Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2015, 12, 102–110

INTERACTIONS WITHIN MACROPHYTES IN SOME SMALL LAKES FROM POLESIE LUBELSKIE REGION

Joanna Sender*, Marcin Kolejko*, Andrzej Demetraki-Paleolog**

* Department of Landscape Ecology and Nature Protection, University of Life Sciences in Lublin
B. Dobrzańskiego str. 37, 20–262 Lublin, joanna.sender@up.lublin.pl
** Department of Hydrobiology, University of Life Sciences in Lublin
B. Dobrzańskiego str. 37, 20–262 Lublin

Abstract. Due to the significant role of macrophytes in the functioning of lake ecosystems studies have been undertaken to examine whether mutual dependence is present within emergent, floating-leaved, and submerged aquatic macrophytes. The study included 5 small lakes from Polesie Lubelskie region. The research included: qualitative analysis of macrophytes (area occupied by macrophytes, composition, range of individual plant groups of occurrence), quantitative analysis of macrophytes (biomass of macrophytes inhabiting the lake), analysis of distribution as well as characteristics diversity of shoreline and surrounding land use. Because of differences in the environmental conditions, mostly light availability, usage of buffer zone, among the three macrophyte groups, changes in biomass were analyzed in this work suggests that complementarity not competition drive the community. This phenomenon seems to occur only in macrophyte lakes where all three groups are present and the surrounding buffer zones remain natural. In lakes where one of the three groups of macrophytes were missing, it is likely that the ecological roles are fulfilled by other plant groups, such as phytoplankton. The studied lakes represent both phytoplanton and macrophyte type of lakes.

Key words: macrophytes, biomass, shallow lakes, land use, phytolittoral

INTRODUCTION

Many procsss within aquatic ecosystems rely on biological trophic inteactions. These interactions are influenced by abiotic factors including surface and groundwater runoff, accessibility of available forms of minerals and nutrients, biomass concentration and the possibility of removing it (periodic deposit in sediments). In biologically stable lakes, nutrient inputs are balanced with outputs through biotic and abiotic processes. These transformations are both physio-chemical and biological and occur between water and bottom sediment, littoral zone and pelagial or between epilimnion and hypolimnion [Burchardt *et al*. 1998].

In light of todays known findings regarding the behavior of aquatic orgaisms we know that relationships between them are driven by their ability to adapt to environmental stresses. Effects of these reactions on the ecosystem is evident in the rate of its evolution [Burchardt *et al*. 1998]. The ability of organisms to obtain maximum benefit from environmentally stressful conditions in the short-term has subsequent effects on other trophic levels and process within the ecosytem. Studies have shown that the lack of algae in the pelagic zone compensates for qualitative and quantitative richness of macrophyte communities in the shallow littoral zone [Kraska *et al*. 1990].

Much scientific research has been conducted on interactions between macrophytes and other groups of organisms living in freshwaters [Bohr 1997, Pieczyńska 1972, Sand-Jensen and Borum 1991, Diehl and Kornijów 1998, Zuo *et al*. 2015]. In addition, some studies focus on interactions within the community [Best and Visser 1987, Pełechaty 2007]. However, few studies focus on relationships among particular groups of macrophytes. Within a group of organisms it is unclear whether compensation or competition drive coexistance. Due to the significant role of macrophytes in the functioning of lake ecosystems [Gasith and Hoyer 1998, Rejmankova 2011] studies have been undertaken to examine whether mutual dependence is present within emergent, floating-leaved, and submerged aquatic macrophytes.

STUDY AREA AND METHODS

The study included 5 small lakes. Three are categorized as macrophyte lakes: Lipieniec (51˚30'52"N, 23˚31'33"E), Słone (51˚18'17"N, 23˚21'55"E) and Głębokie. Three are categorized as phytoplankton lakes: Cycowskie (51˚17'29"N, 23˚5'57"E) and Syczyńskie (51˚17'12"N, 23˚14'16"E) and Święte (51˚30'31"N, 23˚32'39"E). The study was conducted in the summer 2014 and 2015.

The research included: qualitative analysis of macrophytes (area occupied by macrophytes, composition, range of individual plant groups of occurrence), quantitative analysis of macrophytes (biomass of macrophytes inhabiting the lake), analysis of distribution.

In each lake plants sampled were collected along three transects, spaning from the shoreline to a maximum range of occurrence, every 0.5 m depth. The emergent macrophytes were counted, and then 10 of each plant species were removed to determine their dry weight. Plants with floating leaves and submerged were collected using Bernatowicz's rake [Sender 2012]. Nomenclature of plant was recommended by Mirek *et al*. [2002].

In order to determine the diversity of shoreline and surrounding land use, a buffer zone was designated around each lake extending from the shoreline to 200 m from the lake. Land use types structure analysis was done by a retrospective photointerpretative analysis [Chmielewski *et al*. 1996] with using the satellite scenes from the Rapid Eye satellite (5 spectral channels RGB + RE + NIR, 2009), as well as orthophotomap (2007). Satellite scenes were characterized by lower accuracy (1 pixel represented by 5 m in the field), but spectral channels allowed more precise distinction of different forms of land use types.

In order to determine the similarity of investigated lakes Euclidean distances was applied. For correlation analysis nonparametric Spearmann's rank correlation was used.

RESULTS AND DISCUSSION

The studied lakes are small and only a few-hectares in size. In the buffer zone – 200 m around the lake, meadows generally dominated. Only in the lake Święte and Lipieniec forests were present. The smallest natural buffer zone occurred on Lake Syczyńskie and Glebokie Cycowskie. A large share in the land use surrounding the lakes were farmlands and buildings (Table 1).

Table 1. Characteristic of investigated lakes and land use in their buffer zone

Lake	Depth, m	Lake surface, ha	Forms of land use in buffer zone of 200 m, %						
			standing waters	marshy meadow with succession	forests	shrub communi-ties	farmlands	fallow	compact infrastruc-ture
Głębokie Cycowskie	5.7	12.9	4.5	41.2	0.6	7.8	19.8	2.3	23.8
Lipieniec	7.1	3.7	1.2	33.2	41.5	1.7	21.8		0.5
Słone	8.1	5.4		51.4		23.7	9.9	15.1	
Syczyńskie	1.2	8.4	0.4	41.5		1.7	29.4		27.0
Święte	9.6	4.8	0.1	26.3	37.1	3.7	16.7	14.4	1.8

In general, as the size of the lake decreased the length of the shoreline also decreased, with the exception of lake Święte. Management of shorelines were slightly varied, with meadows being the most prevelant. Święte lake and Lipieniec lake were surrounded mostly by forests. Only along the shores of Lake Słone there were three forms of use present, meadows, shrubs, and fallowed fieldss, and were dominanated by scrub communities (Table 2).

Investigated lakes inhabited diverse number of macrophyte species. The highest number of macrophyte species occurred in lakes Lipieniec and Słone, and the lowest in lake Glebokie Cycowskie. Highest diversity among emergent macrophytes occurred in lake Święte, while submerged and floating leaves in lake Lipieniec (Table 3).

Table 2. Land use of shoreline and width of rushes

Lake	Total length of coastline, m	Rushes participation in the shoreline, %	Management of the shoreline, %					Width of rushes, m				
			M	F	S	F	B	min		mean	max	
Głębokie Cycowskie	1350.6	100	100.0					8.2	M	16.5	49.3	M
Lipieniec	732.3	100	16.2	83.8				5.0	F	11.4	35.9	F
Słone	849.7	100	19.8		53.7	27.1		15.3	M	23.6	31.0	B
Syczyńskie	1120.6	99.1	92.1				7.8	32.5	Ł	43.0	60.2	ZZ
Święte	938.6	54.3	1.5	98.5				6.4	L	14.8	24.2	L

M – meadow, F – forest, S – scrub communities, F – fallow, B – building

Table 3. Species composition in investigated lakes

Species	Lake									
	Głębokie Cycowskie		Lipieniec		Słone		Syczyńskie		Święte	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Typha angustifolia	12	9			8	5				
Phragmites australis	18	14	34	40	6	9	11	16		
Typha latifolia			1	3			5	5	2	6
Glyceria aquatica			2	6						
Schoenoplectus lacustris			2	7	6	9	2	3	1	1
Iris pseudacorus			1							
Peucedanum palustre			1							
Eleocharis palustris	8	21								44
Juncus effusus			1							
Lythrum salicaria			1							
Calla palustris									1	
Carex pseudocyperus				1					2	2
Carex elata									2	2
Sparganium erectum					1	1				
Thelypteris palustris							1			
Salix cinerea	1				2		1		2	1
Salix pentandra					1		1		2	
Comarum palustre									1	1
Nuphar lutea	2	3	3		2	2			3	3
Hydrocharis morsus-ranae	1	1	1	2			2	2		
Potamogeton natans			2	3						
Lemna minor			1	2			2	2		
Utricularia vulgaris			2	2	1	1				
Lemna trisulca			1	1						
Nymphea alba			1	1	1	1			2	2
Spirodela polyrhiza			1	2		1	2	1		
Ceratophyllum demersum	5	5	5	5			1	1		
Stratiotes aloides			4	5	1	1				
Elodea canadensis			2	2						
Potamogeton compressus			1	1						
Myriophyllum spicatum					3	3				
Total numer of species	**7**	**6**	**20**	**16**	**11**	**10**	**10**	**7**	**10**	**9**

In the studied lakes, biomass and area inhabited by different groups of macrophytes varied. The largest area occupied emergent macrophytes in the lake Syczyńskie, with the highest values of biomass. Emergent macrophytes reached the lowest values of the examined parameters in lake Święte (Table 4).

Table 4. Surface and biomass particular group of macrophytes in investigated lakes

Group of macrophytes	Parameter	Lake				
		Głębokie Cycowskie	Lipieniec	Słone	Syczyńskie	Święte
Emergent	surface, ha	2.01	0.60	1.50	**3.60**	0.50
	biomass on the surface phytolittoral, t/ha	2.02	1.88	1.50	**2.15**	0.23
	macrophyte biomass in the lake, t/ha	0.26	0.24	0.23	**0.48**	0.03
Plant with floating leaves	surface, ha	0.40	**0.50**	0.20	0.20	0.15
	biomass on the surface phytolittoral, t/ha	0.74	0.39	0.27	0.03	3.29
	macrophyte biomass in the lake, t/ha	0.21	0.34	0.16	0.01	**0.47**
Submerged	surface, ha	1.30	**2.10**	1.40	0.10	-
	biomass on the surface phytolittoral, t/ha	1.10	1.60	1.00	0.03	-
	macrophyte biomass in the lake, t/ha	0.25	**0.93**	0.21	0.002	-

Macrophytes with floating leaves occupied the largest area in the lake Lipieniec, while greatest biomass was reached in lake the Święte. Submerged macrophytes, appeared in four of the investigated lakes. Submerged macrophyte cover and was lowest in the lake Syczyńskie, while the greatest was found in lake Lipieniec (Table 4).

The results indicate that increases in number of species were not related to macrophyte biomass in investigated lakes (correlation -0.21, $p < 0.05$). Similarly, the number of species did not affect the surface of phytolittoral (correlation 0.19, $p < 0.05$). A highly significant correlation was found between macrophyte cover and biomass of all group of macrophytes (correlation 0.91, $p < 0.05$).

Macrophyte biomass was dominated by floating leaved plants in all studied lakes besides lake Święte, in which emergent macrophytes dominated. Total biomass of macrophytes determined in tonnes per hectare of area occupied by macrophytes was similar in all studied lakes and ranged from 2.14 t/ha in the lake Syczyńskim to 3.98 t/ha in the lake Lipieniec. In Lake Łuknajno, which is shallow and eutrophic (the southern part of the Great Masurian Lakes), mean biomass was similar and reached 3.4 t/ha [Królikowska 1997]. In following years of a slight increase in biomass of emergent macrophytes and decrease in submerged macrophytes (Fig. 1) was noted in all lakes.

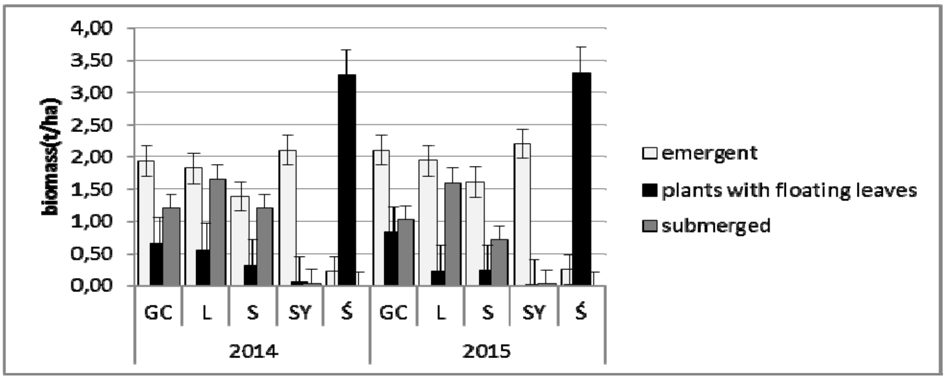

Fig. 1. Biomass of three groups of macrophytes in years 2014 and 2015

In investigations of 139 lakes from Canada show that it depends on the group of macrophytes. Light was found to be the best descriptor of the cover and biomass of submerged plants. Conversely, emergent macrophytes are most strongly affected by lake morphometry, and in particular by its average slope [Duarte *et al*. 1986], as well as according to study of some Sweden eutrophic lakes, depth and type of bottom sediments [Weisner 1991].

Emergent macrophytes occurred in each of the studied lakes. The width of the belt occurs along the shore changed regardless of the buffer zone usage (Table 2). In the following years the width of the belt was not subject to change, but a significant reduction was observed with colonization depth of all macrophytes groups (Fig. 2).

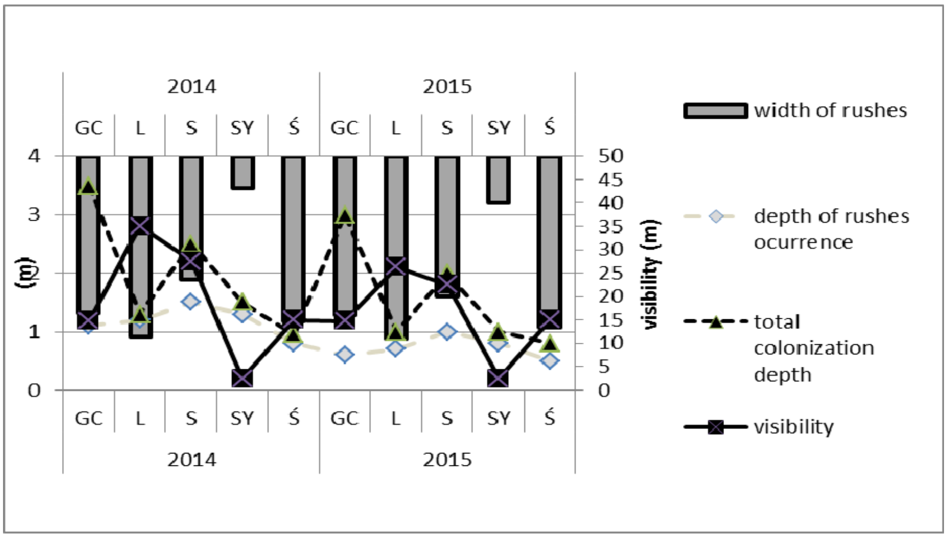

Fig. 2. Rushes characteristic and visibility in investigated lakes

The probable cause of these changes were occurring in 2015, specific to the region's hydrological conditions, manifested in long-term lack of rainfall, which resulted in lower water levels in lakes up to 0.5 m.

In the studied lakes, generally, the total biomass of all groups of macrophytes were reversely correlated: if emergent macrophytes biomass was higher the biomass of submerged macrophytes decreased.

This trend, however, is not confirmed in lakes where any of the three groups of macrophytes are missing, mostly lakes dominated by phytoplankton. In these cases, the effects of any environmental factors destabilize the processes occurring within the macrophyte groups present. In the lake Święte, where the buffer zone was dominated by forest and shrub communities on the converted peat-bog, the phytolittoral zone was dominated only by plants with floating leaves and emergent macrophytes were depauperate. In contrast the buffer zone of lake Syczyńskie was highly anthropogenically modified, and the phytolittoral zone was dominated by emergent macrophytes and submerged macrophytes were sparse. In the other lakes where land use in the buffer zone was natural, among different groups of macrophytes, complementarity occurred. Depending on the growth of biomass between different groups were significantly correlated. In macrophyte-dominated lakes, increases in biomass emergent macrophytes were correlated with decreased biomass of submerged (0.71, $p < 0.05$), and conversely an increase in biomass submerged macrophytes was correlated with a reduction in the submerged biomass (0.55, $p < 0.05$).

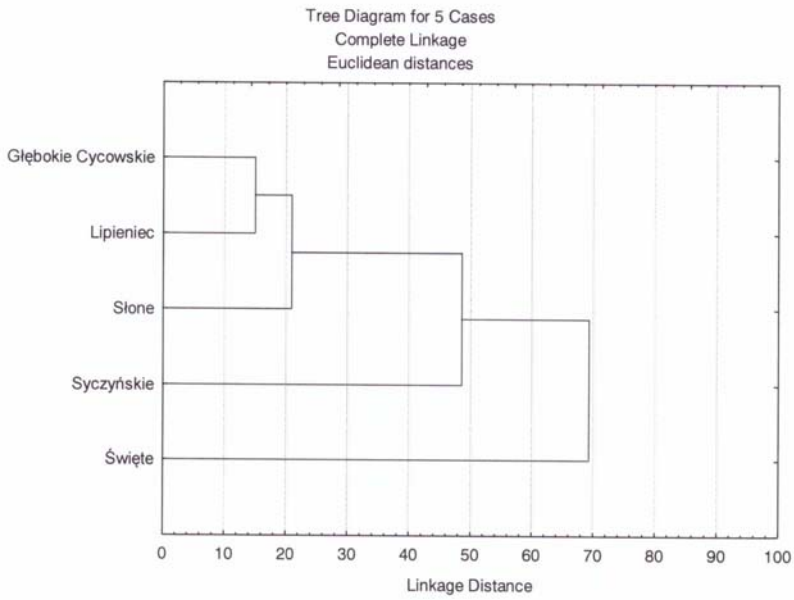

Fig. 3. Floristic and morphological similarity of investigated lakes

On the basis of standardized data from the buffer zone, morphometry lakes, and qualitative and quantitative composition of macrophytes a similarity analysis was performed. According to this analysis, phytoplankton lakes were separated form the other macrophytes lakes (Fig. 3).

CONCLUSIONS

Because of differences in the environmental conditions, mostly light availability, among the three macrophyte groups, changes in biomass were analyzed in this work suggests that complementarity not competition drive the community. This phenomenon seems to occur only in macrophyte lakes where all three groups of are present and the surrounding buffer zones remain natural. In lakes where one of the three groups of macrophytes were missing, it is likely that the ecological roles are fulfilled by other plant groups, such as phytoplankton. The studied lakes represent both phytoplanton and macrophyte type of lakes.

REFERENCES

Best E.P., Visser H.W.C., 1987. Seasonal growth of the submerged macrophyte *Ceratophyllum demersum* L. in mesotrophic Lake Vechten in relation to insolation, temperature and reserve carbohydrates. Hydrobiologia 148(3), 231–243.

Bohr R., 1997. Zbiorowiska glonów peryfitonowych jezior Polski północnej. Zesz. Nauk. UMK, Biologia 9, 17.

Burchardt L., Kokociński M., Machowiak-Bennett D., Messyasz B., Nagengast B., Owsiany P., Pełachaty M., 1998. Czy zmiany w zbiorowisku fitoplanktonu są odzwierciedleniem zmian przebiegających w litoralu jeziora Skrzynka (Wielkopolskie Park Narodowy) w latach 1929–1998. W: Radwan S. (red.). Ekotony słodkowodne – struktura, rodzaje i funkcjonowanie. Wyd. UMCS. Lublin, 257– 262.

Chmielewski T.J., Olenderek H., Sielewicz B., 1996. Fotointerpretacyjna analiza retrospektywna zmian struktury ekologicznej Kampinoskiego Parku Narodowego w ostatnim 40-leciu. W: M. Kistowski (red.). Badania ekologiczno-krajobrazowe na obszarach chronionych. Uniwersytet Gdański, Polska Asocjacja Ekologii Krajobrazu, Gdańsk, 125–129.

Diehl S., Kornijów R., 1998. Influence of submerged macrophytes on trophic interactions among fish and macroinvertebrates. In: The structuring role of submerged macrophytes in lakes. Springer, New York, 24–46.

Duarte C.M., Kalff J., Peters R.H., 1986. Patterns in biomass and cover of aquatic macrophytes in lakes. Can. J. Fish. Aquat. Sci. 43, 10: 1900-1908, 10.1139/f86-235.

Gasith A., Hoyer M.V., 1998. Structuring role of macrophytes in lakes: changing influence along lake size and depth gradients. In: The structuring role of submerged macrophytes in lakes. Springer, New York, 381–392.

Kraska M., Szyszka T., Szczepanowski P., 1990. Kształtowanie struktury planktonu przez makrofity w Jeziorze Budzyńskim i Jelonek. W: Funkcjonowanie ekosystemów wodnych, ich ochrona i rekultywacja. Cz. 2. Ekologia jezior, ich ochrona i rekultywacja. Eksperymenty na ekosystemach. Red. Z. Kajak. Wyd. SGGW, Warszawa, 20–25.

Królikowska J., 1997. Eutrophication processes in a shallow, macrophyte-dominated lake – species differentiation, biomass and the diistribution of submerged macrophytes in Lake Łuknajno (Poland). Hydrobiologia 342/343, 411–416.

Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M., 2002. Krytyczna lista roślin naczyniowych Polski. Instytut Botaniki PAN, Kraków.

Pełechaty M., 2007. Does nymphaeid distribution reflect the spatial heterogeneity of abiotic conditions in a shallow lake? Belg. J. Bot. 140, 1, 73–82.

Pieczyńska E., 1972. Production and decomposition in the eulittoral zone of lakes. In: Productivity Problems of Freshwaters. Proc. Symp. IBP–UNESCO, Warszawa–Kraków, 271–281.

Rejmankova E., 2011. The role of macrophytes in wetland ecosystems. J. Ecol. Environ. 34(4), 333–345.

Sand-Jensen K., Borum J., 1991. Interactions among phytoplankton, periphyton, and macrophytes in temperate freshwaters and estuaries. Aquat. Bot. 41, 1, 137–175.

Sender J., 2012. Qualitative investigations of vascular flora in deep and shallow eutrophic lake. Teka Ochr. Kszt. Środ. Przyr. 9, 206–214.

Zuo S., Fang Z., Yang S., Wan K., Han Y., 2015. Effect of allelopathic potential from selected aquatic macrophytes on algal interaction in the polluted water. Biochem. Systemat. Ecol. 61, 133–138.

Weisner S.E.B., 1991. Within-lake patterns in depth penetration of emergent vegetation. Freshwater Biol. 26, 1, 133–142.

INTERAKCJE WŚRÓD MAKROFITÓW W WYBRANYCH MAŁYCH JEZIORACH POLESIA LUBELSKIEGO

Streszczenie. Wodne rośliny naczyniowe – makrofity pełnią w zbiornikach wodnych szereg funkcji, z tego też względu podjęto badania, których głównym celem było zbadanie, czy w obrębie trzech podstawowych grup makrofitów wodnych – wynurzonych, o liściach pływających i zanurzonych – zachodzi zjawisko wzajemnego kompensowania. Badaniom poddano 5 małych jezior Polesia Lubelskiego. Obejmowały one analizę jakościową makrofitów (określenie powierzchni zasiedlanej przez makrofity, składu, zasięgu występowania poszczególnych formacji roślinnych), analizę ilościową makrofitów (określenie biomasy poszczególnych grup roślin oraz wszystkich makrofitów zasiedlających jeziora), analizę rozmieszczenia oraz charakterystykę zagospodarowania strefy buforowej jezior. Zjawisko zależności zmian biomasy wśród makrofitów poszczególnych grup, analizowane w niniejszej pracy, możemy określać jako zjawisko kompensacji, a nie konkurencji ze względu na odmienne warunki siedliskowe, a przede wszystkim dostęp światła, odległości od linii brzegowej oraz sposób jej zagospodarowania. Jest ono możliwe tylko w jeziorach tzw. makrofitowych, czyli takich, gdzie rozwijają się 3 podstawowe grupy makrofitów, a zagospodarowanie strefy buforowej nie było przekształcone przez człowieka. W jeziorach, w których brakuje jakiejś formacji roślin, prawdopodobnie kompensującą funkcję przejmują inne grupy producentów, takie jak fitoplankton. Badane jeziora reprezentowały 2 typy jezior: fitoplanktonowe i makrofitowe.

Słowa kluczowe: makrofity, biomasa, płytkie jeziora, użytkowanie terenu, fitolitoral