Ecological Status of Durowskie Lake

Macrophytes

Evaluation of the ecological status of Lake Durowskie near Wagrowiec in Poland using the macrophytes as indicators.

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1. Introduction

In the last decades many European lakes have been deeply affected by human activities and experienced eutrophication (Gruber & Galloway 2008). This study explores the situation in Durowskie Lake, situated in Wągrowiec, near Poznan. The water quality of the lake decreased in the last years due to the introduction of nutrients and pollution. Some possible sources of uploads are the eutrophic inflow form 5 upstream lakes, polluted groundwater and human activities occurring in and around the lake (e. g. recreational activities and formerly sewage introduction) (Messyasz pers. comm.).

The lake has a surface of 143, 7 ha; it reaches a depth of more than 14 meters and it is characterized by a fast growing steepness from the shore. It is a highly eutrophicated stratified lake which experiences anaerobic conditions in the hypolimnion and a reduced transparency due to high phytoplankton concentrations.

These chemical and geophysical features favor the occurrence of cyanobacteria that produce algal blooms, which can be have negative impacts on the recreational use of the lake. The steep slope of the lake makes it difficult for macrophytes to develop lake-wards and to construct wide belts along the litoral which can offer a filtrating system and can improve the water quality.

In order to explore the water quality and the ecological conditions of the Durowskie Lake, three working groups analyzed three different environmental components, macrozoobenthos, chemical parameters and macrophytes. This study reports on the results of the study of submerged and emergent macrophytes. Indeed the aim of our study is to explore the ecological status, as defined in the European water framework directive (WFD, 2000/60/EC), of this particular lake using the state of macrophytes as indicator. This objective is pursued through the evaluation of the structure, distribution and biodiversity of macrophytes, using the Ecological Status Macrophytes Index (ESMI) (Cicierska 2004). The macrophytes communities of the river ecosystems at the inflow and the outflow of Durowskie Lake were also analyzed in order to understand the possible sources of eutrophication and pollution. The MIR index (Instytut ochrony środowiska 2006b) was used to classify the ecological status of these river reaches. Furthermore, a comparison with the situation of the plant associations in 1994 is performed, intending to investigate the dynamic of the vegetation.

Macrophytes were chosen to explore water quality and ecological status given that they are considered good indicators for environmental conditions (Schaumburg *et al.* 2004). They have been investigated for many decades leading to the development of numerous indexes to determine the ecological status of lake and river ecosystems (Schaumburg *et al.* 2004, Cicierska 2004). In order to comply with the WFD European countries developed their own indexes that match local conditions (Penning 2008). In Poland the Ecological Status Macrophytes Index (ESMI) is used to classify lakes according to their macrophytes communities (Instytut ochrony środowiska 2006a), whereas rivers are classified with the help of the MIR-index (Macrophytes Index for Rivers) (Instytut ochrony środowiska 2006b).

2. Methods

To determine the phytosociological associations of the macrophytes of Durowskie Lake, the data of all patches of vegetation encountered along the shoreline of the lake were recorded. A standardized protocol was created which can be followed for the monitoring of the ecological status of Durowskie lake in future years (appendix). We gathered information on (i) the species composition with the coverage of each species on the Braun-Blanquet scale (tab. 2), (Braun-Blanquet 1928) (ii) the geographical position, (iii) the maximum and minimum water depth of the patch, (iv) the maximum distance from the shore and (v) the extent (length and width) of each patch of vegetation (tab. 1).

Tab. 1: Data that were recorded

a) species composition with coverage for each species on Braun-Blanquet scale
b) geographical position
c) maximum and minimum water depth of each patch (m)
d) maximum distance from the shore (m)
e) length and width of each patch (m)

To retrieve submerged macrophytes we used a specially designed tool (anchor) on a rope that scratches along the bottom of the lake and gathers the submerged plants.

Tab. 2: Vegetation coverage classes according to Braun-Blanquet (1928)

code	coverage (%)
+	<1
1	1-10
2	10-25
3	25-50
4	50-75
5	>75

For each plot we defined the plant association according to Podbielkowski & Tomaszewicz (1996).

The primary data were used to construct a map and evaluate the vegetation cover for emergent and submerged macrophytes. The GPS positions and information on the respective phytosociological associations and the patch size were imported in MapSource program (version 6.15.6, © Garmin). The program was used in order to visualize and calculate the area covered by each association for each patch studied.

This allowed us to calculate the ESMI-index (Ecological Status Macrophyte Index), which has been developed in Poland in order to estimate the ecological status of lakes to comply with the European water framework directive (2000/60/EC).

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

The ESMI-index is based on the Shannon-Wiener index (H), which was originally conceived to estimate biodiversity. n_i is the plant covered surface area that is covered by the respective association. N is the total area that is covered by plants. To facilitate the calculation N can be set to 100 and n_i expressed as the percentage of the plant covered area that is covered by each association.

$$H = \sum \frac{n_i}{N} * \ln\left(\frac{n_i}{N}\right)$$

H_{max} is the natural logarithm of the number of associations encountered (m).

$$H_{max} = \ln(m)$$

Z indicates the percentage of the area which is actually covered by macrophytes of the lake surface which could be covered under optimal water quality conditions (0m-2,5m depth) (A).

$$Z = \frac{N}{A}$$

P is the total lake surface which in case of the Durowskie lake is 143,7 ha. The ESMI-values are to be interpreted according to table 3.

Tab. 3: ESMI values and classes of ecological status of deep stratified lakes (Instytut ochrony środowiska 2006a)

Deep stratified lakes	
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

An complete explication and evaluation of the ESMI-index can be found in the manual of the Instytut ochrony środowiska (2006a).

We furthermore recorded the same data we gathered for the lake also for the river at the inflow of the lake and at the outflow of the lake. The index used to evaluate ecological conditions for the river reaches is the Macrophyte Index for Rivers (MIR) (Instytut ochrony środowiska 2006b).

$$MIR = \frac{\sum L_i * W_i * P_i}{\sum W_i * P_i} * 10$$

L_i is an indicator factor that has been defined for each species. These factors have been adjusted to the country-specific conditions in Poland in order to guarantee representativity. L_i is weighed according to the weight factor W_i. P_i is the coverage for each species on a 9-degree scale (table 4, Instytut ochrony środowiska 2006b).

Tab. 4: Coverage classes for the calculation of MIR-index (Instytut ochrony środowiska 2006b)

Coverage Class	Percent of coverage
1	< 0,1%
2	0,1-1%
3	1-2,5%
4	2,5-5%
5	5-10%
6	10-25%
7	25-50%
8	50-75%
9	75-100%

MIR – values are to be interpreted according to table 5 (Instytut ochrony środowiska 2006b).

Tab. 5: MIR values and classes of ecological status of sandy and organic rivers (Instytut ochrony środowiska 2006b)

Ecological status	Sandy and organic rivers
very good	≥ 44,5
good	(44,5-35,0>
moderate	(35,0-25,4>
poor	(25,4-15,8>
bad	<15,8

3. Results and Discussion

3.1 Associations

During the examination of the transects we found 15 phytosociological associations (tab. 6).

The following information on the associations we found in Durowskie lake has been compiled based on Podbielkowski & Tomaszewicz (1996).

The most frequent association in Durowskie lake is *Phragmitetum communis* (66,11 % of the plant cover), which is typical for eutrophic lakes. This is a group of water plants is growing near the shoreline. It grows in stagnant waters up to a depth of ~3 m or in slowly running waters.

Patches often cover a large surface and are producing an important amount of biomass which leads to the accumulation of organic material. *P. communis* and *Typha angustifolia* were observed to grow in association in Durowskie lake.

Tab. 6: Phytosociological associations of Lake Durowskie

Association	Surface m^2	%
Phragmitetum communis (Garms 1927) Schmale 1931	59448	66,11
Typhetum angustifoliae (Allorge 1922) Soó 1927	24910	27,70
Nymphaeo-Nupharetum luteae Tomaszewicz 1977	3969	4,41
Acoretum calami Kobendza 1948	528	0,59
Sparganietum erecti Roll 1938	460	0,51
Myriophylletum spicati Soó 1927	124	0,14
Caricetum acutiformis Sauer 1937	94	0,10
Caricetum ripariae Soó 1928	92	0,10
Scirpetum lacustris (Allorge 1922) Chouarge 1924	92	0,10
Eleocharitetum palustris Schennikov 1919	84	0,09
Glycerietum maximae Hueck 1931	55	0,06
Potametum perfoliati W. Koch 1926	26	0,03
Najadetum marinae	20	0,02
Ceratophylletum demersi Hild 1965	15	0,02
Typhetum latifoliae Soó 1927	8	0,01
Total	89925	100,00

Typhetum angustifoliae (typical for eutrophic and mesotrophic lakes) has the second largest cover (27,7 % of the plant cover). If it growth in competition with *P. communis* it is usually replaced by the reed in the long term.

Nymphaeo-Nupharetum luteae constitutes 4,41 % of the plant cover and usually occurs in lakes with high concentration of nutrients.

Acoretum calami is a euhemerob neophyte in polish lakes. To grow it needs nutrient-rich water. It is able to survive in water bodies with high volume of phosphate and nitrogen.

In large lakes we often find *Sparganietum erecti* in association with *P. communis* and *T. angustifoliae*. Typical for eutrophic waters.

Myriophylletum spicati is a submerged plant community of eutrophic lakes.

Caricetum acutiformis grows on wet areas and covers shores of lakes. Its main species *Carex acutiformis* forms close belts near the shore.

Caricetum ripariae is similar to *Caricetum acutiformis.*

Scirpetum lacustris as well as *Eleocharietum palustris* need a eutrophic environment and often covers large surfaces.

Glycerietum maximae grows in shallow seasonally dry stagnant or running waters. In big lakes we can see *G. maximae* near *Caricetum ripariae* or *Caricetum acutiformis*. Associations of high productivity.

Potamogetum perfoliati is an association of submerged plants growing in meso- or eutrophic, stagnant or running waters.

Ceratophylletum demersi forms a close belt of submerged plants. The main species is *Ceratophyllum demersum.* It shows optimal growth in shallow, stagnant, eutrophic waters but can also be observed in meso- and oligotrophic lakes.

Typhetum latifoliae is growing in shallow stagnant or slowly running waters. Usually we can see this association in eutrophic waters.

3.2 The ecological status of the inflow and the outflow of the lake

The inflow of Durowskie Lake is Struga Gołaniecka coming from Kobyleckie lake in the North. The species we observed in the inflow of the lake are summed up in tab. 7.

Tab. 7: Species composition, MIR-indicator values and cover class for the inflow of Lake Durowskie

SPECIES	Indicator value (L)	Weight (W)	Cover class (P)
Nuphar lutea	4	2	2
Rumex hydrolapathum	4	1	1
Mentha aquatica	5	1	1
Iris pseudacorus	6	2	1
Phalaris arundinacea	2	1	1
Solanum dulcamara	na	na	na
Potamogeton perfoliatus	4	2	1
Calystegia sepium	na	na	na
Sparganium ramosum	3	1	4
Glyceria maxima	3	1	1
Phragmites australis	na	na	na
Typha latifolia	2	2	1
Carex acutiformis	4	1	1
Carex riparia	4	2	4

We obtained a MIR-index value of 37,8 which indicates good ecological status of the river at the inflow. It is possible that the very low cover values of the species occurred because the river at the sampling transect was shaded by trees. Additional measurements for other components that are necessary to determine the ecological status of rivers for the European water framework directive (fish fauna etc.) and criteria that determine the chemical status would yield a more complete image of the status of the water body at the inflow of lake Durowskie.

Tab. 8: Species composition, MIR-indicator values and cover class for the outflow of Lake Durowskie

SPECIES	Ind value	W	Cover
Myriophyllum spicatum	3	2	4
Cladophora sp.	1	2	4
Sparganium ramosum	3	1	1
Rorippa amphibia	3	1	4
Phalaris arundinacea	2	1	2
Potamogeton perfoliatus	4	2	2
Solanum dulcamara	na	na	na
Lysimachia thyrsiflora	7	3	1
Iris pseudacorus	6	2	1
Potamogeton pectinatus	1	1	7
Acorus calamus	2	3	3
Butomus umbellatus	5	2	6
Glyceria maxima	3	1	1
Lycopus europaeus	na	na	na
Stachys palustris	2	1	1
Phragmites australis	na	na	na

The MIR-value at the outflow of lake Durowskie is 30,6 which indicates a moderate ecological status of the water at the outflow (for list of species see tab. 8). The decrease in ecological status from the inflow to the outflow is probably due to the anthropogenic activity (recreational activities like fishing etc.) that take place around the lake, especially in the surroundings of the city of Wągrowiec. The sediments of the lake continue to release nutrients. The latter factor is difficult to treat and ameliorate. Moreover in order to decrease the impact of the anthropogenic pressures a better regulation of recreational activities, like the feeding of fish, are expected to have very positive effects.

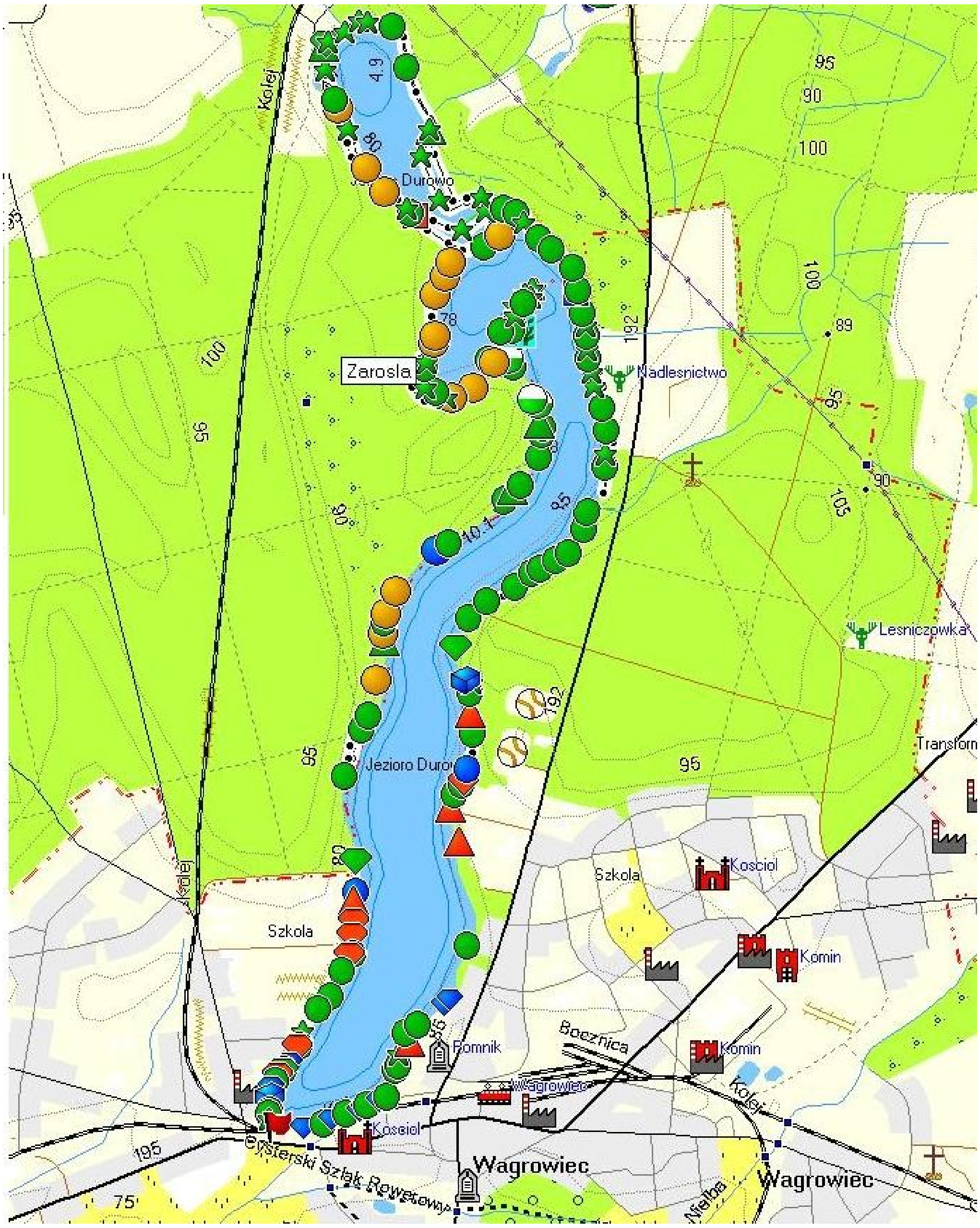

Fig. 1: Map of the phytosociological associations of the Durowskie Lake

3.3 Analysis of macrophyte distribution

In the North and central part of the lake was found that the associations have a more consistent cover, for example the belt of *Phragmitetum, Typhetum* and *Nymphaeo - Nupharetum luteae,* which are common association for eutrophic lakes.

Exclusively in the Northern bay we recorded the submerged community of *Najadetum marinea* which indicates good water quality even though the current extension is not large.

In addition *Caricetum acutiformis and Sparganietum erecti* are reported only in the upper area of the lake.

In the Southern part, where the recreational activities take place, the associations show a more fragmented pattern, as illustrated in the map (Fig.1). Although the Southern part of the lake register a slightly higher number of associations. *Acoretum calami,* non native association, *Typhetum latifolia,* and *Myrophylletum spicati* are reported only in the lower part of the lake.

To explain these results it is important to consider the geomorphologycal features of the lake. The lake has a glacial origin and it can be defined as a tunnel-valley lake. It reaches a depth of more than 14 meters and it is characterized by a steep shore and it is surrounded by hills. The composition of the soil is mainly sand and clay, easily eroded and transported sediments, enhancing the steepness of the walls of this tunnel-valley lake. Due to the North-South extension of the lake but the West-East predominant direction of the wind, jointly with the valley structure of the lake, this water body does not experience strong winds. This conditions lead to high surface temperature which thus differs from temperature of the lower layers. The reduced wind current and the differences among the temperatures of the layers enhance the stratification of the water. All these circumstances boost the growth of cyanobacteria. These communities reduce the penetration of light that together with the geophysical characteristics of the area, diminish the possibility for macrophytes to extend to deeper zones.

Indeed the northern area is more shallow with a flatter slope offering better conditions for the development of extended belts of vegetation, while in the South, the steep slope reduce the possibility for associations to develop in width. Moreover, the

anthropogenic pressure, might constitute an important factor influencing the shorter length and higher fragmentation of the plant patches in the South area, as showing in the map (Fig 1).

Not many submerged macrophytes were recorded, *Potamogetum perfoliati* and *Najadetum marinae*, probably due to the reduced light availability. The submerged macrophytes are competitors of phytoplankton and might be a sink for nutrients.

Moreover they can offer a shelter to zooplankton which can have an effect due to their position in the trophic web (predator of phytoplankton). These communities also reduce the resuspension of organic sediments. Many species of macrophytes release phytochemicals which inhibit phytoplankton growth. Fish, in particular predators like the pike, use these associations as spawning and breeding grounds.

3.4 Comparison of the macrophyte associations of Durowskie Lake between 1994 and 2009

With the help of a map of the macrophyte cover of Durowskie lake of 1994 (Nagengast 1998) we compared the phytosociological associations 15 years ago with the present day situation (Fig.2). In 1994 the water quality of Durowskie lake was better than today (2009). The Secchi-disc transparency in 1994 was 2,5 m. In 2009 we recorded only 1m Secchi-disc transparency. Macrophytes depend on sunlight to be able to do photosynthesis. As a rule of thumb we can say that macrophytes are able to grow in depth until approximately the double of the Secchi-disc transparency (2009: 2 m, 1994: 5 m). This explains much of the differences encountered in species abundance and distribution in the lake between 1994 and 2009.

Generally we find a strong decrease in submerged macrophytes within the last 15 years. In particular we observed a decrease in the surface covered by *Polygonetum natantis* Soó 1927, *Parvopotamo-Zannichellietum* W. Koch 1926, *Myriophylletum spicati* Soó 1927, *Potamogeton lucentis* Hueck 1931 and *Ceratophylletum demersi* Hild 1965. The former three associations disappeared completely from the lake, whereas the latter two decreased in surface and are now confined to shallower areas of the lake.

In 1994 we find a typical lake macrophyte zonation with a zone of emergent macrophytes near the shore and a zone of submerged macrophytes in the deeper areas (fig. 2). In 2009 the water transparency has decreased so much that no zone of submerged macrophytes can be found lake-wards of the belt of emergent macrophytes anymore.

Emergent macrophytes react with a larger time-lag to the changes in water quality as they are independent of the water transparency for their photosynthesis. Thus we did not observe significant differences in the cover of emergent macrophytes between 1994 and 2009. *Phragmitetum communis* and *Typhaetum angustifoliae* constitute still the main cover plants. We observed a slight increase in the surface covered by *Nymphaeo albae – Nupharetum luteae* since 1994.

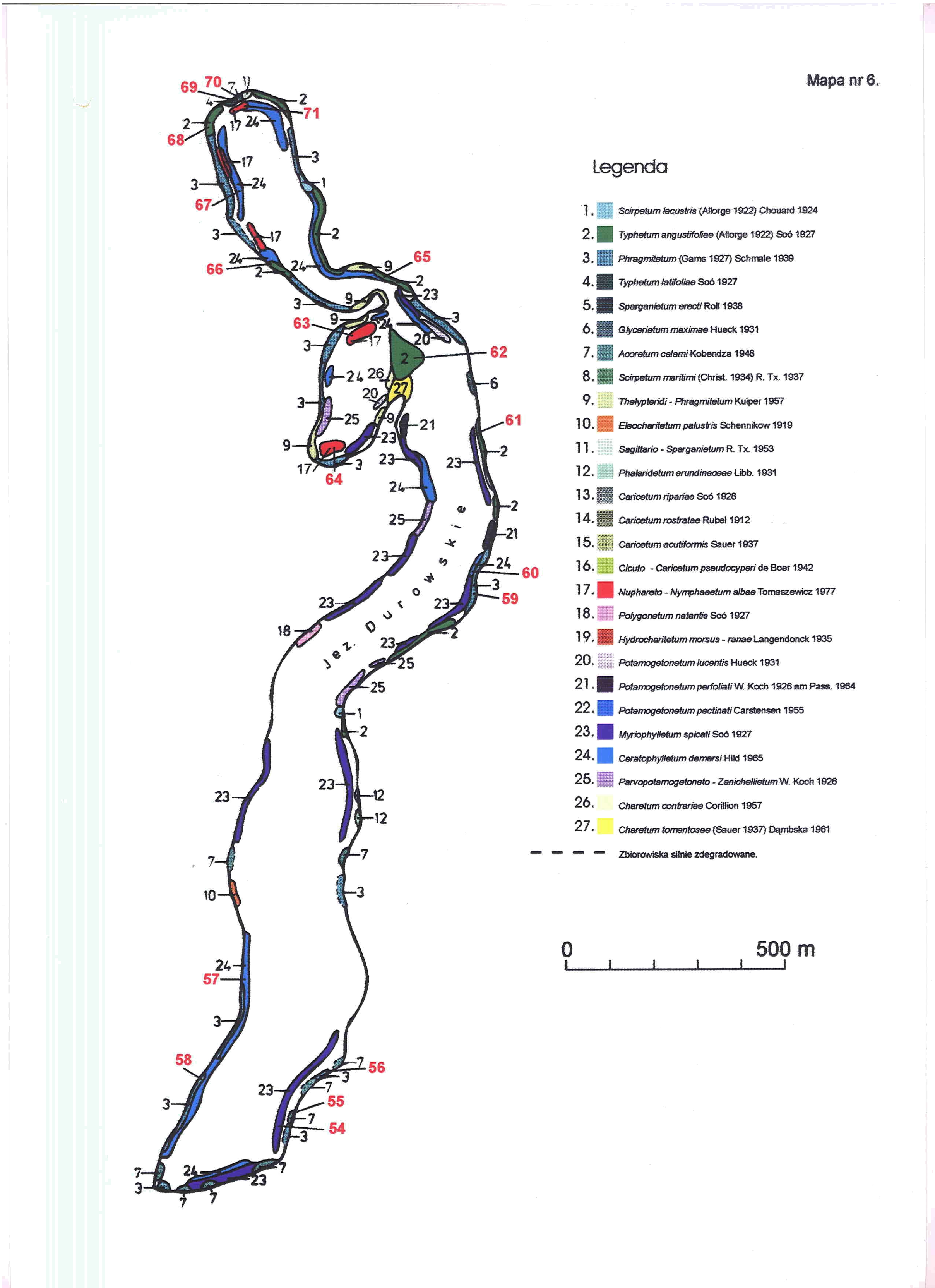

Fig. 2: Map of the macrophyte associations in Lake Durowskie from 1994 (Nagengast 1998)

4. Conclusions

From these results we can conclude that the lake experiences eutrophic conditions which favor the development of associations of emergent macrophytes such as *Phragmitetum* and *Typhaetum.* The low light availability, below 1 m, led to a decrease in submerged macrophytes.

From our study, as expected, we can not yet observe clear effects of the restoration methods due to the fact that macrophytes respond with a time lag to changes in water quality. Therefore future monitoring will show whether the restoration measures produce amelioration of the ecological status.

If the restoration efforts lead to better water quality, we expect that submerged macrophytes would recover and spread to deeper areas (up to 2,5 m depth or even more). This result will probably be followed by a positive feedback effect on the water quality of the lake since macrophytes have the above explained ecological features. The results concerning the inflow and outflow show the inflow is not the only source of pollution and eutrophication of the Durowskie lake. This consideration lead to the need to reconsider the role of Wagrowiec and the recreational activities for the water quality and the ecological status of the lake. Therefore it seems necessary to include further measures in the restoration which regulate for example the input of nutrients into the lake.

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