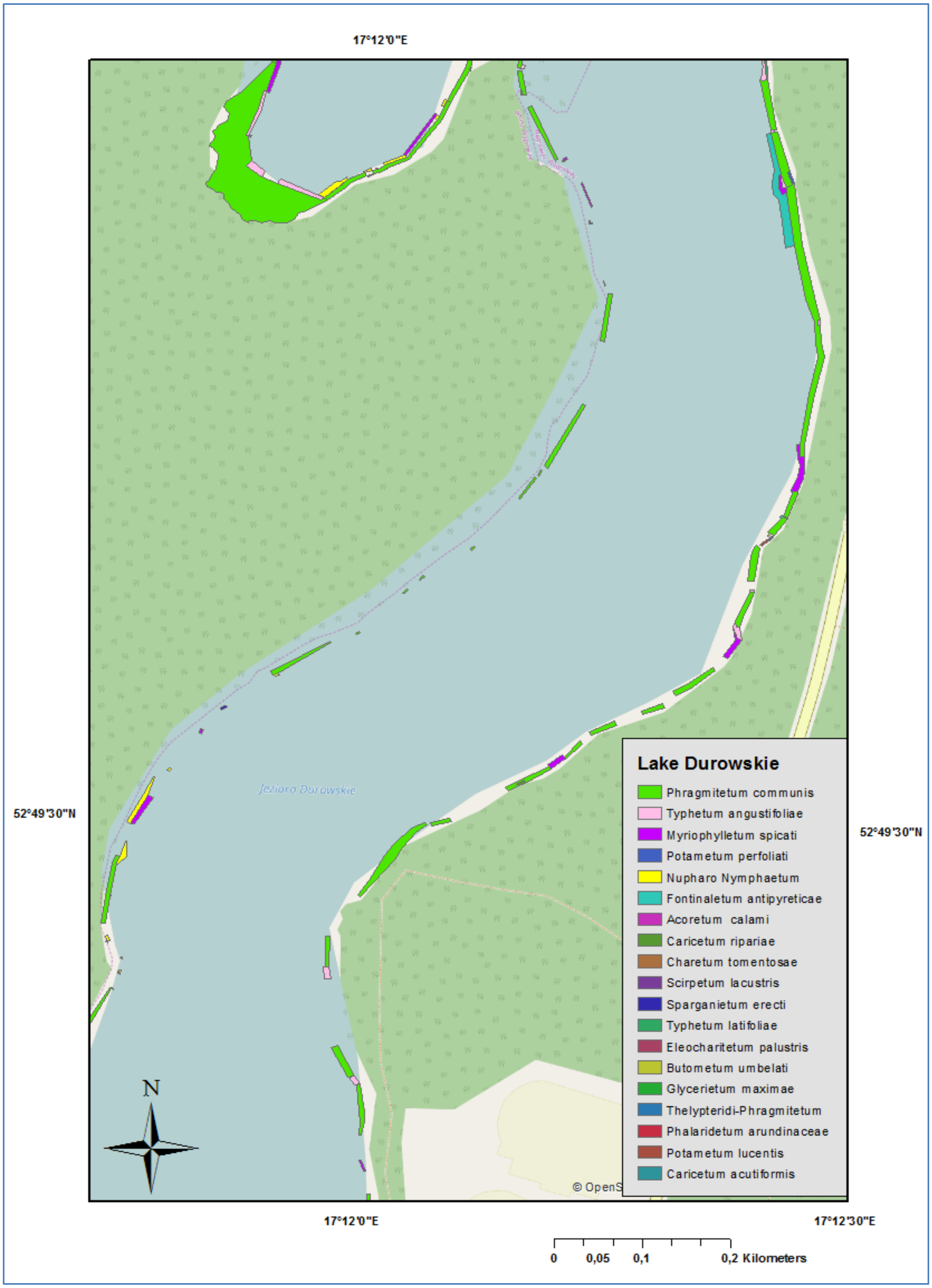

Figure 3: Middle part of the lake

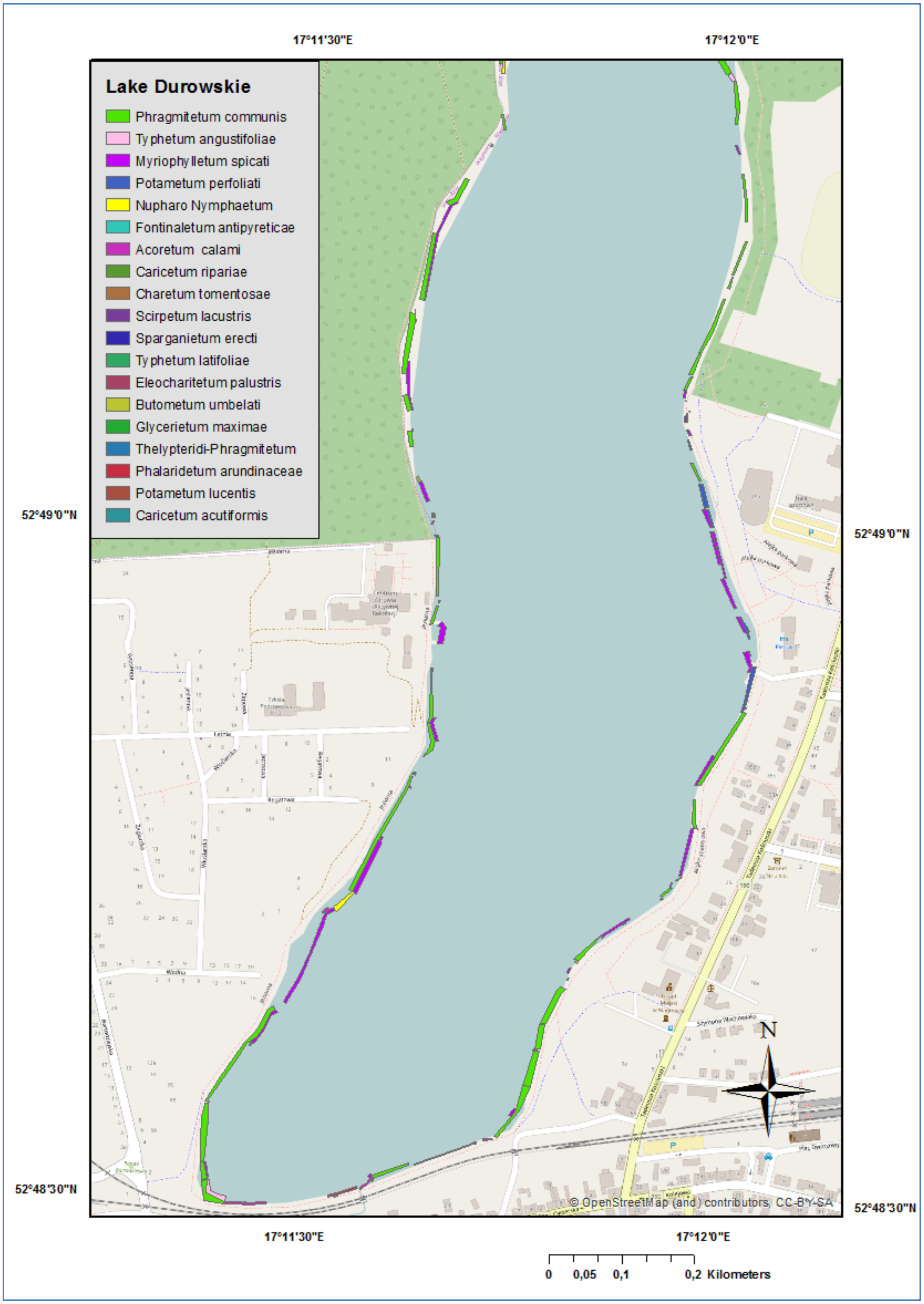

Figure 4: Southern part of the Lake

Figures 2, 3 and 4 show the distribution of macrophytes association along the littoral zone of the lake. The study map was sub-divided into three parts to show the patches clearly. The Northern part shows much wider and larger patches, and this is related to morphology and low anthropogenic activities on this part of the lake. The middle part has comparatively lower macrophyteic coverage area which might be the shadow effects from trees. In the southern part because of the narrow shoreline the littoral zone is also thinner.

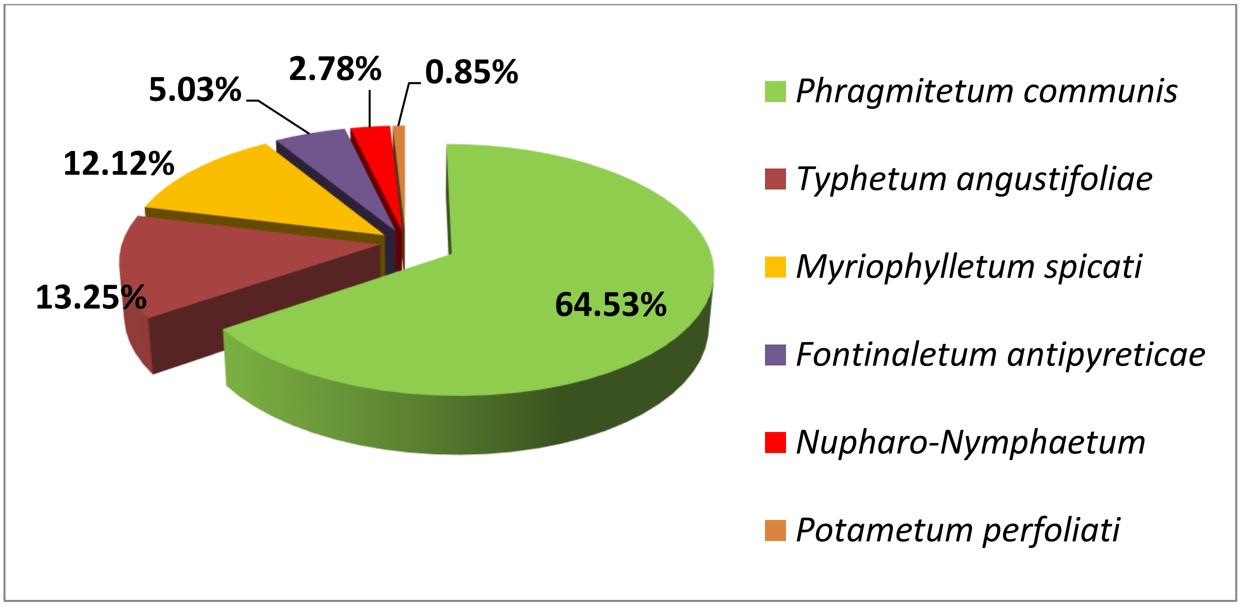

Figure 5: Dominant macrophytes association 2017.

Phragmitetum communis is the dominant association occupying 64.53% of the total coverage area followed by *Typhetum angustifolia* (13.25%) and Myriophylletum Spicati (12.12%).

3.2. Comparison with the previous year

From 2009 there is a clear trend in the increase of the submerged coverage in the Lake Durowskie. In 2017 total submerged coverage area is around 20,000m^2 which is 23% higher than previous year (Figure 6). *Myriophylletum spicati* comprises the large portion of the submerged macrophytes area.

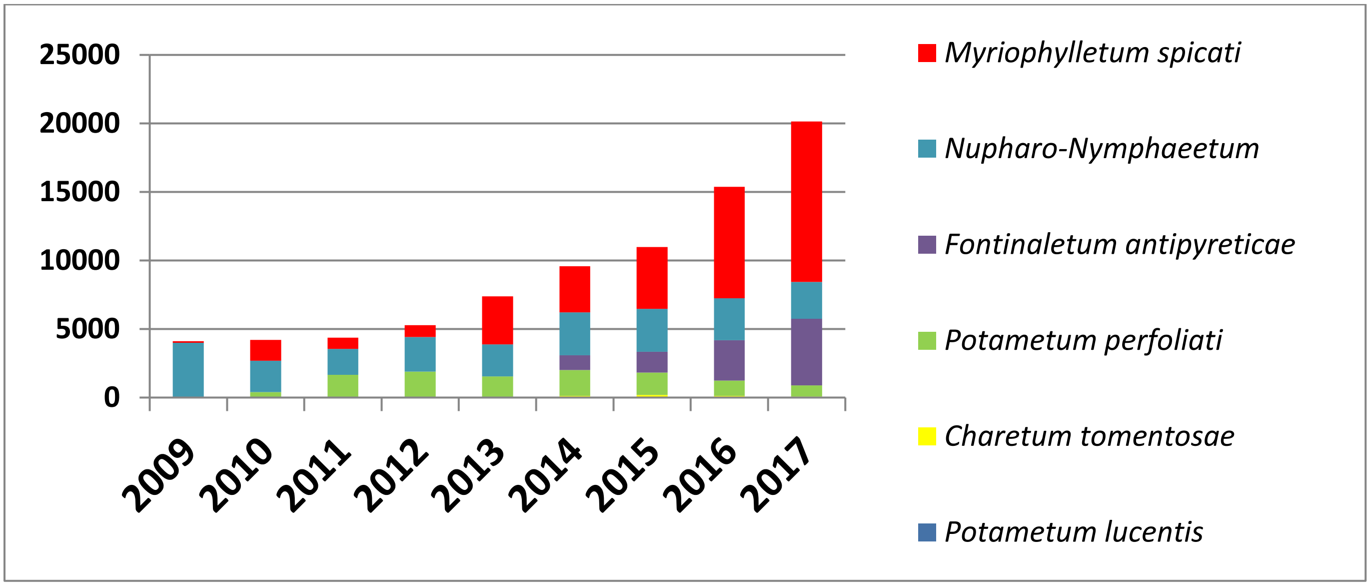

Figure 6: Comparison of submerged plant association

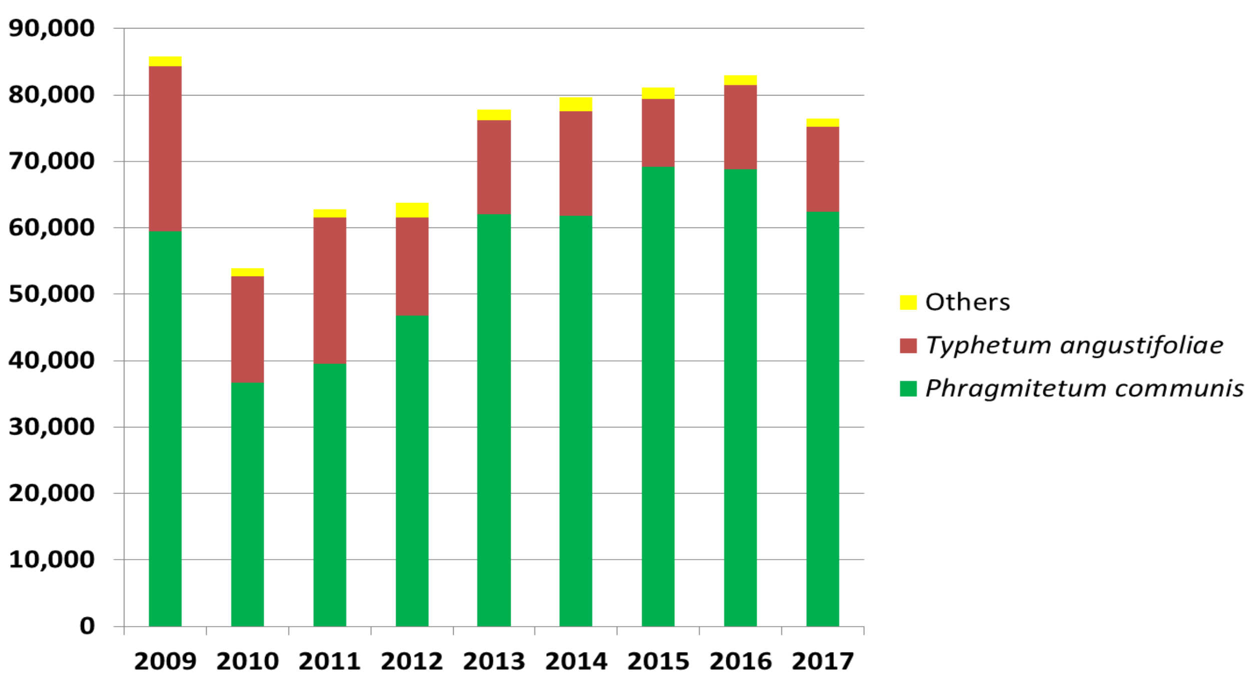

Figure 7: Comparison of emergent plant association

However, the emergent macrophytes have the largest share in the littoral zone in Lake Durowskie. Though the trend of the coverage is upward, this year it decreased. It is also very clear that the percentage of *Phragmitetum communis* association decreased where as *Typhetum angustifolia* remain same.

Figure 8 is depicting the total macrophyte coverage area of lake Durowskie from 2009 to 2017. Though this year a small decrease of 2% is appeared, in general the overall trend is good. A comparison between 2016 and 2017 was made for coverage of macrophytes association in table 7 to investigate more. There is no enormous difference in coverage areas for most of the plants association except for a 9.3% reduction of *Phragmitetum communis*. An increase of 44% and 64% of *Myriophylletum spicati* and *Fotinaletum antipyreticae* respectlivly observed. *Phalaridetum arundinaceae* was only found in small patch with coverage of 2.1%.

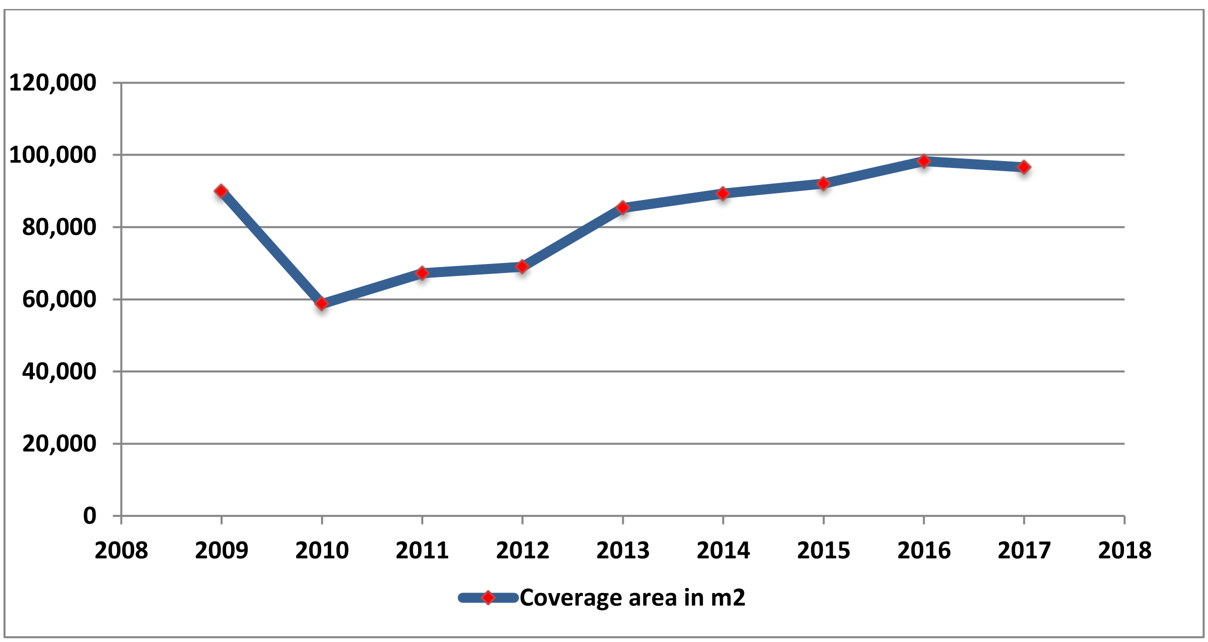

Figure 8: Coverage area of macrophytes along the years from 2009 to 2017

Table 6: Comparison of Plant association coverage between 2016 and 2017

Plant Association	Coverage (m2)		Difference	
	2016	2017	Total area	%
Phragmitetum communis (Garms 1927 , Schmale 1931)	68 751	62346,3	-6404,7	-9.316
Typhetum angustifoliae (Allorge 1922 , Soo1927)	12 694	12804,6	110,6	0.871
Myriophylletum spicati (Soo 1927)	8 136	11713,3	3577,3	43.968
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3 060	2685,9	-374,1	-12.227
Fontinaletum antipyreticae (Kaiser 1936)	2 950	4855,0	1905,0	64.576
Potametum perfoliati (W, Koch 1926)	1 104	817,0	-287,0	-25.993
Acoretum calami (Kobendzz 1948)	714	368,5	-345,5	-48.392
Caricetum ripariae (Soo 1928)	327	337,9	10,9	3.329
Charetum tomentosae (Corillion 1957)	112	31,7	-80,3	-71.724
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	108	136,7	28,7	26.573
Typhetum latifoliae (Soo 1927)	86	115,1	29,1	33.845
Butometum umbelati (Konczak 1968)	75	64,7	-10,3	-13.708
Sparganietum erecti (Roll 1938)	69	82,2	13,2	19.072
Eleocharitetum palustris (Schennikov 1919)	39	154,5	115,5	296.257
Glycerietum maximae (Hueck 1931)	19	21,4	2,4	12.825
Thelypteridi-Phragmitetum (Kuiper 1958)	18	37,9	19,9	110.693
Caricetum acutiformis (Eggler 1933)	13	1,1	-11,9	-91.702
Potametum lucentis (Hueck 1931)	11	36,0	25,0	227.305
Phalaridetum arundinaceae	0	2,1	2,1	
Total	**98,286**	**96611,8**		

3.2 Depth of Submerged associations

For submerged and floating species *(Charetum tomentosae*, *Fontinaletum antipyreticae*, *Myriophylletum spicati*, *Nupharo-Nymphaeetum*, *Potametum lucentis* and *Potametum perfoliati*.) max depth of their presence were estimated. The Table 6 shows the area of the submerged associations, the frequency of patches of the association that was found (number of polygons created), the average area and the maximum depth during the data collection. They are responsible for 32,907.4 m² of the total area of the macrophytes identified, which means around 34%.

Table 7: Maximum depth of submerged macrophytes association

Water plant association	Area m²	Frequency of patches	Average area (m²)	Max depth (m)
Fontinaletum antipyreticae	4855.0	5	971.00	4.1
Myriophylletum spicati	11713.3	62	188.92	2.8
Nupharo-Nymphaetum	2685.9	41	65.51	2.8
Potametum perfoliati	817.0	18	45.39	2.2
Charetum tomentosae	31.7	1	31.67	1.5
Total	**32907.4**			

3.3. Species association of the outflow

In the out flow of the lake to the river 16 plant species were identified. *Butomus umbellatum* species is the dominant species followed by *Myriophyllum spicatum* and *Potamogeton pectinatus. Mentha aquatic* were documented in the outflow which is absent in the Lake.

Table 8: Species composition on the outflow

Plant species	Coverage (%)
Butomus umbellatum	25
Acorus calamus	1,5
Phalaris arundinacea	2
Potamogeton pectinatus	3
Myriophyllum spicatum	4
Mentha aquatica	1
Alage	
Cladophora glomerata	8
Hildenbrandia rivularis	1

3.4 Ecological Status of the lake

ESMI and MIR indices were used to measure the quality of the Lake Durowskie. Table 9, represents the results of the ESMI and MIR from 2017 and in comparison with results from previous years. The ESMI and MIR values are 0.18 and 29.09 respectively in 2017. So according to the both of the indices the ecological condition of the Lake Durowskie is moderate.

Table 9: ESMI and MIR results from 2009 to 2017

Index	2009	2010	2011	2012	2013	2014	2015	2016	2017
ESMI	0,109	0,103	0,118	0,12	0,136	0,149	0,142	0,171	**0,18**
MIR	30,6	31,7	29,8	33,41	26,05	28,95	36,36	37,75	**29.09**

These indices are interpreted in accordance with the following result table in Ciecierska and Dynowska (2013)(Table 7).

Table 10: Range of values for ESMI and MIR

Ecological status	ESMI Index	MIR Index
Very good	0.680-1.000	≥44.5
Good	0.340-0.679	44.5-35.0>
Moderate	0.170-0.339	35.0-25.4>
Poor	0.090-0.169	25.4-15.8>
Bad	<0.090	<15.8

4. Discussion

Nineteen (19) macrophytes associations were identified in the littoral zone of Lake Durowskie compared to 18 in 2016. The total area covered by submerged species increased by 33% while the coverage of emergent species decreased by 6.25% compared to 2016.

Phragmitetum communis, a dominant association of emergent species recorded a decline of 9.8% in coverage area in relation to 2016. The presence of these species of macrophytes do not indicate good water quality and mostly grow on eutrophic lakes but also found on other types of lake (Köbbing et al., 2016). The second most abundant species of emergent plants in terms of coverage is *Typhetum angustifoliae* with a coverage of 13.25% in 2017. This species of macrophyte is occur in eutrophic to mesotrophic conditions in lakes (Kozak & Goldyn, 2016); they were found in about 35 patches in close association to the *Phragmitetum communis*.

Myriophyletum spicati which is an important submerged species has continually increased over the years. In 2017 the coverage of the species is increased by 3.83%. They are good water indicators which tolerate low water temperature and begin to photosynthesize early in spring under good light conditions on sediments (Podbielkowski and Tomaszewski, 1979). Submerged species is a structuring element in lakes and has the ability to stabilize the clearwater state (Lauridsen *et al,* 2003). Macrophytes especially submerged species outcompete with algae and allelopathy effect on phytoplankton (Donk & Bund, 2002). So substantial increase of submerged macrophytes in the Lake is a good sign for the ecosystem. However, *Charatetum tomentosae*, an essential bio-indicator of meso-eutrophic lakes showed a decrease of 0.077% in relation to the 2016 results.

The ESMI value of 0.18 for 2017 is higher than the figure for 2016, which indicates that the Ecological Status of Macrophytes Index for the lake is moderate and has shown a rising trend in the long term. The MIR value of 29.09 for 2017 is lower than the value of 37.75 for 2016. Although there have been fluctuations in the MIR values since restoration measures began, the moderate value recorded for the current year can be attributed to high precipitation of the present year. In addition, this outflow is receiving rainwater discharge which contains high nutrient load.

The additional one species identified this year is *Phalaridetum arundinacea* (red canary grass), an emergent species which was last seen in 2012 re-occurred within a coverage area of 2.10m²; it is an invasive species that can pose serious threat to native plants and can cause loss of biodiversity (Lavergne & Molofsky, 2004). Probably the rare occurrence of this species could be the absence of favourable conditions that enable them to thrive in the lake.

Under-water light conditions, which reflect turbidity, are an important limiting factor for macrophyte diversity (Bakker et al., 2013). In the Lake Durowskie max depth were collected for each sample, which indicate that maximum depth of submerged species decreased from the last year Annex). For example, in 2016 *Fontinaletum antipyreticae* found up to 4.5m whereas, this year it is 4.1 (Macrophytes report 2016). It also indicates that water visibility decreased in this year.

In summary, the ecological status of Lake Durowskie is in moderate condition. It has been almost eight years that restoration initiatives were taken since 2009. So, in this point of time to improve the water quality of lake by the means of macrophytes we are proposing following recommendations.

4.1 Recommendations

Chara species is an indicator of good water quality. In Lake Durowskie, Chara species has only one patch in the last four years. Most likely, because of the small population it is unable to spread to various parts of the lake. Replant the chara species in different part of the lake especially. Dense charophyte vegetation enhances water quality and reduces phytoplankton growth, and they also lead to long term immobilization of nutrients. Furthermore, they are wintergreen which causes less oxygen depletion than annual submerged plants (Hilt et al., 2006). However, replantation of submerged species with turions and seed to have more diversity in the lake.

We strongly recommend taking initiatives to restore the water quality of the upstream lake. *Spirodela plyrhiza* is abundant in the upstream lake which is an indicator for eutrophic water quality. Moreover, Lake Durowskie receives high nutrient input from the upstream lake (Physio-chemical report 2016). Reducing the discharge of nutrients from the point sources is the primary measure to control eutrophication (Xu et al., 2014).

Lastly, we recommend the consideration of macrophytes as a phytoremediation measure to restore the water quality, not only as a biological indicator (Xu et al., 2014). Provided the restoration target is to reduce nutrient load from Lake Durowskie, it is possible to achieve it. Phytoremediation is an eco-friendly, cost effective and promising tool (Xu et al., 2014). In several lakes *Phragmitetum communis* and *Typhetum angustifoliae* species were successfully used to control the water quality.

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Annex 1. List plant and algae recorded in the outflow

Plant species	Coverage (%)
Butometum umbellatum	25
Acorus calamus	1,5
Phalaris arundinacea	2
Solanum dulcamara	+
Calystegia sepium	+
Eupatorium cannabinum	+
Potamogeton pectinatus	3
Myriophyllum spicati	4
Minta aquatica	1
Ranunculus repens	+
Urtica dioica	+
Rorippa amphibia	+
Lycopus europaeus	+
Lysimachia thyrsflora	+
Scrophularia alata	+
Poa palustris	+
Alage	
Cladophora glomerata	8
Hildenbrandia rivularis	1

Annex 2. Calculation of MIR value

Species	Coverage value	P Cover of species in % (in situ)	L	W	L*W*P	W*P
Butomus umbellatus	25%	6	5	2	60	12
Acorus calamus	1.5%	3	2	3	18	9
Phalaris arundinacea	2%	3	2	1	6	3
Potamogeton pectinatus	34%	7	1	1	7	7
Myriophyllum spicatum	4%	4	3	2	24	8
Mentha aquatica	1%	2	5	1	10	2
Lysimachia thyrsiflora	+	1	7	3	21	3
Scrophularia umbrosa	+	1	4	1	4	1
Chladophora glomerata	8%	5	1	2	10	10
					160	**55**
				Σ (L*W*P) / Σ W*P	**2.909091**	
				MIR	**29.09**	

Note *The species Ranunculus repens, Solanum dulcamara, Bidens frondosa, Calystegia sepium, Poa palustris and Scrophularia alata were also found in the site but they are not bio indicators, therefore were omitted.*

Annex 3. Calculation of ESMI value

Macrophytes association	Frequency of patches	Total area	ni/N	ln(ni/N)	ExF	% of frequency of patches	area %
Phragmitetum communis	92	62346.3	0.6453	-0.43799728	-0.28265171	28.66	64.533
Typhetum angustifoliae	35	12804.6	0.1325	-2.02089688	-0.26784268	10.90	13.254
Myriophylletum spicati	62	11713.3	0.1212	-2.10997836	-0.25581502	19.31	12.124
Fontinaletum antipyreticae	5	4855.0	0.0503	-2.99069346	-0.15029005	1.56	5.025
Nupharo Nymphaetum	41	2685.9	0.0278	-3.5827021	-0.09960083	12.77	2.780
Potametum Perfoliati	18	817.0	0.0085	-4.77277288	-0.04036285	5.61	0.846
Acoretum calami	14	368.5	0.0038	-5.56907174	-0.02124055	4.36	0.381
Caricetum ripariae	21	337.9	0.0035	-5.6557514	-0.01978011	6.54	0.350
Eleocharitetum palustris	6	154.5	0.0016	-6.43800197	-0.01029822	1.87	0.160
Scirpetum lacustris	4	136.7	0.0014	-6.56067873	-0.00928287	1.25	0.141
Typhetum latifoliae	3	115.1	0.0012	-6.73259839	-0.00802144	0.93	0.119
Sparganietum erecti	2	82.2	0.0009	-7.06979248	-0.00601222	0.62	0.085
Butometum umbelati	9	64.7	0.0007	-7.30840551	-0.00489579	2.80	0.067
Thelypteridi-Phragmitetum	1	37.9	0.0004	-7.84285351	-0.00307869	0.31	0.039
Potametum lucentis	2	36.0	0.0004	-7.8948381	-0.00294211	0.62	0.037
Charetum tomentosae	1	31.7	0.0003	-8.02312738	-0.00262993	0.31	0.033
Glycerietum maximae	3	21.4	0.0002	-8.41334708	-0.0018668	0.93	0.022
Phalaridetum arundinaceae	1	2.1	0.0000	-10.7546149	-0.00022958	0.31	0.002
Caricetum acutiformis	1	1.1	0.0000	-11.4026903	-0.00012732	0.31	0.001
Total	**321**	**96611.8**			**-1.18696876**	**100**	**100**
				H	1.1870		
				H_{max}	2.9444		
				Z	0.46093		
				exp(N/P)	1.06779		
				Exp[ ]	0.82003		
				ESMI	0.180		

Annex 4: Coverage area of macrophytes associations in Lake Durowskie from 2009 to 2017

Name of associations	2009		2010		2011		2012		2013		2014		2015		2016		2017	
	Total area [m2]	%	Total area [m2]	%	Total area [m2]	%	Total area [m2]	%	Total area [m2]	%	Total area [m2])	%	Total area [m2])	%	Total area [m2]	%	Total area [m2]	%
Phragmitetum communis	59,448	66.11	36,691	62.48	39,504	58.77	46,745	67.7	62,077	72.78	61,762	69.15	69,201	75.16	68,751	69.95	62346.30	64.533
Typhetum angustifoliae	24,910	27.7	16,001	27.25	21,987	32.71	14,743	21.35	14,167	16.61	15,829	17.72	10,144	11.02	12,694	12.92	12804.60	13.254
Myriophylletum spicati	124	0.14	1,520	2.59	833	1.24	850	1.23	3,498	4.1	3,373	3.78	4,512	4.9	8,136	8.28	11713.30	12.124
Nupharo-Nymphaeetum	3,969	4.41	2,300	3.92	1,872	2.79	2,540	3.68	2,324	2.72	3,130	3.5	3,141	3.41	3,060	3.11	2685.90	2.780
Fontinaletum antipyreticae	-	-	-	-	-	-	-	-	-	-	1,082	1.21	1,514	1.64	2,950	3	4855.00	5.025
Potametum perfoliati	26	0.03	387	0.66	1,668	2.48	1,882	2.73	1,547	1.81	1,876	2.1	1,629	1.77	1,104	1.12	817.00	0.846
Acoretum calami	528	0.59	871	1.48	651	0.97	862	1.25	851	1	964	1.08	758	0.82	714	0.73	368.50	0.381
Caricetum ripariae	92	0.1	27	0.05	192	0.28	997	1.44	296	0.35	448	0.5	319	0.35	327	0.33	337.90	0.350
Charetum tomentosae	-	-	-	-	-	-	-	-	-	-	87	0.1	160	0.17	112	0.11	31.70	0.033
Scirpetum lacustris	92	0.1	54	0.09	57	0.08	48	0.07	130	0.15	135	0.15	171	0.19	108	0.11	136.70	0.141
Typhetum latifoliae	8	0.01	4	0.01	12	0.02	10	0.01	38	0.04	49	0.05	49	0.05	86	0.09	115.10	0.119
Butometum umbelati	-	-	24	0.04	68	0.1	107	0.15	82	0.1	57	0.06	71	0.08	75	0.08	64.70	0.067
Sparganietum erecti	460	0.51	102	0.17	228	0.34	58	0.08	84	0.1	164	0.18	156	0.17	69	0.07	82.20	0.085
Eleocharitetum palustris	84	0.09	70	0.12	34	0.05	124	0.18	54	0.06	87	0.1	77	0.08	39	0.04	154.50	0.160
Glycerietum maximae	55	0.06	36	0.06	2	0	7	0.01	39	0.05	139	0.16	30	0.03	19	0.02	21.40	0.022
Thelypteridi-Phragmitetum	-	-	-	-	-	-	35	0.05	-	-	31	0.03	60	0.07	18	0.02	37.90	0.039
Caricetum acutiformis	94	0.1	38	0.06	58	0.09	-	-	-	-	14	0.02	43	0.05	13	0.01	1.10	0.001
Potametum lucentis	-	-	-	-	-	-	-	-	5	0.01	38	0.04	28	0.03	11	0.01	36.00	0.037
Scirpetum tabernaemontanii	-	-	-	-	-	-	-	-	-	-	-	-	2	0	-	-		
Phalaridetum arundinaceae	-	-	-	-	-	-	23	0.03	-	-	-	-	1	0	-	-	2.10	0.002
Potamogetum pectinati	-	-	30	0.05	49	0.07	17	0.02	105	0.12	25	0.03	-	-	-	-		
Polygonetum natantis	-	-	1	0	-	-	-	-	1	0	-	-	-	-	-	-		
Ceratophylletum demersi	15	0.02	570	0.97	-	-	-	-	-	-	-	-	-	-	-	-		
Najadetum marinae	20	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-		
Cicuto-Caricetum pseudocyperi	-	-	-	-	-	-	-	-	-	-	17	0.02	-	-	-	-		
Iridetum pseudacori	-	-	-	-	-	-	-	-	-	-	13	0.01	-	-	-	-		
Total	**89,925**	**100**	**58,726**	**100**	**67,214**	**100**	**69,048**	**100**	**85,298**	**100**	**89,320**	**100**	**92,066**	**100**	**98,286**	**100**	**96112**	**100**