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QUANTITATIVE INVESTIGATIONS OF VASCULAR FLORA IN DEEP AND SHALLOW EUTROPHIC LAKE

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Summary. In lakes, especially shallow and small vascular plants is a major producer of organic matter, affecting the growth of bottom sediments in lakes. Vascular plants constantly changing in time, the pace of these changes is different depending on the group of macrophytes. Emergent macrophytes subject slow changes, while submerged, especially in shallow lakes are more sensitive to changes in habitat conditions. The aim of this study was the quantitative analysis of vascular flora of two eutrophic lakes: Maśluchowskie and Uścimowskie, located on the Łęczyńsko-Włodawskie Lakeland, in the district Uścimów. Investigated lakes represent two different alternate states of lakes. Lake Maśluchowskie is a reservoir dominated by macrophytes, and Uścimowskie by phytoplankton. Lakes as regards of trophy are similar – eutrophic. However, they are floristically different. They have a different range of macrophytes occurrence, surface, and their species composition. In deep lake Maśluchowskie submerged plants constituted nearly 50% of phytolittoral, in Lake Uścimowskie this group of plants, almost was not there, appeared only in the belt rushes occupying little more than 1%.Qualitative and quantitative analysis of macrophytes structure in studied lakes, support the conclusion that the Lake Uścimowskie represents bad ecological status, in contrast to the Lake Maśluchowskie.

Key words: macrophytes, phytolittoral, usage of catchment area, eutrophic lakes, quantity structure

INTRODUCTION

In lakes, especially shallow and small, vascular plants are a major producer of organic matter, affecting the growth of bottom sediments in lakes. Appearing of oxygen in such lakes decreases may cause a temporary exclusion from biological production of certain parts of the lakes for most of the year. Released in this way, processes of mineralization cause rapid accumulation of organic compounds. The degree of impact on the lake of vascular plants depends on their mass and distribution in the reservoir [Bernatowicz and Radziej 1960].

Vascular plants constantly are changing in time, the pace of these changes is different depending on the group of macrophytes. Emergent macrophytes are

changing slowly [Bernatowicz 1959, Sender 2009], while submerged, especially in shallow lakes are more sensitive to changes in habitat conditions [Scheffer and van Nes 2007, Sender 2011]. The presence of submerged macrophytes in lakes has a very beneficial effect. Creating a underwater meadows, they can isolate the sediments from the water column thereby reducing the re-suspension of nutrients to water [Graneli and Solander 1988]. One factor that differentiates this process is a morphometry of the lake, especially surface and depth as well as pressure from the catchment area. Changes in a vascular flora of lakes strongly depend on the climatic conditions which could completely change the composition of submerged macrophytes [Bernatowicz 1963]. There are many factors limiting a development of macrophytes in reservoirs, like among other the impact of wind fluctuations, water level and algal blooms [Ozimek 1992].

In lakes with a small share of phytolittoral in total surface macrophytes may have small and only local effect on the whole ecological processes.

The aim of this study was the quantitative analysis of vascular flora of two eutrophic lakes with different morphometric parameters.

STUDY AREA AND METHODS

The study included two lakes Maśluchowskie and Uścimowskie, located on the Łęczyńsko-Włodawskie Lakeland, in the Uścimów district. Lake Maśluchowskie is small, because only 26 ha reservoir with a great depth. Lake Uścimowskie has two times greater surface area and almost three times greater catchment area than Maśluchowskie Lake (Tab. 1). The dominant way of catchment area use of studied lakes is agriculture, which constitute over 60%.

Table 1. Morphometric parameters of studied lakes

Parametr	Uścimowskie	Maśluchowskie
Surface, ha	66.7	26.7
Depth max, m*	6.7	10.8
Depth mean, m	2.7	4.6
Length of shoreline, m	3746	2107
Capasity, tys. m^2	1795	1231
Surface of catchment area, ha	318.36	113.86

* depth measurements using the Lowrance sonar

The degree of macrophytes influence on the lake functioning depends on their quantitative relations. Quantitative relations of flora in lakes studied were determined on the basis of: biomass, density, species composition and coverage of particular groups of macrophytes. The study was conducted in two growing seasons in the years 2011, 2012. Macrophytes were analyzed in horizontal transects from a shoreline to the maximum range of their occurrence. Transects were located in the northern and southern part of the tank, because of diverse vegeta-

tion structure and land use near the lake. In transects, samples were collected every 0.5 m depth, for this purpose floral rake was used with samples area 0.16 m^2 [Bernatowicz 1960, Sender 2004]. Phytolittoral surface determined on the basis of real vegetation maps and aerial photos of the lakes using Macrostation vr 8th program. To determine the occurrence ranges of plants and depth Lowrance sonar were used (Mark 4).

Simultaneously with the floristic research, water physical and chemical factors were analyzed. Tests points were in zone of shallow litoral, as well as on the edge of rushes In each chosen transect. Analyses included: pH, temperature, electrolytic conductivity, oxygen content, total P, total N, water hardness. The following instruments were used to determine physical and chemical properties of water: OXI 330 oxymeter made by WTW (oxygen content, temperature), electronic conductivity meter made by Hanna (electrolytic conductivity), microchip Slandi SP300 pH-meter (water reaction). The content of biogenic nitrogen and phosphorus compounds was determined using the microchip Slandi photometer LF 205. For lakes Carlson's (1977) Trophic State Index (TSI) was calculated, based on visibility of Secchi disk (SD), nitrogen (TN) and phosphorus (TP) content.

RESULTS AND DISCUSSION

Studied lakes were characterized by differences in the content of physicochemical parameters in water. Water temperature of studied lakes was high, reaching slightly higher values in Lake Uścimowskie (Tab. 2). In higher temperature a solubility of oxygen decreases and a rate of biochemical processes consuming oxygen increases. Consumed in the biochemical process oxygen is replenished with oxygen from the atmosphere and oxygen from photosynthesis.

Waters of Maśluchowskie Lake had significantly lower concentrations of oxygen, corresponding to the second or even third class of water purity [Rozporządzenie… 2004]. In waters of Uścimowskie Lake oxygen supersaturation occurred, which may prove intense photosynthesis processes occurring there. This situation occurs most frequently in reservoirs rich in biogenic elements. For animal organisms, such supersaturation is unfavorable.

Catchments of studied lakes are agricultural. Water flowing from a land used for agriculture are characterized by 2–4.5 times higher content of total nitrogen (N) in relation to those of semi-natural areas [Koc *et al*. 1996]. A movement of nutrients depends mainly on the type and level of intensification of agricultural production, soil susceptibility to erosion, and their permeability [Smoroń 1996, 2012].

Table 2. Selected physico-chemical parameters of waters in studied lakes

Lake	Uścimowskie		Maśluchowskie	
Feature	north	south	north	south
Secchi disc visibility, m	1.0	0.51	1.2	1.55
Temperature, ^{o}C	23.4	24.7	24.7	21.4
Oxygen concentration in water, $mgO_2 \cdot l^{-1}$	16.4	11.6	5.35	4.7
Electrolytic conductivity, $\mu S \cdot cm^{-1}$	338	325.2	119.1	116
pH	8.12	8.26	7.71	7.41
% O_2	134.8	129	61.2	54.5
$N\text{-}NH_4^+$, mg $N \cdot l^{-1}$	0.77	0.568	1.042	0.72
$N\text{-}NO_3^-$, mg $N \cdot l^{-1}$	< 0.10	< 0.10	0.12	< 0.10
$P\text{-}PO_4^{3-}$, mg $PO_4 \cdot l^{-1}$	> 5.0	0.941	0.286	0.301
P total, mg $PO_4 \cdot l^{-1}$	0.719	0.329	0.554	0.65
N total, mg $N \cdot l^{-1}$	1.31	1.93	1.41	1.59
Hardness, mval$\cdot l^{-1}$	8.55	8.93	4.54	4.6
TSI SD	60	70	57	54
TSI TN	58	64	59	61
TSI TP	66	54	62	64
TSI Carlsona	61.3	62.6	59.6	59.7

Phosphorus is one of the basic elements necessary for life, 1 mg of phosphorus can produce 50–250 mg of biomass. Organic phosphorus compounds are contained in the biomass after death of mineralized by microorganisms and enzymes into soluble phosphates. In addition, phosphorus in natural waters can come from soils fertilized with phosphate and sewage pollution. In the studied lakes, analyzed nutrient concentrations were relatively high and in general evaluation trophic status, based on the TSI index, both lakes are classified as eutrophic lakes [Carlson 1977, Walker 1979] (Tab. 2).

Investigated lakes were floristically diverse. Visibility, measured by Secchi disc was, little more than 0.5 m in Uścimowske Lake, while in Maśluchowskim Lake over 1.5 m. The result was a range of particular groups of macrophytes occurrence, especially submerged (Fig. 1).

Surface inhabited by macrophytes was different in investigated lakes. In Lake Uścimowskie macrophytes occupy 14.3 hectares of the lake, which constituted about 21% of the reservoir. It was strongly dominated by emergent macrophytes covering up to 13 hectares. In Maśluchowskie Lake macrophytes occupied together 9.44 hectares, what is about 35% of the reservoir (Tab. 3). The share of individual groups of macrophytes was almost equal: 4.9 ha emerged, 4.54 ha submerged. The values of biomass in the studied lakes, especially submerged macrophytes are lower than in the Mazurian lakes dominated by *Chara* species [Królikowska 1997].

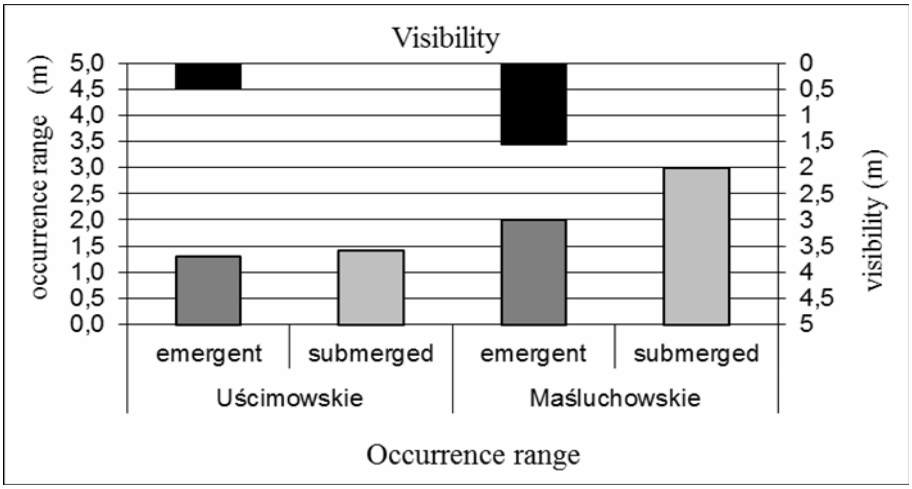

Fig. 1. Secchi disk visibility and range occurrence of macrophytes in studied lakes

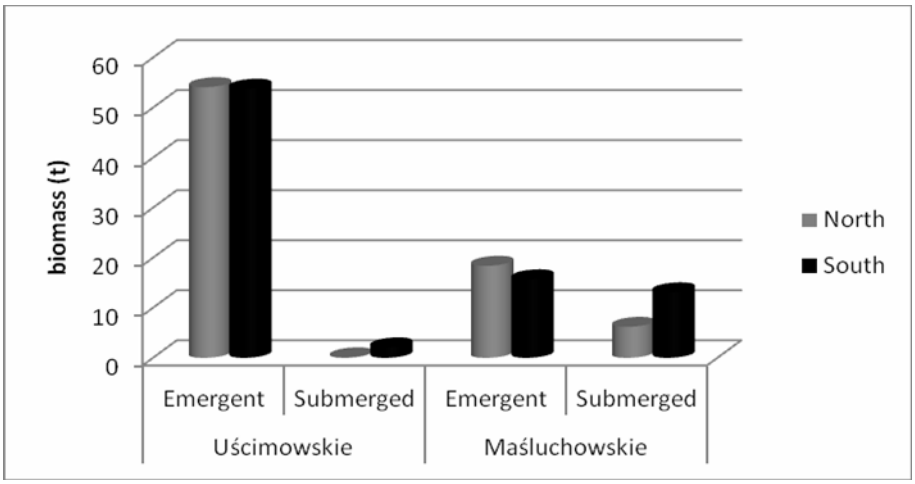

Fig. 2. Biomass, particular group of macrophytes in different stands in investigated lakes

Table 3. Biomass of macrophytes (dry weight) in investigated lakes

Parameter	Macrophytes group	Uścimowskie	Maśluchowskie
Phytolittoral surface, ha	E	13	4.9
	S	1.3	4.54
Dry weight (t) phytolittoral surface per 1 ha	E	3.8	1.8
	S	0.07	1.15
Dry weight (t) total lake surface per ha	E	0.8	0.63
	S	0.01	0.4

Analyzed lakes differed not only the surface occupied by macrophytes, but also their biomass. These differences were significant among two studied groups of plants. In Lake Uścimowskie emergent macrophytes reached very high values of biomass (Fig. 2). There were also important differences between the stands of research. In southern transects of the Uścimowskie Lake submerged macrophytes lacked almost completely. In both lakes, tendency of macrophytes complementarity was marked. Lower values of biomass one group affect the higher values of the analyzed features of the second group (Fig. 2). Situation can be explained by retention of nutrients flowing from the catchment by a group of emergent macrophytes and limited their access to submerged macrophytes [Pieczyńska 1993].

In both lakes, the northern part of the lakes was characterized by lower values of biomass and lower species diversity of macrophytes. In the catchment in the northern part of lakes buildings have a greater share. However, in the southern part of the lake mainly agriculture (meadows, fields).

In studied lakes, the biomass distribution at each depths was clearly mixed. In Lake Uścimowskie highest values of biomass occurred at a depth of 0.5 m, where there were mainly emergent macrophytes (Fig. 3). In Lake Maśluchowskie highest values, regardless of the research position, occurred at a depth of 2 m, inhabited by submerged macrophytes. In the northern part of the lake macrophytes were up to 2.5 meters deep, reaching low values of biomass (Fig. 3).

In investigated lakes *Ceratophyllum demersum* had the highest share in the biomass among submerged macrophytes, in lake Maśluchowskie also *Myriophyllum* sp. (Tab. 4). *Typha latifolia* dominated in the biomass of emergent macrophytes in

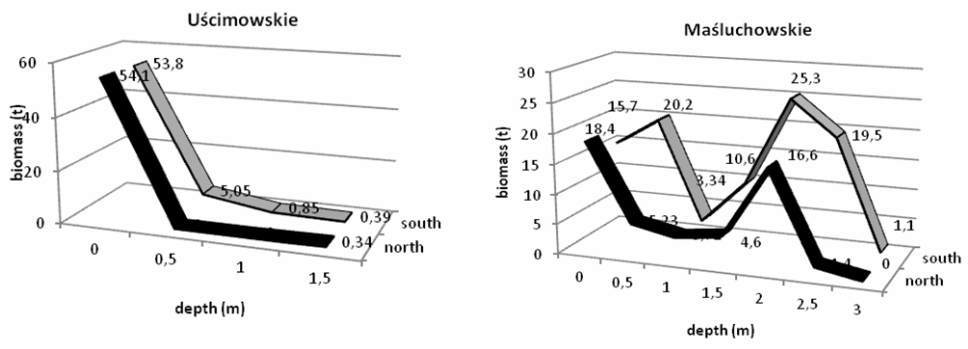

Fig. 3. Macrophyte biomass at each depths in the distinguished sites studied lakes

Table 4. The share of particular species in total biomass of macrophytes in studied lakes

Species	Uścimowskie	Maśluchowskie
Submerged macrophytes		
Utricularia vulgaris L.	18.9	
Ceratophyllum demersum L.	70.8	46.7
Hydrocharis morsus-ranae L.	1.7	0.5
Stratiotes aloides L.	3.6	
Nuphar lutea (L.) Sibth. & Sm.	4.6	
Lemna minor L.	0.4	0.1
Myriophyllum verticilatum L.		20.8
Myriophyllum spicatum L.		31.3
Polygonum amphibium L.		0.7
Emergent macrophytes		
Typha angustifolia. L.	20.6	18.9
Phragmites australis (Cav.) Trin. ex Steud. 1841	37.2	58.3
Glyceria maxima (Hartm.) Holmb.		16.8
Eleocharis palustris (L.) Roem. & Schult.		6.0
Acorus calamus L.	11.2	
Typha latifolia L.	30.9	

Lake Uścimowskie, and *Phragmites australis* in Lake Maśluchowskie (Tab. 4). *Typha latifolia* is a species typical of eutrophic waters, prefers water rich in nutrients. The dominant species found in studied lakes are characterized by wide range of ecological tolerance. Only in Uścimowskie Lake there were floating-leaved macrophytes, typical of the lakes rich in nutrients [Scheffer and van Nes 2007].

CONCLUSIONS

Investigated lakes represent two different alternate states of lakes. Maśluchowskie Lake is a reservoir dominated by macrophytes, and Uścimowskie Lake by phytoplankton.

Lakes as regards of trophy are similar – eutrophic. However, they are floristically different. They have a different range of macrophytes occurrence, surface, and their species composition.

Agricultural usage of catchment area shaped in the first place habitat conditions affecting a trophy lake. Distribution, colonization, biomass of plant vegetation may depend mainly on the morphometry of the lake (among others depth, area of basins).

In deep Maśluchowskie Lake submerged plants constituted nearly 50% of phytolittoral, whereas in Uścimowskie Lake this group of plants, almost was not there, appeared only in the belt rushes occupying little more than 1%.

Qualitative and quantitative analysis of macrophytes structure in studied lakes, support a conclusion that Uścimowskie Lake represents bad ecological status, in contrast to Maśluchowskie Lake.

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BADANIA ILOŚCIOWE FLORY NACZYNIOWEJ GŁĘBOKIEGO I PŁYTKIEGO JEZIORA EUTROFICZNEGO

Streszczenie. Celem badań były analiza ilościowa flory naczyniowej dwóch jezior eutroficznych o różnych parametrach morfometrycznych. Badaniami objęto dwa jeziora; Uścimowskie i Maślu-chowskie, położone w granicach Pojezierza Łęczyńsko-Włodawskiego. W ocenie ogólnej stanu troficznego, na podstawie indeksu TSI, oba mieściły się w grupie jezior o charakterze eutroficz-

nym. Badane jeziora były zróżnicowane florystycznie. Różna była też powierzchnia zasiedlana przez makrofity. W jeziorze Uścimowskim makrofity zajmowały 14,3 ha i zdecydowanie dominowały makrofity wynurzone. W jeziorze Maśluchowskim łącznie makrofity zajmowały 9,44 ha, zaś zanurzone stanowiły blisko połowę fitolitoralu. Badane jeziora reprezentują dwa odmienne stany. Jezioro Maśluchowskie jest zbiornikiem typowo makrofitowym, zaś Uścimowskie fitoplanktonowym. Analiza struktury jakościowej i ilościowej makrofitów omawianych jezior pozwala na stwierdzenie, iż jezioro Uścimowskie reprezentuje zły stan ekologiczny w przeciwieństwie do dobrego stanu jeziora Maśluchowskiego.

Słowa kluczowe: flora naczyniowa, jezioro eutroficzne, struktura ilościowa, fitolitoral