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The influence of hydromorphological modifications of the littoral zone in lakes on macrophytes

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Abstract

The study aimed at determining the influence of hydromorphological modifications of the littoral zone in lakes on the occurrence and quantitative diversity of macrophytes. The field research was carried out at the peak of the growing season (June – September) between 2006 and 2009. Altogether, 457 transects were studied, located in 5 lakes. Studies on the hydromorphology were performed with the method of Lake Habitat Survey (LHS), and on macrophytes − with the method of transects. The studied sites were divided into 3 groups of different intensity of morphological transformations. The identified groups constituted the starting point for the analysis of influence exerted by transformations on macrophytes. The obtained results indicate that hydromorphological modifications of lakes are an important ecological factor affecting the occurrence and quantitative diversity of macrophytes. The transformations recorded in the studied reservoirs resulted mostly from recreational exploitation. They were responsible for mechanical elimination of dominant species, which led to an increased number of taxa, synanthropization and an average level of hemeroby as well as a decrease in the total vegetation cover. Helophytes were the most negatively affected group by the transformations, which reduce their contribution in the vegetation cover, whereas macroscopic filamentous algae and elodeids were positively affected.

INTRODUCTION

The occurrence of macrophytes in aquatic ecosystems is conditioned by miscellaneous environmental parameters, for instance: water movement, the type of substrate, light conditions, water reaction, availability of biogenic substances and hydromorphological transformations. From among all environmental factors of anthropogenic origin that affect macrophytes, the effect of hydromorphological transformations is the least identified (Janauer 2003, Lacoul & Freedman 2006, Sutela et al. 2013). At the same time, the research carried out on other groups of organisms (e.g. invertebrates, fish) indicates that transformations are one of the most important environmental factors (Soszka et al. 2012, McGoff et al. 2013, Sutela et al. 2013). Many macrophyte metrics, such as species richness or taxonomic composition, depend on both water quality and sediments, therefore it is very difficult to find relationships between macrophytes in eutrophic water and hydromorphological features. Nutrient enrichment can also compensate for hydromorphological degradation (Hellsten & Dudley 2006).

From the middle of the last century, density of buildings along the shoreline of many lakes located in the attractive tourist areas has significantly increased (Ostendorp et al. 2004). This problem applies in

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particular to large and easily accessible reservoirs, surrounded by forests (Schnaiberg et al. 2002, Walsh et al. 2003). Morphological transformations of lakes are usually characterized by lower intensity as compared to rivers (Søndergaard & Jeppesen 2007, Rowan et al. 2012). Especially many rivers and streams in urban areas are very strongly modified (Wardas et al. 2010). Hydromorphological modifications of lakes are limited to tourism and recreational pressure, and thus to mowing of plants, building of piers, including angling ones, harbors for boats and mowing of littoral vegetation, in order to create beaches and bathing sites (Elias & Meyer 2003). This induces some disturbance in the equilibrium of an ecosystem, changes in the taxonomic composition of aquatic organisms and disappearance of sensitive biotopes (Hellsten & Dudley 2006).

The Water Framework Directive describes hydromorphological quality elements of lakes as hydrological regime and morphological conditions (European Commission 2000). Hydromorphology is important for defining lakes at high ecological status, but also has an important role in designating and establishing appropriate monitoring strategies for Artificial Water Bodies (Rowen et al. 2004). McParland & Barret (2009) emphasize the importance of individual elements of lake morphology for macrophytes: (a) changes in the water level − influence on light conditions; (b) bottom substrate – determines the amount and the type of nutrients available; (c) hydromorphological transformations – cause the destruction or fragmentation of habitats. Strong tourism pressure also increases the contamination and degradation of a waterbody (Drzewiecki 1997). Macrophytes as a group of organisms that occur in the littoral zone on the borderline between water and land are particularly sensitive to changes in the water level (Keto et al. 2006, Zieliński et al. 2011), but this relationship is not clear. For example Rørslett (1991) reported that small changes in the water level (about 1-3 m) contribute to an increase in the biodiversity of lakes. On the other hand Zohary and Ostrovsky (2011) showed that lakes with a variable water level have lower species richness, a larger number of alien species and fewer rare species.

The present paper constitutes an attempt at defining the influence of hydromorphological modifications of the littoral zone in selected lakes on the occurrence and quantitative diversity of macrophytes.

MATERIALS AND METHODS

The field studies were carried out at the peak of the growing season (July – August) between 2006 and 2009 with the transect method. Transects perpendicular to the shoreline of 10 m width were distributed every 50 m. The first transect was located randomly. The research covered 5 lakes from northern Poland with a total of 457 transects laid out. All the investigated reservoirs are large and open (flow-through) water bodies, which represent a similar trophic type – eutrophic. Basic morphometric data of the lakes, altitude above sea level and the number of research sites (transects) are included in Table 1.

The macrophyte survey was conducted in all transects. The research was carried out to a maximum colonization depth of plants. The survey includes a list of taxa and their estimated ground cover. The presence of each species was recorded with their percentage cover using a nine-point scale (Table 2).

With reference to hydromorphology, elements of the LHS method − Lake Habitat Survey − were applied in each of the transects. The LHS protocol provides a method for description and assessment of the physical habitat of lakes by quantitative description of the canopy, the dominant littoral substrate, and human activities along the shoreline (Rowan et al. 2004, Rowan et al. 2006). The LHS protocol requires that the shoreline and riparian habitat are assessed at random and evenly spaced locations (transects) (Rowan et al. 2006). A detailed questionnaire is filled out at each of the transects that scores habitat features in the shore, riparian and littoral zones. The riparian zone extends 15 m landward from the edge of the bank, the littoral zone is the area from the waterline to 10 m offshore, and the shore zone is the region between the edge of the bank and the current waterline. Human pressure on each transect is assessed up to 50 m from the waterline (Rowan et al. 2004). The study focused on the shore zone and human pressure. The shore zone includes an assessment of the predominant bank material, bank face modifications, evidence of bank face erosion as well as the presence and features of beaches (Rowan et al. 2004). Human pressure included records of the presence of any type of the human pressure, for example: commercial activities, residential areas, tracks and footpaths, camping grounds, docks, marinas and platforms for boats, dykes or revetments, recreational beaches, dumps or

Table 1

Basic data on the studied lakes

No.	Lake	Number of transects	Altitude asl (m)	Area (ha)	Average depth (m)	Schindler coefficient
1	Błędno	150	52.8	742.5	3.5	49.3
2	Chodzieskie	105	54.2	115.6	3.1	10.9
3	Niskie Brodno	60	67.5	87.2	4.2	13.0
4	Strażym	83	71.0	73.4	3.5	80.1
5	Łokacz	59	32.3	48.8	1.8	209.7
	TOTAL	457				

Table 2

Cover coefficients of macrophytes applied in the research

Cover coefficient	Percentage cover contribution
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%

landfills, pipes and outfalls, dredging as well as aquatic vegetation removal (Rowan et al. 2004).

The average level of hemeroby, the total synanthropization index, the number of taxa, the total cover of macrophytes and percentage contribution of ecological groups of macrophytes were calculated for the studied transects.

The ecological concept of hemeroby is a measure of the total human impact on natural ecosystems. The hemeroby system, as a disturbance of vegetation, was developed in Central Europe by Sukopp (1972). Habitats and vegetation types are classified on a scale of ahemerob (natural) to polyhemerobic (non-natural). At the end of the scale, there is a metahemerobe level, assigned to locations devoid of vegetation. A high degree of hemeroby corresponds to a lower human influence on a natural environment. The average level of hemeroby (He) was calculated with the 100-degree index proposed for western Poland by Chmiel (1993):

$$He = \frac{\sum_{i=1}^{n} He_i \cdot p_i}{\sum_{i=1}^{n} p_i}$$

where:

He – an average level of hemeroby,

He_i – a hemeroby index of individual species (Chmiel 1993),

p_i – cover of individual species in the 9-degree scale.

The concept of synanthropization of flora (Faliński 1972), with the historical-geographical origin of species taken into account, allows for the broad view of changes in the floristic diversity, which result from the human activity. The total synanthropization index (Syn_{tot}) determines the contribution of species that prefer transformed habitats (apophytes), as well as species of alien origin (anthropophytes) in the entire vascular flora, i.e. spontaneophytes and anthropophytes. The total synanthropization index was calculated for the studied transects using the following formula (Jackowiak 1990):

$$Syn_{tot} = \frac{Ap + A}{Sp + A} \cdot 100$$

where:

Syn_{tot} – the total synanthropization index,

Ap – percentage contribution of apophytes,

A – percentage contribution of anthropophytes,

Sp – percentage contribution of spontaneophytes.

Analysis of the macrophytes' species diversity was performed with the use of two indices: the number of taxa and the total cover. The total cover is an indirect measure of macrophytes biomass (Daubenmire 1959). Furthermore, the percentage contribution of ecological groups of aquatic plants in terms of macrophyte cover was calculated at every site. Appendix 1 shows the list of all macrophyte taxa found in the surveyed lakes with assigned ecological groups. Helophytes, nymphaeids and elodeids include vascular plants rooted in the bottom, helophytes – with shoots above the water surface, nymphaeids – with floating leaves and elodeids – with shoots under the water surface. The ecological group of filamentous algae in the lakes includes mainly green algae, which produce colonial thallus visible to the naked eye.

The studied transects were divided into 3 groups (degrees) of hydromorphological transformations: none or slight (1) – 296 transects, moderate (2) – 113 transects, as well as strong or very strong (3) – 48 transects. They provided the basis for statistical analyses. None or slight morphological modifications (the 1st degree) include transects without anthropogenic pressure, as well as transects with a bank slightly (<1/3 width of transect) trampled by livestock or humans, and riparian plants or macrophytes removed. Removal of macrophytes, i.e. their leafy parts is carried out in order to clear the water surface for recreational activities, such as sailing, swimming and fishing. Moderate morphological modifications (the 2nd degree) include transects with a significantly (>1/3 width of transect) trampled bank and riparian plants or macrophytes removed; transects with partly (<1/3 width of transect) recreational beaches, banks resectioned and reinforced by artificial materials (i.e. concrete, wood piling, gabion, rip-rap), as well as the presence of wooden fishing platforms. Strong and very strong morphological transformations (the 3rd degree) include transects with the presence of marinas and platforms for boats, dredging and extraction of littoral substrates, as well as transects with extensively (>1/3 width of transect) recreational beaches, resectioned and reinforced banks.

Most of the analyzed parameters did not meet the criteria of the normality of distribution and homogeneity of variance. Despite the attempts to transform the data for normal distribution, no entirely satisfactory results were obtained. Therefore, the H test of Kruskal-Wallis was applied as a nonparametric equivalent of univariate analysis of variance. Apart from the aforementioned test, also a multiple comparison of average ranks for all samples was performed, in order to define which degrees of transformations of individual variables significantly differ from each other.

RESULTS

Species richness

In the course of the research, 94 taxa of macrophytes were found (Appendix 1). The number of taxa observed in individual lakes was similar. The largest number of taxa was recorded in Lake Błędno (69) and the smallest in Lake Niskie Brodno (59). The largest ecological group of macrophytes was represented by halophytes (65 taxa). Other ecological groups consisted of the following number of taxa: elodeids − 14, nymphaeids − 6, pleustophytes − 5, filamentous algae − 3, charids − 1 (only *Chara globularis*). Filamentous algae were represented by: *Cladophora* sp., *Oedogonium* sp. and *Vaucheria* sp. (Appendix 1). Commonly dominant species (present >50% of the transects) were as follows: *Phragmites australis* (in all 5 lakes), *Typha angustifolia* (in 4 lakes), *Ceratophyllum demersum* (in 3 lakes), *Nuphar lutea* (in 2 lakes) as well as *Elodea canadensis* and *Lemna minor* (in 1 lake).

Indices of synanthropization and species diversity

Each of the analyzed indices was significantly affected by hydromorphological transformations of the littoral zone of the lakes (Table 3). Values of the *H*-statistic of the Kruskal-Wallis test ranged between $H = 13.22$, $p = 0.001$ (the total cover) and $H = 76.72$, $p < 0.001$ (the number of taxa). Together with the increased degree of modifications, also values of the index of hemeroby (Fig. 1a), the total synanthropization index (Fig. 1b) as well as the number of taxa (Fig. 1d) increased. Along natural transects or transects slightly hydromorphologically transformed (the 1st degree of transformations), the hemeroby index took on values within the range of 41.2-41.4, while at the sites strongly and very strongly transformed (the 3rd degree of transformations), it increased up to the level of 41.9-42.8 (Fig. 1a). Similarly, together with an increase in the extent of modifications, the total synanthropization index increased from 11-14 (the 1st degree) to 20-28 (the 3rd degree) (Fig. 1b), as well as the number of taxa increased from 6-7 to 12-15 (Fig. 1d). The opposite relationship was observed for the total cover of macrophytes. Together with an increase in the extent of transformation, the total cover decreased (Fig. 1c.) from 79-87% at natural or morphologically slightly

Table 3

Analysis of the relationship between macrophyte indices and the degree of morphological transformations of the lakes with the H test of Kruskal-Wallis

Detailed list	*H*	*p*	1 of 2	1 of 3	2 of 3
Index of hemeroby	**18.90**	**<0.001**		***	
Total synanthropization index	**44.20**	**<0.001**	***	***	
Total cover	**13.22**	**0.001**		***	*
The number of taxa	**76.72**	**<0.001**	***	***	*
Contribution of helophytes	**17.69**	**<0.001**		***	**
Contribution of elodeids	**13.18**	**0.001**		***	**
Contribution of nymphaeids	**6.99**	**0.030**		*	
Contribution of filamentous algae	**7.10**	**0.029**		*	*

Significant relationships are marked in bold. The level of significance: * p<0.05, ** p<0.01, *** p<0.001

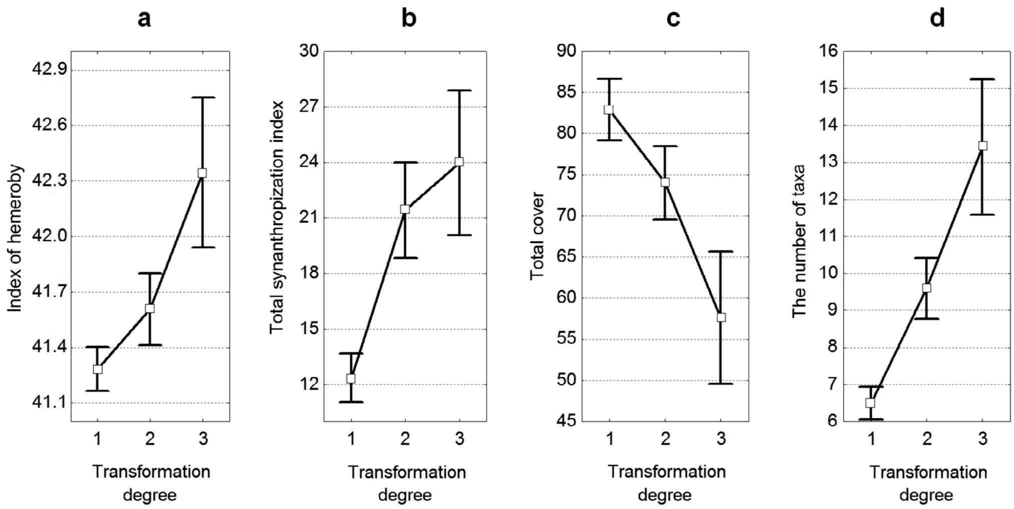

Fig. 1. Values of indices: hemeroby (a), total synanthropization (b), total cover of macrophytes (c) and the number of taxa (d) according to 3 degrees of hydromorphological modifications of the lakes. Square symbols denote average values, whiskers – 95% confidence interval.

transformed sites (the 1st degree) up to 50-66% at sites strongly and very strongly transformed (the 3rd degree). It resulted mainly from mechanical destruction of vegetation at the transformed sites.

Ecological groups of macrophytes

Each of the ecological groups of macrophytes was significantly affected by hydromorphological transformations of the lakes' littoral zone (Table 3). The research revealed that among ecological groups of macrophytes, helophytes, elodeids and filamentous algae were the most important in terms of their response to morphological degradation of the littoral zone. The value of the *H*-statistic of Kruskal-Wallis test ranged between $H = 6.99$, $p = 0.03$ (contribution of nymphaeids) and $H = 17.69$, $p < 0.001$ (contribution of helophytes). Helophytes and nymphaeids responded negatively to morphological transformations of the littoral zone with the decreased contribution in the vegetation cover, whereas elodeids and filamentous algae responded positively (Fig. 2). At the natural, slightly and moderately transformed sites (the 1st and the 2nd

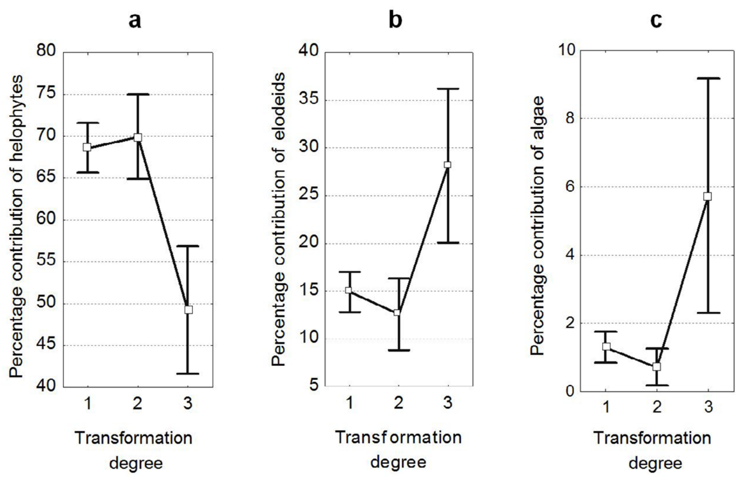

Fig. 2. Contribution of ecological groups of macrophytes: helophytes (a), elodeids (b) and filamentous algae (c) according to 3 degrees of hydromorphological modifications of the lakes. Square symbols denote average values, whiskers – 95% confidence interval.

degree of modifications), the contribution of elodeids varies within the range of 9-16%, whereas at strongly or very strongly transformed sites (the 3rd degree of modifications), their contribution was increasing up to the level of 20-36% (Fig. 2b). Similarly, together with an increase in the extent of modifications, the percentage contribution of algae increased from 0.1-1.8% (the 1st and 2nd degrees) up to the level of 2.2-9.6% (the 3rd degree) (Fig. 2c). The opposite relationship was observed for the contribution of helophytes. Together with an increase in the modification degree, their percentage contribution was decreasing (Fig. 2a) from 65-75% at the 1st and the 2nd degree of transformations up to the level of 42-57% at the 3rd degree of transformations.

DISCUSSION

Transformations in the hydromorphology of the Polish lakes result mostly from the tourism-recreational pressure, and are generally reduced to mowing of ecotone vegetation, construction of piers (including angling piers), harbors for boats, as well as mowing of the littoral vegetation and fishing out hydrophytes in order to create beaches and bathing sites. Protection of shores exploited for recreation is less common (Piotrowicz 1990, Drzewiecki 1997). Aquatic vegetation within the zone of recreational impact is subject to bidirectional influence: on the one hand, it is mechanically destroyed as a consequence of mowing, fishing out and trampling (Lacoul & Freedman 2006), creation of beaches, swimming, angling and fishing places (Hellsten & Riihimäki 1996), on the other hand, the rush zone extends as a result of the increasing fertility of lakes (Srivastava et al. 1995). Apart from recreational exploitation of waters, these processes occur in lakes also in the vicinity of grazing lands for farm animals (Hellsten 2000, Janauer 2003).

Most aquatic plant communities are characterized by a narrow hemeroby spectrum (prefer one grade of hemeroby). These are phytocenoses represented by syntaxa sensitive to changes in the intensity of anthropopressure and occurring in semi-natural habitats (from oligo-mesohemeroby to meso-β-euhemeroby) (Chmiel 1993, Ziarnek 2007). This is confirmed by the results of the presented research, where the index of hemeroby had a narrow range of values (31-56) corresponding to the mesohemeroby grade. Average values were even less varied and ranged between 41.3 ± 0.15 and 42.3 ± 0.8.

Due to homogeneity of abiotic conditions, usually dense, monospecies phytocoenoses occur in the lakes, which cover considerably large areas of the littoral zone (Lenssen et al. 1999). Partial elimination of the dominant species, as a consequence of mowing and fishing out, results in the development of new ecological niches, which can be occupied by new taxa. Consequently, we can observe an increase in the species richness together with a reduction in the total cover (Lenssen et al. 1999). This kind of phenomenon was also observed in the studied lakes. Strong and very strong transformations in the lakes cause mechanical, partial elimination of the dominant species biomass, which results in the development of new ecological niches that could be occupied by new taxa (Hellsten & Dudley 2006). This is confirmed by the total cover decrease at the lacustrine sites together with the increase in the transformation degree. Extension of infrastructure is often accompanied by changes in the exploitation method within the littoral zone, mainly elimination of woodlots and consequently the reduced shading over the water surface, which directly affects the macrophytes (Abernethy et al. 1996, Staniszewski et al. 2006). The presence and density of the building development in the coastal zone has a significant impact on aquatic vegetation and rushes. In areas with dense buildings in the coastal zone, first of all rushes and plants with floating leaves were eliminated. However, no effect of this kind of transformation was found in the submerged vegetation (Jennings et al. 2003). Embankments make enrooting of vascular plants difficult, and thus they reduce their competition and enable the structural algae to occupy newly developed ecological niches. This brings about some considerable changes in the structure of ecological groups of macrophytes and biodiversity (Baattrup-Pedersen & Riis 2004, Bernez et al. 2004, Schaumburg et al. 2004).

The adverse effect of morphological transformations in the lakes was observed for the emergent plants (helophytes). Together with the increased transformations, the contribution of this group was decreasing. Emergent plants building the rush communities are less sensitive to changes in physicochemical parameters of the water, but are highly responsive to all changes in the morphology of the habitat (Hellsten 1997, 2000). Due to ecotone character, the rush zone is characterized by higher biodiversity compared to large, homogeneous habitats of open water (nymphaeids, elodeids). At the same time, it is the most endangered part of aquatic

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ecosystems, due to the land vicinity and the possibility of direct anthropogenic influence, e.g. through intentional mechanical removal of macrophytes and technical shore protection (Janauer 2003).

Macroscopic, filamentous algae are an important group attached to degraded waters, both in the hydromorphological and trophic aspect (Ostendorp et al. 2004, Bosch et al. 2009). It probably resulted from the limited competition of vascular plants, as well as from the local increase in the concentration of biogenic substances in the water near beaches. Strong transformations bring about the elimination of vascular plants through mechanical destruction and hindered enrooting in the substrate of anthropogenic origin. Algae have short life cycles and hence they easily take over the ecological niches vacated by vascular plants (Szmeja 2006). The spring increase in the population size of the majority of algae begins earlier than for vascular macrophytes. *Cladophora* sp. become active already at a temperature of 7°C. Therefore, long before the growth of vascular plants begins, algae form a dense mat that effectively suppresses their development. Furthermore, macroscopic algae uptake biogenic elements faster and more effectively compared to vascular macrophytes (Whitton & Kelly 1995).

The littoral zone is highly variable in terms of habitat, and the relationships between hydromorphological conditions and aquatic plants are often local. The relationship between the hydromorphological changes and macrophytes are more evident in oligotrophic lakes of Scandinavia than in lowland, naturally eutrophic lakes in Central Europe (Hellsten & Dudley 2006).

CONCLUSIONS

1. Hydromorphological modifications of lakes are an important ecological factor affecting the occurrence and quantitative diversity of macrophytes. Significant changes in the contribution of different ecological groups of macrophytes were observed together with the increased extent of morphological transformations.
2. Anthropogenic transformations of the littoral zone in the studied lakes usually resulted from recreational exploitation and fishing, which were responsible for mechanical, partial elimination of the dominant species biomass, and consequently an increased number of taxa, synanthropization and an average level of hemeroby, as well as a decrease in the total cover.
3. Helophytes were the most negatively affected group by the transformations, which reduce their contribution in the vegetation cover, whereas macroscopic filamentous algae and elodeids were positively affected.

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Appendix 1

The list of all macrophyte taxa found in surveyed lakes with assigned of ecological groups

No.	Macrophyte species	Ecological groups	Lake				
			Błędno	Chodzieskie	Niskie Brodno	Strażym	Łokacz
1	*Acorus calamus*	helophytes	*	*	*	*	*
2	*Agrostis stolonifera*	helophytes	*	*			*
3	*Alisma plantago-aquatica*	helophytes	*	*	*	*	*
4	*Batrachium circinatum*	elodeids		*	*	*	*
5	*Berula erecta*	helophytes	*	*	*	*	*
6	*Bidens cernua*	helophytes	*				*
7	*Bidens frondosa*	helophytes	*	*	*	*	*
8	*Bidens tripartita*	helophytes	*	*			*
9	*Butomus umbellatus*	helophytes	*	*	*	*	
10	*Caltha palustris*	helophytes		*			*
11	*Calystegia sepium*	helophytes	*	*		*	
12	*Carex acutiformis*	helophytes	*	*	*	*	
13	*Carex elata*	helophytes				*	
14	*Carex gracilis*	helophytes	*				*
15	*Carex hirta*	helophytes	*	*			
16	*Carex nigra*	helophytes					*
17	*Carex paniculata*	helophytes	*	*	*	*	*
18	*Carex pseudocyperus*	helophytes	*	*	*	*	*
19	*Carex riparia*	helophytes	*	*	*		*
20	*Carex rostrata*	helophytes					*
21	*Carex vesicaria*	helophytes				*	
22	*Ceratophyllum demersum*	elodeids	*	**	**	**	*
23	*Ceratophyllum submersum*	elodeids	*				
24	*Chara globularis*	charids			*	*	
25	*Cicuta virosa*	helophytes	*	*	*	*	*
26	*Cladophora* sp.	filamentous algae	*	*	*	*	*
27	*Cyperus fuscus*	helophytes	*				
28	*Eleocharis palustris*	helophytes	*	*	*	*	
29	*Elodea canadensis*	elodeids		*	*	*	**
30	*Epilobium hirsutum*	helophytes	*	*	*		*
31	*Epilobium palustre*	helophytes	*		*		
32	*Equisetum fluviatile*	helophytes			*	*	
33	*Equisetum palustre*	helophytes	*	*	*	*	*
34	*Eupatorium cannabinum*	helophytes	*	*	*	*	*
35	*Fontinalis antipyretica*	elodeids				*	
36	*Galium palustre*	helophytes	*	*		*	*
37	*Glyceria maxima*	helophytes	*	*	*	*	*
38	*Hydrocharis morsus-ranae*	nymphaeids	*	*	*	*	*
39	*Hydrocotyle vulgaris*	helophytes	*				
40	*Iris pseudacorus*	helophytes	*	*	*	*	*
41	*Jumcus articulatus*	helophytes	*	*			*
42	*Juncus effusus*	helophytes				*	
43	*Lemna gibba*	pleustophytes					*
44	*Lemna minor*	pleustophytes	*	*	*	*	**
45	*Lemna trisulca*	pleustophytes	*	*	*	*	*
46	*Lycopus europaeus*	helophytes	*	*	*	*	*
47	*Lysimachia thyrsiflora*	helophytes	*			*	*
48	*Lysimachia vulgaris*	helophytes	*	*	*		*
49	*Lythrum salicaria*	helophytes	*	*	*	*	
50	*Mentha aquatica*	helophytes	*	*	*	*	*
51	*Myosotis palustris*	helophytes	*	*	*	*	*
52	*Myriophyllum spicatum*	elodeids	*	*	*	*	*
53	*Najas marina*	elodeids			*		
54	*Nuphar lutea*	nymphaeids	*	*	**	**	*
55	*Nymphaea alba*	nymphaeids	*	*	*	*	*
56	*Oedogonium* sp.	filamentous algae	*	*		*	
57	*Petasites hybridus*	helophytes	*				

cont.

No.	Macrophyte species	Ecological groups	Lake				
			Błędno	Chodzieskie	Niskie Brodno	Strażym	Łokacz
58	*Peucedanum palustre*	helophytes	*		*	*	*
59	*Phalaris arundinacea*	helophytes					*
60	*Phragmites australis*	helophytes	**	**	**	**	**
61	*Polygonum amphibium*	helophytes	*	*	*		
62	*Polygonum amphibium* f. *natans*	nymphaeids	*		*	*	
63	*Polygonum hydropiper*	helophytes	*	*			*
64	*Potamogeton compressus*	elodeids			*	*	*
65	*Potamogeton crispus*	elodeids			*		*
66	*Potamogeton friesii*	elodeids		*			
67	*Potamogeton lucens*	elodeids	*	*	*	*	
68	*Potamogeton natans*	nymphaeids			*	*	
69	*Potamogeton pectinatus*	elodeids	*	*	*	*	*
70	*Potamogeton perfoliatus*	elodeids	*		*	*	
71	*Potamogeton trichoides*	elodeids	*				
72	*Ranunculus repens*	helophytes	*	*	*		*
73	*Ranunculus sceleratus*	helophytes	*	*			*
74	*Rorippa amphibia*	helophytes	*	*	*	*	
75	*Rumex hydrolapathum*	helophytes	*	*	*	*	*
76	*Rumex maritimus*	helophytes	*				
77	*Sagittaria sagittifolia*	helophytes	*	*		*	
78	*Schoenoplectus lacustris*	helophytes	*	*	*	*	*
79	*Scirpus sylvaticus*	helophytes		*	*	*	
80	*Scutellaria galericulata*	helophytes	*			*	*
81	*Sium latifolium*	helophytes	*	*	*	*	*
82	*Solanum dulcamara*	helophytes	*	*	*	*	*
83	*Sparganium emersum*	helophytes				*	*
84	*Sparganium erectum*	helophytes	*	*	*	*	*
85	*Spirodela polyrrhiza*	pleustophytes	*	*	*	*	*
86	*Stachys palustris*	helophytes	*	*		*	*
87	*Stratiotes aloides*	nymphaeids			*	*	
88	*Thelypteris palustris*	helophytes	*		*	*	*
89	*Typha angustifolia*	helophytes	**	**	*	**	**
90	*Typha latifolia*	helophytes	*	*	*	*	*
91	*Utricularia vulgaris*	pleustophytes				*	
92	*Vaucheria* sp.	filamentous algae		*			*
93	*Veronica anagallis-aquatica*	helophytes		*	*	*	*
94	*Veronica beccabunga*	helophytes		*			*
		Number of species	69	62	59	64	62

* - present taxa, ** - dominant taxa (present > 50% of transects)