Macrophytes as an indicator for environmental changes

[1]Magdalena Warach, [2]Yueming Qu, [3]Philipp Paysen

[1]Instiut of Biology, Adam Mickiewicz University, Poznań, Poland

[2]Department of Hydrology and Water Resources Management, Institute for Natural Resource Conservation, Christian-Albrecht University in Kiel, Germany

[3]Instiut of Geography, Christian-Albrecht University in Kiel, Germany

Instructor: Prof. Dr. Ryszard Gołdyn

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

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1 Introduction

Macrophytes as one of the important functional group of aquatic ecosystems, can have a significant effect on structure and function of aquatic ecosystems (Jeppesen et al., 1998). Macrophytes in aquatic ecosystems are not only important primary producers, but also a major contributor to the aquatic ecosystem primary productivity and secondary productivity. Furthermore, macrophytes are an important part of the aquatic ecosystem material circulation and energy flow. At the same time, in many areas submerged macrophytes are also important to oxygen water provisioning. Studies have found that biodiversity in such areas is often much higher than in other regions. While the abundance of macrophytes in lake ecosystems affect the physical, chemical and biological factors (Scheffer, 1998). They served as a barrier surrounding the lake to obstruct the erosion from land by precipitation. Macrophytes mediate biogeochemical cycles of nitrogen and phosphorus in lakes and other waters (Nogueira et al., 1996), stable bottom quality and regulate sediment nutrient release (Pluntke & Kozerski, 2003; Li et al, 2008; Salgado et al, 2009), regulating wetland hydrological situation (Gosselink & Tuner, 1978). Furthermore, they also have allopathic effects to control phytoplankton, and provide refuges for small fishes and zooplankton (Wetzel, 1983), which increase landscape diversity and enhance ecosystem stable resilience. In this case, macrophyte serves as a good indicator to the water quality and environmental changes of the lake.

The lake Durowskie is located in west Poland, situated in the direction northward-southward in the Wielkopolska Region. Its coordinates are N 52°49'6'' and E 17°12'1''. It is a postglacial lake, with elongated shape. Struga Gołaniecka River flows through the lake, supplying it with nutrients from the catchment area. Five other lakes situated on the river course above the Durowskie Lake are strongly eutrophicated, with cyanobacterial water blooms. The river catchment area is typically agricultural. Forests cover only 19% of its surface. Nevertheless, the Lake Durowskie is surrounded by forest from the north, but the town Wągrowiec is adjacent to the southern part of the lake. Its surface is 143.7 ha and the maximum depth is 14.6 m. the lake plays an important role for recreation for the people of Wągrowiec as well as for tourists. In this area, people take advantage of swimming, sailing and fishing, especially in summer time. While, at the same time the growth of tourism in this area leads to deterioration of the lake ecosystem. One of the typical results is eutrophication, and algae

bloom. Few years ago, it was strongly eutrophic with cyanobacteria blooms. To improve the lake water quality and restore ecosystem services, the local Authority decided to start restoration measures from 2009, using three methods: oxygenation of hypolimnetic waters using wind aerators, phosphorus immobilization using iron treatment, and bio manipulation measures - stocking the lake with pike fingerlings (Goldyn et al. 2013).

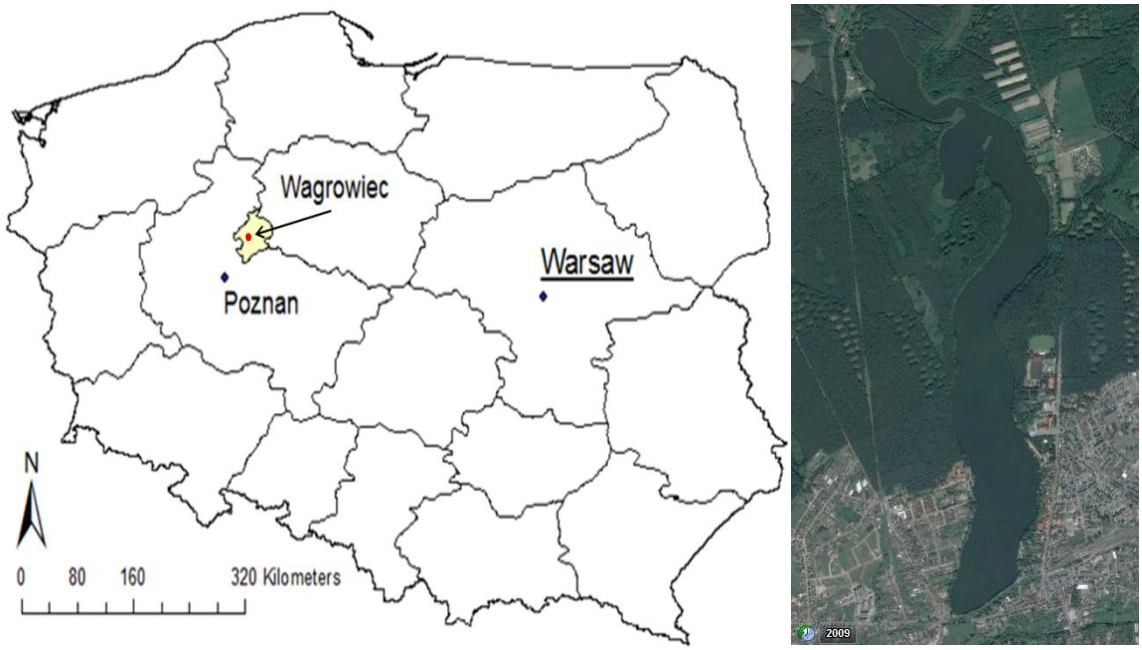

Figure 1: Location of Wagrowiec (left) and aeril image of the region

Table 1: Basic data of the Lake Durowskie (Goldyn et al. 2013))

Location	Commune and district Wągrowiecki
Surface	143.7 ha
Volume	11322.9 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

The main goal of this study is to investigate the current situation of macrophytes in the lake, and the changes of environmental condition along these years of treatments, based on macrophytes as an ecological indicator. The result contributes to monitor the effect of the implementation of measures, at the same time, provide useful scientific information for the sustainable of lake management.

2 Material and Methods

2.1 Data record

From the 29th - 3rd July 2015 emerged and submerged, as well as floating macrophyte associations of the whole Lake Durowskie and the outflow in the south of the lake were characterize. Therefore a GSP were used and the coordinates of the beginning of a new association were taken. Furthermore the widths of each association were assessed in order to calculate the spatial area of each patch.

To find and characterize submerged macrophyte association an anchor were used, as it would collecting samples from submerged macrophytes when it`s scratching over the bottom.

In the second week (6th until 10th July 2015) the data analysis took place. First the GPS coordinates were imported via QGIS (http://www.qgis.org/de/site/) and saved as an ESRI shape file. Afterwards ArcGIS (http://www.arcgis.com/features/) were used to analyze the spatial area of each association as well as for illustrating the results. To analyze the total spatial area of the associations, each patch of each association were digitized by creating polygons. Following, the spatial cover in m² were calculated for each patch and summed up to the total area in m² for each macrophyte association in the Lake Durowskie.

2.2 Evaluation

To determine the ecological state of the Lake Durowskie the Ecological State Macrophyte Index (ESMI) were calculated (Ciecierska und Kolada 2014) as well as the Macrophyte River Index (MIR) (Szoszkiewicz et al. 2006) for the outflow which indicates the ecological state of rivers. In order to calculate the ESMI, equation (1) was applied.

where:

with:

H –	diversity index of phytocenosis
ni –	area polygons one of associations in percent per cover
N-	all cover of macrophytes
H_{max} –	coefficient of variation of the theoretical maximum
S-	number of associations
Z-	occupancy index
Izob. 2.5m –	area of littoral limited by isobaths 2.5m (=20.96 ha)
P-	area of the lake (=143.7 ha)

The calculated result could then been classified as shown in Table 2.

Table 2: Classification of the ecological state by ESMI and MIR index

State	ESMI	MIR
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

To calculate the MIR equation (5) were used. The classification is also shown in Table 2.

where:

L - indicator value for each associations

P- coverage for each species

W- weigh factor

Table 3: The MIR calculation

Species	L	W	P	L*W*P	W*P
Myriophyllum spicatum	3	2	6	36	12
Potamogeton perfoliatus	4	2	7	56	14
Hildenbrandia rivularis	6	1	5	30	5
Cladofora glomerata	1	2	7	14	14
Phalaris arundinacea	2	1	2	4	2
Acorus calamus	2	3	2	12	6
Butomus umbellatus	5	2	7	70	14
Rorippa amphibia	3	1	2	6	2
Mentha aquatica	5	1	2	10	2
SUM				280	77

Table 3 show the values of the indicator value for each species, the coverage for each species, and the weigh factor. The coefficient, which was used to determinate the cover of species in % and is displayed and compered in the next table.

Table 4: Cover coefficient P

Cover Coefficient of P	Cover of Species in %
1	<0,1%
2	0,1-1%
3	1-2,5%
4	2,5-5%
5	5-10%
6	10-25%
7	25-50%
8	50-75%

9	75-100%

3 Results

3.1 Macrophytes association

Macrophytes association can be used as an indicator for the ecological state of water bodies, as they respond to environmental changes by changing their taxonomic composition (Schaumburg et al. 2004). In this report we used macrophyte associations to indicate the ecological state of the Lake Durowskie. The types of associations we found are shown in Table 5.

Table 5: Phytosociological associations of Lake Durowskie 2015

Association	Area in m²	Area in %
Phragmitetum communis (Garms 1927 , Schmale 1931)	69201	75.16%
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	10144	11.02%
Myriophylletum spicati (Soo 1927)	4512	4.90%
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3141	3.41%
Potametum perfoliati (W. Koch 1926)	1629	1.77%
Fontinaletum antipyreticae (Kaiser 1936)	1514	1.64%
Acoretum calami (Kobendzz 1948)	758	0.82%
Caricetum rippariae (Soo 1928)	319	0.35%
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	171	0.19%
Charetum tomentosae (Corillion 1957)	160	0.17%
Sparganietum erecti (Roll 1938)	156	0.17%
Eleocharitetum palustris (Schennikov 1919)	77	0.08%
Butometum umbelati (Konczak 1968)	71	0.08%
Thelypteridi-Phragmitetum (Kuiper 1958)	60	0.07%
Typhetum latifoliae (Soo 1927)	49	0.05%
Caricetum acutiformis (Eggler 1933)	43	0.05%
Glycerietum maximae (Hueck 1931)	30	0.03%
Potametum lucentis (Hueck 1931)	28	0.03%
Scirpetum tabernaemontanii	2	0.00%
Phalaridetum arundinaceae	1	0.00%
Total	**92066**	**100.00%**

Figure 3 and Figure 4 show the distribution of macrophyte associations along the shoreline of Lake Durowskie. The northern part shows really wide and large patches up to 30m, while

the southern macrophyte belt isn`t wider than 6 -7m except for a wide patch in the very south.

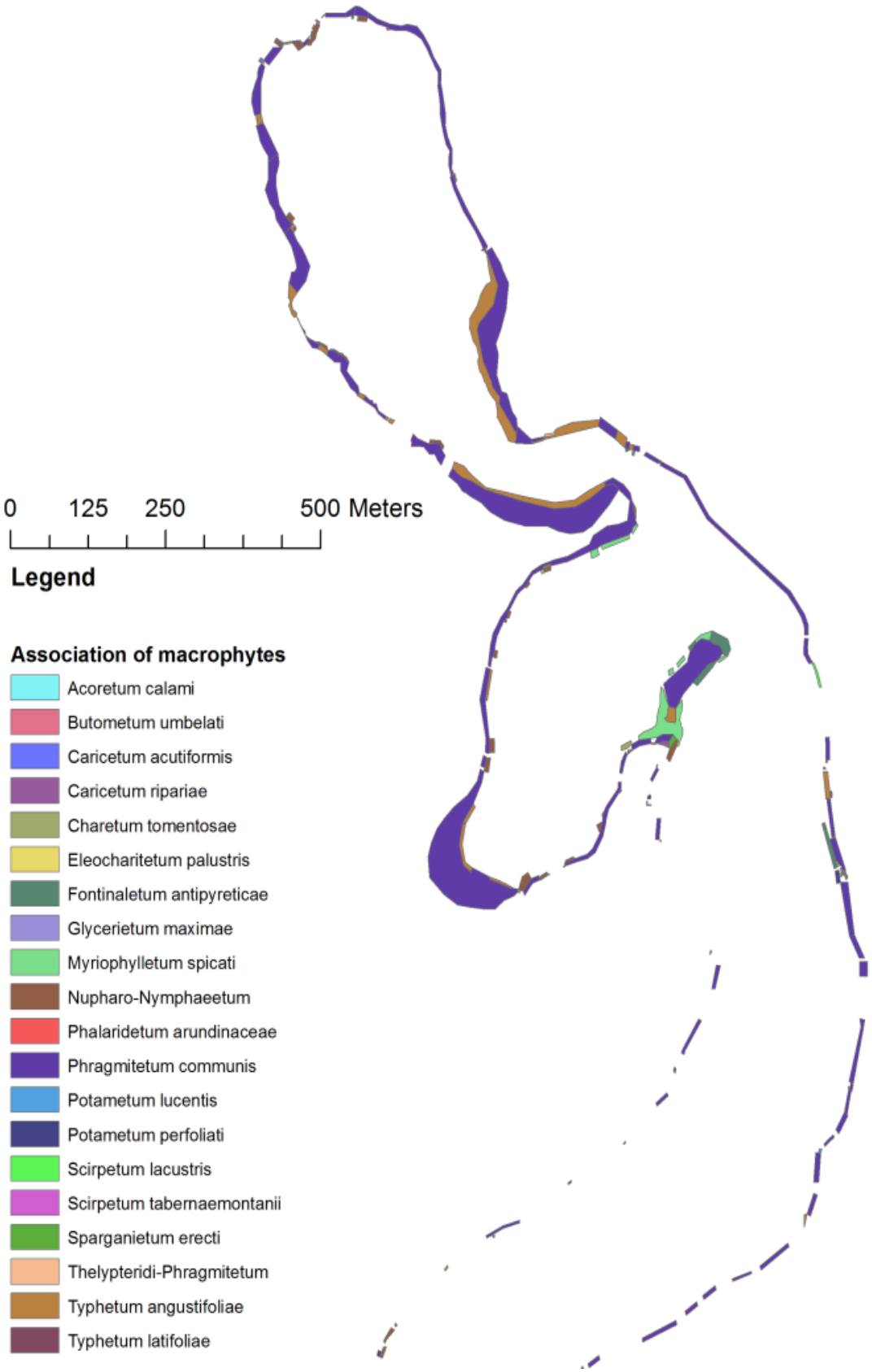

Figure 2: Spatial distribution of macrophytes in the northern part of Lake Durowskie

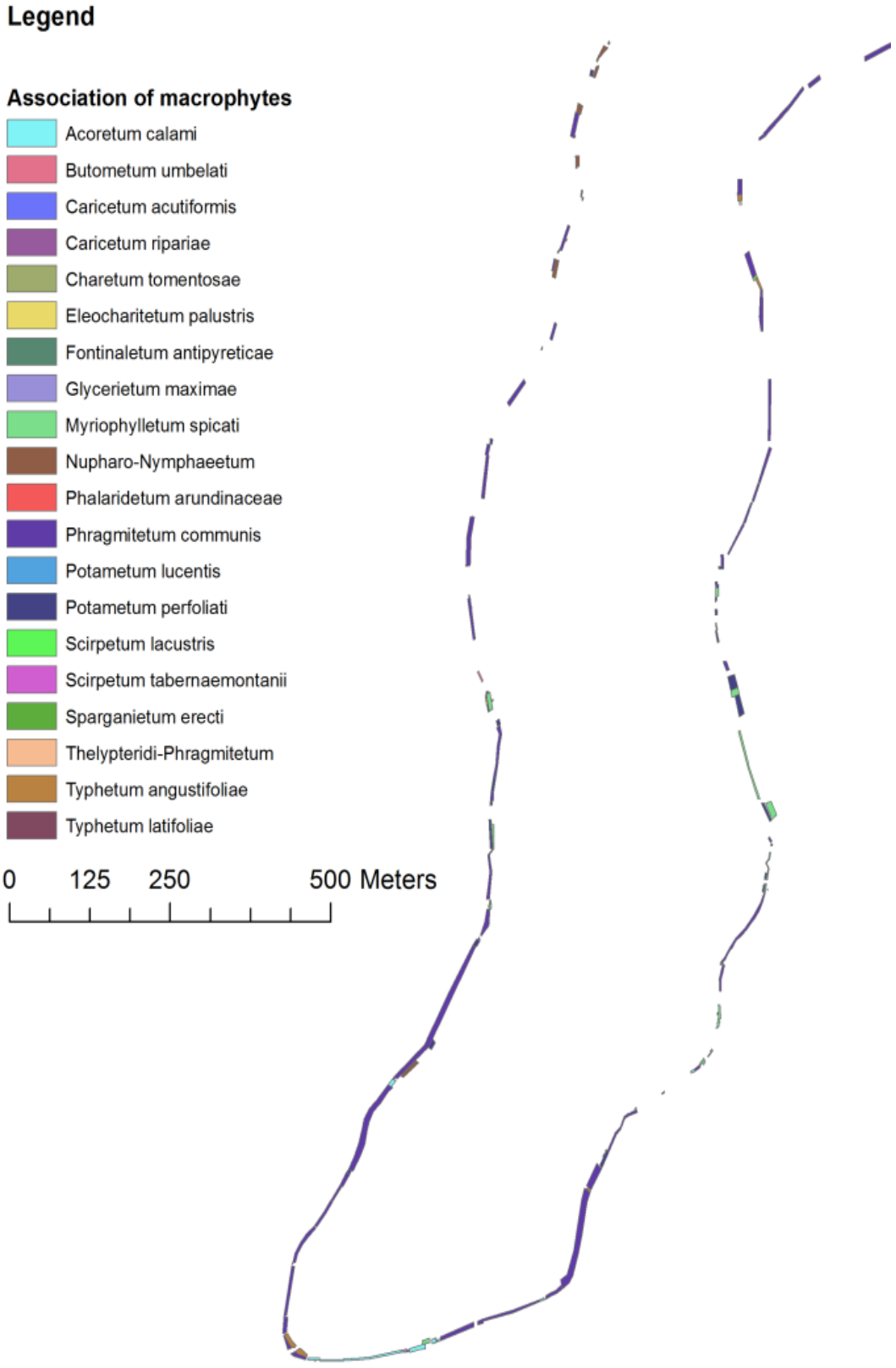

Figure 3: Spatial Distribution of macrophytes in the southern part of Lake Durowskie

Furthermore, the southern macrophyte belt shows much more gaps between small patches than the northern one.

We found 20 associations along the shoreline of the Lake Durowskie. Six associations are dominating the macrophyte-belt. The largest cover shows *Phragmitis communis* (Garms 1927, Schmale 1931) with a share of 75.16% of all assessed associations. This association occurs at eutrophic to mesotrophic conditions. It is present at the whole lake, with a very high density in the northern part, while other associations are less spredded as for example *Thyphetum augustifoliae* (Allorge 1922, Soo1927). *Thyphetum augustifoliae* appears more in the north than in the south of Lake Durowskie. It can be seen as an indicator of mostly eutrophic conditions. It has a share of 11.02%. In the south we just find five small patches, while in we find a high abundance in the north. A similar pattern, but with a lower gradient, shows the association *Nupharo-Nymphaeetum* (Tomaszewicz 1977) with 3.41%. However, several plants of *Nymphaea sp.* were spreading along the shoreline. *Nupharo-Nzmphaeetum* is preferring mesotrophic conditions, but also growing in eutrophic conditions . Prominent is the association *Fontinaletum antipyreticae* (Kaiser 1936) which is only present in the northern part of Lake Durowskie and a share of 1.64% coverage (1514m²). We also measured a high maximum depth for *Fontinaletum antipyreticae* of 8m. So this association is spreading into deeper water. Figure 4 shows the six most abundant macrophyte associations in the Lake Durowskie.

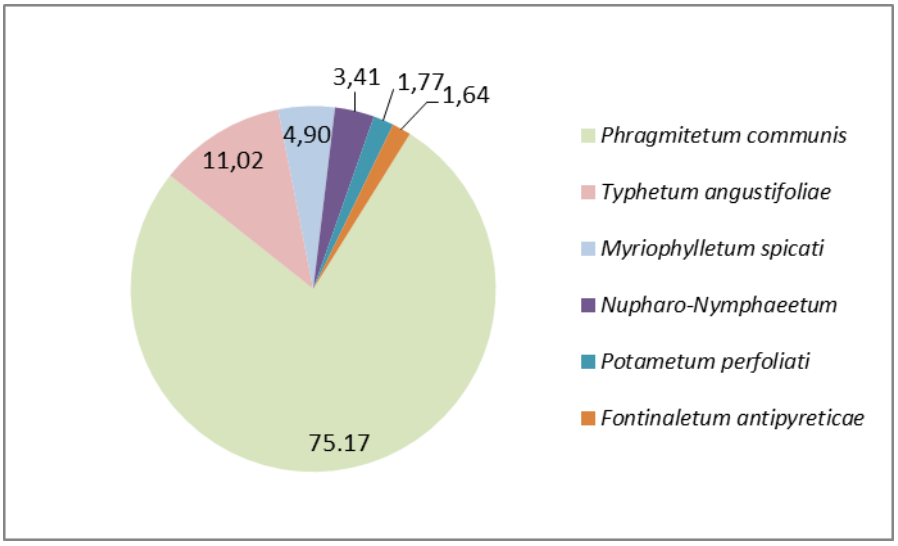

Figure 4: Dominant species in Lake Durowskie with the important submerged associations *Myriophylletum specati, Nupharo-Nymphaeetum and Potametum perfoliati*

3.2 Trend of occurrence and abundance

As mentioned above *Phragmitis communis* is spreading all along the shoreline. We assessed 5.68 ha coverage in the north and 1.24 ha in the south. *Thyphetum augustifoliae* has a high abundance in the north with a cover of 0.97 ha (13.01% of the northern macrophyte coverage), but just a small in the south 0.04 ha (2.42% of the southern macrophyte coverage). The submerged and floating associations *Myriophylletum spicati* (north: 0.31 ha, south: 0.14 ha), *Nupharo-Nymphaeetum* (north: 0.25 ha, south: 0.07 ha) *and Potametum perfoliati* (north: 0.01 ha, south: 0.15 ha) also show different distributions between the northern and southern part of Lake Durowskie.

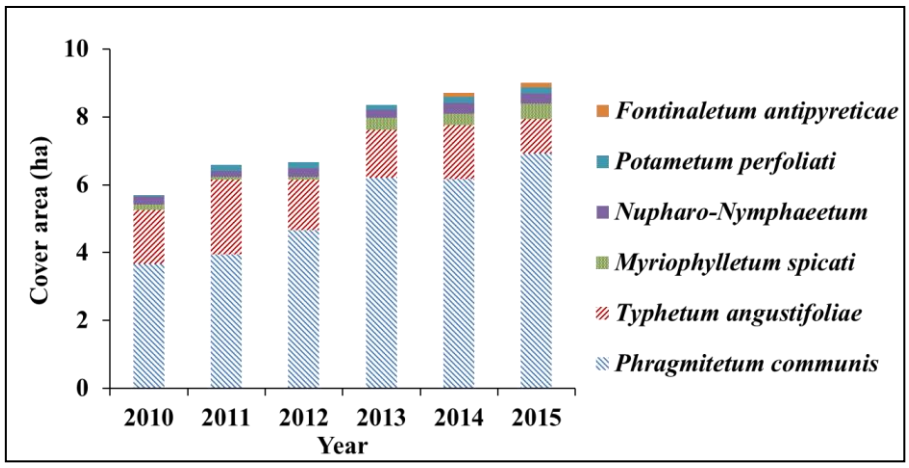

Figure 5: Dominant macrophyte association

Considering the dominant macrophyte associations we see an increase in emerged as well as submerged macrophyte associations during the period 2010 – 2015 (Figure 5). *Phragmitetum communis* shows an small increase compared to 2014. Whereas *Thyphetum augustifoliae* denotes a downwards trend. In 2014 *Fontinaletum antipyreticae* and *Charetum tomentosae* appeared for the first time. *Fontinaletum antipyreticae* shows a light increase of 432 m^2 coverage in 2015, while *Charetum tomentosae* increased by 73 m^2 (Figure 6).

As mentioned above the share of submerged macrophytes was calculated, as submerged macrophytes are very important for a good ecological state of a lake. The total share of submerged macropytes increased from 7.2% up to 8.5% in 2015. Figure 6 shows the total cover area of submerged macrophyte associations from 2010 – 2015 in ha.

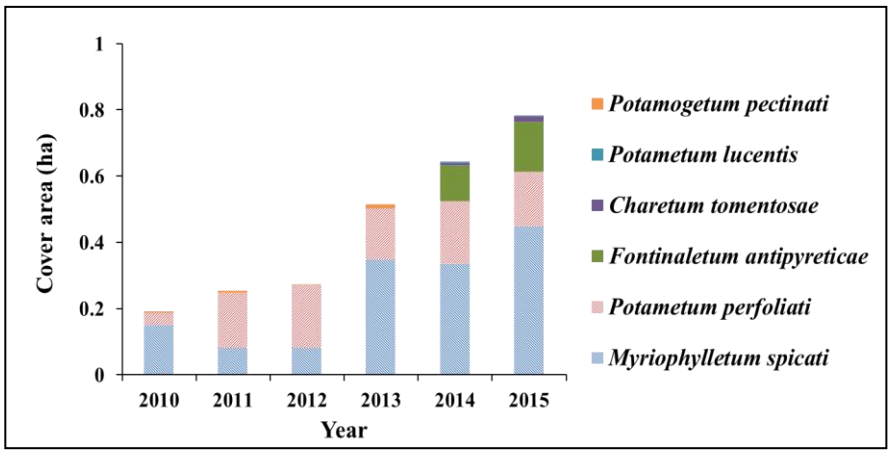

Figure 6: Variation of submerged associations' cover area

3.3 Ecological state of the lake

In order to assess the ecological state of the lake Durowskie the indices EMSI and MIR were calculated. The EMSI calculates the ecological state of the lake Durowskie. We calculated an EMSI of 0.142. Therefore we can classify the ecological state, based on the EMSI, as poor Table 6. It is a slightly poorer value than in 2014 (0.149).

The MIR was calculated with 36.36. That means a significant improvement of one category from ‘moderate’ to a good ‘state’. The MIR of 2014 was calculated with 28.95.

Table 6: Results of ESMI and MIR calculation during the period 2012 - 2015

Index	2010	2011	2012	2013	2014	2015
ESMI	0.103	0.118	0.12	0.136	0.149	0.142
MIR	31.7	29.8	33.41	26.05	28.95	36.36

4 Conclusion

In the study we founded 20 associations in the lake. Among them, there are 6 associations belong to submerged communities. The submerged macrophytes show an increase both on communities and cover area. Especially, the two new settlers from submerged group, *Charetum tomentosae* and *Fontinaletum antipyreticae*, take a firm stand in the lake and spread to larger cover area from last year to this year. Based on macrophytes indicator (ESMI) in the lake, it shows a poor ecological state of the lake. However, based on indicator (MIR) at the outlet of the lake, it reaches to good condition in this year. The result presents a promising change to better condition along all these years. It is advisable to maintain good water transparency in following spring, for a better growing of submerged macrophytes

5 References

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6 Appendix

Table1: Macrophyte coverage in m² and percentage (2010 – 2015)

Association	2015		2014		2013		2012		2011		2010	
	total are [m²]	in %	total are [m²]	in %	total are [m²]	in %	total are [m²]	in %	total are [m²]	in %	total are [m²]	in %
Phragmitetum communis (Garms 1927 , Schmale 1931)	69201	75.16%	61762	69.15%	62077	72.78%	46745	67.70%	39504	46.31%	36691	62.48%
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	10144	11.02%	15829	17.72%	14167	16.61%	14743	21.35%	21987	25.78%	16001	27.25%
Myriophylletum spicati (Soo 1927)	4512	4.90%	3373	3.78%	3498	4.10%	850	1.23%	833	0.98%	1520	2.59%
Nupharo-Nymphaeetum (Tomaszewicz 1977)	3141	3.41%	3130	3.50%	2324	2.72%	2540	3.68%	1872	2.19%	2300	3.92%
Potametum perfoliati (W. Koch 1926)	1629	1.77%	1876	2.10%	1547	1.81%	1882	2.73%	1667.5	1.95%	387	0.66%
Fontinaletum antipyreticae (Kaiser 1936)	1514	1.64%	1082	1.21%	-	-	-	-	-	-	-	-
Acoretum calami (Kobendzz 1948)	758	0.82%	964	1.08%	851	1.00%	862	1.25%	651	0.76%	871	1.48%
Caricetum ripariae (Soo 1928)	319	0.35%	448	0.50%	296	0.35%	997	1.44%	191.5	0.22%	27	0.05%
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	171	0.19%	135	0.15%	130	0.15%	48	0.07%	57	0.07%	54	0.09%
Charetum tomentosae (Corillion 1957)	160	0.17%	87	0.10%	-	-	-	-	-	-	-	-
Sparganietum erecti (Roll 1938)	156	0.17%	164	0.18%	84	0.10%	58	0.08%	228	0.27%	102	0.17%
Eleocharitetum palustris (Schennikov 1919)	77	0.08%	87	0.10%	54	0.06%	124	0.18%	34	0.04%	70	0.12%
Butometum umbelati (Konczak 1968)	71	0.08%	57	0.06%	82	0.10%	107	0.15%	67.5	0.08%	24	0.04%
Thelypteridi-Phragmitetum (Kuiper 1958)	60	0.07%	31	0.03%	-	-	35	0.05%	-	-	-	-
Typhetum latifoliae (Soo 1927)	49	0.05%	49	0.05%	38	0.04%	10	0.01%	12	0.01%	4	0.01%
Caricetum acutiformis (Eggler 1933)	43	0.05%	14	0.02%	-	-	-	-	58	0.07%	38	0.06%
Glycerietum maximae (Hueck 1931)	30	0.03%	139	0.16%	39	0.05%	7	0.01%	2	0.00%	36	0.06%
Potametum lucentis (Hueck 1931)	28	0.03%	38	0.04%	5	0.01%	-	-	-	-	-	-
Scirpetum tabernaemontanii	2	0.00%	-	-	-	-	-	-	-	-	-	-
Phalaridetum arundinaceae	1	0.00%	-	-	-	-	23	0.03%	-	-	-	-
Potamogetum pectinati	-	-	-	-	105	0.12%	17	0.02%	49	0.06%	30	0.05%
Polygonetum natantis	-	-	-	-	1	0.00%	-	-	-	-	1	0.00%
Ceratophylletum demersi	-	-	-	-	-	-	-	-	-	-	570	0.97%
Total	**92066**	**100%**	**89320**	**100%**	**85298**	**100%**	**69048**	**100%**	**67213.5**	**100%**	**58726**	**100%**

Table2: Macrophyte coverage in m² and percentage for the northern and southern part (2010 – 2015)

Northern Associations			
	Association	**Total area [m²]**	**In %**
1	Phragmitetum communis	56833.33	76.01
2	Typhetum angustifoliae	9726.27	13.01
3	Myriophylletum spicati	3140.97	4.20
4	Nupharo-Nymphaeetum	2452.08	3.28
5	Fontinaletum antipyreticae	1514.12	2.02
6	Caricetum ripariae	319.00	0.43
7	Sparganietum erecti	154.89	0.21
8	Charetum tomentosae	152.80	0.20
9	Scirpetum lacustris	142.23	0.19
10	Potametum perfoliati	118.40	0.16
11	Thelypteridi-Phragmitetum	60.10	0.08
12	Caricetum acutiformis	42.48	0.06
13	Typhetum latifoliae	41.08	0.05
14	Potametum lucentis	28.34	0.04
15	Acoretum calami	26.14	0.03
16	Eleocharitetum palustris	19.38	0.03
17	Butometum umbelati	1.34	0.00
Total		**74772.95**	**100.00%**
Southern Association			
1	Phragmitetum communis	12367.67	71.52
2	Potametum perfoliati	1510.60	8.74
3	Myriophylletum spicati	1371.19	7.93
4	Acoretum calami	731.86	4.23
5	Nupharo-Nymphaeetum	688.92	3.98
6	Typhetum angustifoliae	417.70	2.42
7	Butometum umbelati	69.64	0.40
8	Eleocharitetum palustris	57.84	0.33
9	Glycerietum maximae	29.50	0.17
10	Scirpetum lacustris	28.89	0.17
11	Charetum tomentosae	7.20	0.04
12	Typhetum latifoliae	7.45	0.04
13	Scirpetum tabernaemontanii	2.24	0.01
14	Phalaridetum arundinaceae	1.09	0.01
15	Sparganietum erecti	1.02	0.01
Total		**17292.81**	**100.00%**