Macrophytes as an indicator for environmental changes in Lake Durowskie

[1]Ahuana Loçano de Come, [2]Lorena Arredondo Tagle, [3]Magdalena Wojnarowska, [4]Michał Brzozowski, [5]Sonia Rashid

[1, 2] Environmental Management Master, Christian-Albrecht University in Kiel, Germany
[3, 4] Master of Science, Adam Mickiewicz University, Poznan, Poland
[3] Aplied Ecology Master, Christian-Albrecht University in Kiel, Germany

Instructor: Prof. Dr. Ryszard Gołdyn

Department of Water Protection, Institute of Environmental Biology, Adam Mickiewicz University, Poland

Summer School

26.06.2016 to 10.07.2016

Index

List of Tables

List of Figures

1. Introduction

Understanding the complex functioning and role of macrophytes is a critical aspect of restoration and management of aquatic ecosystems, for instance lakes. Depending on the content of nutrients as well as succession of lakes, we distinguish between three types of lakes eutrophic, oligotrophic and dystrophic (Podbielkowski and Tomaszewicz 1979).

Lake Durowskie is a particular example, which is the most popular tourist attraction and has a broad range of ecological and socio-economic values in Wągrowiec, Poland. It has importance for recreational activities, tourism, fishing, etc. Also, it is home of many different floral and faunal species indicates the high ecological value. In general, it is surrounded by forest from the north and the town of Wągrowiec is adjacent in the south.

The local population and tourists use this area for water sport and other recreational activities (Gołdyn et al. 2013). In addition, the upper river inflow to the lake had been used for untreated sewage disposal for several years and hence increased the phosphorus content of the water (Macroinvertebrate report 2014). Furthermore, the catchment area around the upper lakes has been typically used for agricultural activities.

As a result of these unsustainable anthropogenic activities, the water quality of the lake has been degraded. The ecological state of Lake Durowskie became severely eutrophic (Gołdyn et al. 2013), though the sewage disposal activity has been stopped since 2006 (Macroinvertebrate report 2014).

It was reported that a large bloom of cyanobacteria happened during the summer in 2008. Immediately after that, the local sanitary authorities had to close the lake for recreational activities. Realising the overall importance of this lake, the responsible authority decided to launch a research project aiming to identify the problems and monitor the status of the lake. As part of this project, study on macrophyte is being carried out since 2009 (Gołdyn et al. 2013).

Aquatic macrophytes play an important role in the structuring and functioning of different communities where they are present. Several types (e.g. submerged, floating leaves, emergent, etc.) of macrophytes are found in the aquatic environment. They increase habitat complexity, heterogeneity and spawning ground for various organisms such as invertebrates, fishes and waterfowl. Generally these plants colonize the shallow zone of the watercourses, influencing key ecological processes (e.g. nutrient cycling) and attributes of other aquatic assemblages (e.g., species diversity). Moreover, macrophytes contribute to the transfer of chemical components from sediment to water and sediment accumulation and influence physico-chemical processes of the water column, e.g. oxygen, inorganic carbon, pH and alkalinity. Furthermore, several species of macrophytes produce considerable amount of refractory matter (e.g. fibrous material), which elevate the carbon sequestration in aquatic ecosystems, retention of solids and nutrients by their submerged roots and leaves, thus reducing the nutrients concentration in the water. Finally, they provide protection against waves and winds, which also promotes the stabilization of shores and a reduction in erosion and sediment resuspension (Thomaz & da Cunha 2010).

Communities of hydro-macrophytes such as submerged ones are used as an indicator of the status of the lake ecosystem over time. Charophytes are particular examples of clear state of water and hence ensure good aquatic environment when grows extensively (Pełechaty & Pronin 2015).

The objectives of the present study are firstly, to understand the role of macrophytes on the functioning of lake ecosystem. Secondly, to determine the ecological status of the Lake Durowskie based on the ESMI and MIR indices, following the requirements of WFD. Finally, to compare the findings of the present study with those of the studies conducted in the years 2009 to 2015 in order to get information of changes in the status of the lake.

2. Material and Methods

2.1. Study area

The Lake Durowskie (Figure 1), located in the city Wągrowiec, Northwest of Poland was selected purposively to conduct the macrophyte study. Its geographical location lies between N 52°49'6'' and E 17°12'1''. It is a postglacial lake with elongated shape, with a surface of 143.7 ha and maximum depth recorded of 14.6 m (Table 1).

It is the seventh and final lake in the catchment area, therefore its ecosystem has been strongly influenced by their inflow. Struga Gołaniecka is the river that flows through this lake.

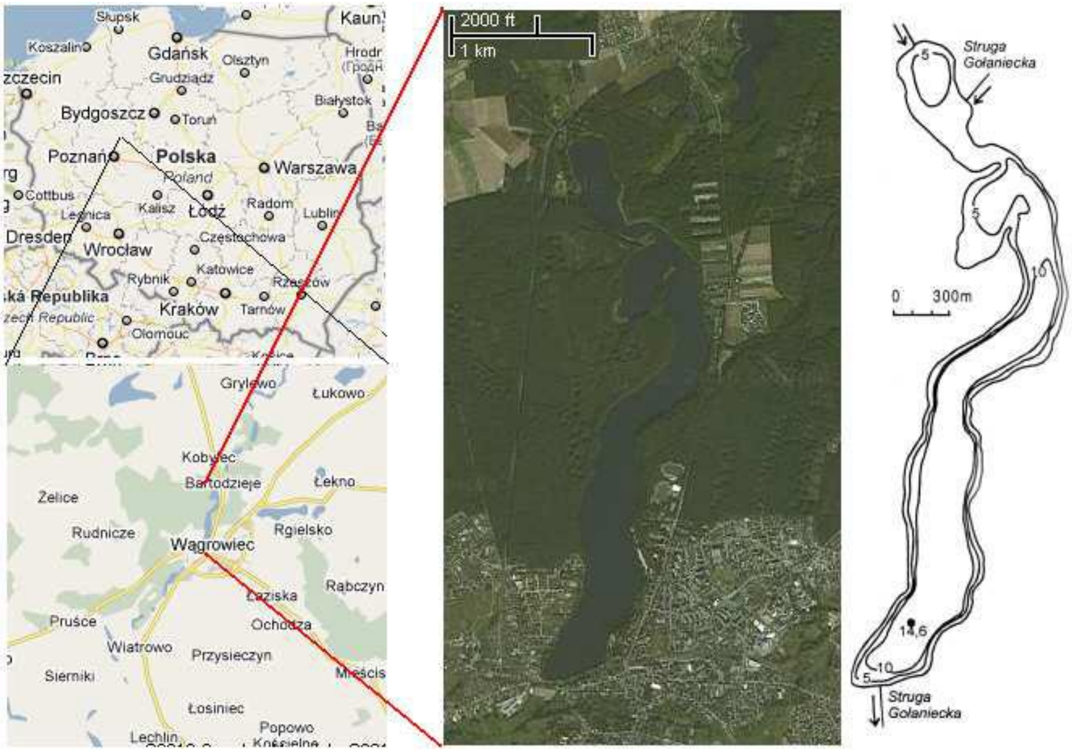

Figure 1: (a) Location and (b) bathymetric map of Lake Durowskie, Wągrowiec. (from maps.google.com and Goldyn & Messyasz 2008 apud Robiansyah et al. 2010).

Table 1: Basic data of Lake Durowskie (Goldyn et al. 2013 apud Warach et al. 2015)

Location	Commune and district Wągrowiec
Surface	143.7 ha
Volume	11,322.9 m^3
Maximum depth	14.6 m
Average depth	7.9 m
Surface of the entire catchment area	361.1 km^2
Main tributary	Struga Gołaniecka

2.2. Field data collection

Field data were collected during the first week (from June 27 to July 2nd). Different macrophyte communities were identified and recorded on the littoral and deeper part of the Lake Durowskie as well as in the outflow at the southern part of lake. Transect sampling method was followed to collect different patches of macrophytes (e.g. rush plants, floating on the surface and submerged plants). Coordinates of starting of each new patches were recorded by GPS. Length and width of the associations were measured to get the spatial coverage of the patches identified. Aerial coverage of macrophytes were determined following the Braun-Blanquet method. Depth in meters of submerged macrophytes were measured to understand the ecological requirements. Simultaneously, presence of submerged macrophytes were examined by the usage of an anchor.

2.3. Data record

The following week (July 4 to July 8), data were analysed in the PC laboratory. At first, GPS coordinates were imported via QGIS and saved as ESRI shapefile. After that, spatial areas of each patch were digitized by creating polygons for each association using the ArcGIS software. In the next step, spatial coverage (m^2) of each association was calculated and summed up to get the total value for each macrophyte association.

2.4. Data analysis

The assessment of the ecological status of the Lake Durowskie based on macrophytes was performed through the use of the following two indices, which are both compliant with the Water Framework Directive of the European Union (2000/60/EC) (Ciecierska and Dynowska 2013).

2.4.1. Ecological State Macrophyte Index (ESMI)

ESMI evaluates two main aspects of macrophyte community patterns: taxonomic composition and abundance. The index values range from 0 to 1, where 1 denotes the theoretical reference value and it decreases as the quality of the ecosystem deteriorates (Ciecierska and Kolada 2014).

It is an index composed of other indices, with the following formulas:

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

From which:

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

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

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

Where:

P = total area of the lake. In our study case is 147.3 ha.

n_i = is the proportion in percentage of the area inhabited by each plant association in the total of the phytolittoral.

$N_{(H)}$ = is the total area vegetated in percentage (100%).

S = is the total number of plant associations in the phytolittoral.

$N_{(ESMI,\ Z)}$ = total phytolittoral area vegetated in m^2.

$P_{isob2.5}$ = is the potential phytolittoral 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.

2.4.2. Macrophyte Index for Rivers (MIR)

MIR identifies the presence of certain macrophytes to indicate the degree of degradation in the rivers, through the following formula (Ciecierska and Dynowska 2013):

$$MIR = \frac{\sum Li \cdot Wi \cdot Pi}{\sum Wi \cdot Pi} \cdot 10$$

Where:

i = individual species.

L* = species indicator value.

Specifies the average trophic level of the environment and ranges from 1 (indicators of eutrophic conditions) to 10 (indicators of oligotrophic water) (Muratov and Szoszkiewicz 2015).

W* = weighting factor.

Is a measure of ecological tolerance of species to trophy and ranges from 1 (plants with a large range tolerance – eurybionts) to 3 (organisms of a narrow tolerance scope – ecological specialists, stenobionts) (Muratov and Szoszkiewicz 2015).

* *L and W values are obtained from the list of bioindicator species used to calculate the MIR, in Ciecierska and Dynowska 2013. It should be noted that the species found in situ that are not in the forementioned list, are not bioindicators and thus are not relevant for this index.*

P = coefficient of coverage for each species.

For the coverage in percentage of each specie identified in situ, the following table (Ciecierska and Dynowska 2013) provides a value assigned:

Table 2: Conversion table for the cover coefficient (P)

Cover coefficient (P)	Cover of species in % (in situ)
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

To determine the index in the Lake Durowskie, we sampled the macrophytes in the river which is the outflow of the lake.

3. Results

3.1 Macrophytes association coverage

For this report, macrophyte associations are used to indicate the ecological state of the Lake Durowskie. The coverage of macrophyte associations observed in 2016 are shown in Table 3.

Table 3: Macrophytes associations coverage in the Lake Durowskie in 2016

Association	Area in m^2	Area in %
Phragmitetum communis (Garms 1927 , Schmale 1931)	68,751	69.95%
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	12,694	12.92%
Myriophylletum spicati (Soo 1927)	8,136	8.28%
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3,060	3.11%
Fontinaletum antipyreticae (Kaiser 1936)	2,950	3.00%
Potametum perfoliati (W. Koch 1926)	1,104	1.12%
Acoretum calami (Kobendzz 1948)	714	0.73%
Caricetum ripariae (Soo 1928)	327	0.33%
Charetum tomentosae (Corillion 1957)	112	0.11%
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	108	0.11%
Typhetum latifoliae (Soo 1927)	86	0.09%
Butometum umbelati (Konczak 1968)	75	0.08%
Sparganietum erecti (Roll 1938)	69	0.07%
Eleocharitetum palustris (Schennikov 1919)	39	0.04%
Glycerietum maximae (Hueck 1931)	19	0.02%
Thelypteridi-Phragmitetum (Kuiper 1958)	18	0.02%
Caricetum acutiformis (Eggler 1933)	13	0.01%
Potametum lucentis (Hueck 1931)	11	0.01%
Total	**98,286**	**100%**

Figures 2, 3 and 4 show the distribution of macrophyte associations along the shoreline of Lake Durowskie in 2016. The map of the lake is divided in three sections, since it provides a much clearer view of the association's appearance and distribution throughout the shoreline.

As it is clearly visible, the northern belt of the lake shows much wider and larger patches with a maximum width of 60 meters. The central part has up to 13 meters wide.

On the other hand, the southern side close to the city, has the widest patch with 20 meters but the images show clearly fewer appearance and bigger gaps between patches.

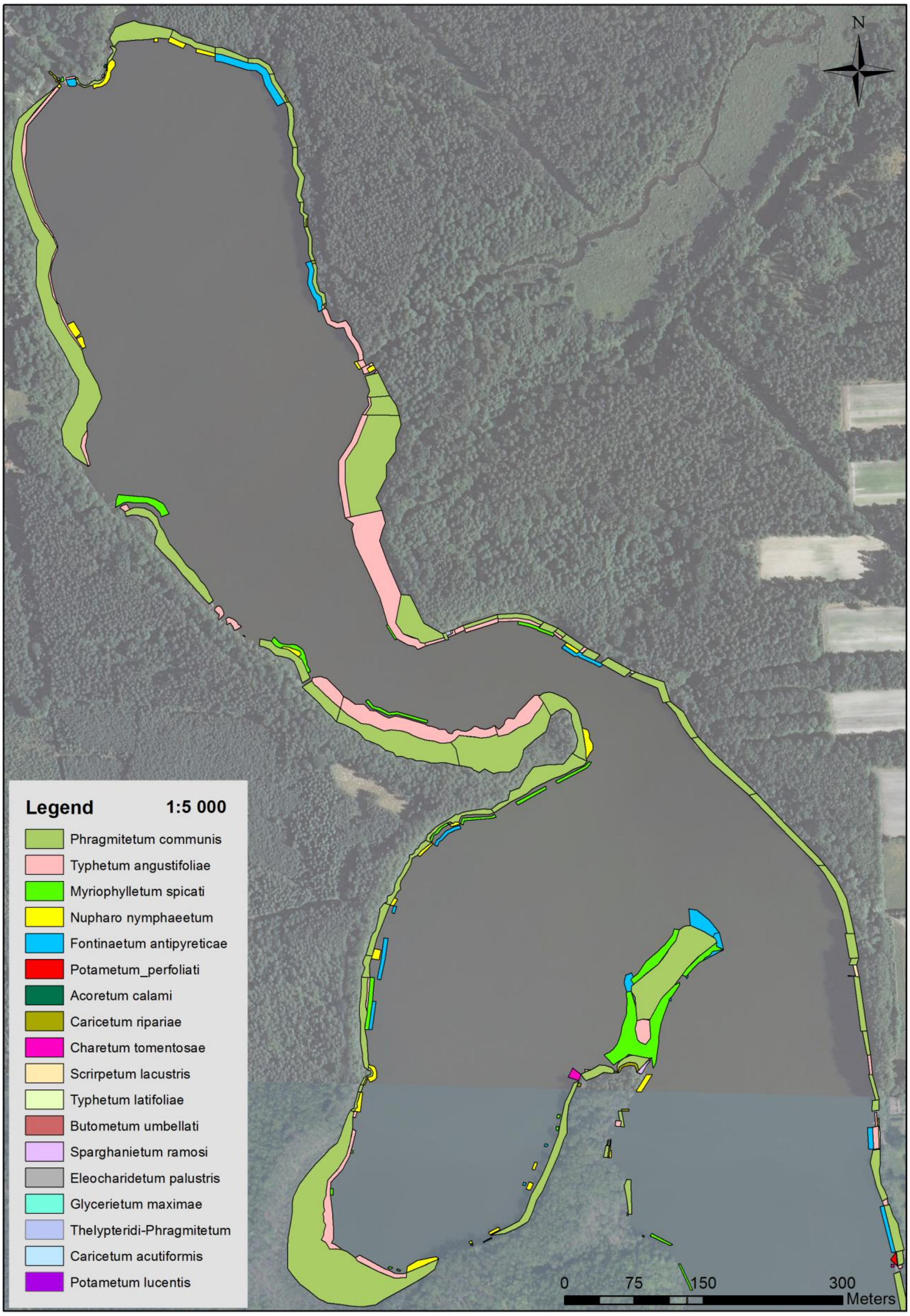

Figure 2: Distribution of macrophytes in the north segment of Lake Durowskie

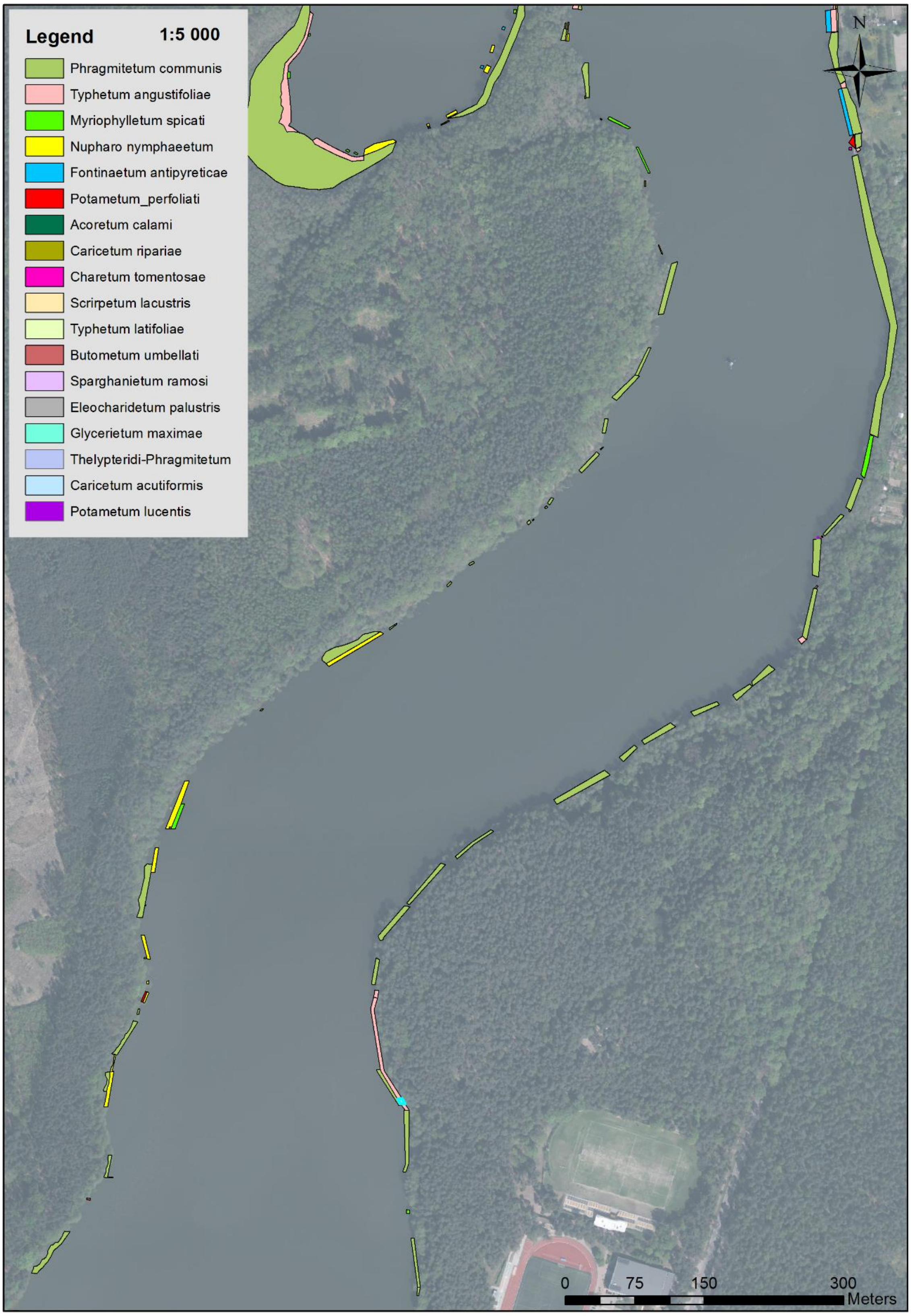

Figure 3: Distribution of macrophytes in the central segment of Lake Durowskie

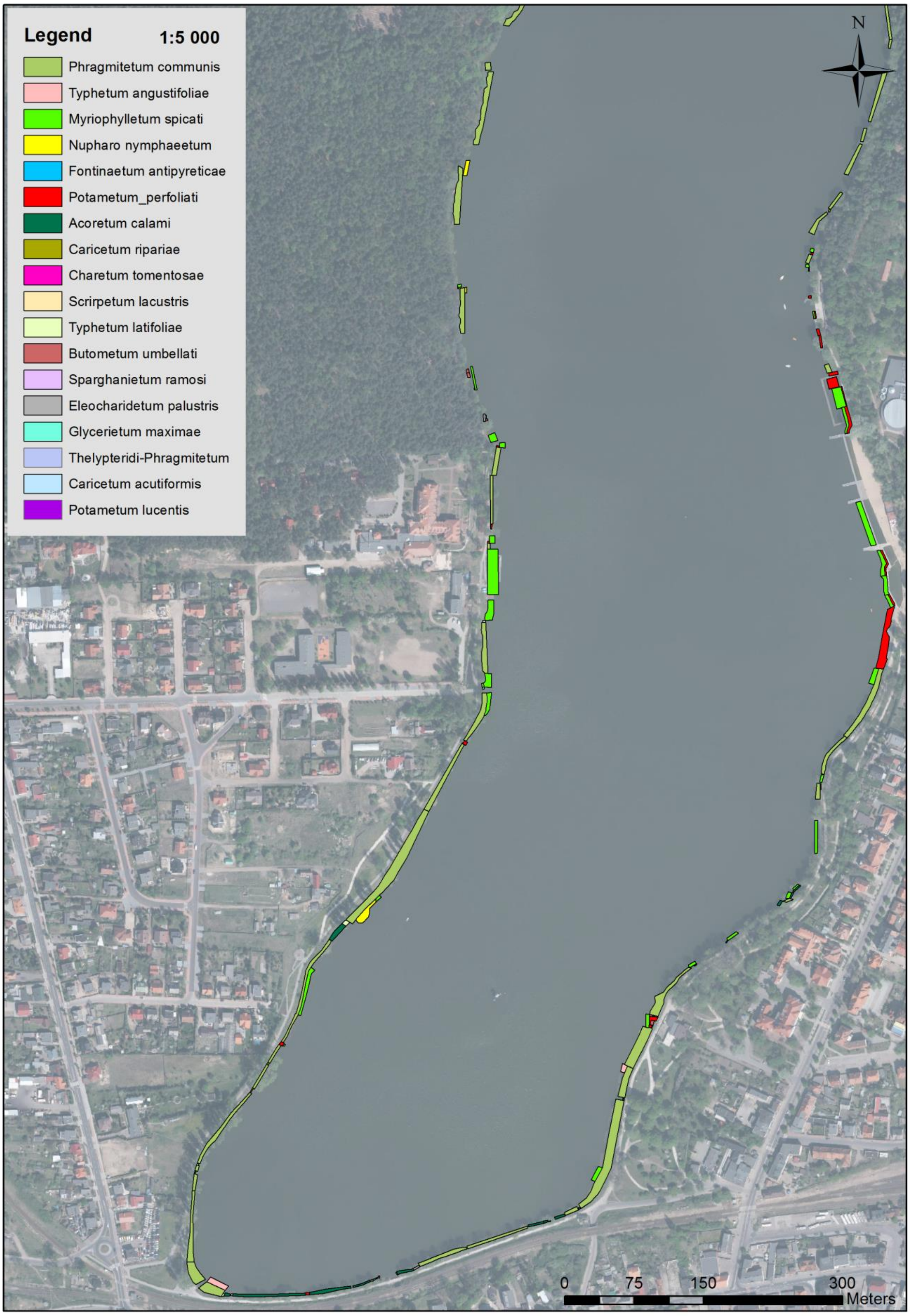

Figure 4: Distribution of macrophytes in the south segment of Lake Durowskie

During the study, eighteen (18) associations were identified along the phytolittoral of the Lake Durowskie. As shown on the Figure 5, the largest association is *Phragmitetum communis* with a proportion of 69.95%, followed by *Typhetum angustifoliae* (12.92%), *Myriophylletum spicati* (8.28%), *Nupharo-Nymphaeetum* (3.11%), *Fontinaletum antipyreticae* (3%) and *Potametum perfoliati* (1.12%).

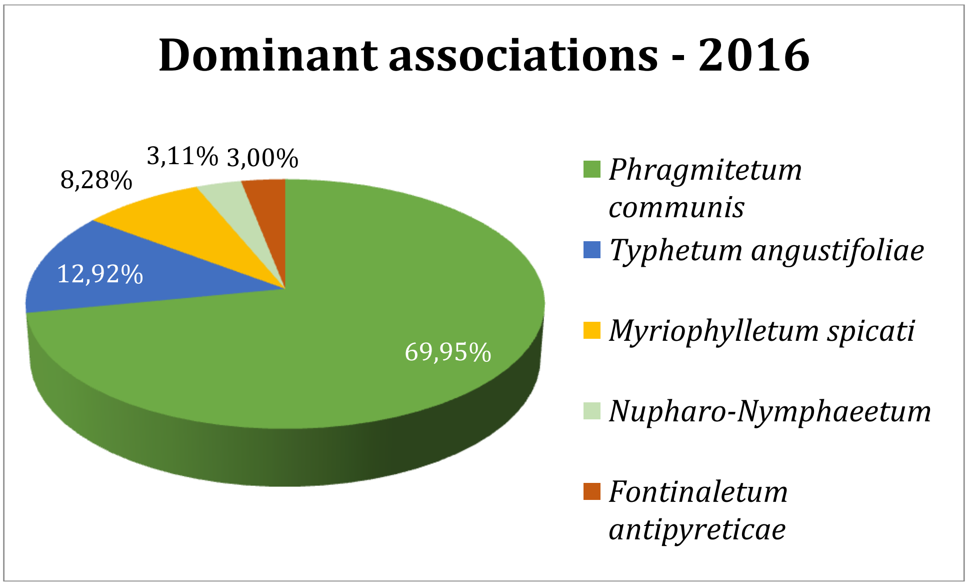

Figure 5: Dominant associations in Lake Durowskie (2016), with the important submerged associations *Myriophylletum spicati* and *Fontinaletum antipyreticae*

Phragmites australis is one of the most broadly distributed wetland plant species worldwide (Köbbing et al. 2013). It shows a steady coverage surface as on the year 2015. It is a characteristic association mainly on the eutrophic habitats. They occur also in meso- and sometimes in oligo- and dystrophic water bodies and at a pH range of 4 – 8.5, which indicates a high tolerance to different conditions. It is often associated to the *Scirpetum lacustris* or *Typhetum angustifoliae*, as it is noticeable along the map. Its high presence predominantly in Figure 2 indicates an initial stage of succession that could lead to a transformation of the lake to a terrestrial ecosystem in the medium or long term (Podbielkowski and Tomaszewski 1979).

Typhetum angustifoliae association, the secondly most identified, requires relatively fertile waters (eutrophic lakes) and is usually found on the furthest depths of the water column. Sometimes in hypertrophic lakes where the sediments have high levels of organic matter and the interstitial water is toxic, it grows through platforms in the horizons and uptakes nutrients (mainly P and N) from the water. When restoration measures are applied to reduce nutrients, the population decreases (Matuszkiewicz 2007).

The association *Myriophylletum spicati* grows mainly in eutrophic waters of oxbow ponds, lakes and sometimes rivers. Its considerable increase of 80% in appearance compared to the previous year is a good indicator for the lake, since this submerged association grows under good light conditions and on the sediments with no requirement of additional species to root. It is a pioneer association because it is able to colonize reservoirs of mineral substrate that are poor in nutrients (Podbielkowski and Tomaszewski 1979).

The association *Nupharo-Nymphaeetum* decreased in 3% with regards to last year. It appears in eutrophic waters, but can be observed in meso- and even dystrophic lakes, with pH between 5 – 8.5. This demonstrates the wide ecological scale of this association. It is characterized by floating leaves on the water table, which means that the leaves cover the surface and do not allow the sunlight through the water column. Only 1/3 phytocoenoses had two species are present together in different proportions. They produce a large amount of phytomass and occupy a large area and they have a large role in overgrowing and water, as well as for fish breeding (Podbielkowski and Tomaszewski 1979).

Fontinaletum antipyreticae increased 95% with regards to last year, it is a submerged association typical for meso- or eutrophic lakes.

Six (6) water plant associations were identified: *Charetum tomentosae*, *Fontinaletum antipyreticae*, *Myriophylletum spicati*, *Nupharo-Nymphaeetum*, *Potametum lucentis* and *Potametum perfoliati*. The Table 4 shows the area of each one of these submerged associations, the quantity of patches of the association that was found (number of polygons created), the average area and the maximum depth that each association was found during the data collection. They are responsible for 15,373 m^2 of the total area of the macrophytes identified, which means around 15%.

Table 4: Water plant associations identified in Lake Durowskie 2016

Water plant association	Area in m^2	Quantity	Average area [m^2]	Max depth [m]
Myriophylletum spicati	8,136	55	148	3.4
Nupharo-Nymphaeetum	3,060	39	78	3
Fontinaletum antipyreticae	2,950	18	164	4.5
Potametum perfoliati	1,104	23	48	3
Charetum tomentosae	112	2	56	2
Potametum lucentis	11	1	11	1.2
Total	**15,373**			

The variation of the coverage of the water plant associations (in m^2) according to the previous years is shown in the Figure 6. The total coverage area of the same associations increased around 40% comparing to the year of 2015.

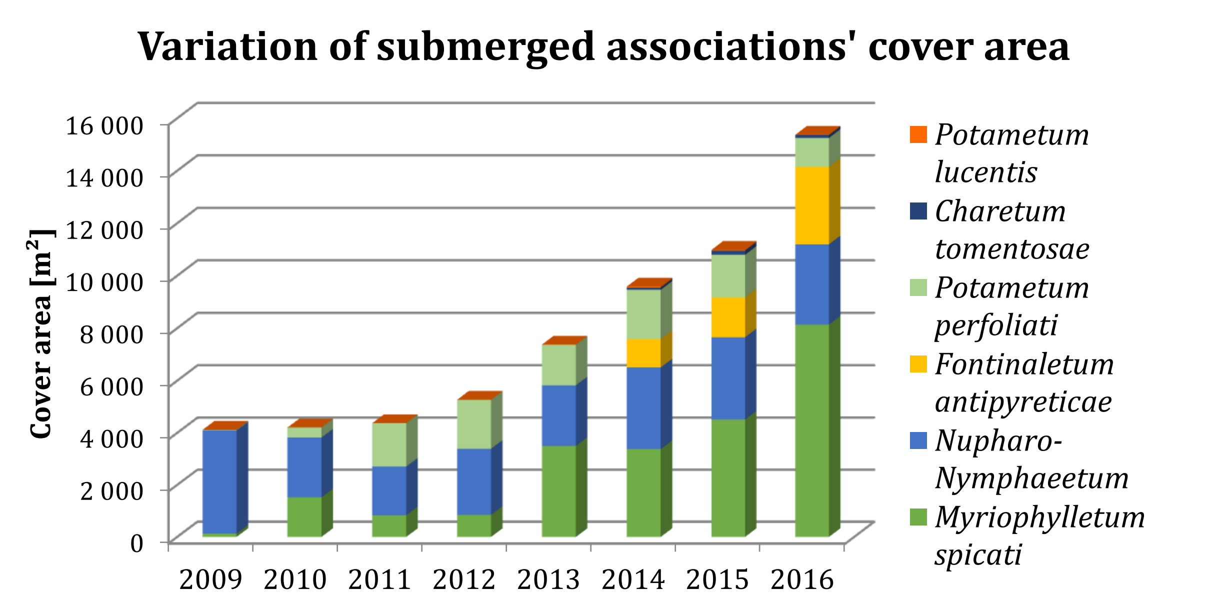

Figure 6: Variation of water plant associations' cover area in Lake Durowskie (2016)

The emergent associations cover about 85% of the total identified. The variation of the coverage of the emergent associations (in m^2) according to the previous years is shown in the Figure 7. The total coverage area of the same associations increased around 2% in comparison to the year of 2015.

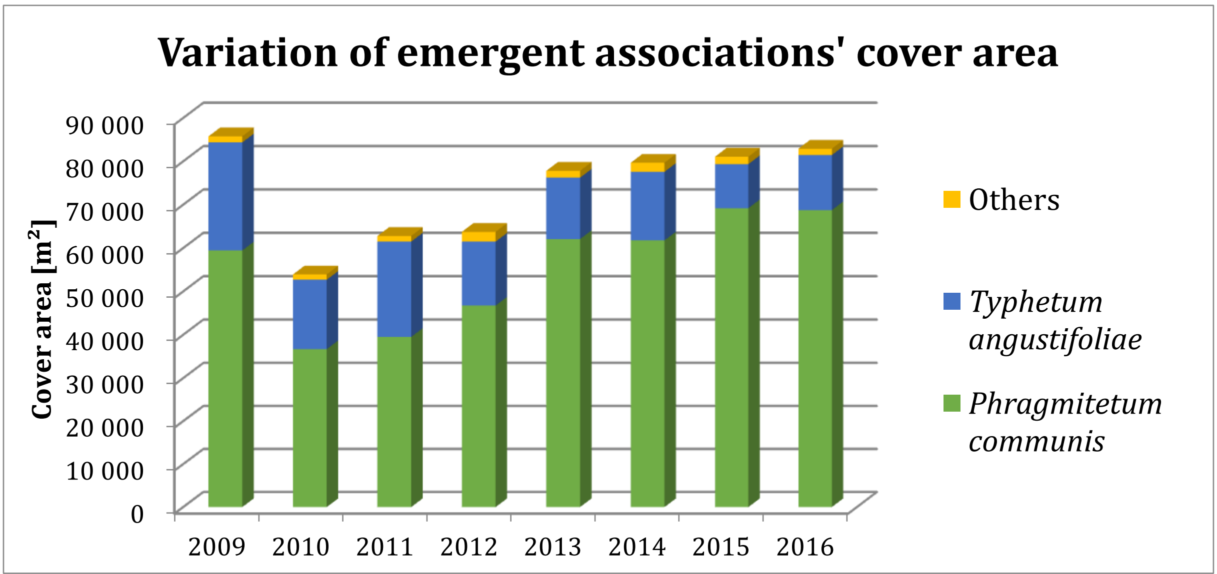

Figure 7: Variation of emergent associations' cover area in Lake Durowskie (2016)

The Table 5 shows the comparison between the surface area occupied by the macrophytes associations in 2016 and 2015 and Figure 9, in the period since and 2016. Some associations showed a significant increase considering the percentage, for example, *Myriophylletum spicati* (80%) and *Fontinaletum antipyreticae* (95%). *Phalaridetum arundinaceae* and *Scirpetum tabernaemontanii* were found in small areas in 2015, but were not identified this year.

Table 5: Comparison of the surface area between years 2015 and 2016

Association	Surface [m²]		Difference [m²]	Difference [%]
	2016	**2015**	**2016-2015**	
Phragmitetum communis (Garms 1927, Schmale 1931)	68,751	69,201	-450	-1%
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	12,694	10,144	2,550	25%
Myriophylletum spicati (Soo 1927)	8,136	4,512	3,624	80%
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3,060	3,141	-81	-3%
Fontinaletum antipyreticae (Kaiser 1936)	2,950	1,514	1,436	95%
Potametum perfoliati (W, Koch 1926)	1,104	1,629	-525	-32%
Acoretum calami (Kobendzz 1948)	714	758	-44	-6%
Caricetum ripariae (Soo 1928)	327	319	8	3%
Charetum tomentosae (Corillion 1957)	112	160	-48	-30%
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	108	171	-63	-37%
Typhetum latifoliae (Soo 1927)	86	49	37	76%
Butometum umbelati (Konczak 1968)	75	71	4	6%
Sparganietum erecti (Roll 1938)	69	156	-87	-56%
Eleocharitetum palustris (Schennikov 1919)	39	77	-38	-49%
Glycerietum maximae (Hueck 1931)	19	30	-11	-37%
Thelypteridi-Phragmitetum (Kuiper 1958)	18	60	-42	-70%
Caricetum acutiformis (Eggler 1933)	13	43	-30	-70%
Potametum lucentis (Hueck 1931)	11	28	-17	-61%
Phalaridetum arundinaceae	0	1	-1	Not found
Scirpetum tabernaemontanii	0	2	-2	Not found
Total	**98,286**	**92,066**	**6,220**	

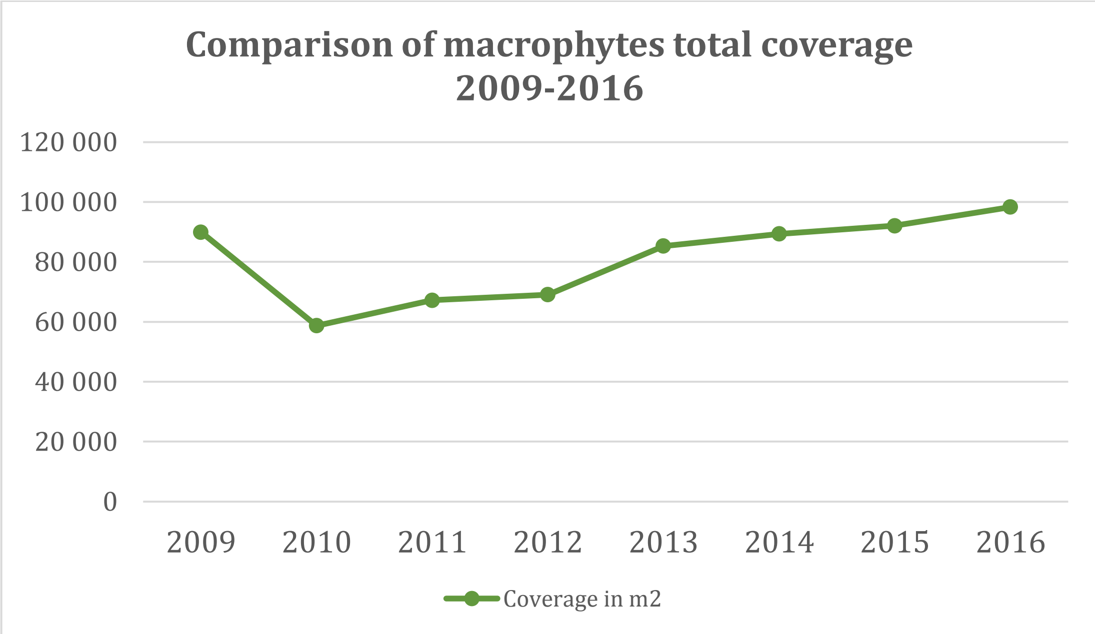

Figure 8: Yearly comparison from 2009 to 2015 of the total cover area of macrophytes in Lake Durowskie

3.2 Result values of ESMI and MIR.

The Table 6 shows the values obtained for both indices in the year 2016, as well as the values from the previous years for comparison:

Table 6: ESMI and MIR results from 2009 to 2016

Index	2009	2010	2011	2012	2013	2014	2015	2016
ESMI	0.109	0.103	0.118	0.12	0.136	0.149	0.142	0.171
MIR	30.6	31.7	29.8	33.41	26.05	28.95	36.36	37.75

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

Table 7: Range of values for ESMI and MIR

Ecological state	Range of values of ESMI	Range of values of MIR
	Deep lakes	Sandy bottom
Very good	0.680 – 1.000	≥46.8
Good	0.340 – 0.679	46.8 – 36.6
Moderate	0.170 – 0.339	36.6 – 26.4
Poor	0.090 – 0.169	26.4 – 16.1
Bad	<0.090	<16.1

Therefore, the ESMI value indicates a moderate ecological state of the lake and the MIR indicates a good ecological state.

4. Discussion and Conclusion

In the present study 18 associations of macrophytes were found in the Lake Durowskie. Among them, there are 6 associations that belong to water plant communities, including the association *Nupharo-Nymphaeetum* with floating leaves. Two associations identified in 2015 were not found this year during the collection of data.

Regarding the total coverage of macrophytes, it was noticed an increase of 6.76% in comparison to the year 2015. This increase shows a favourable trend, since macrophytes have a positive impact in water bodies, acting like traps for nutrients, preventing the excessive increase of phytoplankton, stabilizing sediment deposits and serving as habitats and food for many organisms (Thomaz & da Cunha 2010). However, the association *Charetum tomentosae*, which is considered a very important bioindicator of meso-eutrophic stage, showed a 30% decrease this year.

As for the indices, in ESMI, the obtained result improved from poor (0.142) in 2015 to moderate (0.171) in 2016. And in the case of MIR, it improved from moderate (36.36) in 2015 to good (37.75) ecological state in 2016 (Ciecierska and Dynowska 2013).

It is important to consider that the macrophytes are the indicators that react more slowly to the changes in the water environment of the lake. In general, physical and chemical parameters are the fastest in showing variations, then algae, zooplankton and finally macrophytes. There are many factors that influence these slow changes, including the time required for seed propagation, fish or animal consumption of the macrophytes, the time required to obtain the physical and chemical substances from the sediments, among others.

Finally, the surface of macrophytes as well as the indices for the evaluation of ecological quality through them, show an improvement in this year despite the fact that some of the other indicators currently decreased in quality. Nevertheless, there is a possibility for the macrophytes to have a late reflect of the decrease in water quality observed in some of the other study groups this year.

References

Carpenter, S.R., Lodge, D.M.(1986). 'Effects of submersed macrophytes on ecosystem processes', *Aquatic Botany*, vol. 26, pp. 341-370.

Ciecierska H., Dynowska M. 2013. Biologiczne metody oceny stanu środowiska. Tom II. Ekosystemy wodne. Uniwerytet Warmińsko – Mazurski w Olsztynie. pp 81-98, 119-125.

Ciecierska H., Kolada, A. 2014. ESMI: a macrophyte index for assessing the ecological status of lakes. In: Environmental Monitoring and Assessment. September 2014, Volume 186, Issue 9, pp 5501–5517.

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).

Gołdyn, R., Messyasz, B., Domek, P., Windhorst, W., Hugenschmidt, C., Nicoara, M., and Plavan, G. (2013) 'The response of Lake Durowskie ecosystem to restoration measures', *Carpathian Journal of Earth and Environmental Sciences,* vol. 8(3), pp. 43-48.

Köbbing, J.F. et al. (2013). The utilisation of reed (Phragmites australis): a review.
Online at: http://mires-and-peat.net/media/map13/map_13_01.pdf

Macroinvertebrates Report, 2014. Ecological state of the Lake Durowskie during restoration measures, Adam Mickiewicz University in Poznań. Online at:
http://www.restlake.amu.edu.pl/download/archive-2014/Macrophytes_2014_report.pdf.

Matuszkiewicz W. 2007. Przewodnik do oznaczania zbiorowisk roślinnych Polski. Warszawa: Wydawnictwo Naukowe PWN.

Muratov, R., Szoszkiewicz, K, et al. 2015. An attempt to prepare Macrophyte Index for Rivers for assessment watercourses in Kazakhstan.

Pełechaty, M. and E. Pronin, E. (2015), 'Rola roślinności wodnej i szuwarowej w funkcjonowaniu jezior i ocenie stanu ich wód The role of aquatic and rush vegetation in the functioning of lakes and assessment of the state of their waters', *Studia Limnologica et Telmatologica*, vol. 9(1), pp. 25-34.

Podbielkowski Z, Tomaszewski H. 1979. Zarys Hydro - Botaniki. Państwowe Wydawnictwo Naukowe. 1 - 531pp.

Schaumburg, J., Schranz, C., Hofmann, G., Stelzer, D., Schneider, S. and Schmedtje, U. (2004). 'Macrophytes and phytobenthos as indicators of ecological status in German lakes – a contribution to the implementation of the Water Framework Directive', *Limnologica-Ecology and Management of Inland Waters,* vol. 34, pp. 302–314.

Thomaz, S.M. and da Cunha, E.R. (2010). 'The role of macrophytes in habitat structuring in aquatic ecosystems: methods of measurement, causes and consequences on animal assemblages' composition and biodiversity', *Acta Limnol. Bras.*, vol. 22 (2).

Robiansyah, I., et al. 2010. Macrophytes as indicators of the ecological status of Durowskie Lake. Online at:
http://www.restlake.amu.edu.pl/download/archive-2010/Macrophytes-report_2010.pdf.

Warach, M. et al. 2015. Macrophytes as an indicator for environmental changes. Online at: http://www.restlake.amu.edu.pl/download/archive-2015/Macrophytes_report_2015.pdf.

Annexes

Determination of ESMI index

ASSOCIATION	2016								
	Total area (m^2)	in % (ni)	ni/N	ln(ni/N)	H	H max	Z	N/P	ESMI
Phragmitetum communis (Garms 1927, Schmale 1931)	68,751	69.95	0.6995	-0.3574	-0.2500				
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	12,694	12.92	0.1292	-2.0468	-0.2643				
Myriophylletum spicati (Soo 1927)	8,136	8.28	0.0828	-2.4916	-0.2063				
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3,060	3.11	0.0311	-3.4695	-0.1080				
Potametum perfoliati (W, Koch 1926)	2,950	3.00	0.0300	-3.5061	-0.1052				
Fontinaletum antipyreticae (Kaiser 1936)	1,104	1.12	0.0112	-4.4889	-0.0504				
Acoretum calami (Kobendzz 1948)	714	0.73	0.0073	-4.9248	-0.0358				
Caricetum ripariae (Soo 1928)	327	0.33	0.0033	-5.7057	-0.0190				
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	112	0.11	0.0011	-6.7771	-0.0077				
Charetum tomentosae (Corillion 1957)	108	0.11	0.0011	-6.8135	-0.0075				
Eleocharitetum palustris (Schennikov 1919)	86	0.09	0.0009	-7.0413	-0.0062				
Butometum umbelati (Konczak 1968)	75	0.08	0.0008	-7.1781	-0.0055				
Thelypteridi-Phragmitetum (Kuiper 1958)	69	0.07	0.0007	-7.2615	-0.0051				
Typhetum latifoliae (Soo 1927)	39	0.04	0.0004	-7.8321	-0.0031				
Caricetum acutiformis (Eggler 1933)	19	0.02	0.0002	-8.5512	-0.0017				
Glycerietum maximae (Hueck 1931)	18	0.02	0.0002	-8.6053	-0.0016				
Sparghanietum ramosi	13	0.01	0.0001	-8.9307	-0.0012				
Potametum lucentis (Hueck 1931)	11	0.01	0.0001	-9.0977	-0.0010				
Total	**98,286**	**100.00**	**1**	**0**	**-1.0795**				
					1.0795	**2.8904**	**0.4689**	**0.0684**	**0.171**

Determination of MIR index

SPECIE	% IN SITU	P	L	W	L * W * P	W * P
Potamogeton pectinatus	30%	7	1	1	7	7
Butomus umbellatus	15%	6	5	2	60	12
Mentha aquatica	5%	3	5	1	15	3
Rorippa amphibia	4%	3	3	1	9	3
Acorus calamus	3%	3	2	3	18	9
Hildenbrandia rivularis	1%	3	6	1	18	3
Lysimachia thyrsiflora	+	2	7	3	42	6
Myriophyllum spicatum	+	2	3	2	12	4
Phalaris arundinacea	+	2	2	1	4	2
				Total	**185**	**49**

*** NOTE:** *The species Ranunculus repens, Solanum dulcamara, Bidens frondosa, Calystegia sepium, Poa trivialis and Scrophularia alata were also found in the site but they are not bioindicators, therefore were omitted.*

Macrophyte coverage in area and percentage, 2009 to 2016

Association	2009		2010		2011		2012		2013		2014		2015		2016	
	Total area [m²]	in %	Total area [m²]	in %	Total area [m²]	in %	Total area [m²]	in %	Total area [m²]	in %	Total area [m²]	in %	Total area [m²]	in %	Total area [m²]	in %
Phragmitetum communis (Garms 1927 , Schmale 1931)	59,448	66.11	36,691	62.48	39,504	58.77	46,745	67.70	62,077	72.78	61,762	69.15	69,201	75.16	68,751	69.95
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	24,910	27.70	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
Myriophylletum spicati (Soo 1927)	124	0.14	1,520	2.59	833	1.24	850	1.23	3,498	4.10	3,373	3.78	4,512	4.90	8,136	8.28
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3,969	4.41	2,300	3.92	1,872	2.79	2,540	3.68	2,324	2.72	3,130	3.50	3,141	3.41	3,060	3.11
Fontinaletum antipyreticae (Kaiser 1936)	-	-	-	-	-	-	-	-	-	-	1,082	1.21	1,514	1.64	2,950	3.00
Potametum perfoliati (W, Koch 1926)	26	0.03	387	0.66	1,668	2.48	1,882	2.73	1,547	1.81	1,876	2.10	1,629	1.77	1,104	1.12
Acoretum calami (Kobendzz 1948)	528	0.59	871	1.48	651	0.97	862	1.25	851	1.00	964	1.08	758	0.82	714	0.73
Caricetum ripariae (Soo 1928)	92	0.10	27	0.05	192	0.28	997	1.44	296	0.35	448	0.50	319	0.35	327	0.33
Charetum tomentosae (Corillion 1957)	-	-	-	-	-	-	-	-	-	-	87	0.10	160	0.17	112	0.11
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	92	0.10	54	0.09	57	0.08	48	0.07	130	0.15	135	0.15	171	0.19	108	0.11
Typhetum latifoliae (Soo 1927)	8	0.01	4	0.01	12	0.02	10	0.01	38	0.04	49	0.05	49	0.05	86	0.09
Butometum umbelati (Konczak 1968)	-	-	24	0.04	68	0.10	107	0.15	82	0.10	57	0.06	71	0.08	75	0.08
Sparganietum erecti (Roll 1938)	460	0.51	102	0.17	228	0.34	58	0.08	84	0.10	164	0.18	156	0.17	69	0.07
Eleocharitetum palustris (Schennikov 1919)	84	0.09	70	0.12	34	0.05	124	0.18	54	0.06	87	0.10	77	0.08	39	0.04
Glycerietum maximae (Hueck 1931)	55	0.06	36	0.06	2	0.00	7	0.01	39	0.05	139	0.16	30	0.03	19	0.02
Thelypteridi-Phragmitetum (Kuiper 1958)	-	-	-	-	-	-	35	0.05	-	-	31	0.03	60	0.07	18	0.02
Caricetum acutiformis (Eggler 1933)	94	0.10	38	0.06	58	0.09	-	-	-	-	14	0.02	43	0.05	13	0.01
Potametum lucentis (Hueck 1931)	-	-	-	-	-	-	-	-	5	0.01	38	0.04	28	0.03	11	0.01
Scirpetum tabernaemontanii	-	-	-	-	-	-	-	-	-	-	-	-	2	0.00	-	-
Phalaridetum arundinaceae	-	-	-	-	-	-	23	0.03	-	-	-	-	1	0.00	-	-
Potamogetum pectinati	-	-	30	0.05	49	0.07	17	0.02	105	0.12	25	0.03	-	-	-	-
Polygonetum natantis	-	-	1	0.00	-	-	-	-	1	0.00	-	-	-	-	-	-
Ceratophylletum demersi	15	0.02	570	0.97	-	-	-	-	-	-	-	-	-	-	-	-
Najadetum marinae	20	0.02	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cicuto-Caricetum pseudocyperi (Boer 1942)	-	-	-	-	-	-	-	-	-	-	17	0.02	-	-	-	-
Iridetum pseudacori (Eggler 1933)	-	-	-	-	-	-	-	-	-	-	13	0.01	-	-	-	-
Total	**89,925**	**100.00**	**58,726**	**100.00**	**67,214**	**100.00**	**69,048**	**100.00**	**85,298**	**100.00**	**89,320**	**100.00**	**92,066**	**100.00**	**98,286**	**100.00**