Macrophytes, part of restoration measurements in the Lake Durowskie and an indicator for water quality.

Offered by :

Mahmoud Alnady (Imae, Kiel University, Germany) and Michał B. Kolasa (Environmental protection UAM Poznań, Poland)

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Instructor: Prof. Ryszard Goldyn, Adam Mickiewicz University in Poznań

Introduction

The Lake Durowskie - General description:

Wagrowiec City is one of the most attractive and special places in western part of Poland. Looking for the secrets behind that it was found that the city is a gift created by a water body which called Durowskie Lake. The Lake Durowskie as one of the main sources of life activities in Wagrowiec is a postglacial lake used for a lot of activities like recreation, sports and fishing activities and offer an attractive climate with sandy beach and other enjoyable water activities.

Table 1: General description of the 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 %

The Lake Durowskie pollution and problems:

Because of many reasons Durowskie Lake water's quality has decreased. Previous mentioned activities are playing an important role in this change of the water quality. Nutrient input from the surrounding agricultural areas and the human activities like

waste water treatment plants also can cause this change. The geographical location of the lake made it a receptor for pollutants coming from the upstream lakes carrying a lot of pollutants.

Restoration program and mechanism since 2008:

In 2008 a large bloom of cyanobacteria happened during the summer month. Because of that a restoration program had been launched by the local authorities to restore the lake ecosystem and to improve the water quality. The restoration program started by working in different measurements aspects in the lake to determine the current state and the indicators for the lake improvement like (microinvertebrtes, algae, macrophytes and measuring the inflow and the out flow water quality. One of the restoration actions was establishing two aerators for the oxygen exchange by transport oxygen from the water surface into the bottom layers of the lake to increase the oxygen in the hypolimnion layers in the summer time. Another restoration mechanism was taken by introduce non native spices of fish (Pike and Pikeperch) to manipulate the Phytoplankton growth by increasing the zooplankton.

Macrophytes as an indicator play an important role in the lake management:

The Lake Durowskie has specific littoral area with macrophytes. Many species of macrophytes are distributed on shoreline of the lake with different width from one to ten meters or even more. The well fertilized soil with trees components decomposition offer better habitats for macrophytes growth. This shoreline with plants is important for lake management. Relations between macrophytes and the lake statue from one site human from other site are summarized with the following aspects:

- Pollution (phosphorus contamination):
    - First, plants on shoreline are natural buffer against wind and pollutions (in particular trees, but also emergent water macrophytes)

- Plants consume minerals and nutrients like phosphorus with reduce concentration in the lake. Plants also regulate inflow of human sewage and any other contamination from human activities into the lake.

- Sedimentation and erosion:
  - Plants keep soil more stable in the shoreline, beside it works as shelter against the strong waves effects with is playing an important role with the shoreline erosion. As known that phosphorus can be introduce into the lake by houses, restaurants and other buildings, macrophytes can reduce this by stabilizing suspended solids coming to the lake carried by rain water and other previous activities. Also macrophytes protect the banks from high waves caused by strong wind or motorboats. Macrophytes restore the sediment in the lake by decreasing resuspension rate.

- Phytoplankton:
  - Macrophytes reduce phytoplankton distribution in the lake by strong competition for nutrients. Also macrophytes help to keep clear water statue.
- Biodiversity:
  - Plants offer a refuge and suitable habitat for reproduction for birds, fish, macroinvertebrates and other animals living in the lake.
- Human activities:
  - Two ways interactions between macrophytes and human activities are drawing a lot of the lake characteristics. Fishing as an example showing as human impact on the lake's macrophytes. Anglers are removing a considerable areas from plants over the shore to establish locations for fishing. This sites also are a main entrance for suspensions flow.

As it was shown above macrophytes are playing an important role for the lake ecosystem and management. Ecologist with the help of the local authorities

must aware the community around the lake with the importance of the macrophytes as a guardian of the lake .Macrophytes as well play an important role in Durowskie Lake by it is regulatory functions as mentioned above. Macrophytes in the lake suffer from the human interactions. In our work we will mark the change in the macrophytes growth by the years especially after starting the restoration program in 2009 .

Material and Methods

In our work we measured the occurrence of the macrophytes along the lake shore and in the two banks. Measurements was taken all over the lake water body using rowing boat as a transportation method. A GPS device was used to mark our points of macrophytes. Identification and measuring the different associations was estimated in the marked points. Anchor was used to catch the submerged macrophytes. Length and width of the associations was measured for estimating the coverage area of each associations in the lake. Measuring the depth in the area of the associations was measured using defined length robe. A note book was used to record our data . Notes was taken in the end and in the beginning of each point to determine the association and the dominant spices. In case of separated batches of species noticed, it was recorded as a note. Data were transferred from GPS to the computer and all maps were prepared using ArcGIS Program .

According to the Water Framework Directive of the European Union there are two methods of calculation to find out the ecological state of the water quality. the ESMI (Ecological State Macrophyte Index) and the MIR indices were calculated. MIR index is used as a biological indicator value, which gives an indication of water quality of running waters. and it was calculated using the following equations.

$$ESMI = 1 - \exp\left[-\frac{H}{Hmax} \times Z \times \exp\left(\frac{N}{p}\right)\right.$$

Where:

$$H = -\sum \frac{ni}{N} \times ln\frac{ni}{N}, Hmax = lnS \& Z = \frac{N}{izob.2,5m}$$

H – diversity index of phytocenosis

ni – area of polygons one of association in percent per cover

N – all cover of macrophytes

Hmax - coefficient of variation of the theoretical maximum

S – number of associations

Z – occupancy index

izob. 2.5m – area of littoral limited by isobath 2.5m

P – area of the lake

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

Where:

L = indicator value for each association

P = coverage for each species

W = weight factor

Table 2: The MIR calculation

Species	L	W	P	L*W*P	W*P
Cladophora glomerata	1	2	7	14	14
Butomus umbellatus	5	2	7	70	14
Acorus calamus	2	3	2	12	6
Potamageton pectinatus	1	1	7	7	7
Potamogeton perfoliatus	4	2	1	8	2
Phalaris arundinacea	2	1	1	2	1
Rorippa amphibia	3	1	2	6	2
Myriophyllum spicatum	3	2	3	18	6
Scophularia umbrosa	4	1	1	4	1
Solanum dulcamara	-	-	2	-	-
Salix fragilis	-	-	1		
Hildrebrandia rivularis	6	1	4	24	4
Eupatorium cannabinum	-	-	1	-	-
SUM				**165**	**57**

Table 2 shows the values of the indicator value for each species, the coverage for each species, and the weight factor. The coefficient, which was used to determine the cover of species in % is P and is displayed and compared in Table 3.

Table 3: Cover Coefficient of 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 %

Results

Firstly in the following map showing the distribution of macrophytes associations in the Lake Durowskie (Fig.1 and Fig.2). It is obvious from the maps that the coverage of macrophytes are highly representative more in the Northern part more than the Southern part of the lake. Many gaps appears in the Southern part and it's important information for lake management. Different habitats are represented along the lake shoreline. Forest, agriculture fields and urban areas surrounding the lake.

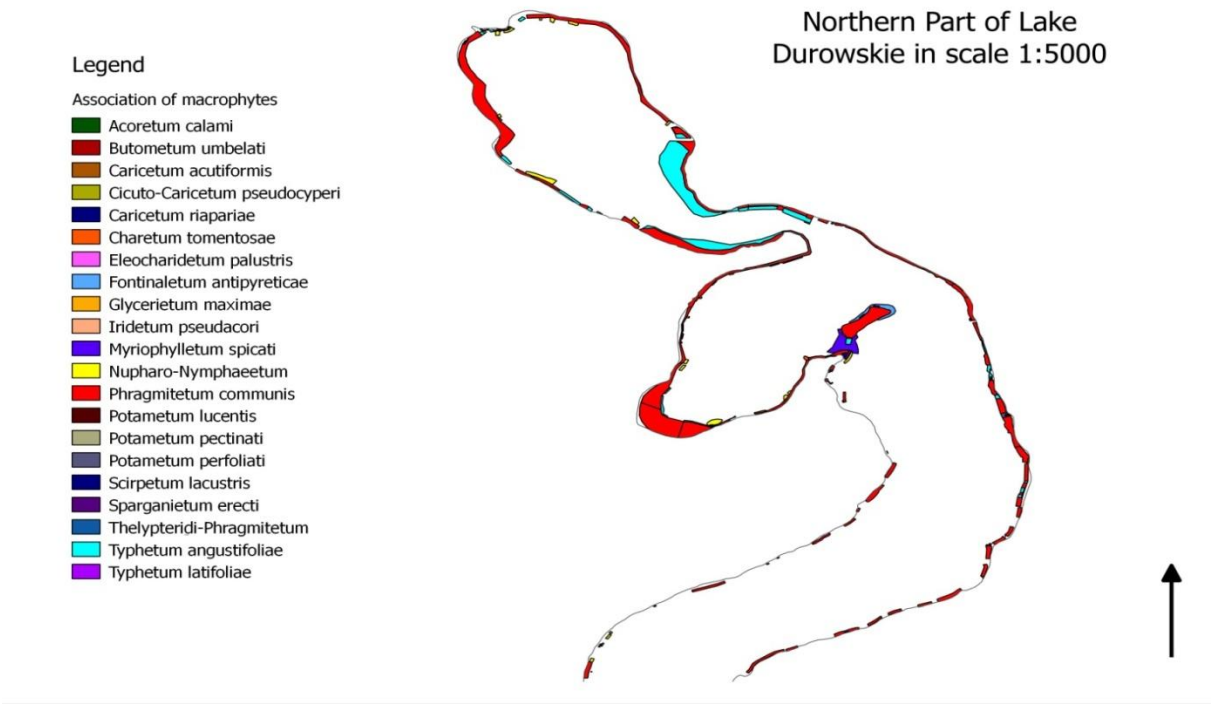

Fig.1: Map of macrophytes associations in the Northern Part of the Lake Durowskie

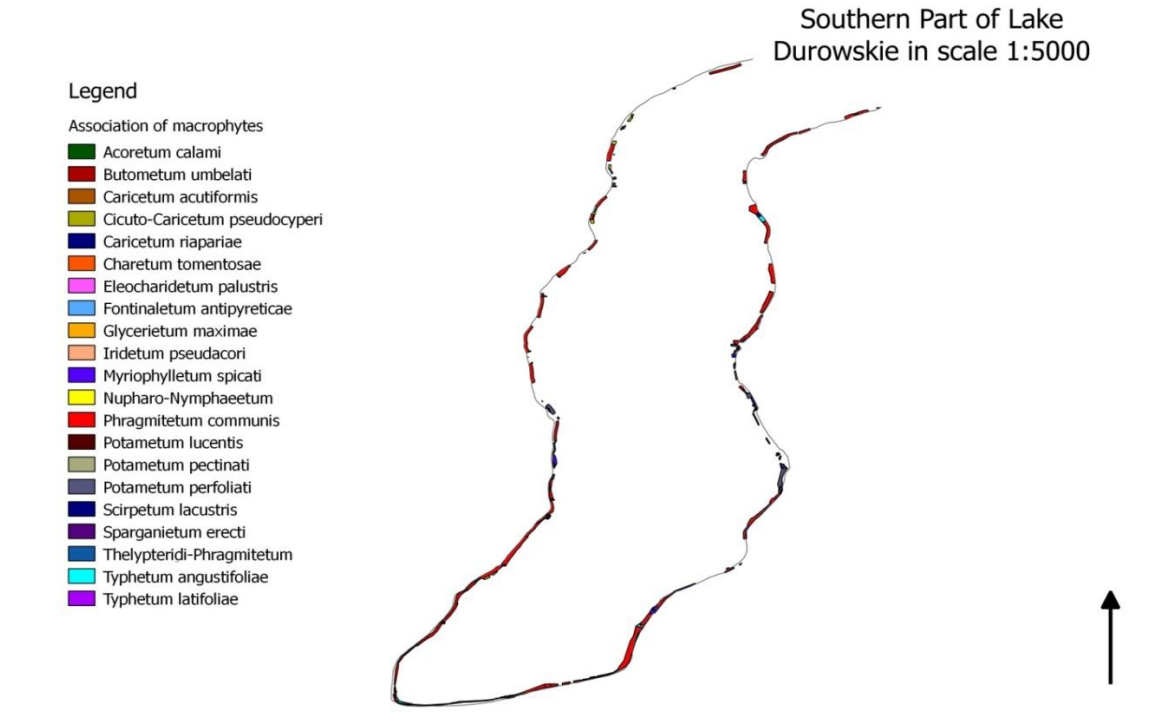

Fig.2: Map of macrophytes associations in the Southern Part of the Lake Durowskie

Table 3: Macrophytes associations coverage in the Lake Durowskie

Association	Area(m^2)	Coverage(%)
Phragmitetum communis (Garms 1927, Schmale 1931)	61762	69,15
Typhetum angustifoliae (Allorge 1922 , Soo 1927)	15829	17,72
Myriophylletum spicati (Soo 1927)	3373	3,78
Nupharo–Nymphaeetum albae (Tomaszewicz 1977)	3130	3,50
Potametum perfoliati (W. Koch 1926)	1876	2,10
Fontinaletum antipyreticae (Kaiser 1936)	1082	1,21
Acoretum calami (Kobendza 1948)	964	1,08
Caricetum ripariae (Soo 1928)	448	0,50
Sparganietum erecti (Roll 1938)	164	0,18
Glycerietum maximae (Hueck 1931)	139	0,16
Scirpetum lacustris (Allorge 1922 , Chouarge 1924)	135	0,15
Eleocharitetum palustrae (Schennikov 1919)	87	0,10
Charetum tomentosae (Corillion 1957)	87	0,10
Butometum umbellati (Konczak 1968)	57	0,06
Typhetum latifoliae (Soo 1927)	49	0,05
Potametum lucentis (Hueck 1931)	38	0,04
Thelypferidi-Phragmitetum (Kuiper 1958)	31	0,03
Potametum pectinati (Carstensen 1955)	25	0,03
Cicuto-Caricetum pseudocyperi (Boer 1942)	17	0,02
Caricetum acutiformis (Eggler 1933)	14	0,02
Iridetum pseudacori (Eggler 1933)	13	0,01
TOTAL	**89320**	**100**

In July 2014 twenty one associations were recorded in the lake. The most dominant associations were as following: *Phragmitetum communis* covers up to 69,15%, *Typhetum angustifoliae c*overs up to 17,72%, *Myriophylletum spicati* covers up to 3,78% and *Nupharo–Nymphaeetum albae* coveres up to 3,50%. Other associations are represented with lower percentage of coverage as it is shown in the table above (Fig.2).

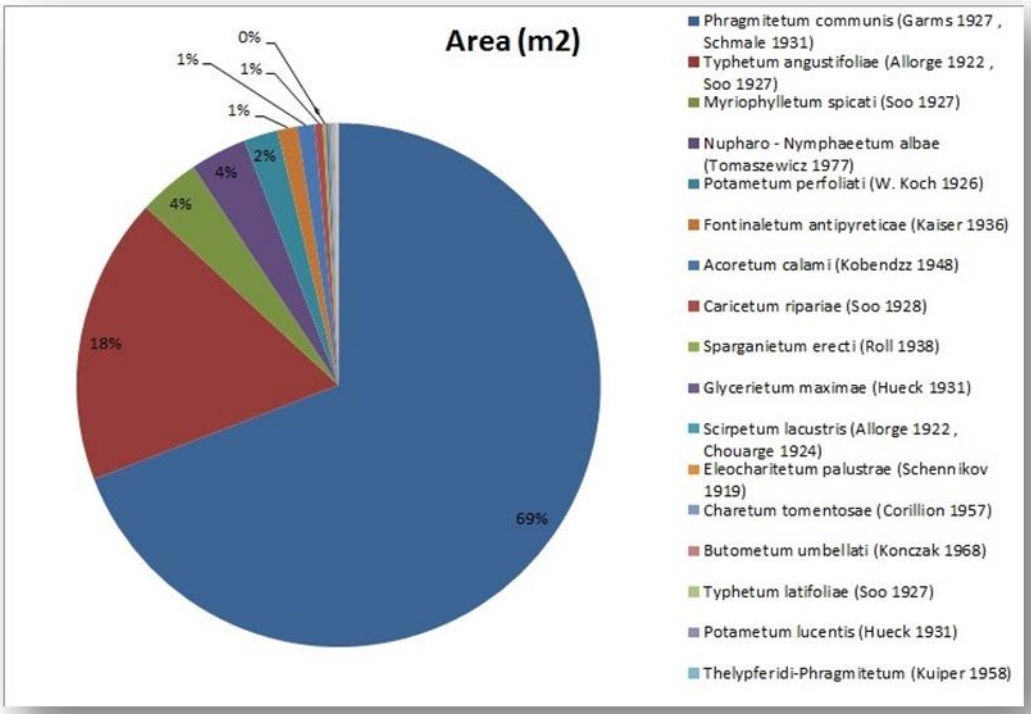

Fig.3: Pie chart for the coverage area expressed in percentage (%).

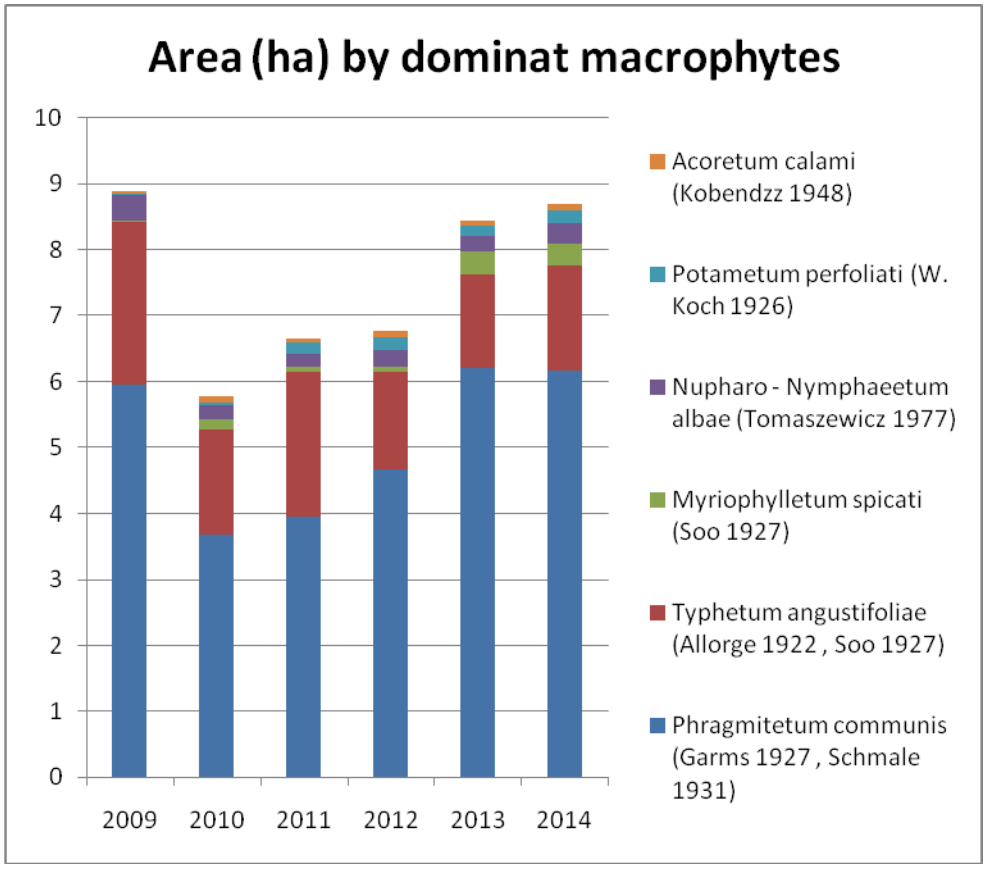

Fig.4: Change in the coverage of dominant macrophytes associations form 2009 to 2014

The same structure flow of dominant associations from to 2009 until to 2014 shows that Phragmitetum is the most represented one. In addition *Typhetum angustifoliae*, *Myriophylettum spicati*, *Nupharo-Nympheetum albae*, *Potametum perfoliati* and *Acoretum calami* are also covering considerable area with a different change from year to other. The dominant species show increasing in the coverage area since to 2010 until to 2014 after the sharp decrease from 2009 to 2010.

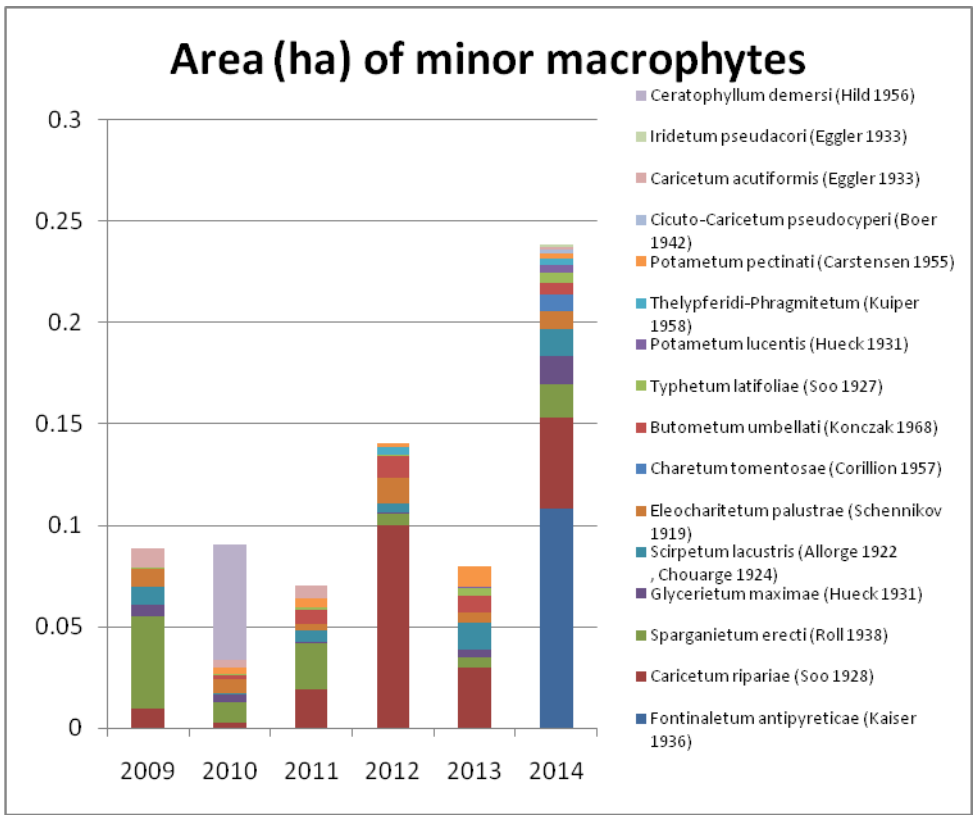

Fig.5: Change in the coverage of minor macrophytes associations form 2009 to 2014

Besides the dominant associations other minor associations cannot be neglected. Some species are indicator for the water quality, for example *Ceratophyllum demersum* witch appear at 2010 (year of less of macrophytes coverage area) is an indicator of eutrophic state of the lake.

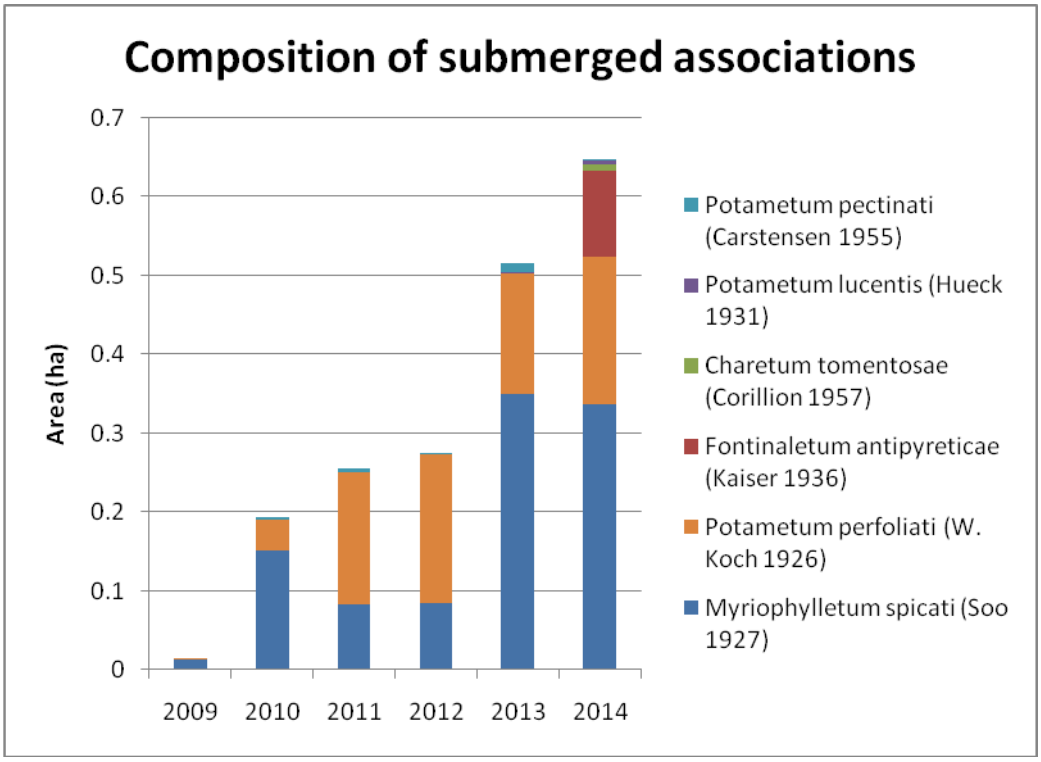

Fig.6: Submerged macrophytes in the Lake Durowskie from 2009 to 2014

Fig.7: New submerged associations *Fontinaletum antipyreticae* and *Charetum tomentosae*

One of the best indicators of water quality are submerged macrophytes, because they need a clear water to growth up. In the Lake Durowskie a positive trend of submerged macrophytes increasing was recorded. Also in July 2014 two new submerged associations (*Fontinaletum antipyreticae* and *Charetum tomentosae*) appeared as an indicator for the water quality improvement.

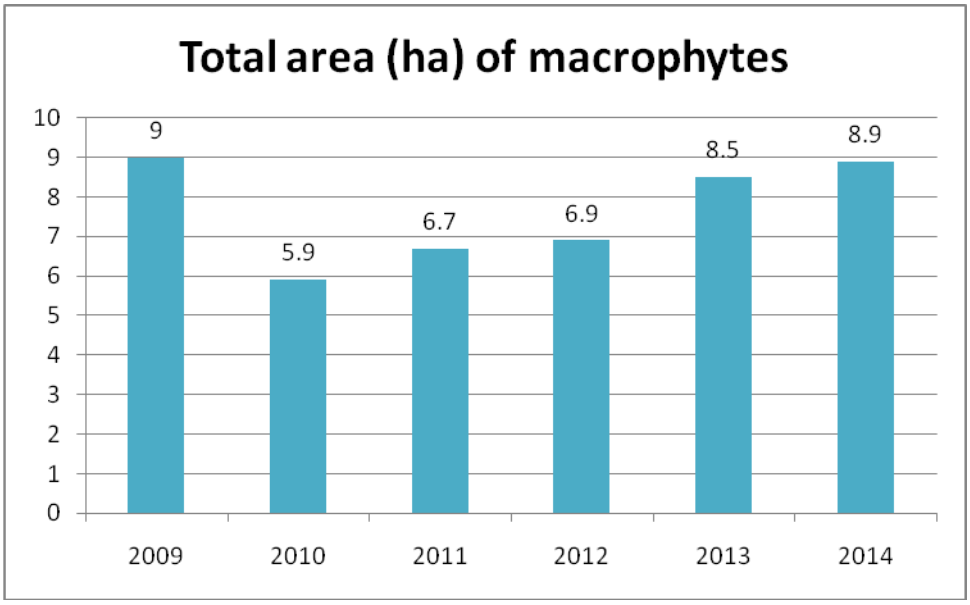

Fig.8: Total area of coverage from 2009 to 2014 in (ha)

In 2010 a sharp decrease in the total coverage area was recorded however there is a steady increase from 2011 until 2014. The total coverage area in 2014 almost the same like 2009. A four hectares of increasing were added in 2014 than 2013.

Table 4 : Change in the species composition in the outflow

Asssociation	2012	2013	2014
Cladophora glomerata		6	7
Butomus umbellatus	6	6	7
Acorus calamus	4	1	2
Potamagetum pectinatus	6	6	7
Potamogeton perfoliatus	1		1
Phalaris arundinacea		1	1
Rorippa amphibian		1	2
Myriophyllum spicatum	4	1	3
Scophularia umbrosa	1	1	1
Solanum dolcamara			2
Salix fragilis			1
Hildrebrandia rivularis			4
Eupatorium canabinum			1
Lysimachia thyrsiflora	1		

A different species composition in the outflow area was recorded. There is appearance four new species: *Solanum dolcamara, Salix fragilis, Hildrebrandia rivularis* and *Eupatorium canabinum,* also in outflow returned *Potamogeton perfoliatus.* Almost every noted species expended more than previous year.

Ecological State Macrophyte Index (ESMI) and Macrophyte Index for River (MIR)

Table 5: Range of values for ESMI and MIR

Ecological state	Range of values of ESMI	Range of values of MIR
	Deep lakes	Organic buttom
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

Table 6: Values of ESMI and MIR for the Lake Durowskie during the period 2009-2014

	2009	2010	2011	2012	2013	2014
ESMI	0,109	0,103	0,118	0,12	0,136	0,149
MIR	30,6	31,7	29,8	33,41	26,05	28,95

Compering the previous years the MIR values of outflow in 2014 started again to show improvement from 26,05 to almost 29. A decrease in the value in 2013 than 2012 witch show highly improvement along the last five years. On the other hand, the ESMI values in 2014 still giving a significant increasing, as an indicator for better state of water quality at lake, but still in the poor level of classification.

Discussion

The geographical distribution of the forest, agriculture activities and urban area (Wągrowiec City) are affecting the macrophytes associations growths. The southern part surrounded by urban areas and human activities has less macrophytes association coverage than the northern part of the lake, witch surrounded by forest and agricultures fields. In the Lake Durowskie noted twenty one associations and they cover 8,9 ha, but 15 of them cover 1% or less. The total coverage of different associations shown that *Phragmitetum* still the most dominant association, it almost reach the same coverage in 2009. However, *Phragmitetum* is not good indicator for the water quality, but it still very important for lake management. The reeds are habitats (refuge and place for reproduce) for birds, macroinvertebrates, fish and other organisms. The restoration of the lake seems to be effective with stopping cutting off of *Phragmiteteum* as it is noted that last two years have more than before. The minor macrophytes coverage has different variation from one year to another. However it recorded higher area of coverage in 2014 than before. *Ceratophyllum demersum* as a minor species also did not appear since 2010. Submerged associations witch consider a good indicators of water quality increase since 2010. Two associations *Fontinaletum antipyreticae* and *Charetum tomentosae* noted to be in the lake witch give us a good indicator for the future state of water quality, because they increase the level of oxygen in littoral area. In general there is positive trend of submerged macrophytes growth witch reflect the importance of restoration in the lake. Basically the ESMI value still show that the Lake Durowskie in the poor level of classification of water quality. However it cannot be ignored that the value is increasing by the time. According to the MIR this year 2014 started again to recover after last year decline.

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