ASSESSMENT OF THE DEGREE OF SYNANTHROPIZATION OF VEGETATION IN THE URBAN LAKES IN OSTRÓDA (MASURIAN LAKE DISTRICT)

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ABSTRACT

Analyses were carried out of the structural and spatial character of the littoral vegetation in four urban lakes in Ostróda: Jakuba, Morliny, Kajkowskie and Perskie. Phytosociological studies made it possible to distinguish 20 phytosociological units representing plant communities from the classes: *Potamogetonetea* and *Phragmiteta*. The extent of anthropogenic changes in the littoral vegetation was examined using synanthropization index calculated for individual lakes. According to the classification proposed in the methods, Lake Morliny was classified as a natural reservoir, Lake Kajkowskie as belonging to the group of synanthropic water bodies (these two lakes were within the series of harmonic development). The other two lakes were classified as anthropogenic, characterised by disharmonic development due to high trophy. These results were confirmed by data on the area occupied in the lakes by particular alliances: *Potamogetonion*, *Nymphaeion*, *Phragmition* and *Magnocaricion*.

KEY WORDS: lake vegetation, phytosociology, anthropopression, lake synanthropization process, urban lakes.

INTRODUCTION

The synanthropization process consists of replacing the given structural elements of a natural system by other elements (Faliński 1972, Rejewski 1981). This process is the subject of many studies, but mostly those concerning communities of land vegetation (Faliński 1966a, b, 1972, 1975, Fukarek 1979, Kornaś 1968a, b, 1972, 1981, 1990, and many others).

The methods used to examine and evaluate anthropogenic changes in land vegetation proved to be of little use in the case of aquatic vegetation.

There are many lakes in the town of Ostróda and its vicinity, in which aquatic vegetation and rushes have never been studied.

The aims of the study were: to examine the phytocenoses of phytolittoral in the lakes under study, to determine the area occupied by individual phytocenoses, to assess the anthropogenic changes induced in vegetation of the surveyed lakes.

STUDY AREA

Structural and spatial analyses of aquatic vegetation were carried out in four lakes in the town of Ostróda: Jakuba, Kajkowskie, Morliny and Perskie (Fig. 1, Table 1).

1. Lake Jakuba (Smrody)

This sub-urban lake is located in south-west suburbs of Ostróda. It extends from the north to the south. North part is connected with Lake Drwęckie by means of a short channel. South end receives waters of a stream flowing from Lake Morliny.

Lake Jakuba for many years used to receive a direct discharge of municipal sewage from part of Ostróda town, as well as a discharge of waste waters from a diary plant. The lake is not used for recreation and tourism due to bad water quality. A busy road runs in the vicinity of the north part.

Lake Jakuba is relatively shallow and does not stratify. Water quality in the lake was established by the Centre of Environmental Surveys and Control (OBiKS) in Olsztyn in spring 1987 (viz. when the lake still received the discharge of pollutants from the dairy plant) and in summer 1987 (when pollution discharge was stopped). The lake is highly polluted; its waters are outside any class of purity, both as regards the purity standards (SOJJ) and the regulation issued by the Council of Ministers. Arable lands extending along the east lake shore also add to its bad state. Lake Jakuba is very susceptible to external impacts, so it has been defined as beyond any class of purity.

2. Lake Kajkowskie (Sajmino, Kajkowo)

This lake is elongated, extending from the north-west to the south-east. It has an outflow located in the south-east part, flowing to Lake Sement Mały and then to the Grabiczek River. A municipal bathing site and beach are located at the north-west lake shore, and a little upward, over a sloping embankment, there is an old cemetery.

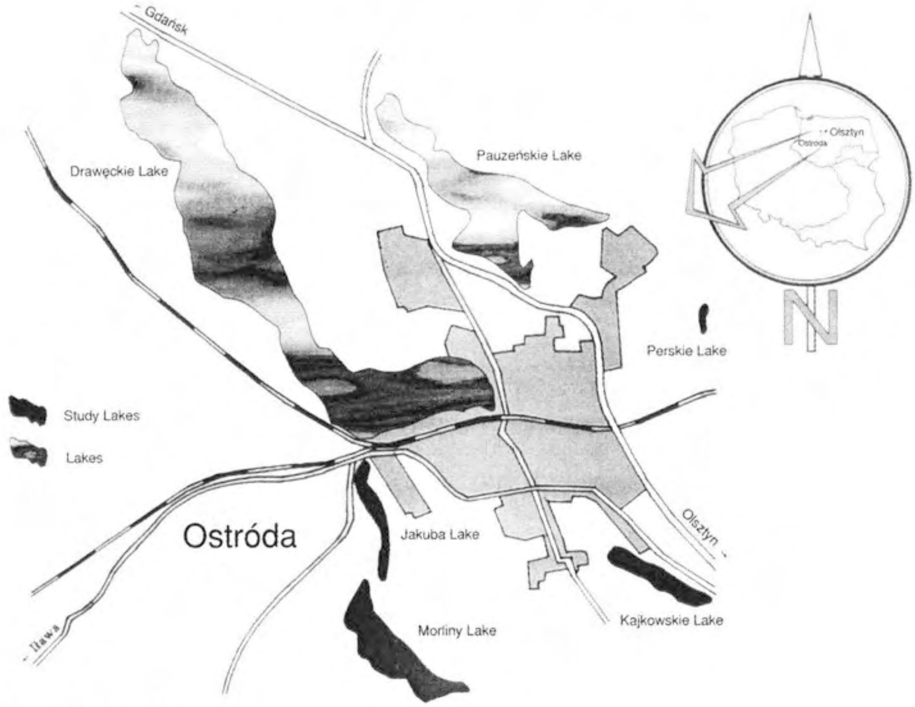

Fig. 1. Situation of urban lakes in Ostróda.

Lake Kajkowskie is not polluted from any point sources. A road from Ostróda to Olsztyn runs over an embankment along the north lake shore. An overall assessment resulting from the studies by OBiKS in Olsztyn (Cydzik, Kudelska, Soszka 1992) classified the lake into class II of purity according to the official standards of lake classification (SOJJ). On the other hand, more liberal norms for surface inland waters issued by the Council of Ministers would classify this lake as belonging to class I of purity.

Lake Kajkowskie is very susceptible to degradation due to a number of natural features which allocate it into the class III of lake susceptibility.

3. Lake Morliny

The lake is elongated, extending from north-west to south-east, with weakly developed shore line. It has three inflows, the most important of which is the one flowing from south-east and carrying waters from Lake Lichtajny. Outflow is directed northward, through Lake Jakuba to Lake Drwęckie. Shores are fairly high, quite steep in places. Some flat areas can be found only at south lake end.

Lake Morliny does not receive any pollution from point sources and is little used for tourism and recreation. There are, however, many places with vegetation treaded in by anglers. Despite low inflow of pollutants, the lake is rich in nutrients and organic substances. Its central part is relatively deep, characterised by thermal and oxygen stratification in summer and winter. Studies on lake quality. Studies on lake quality revealed that its waters belonged to class III of purity according to the regulation issue by the Council of Ministers (if no attention is paid to oxygen index which declassifies the lake) (Cydzik, Soszka, Kudelska 1992). The official standards of water purity (SOJJ) yielded the same result when the analyses were performed in summer. On the other hand, BOD5 above the bottom is a little over the range for class I of water purity. Still overall assessment places the lake in class III of purity. Coliform titre places it in class II. As regards lake susceptibility to external impacts, it has been classifies as belonging to class II.

4. Lake Perskie (Paskierz)

The lake is situated in the drainage basin of the rivers Drwęca-Vistula, with water surface at the level of 86 m above the sea. It is a suburban reservoir. A district of Ostróda called Osiedle is located at the north-west end of the lake. Lake Perskie is small (Table 1), extending from the north-west to the

TABLE 1. Morphometry of urban lakes in Ostróda.

L.p.	Lake name	Lake area (ha)	Max. depth. (m)	Lake length (m)	Lake width (m)	Shore line length (m)	Development of the shore line (m/ha)
1	Jakuba	22.8	6.1	1450	200	3250	143
2	Kajkowskie	29.0	7.8	1350	275	3000	103
3	Morliny	66.0	19.5	1970	475	4600	70
4	Perskie	14.3	10.6	750	250	1800	126

south-east. It is connected with Lake Pauzeńskie by means of a few ditches located in the north-west part, and with Lake Rudut in the south-east part.

METHODS

Phytosociological studies were carried out in 1989–1991, with the phytosociological method commonly used in Middle Europe (Braun-Blanquet 1951), which enables determination of the type of a community comparing floristic composition of the phytocenoses, both qualitative and quantitative one. Phytocenoses were analysed using to releves. One to releve comprised a list of all plants found within the phytocenosis, with attention paid to plant abutance (but without estimates of the degree of sociability, as this feature is of little importance in the case of aquatic plants). The to releves taken in particular community types were synthesized in phytosociological tables (Table 4, 5, 6). The tables present floristic composition of the communities. Constancy, abundance (left column) and coefficient of cover index (right column) were given for particular species constituting components of a given community. Constancy was determined according to the following scale: V – species occurring in 80-100 % of releves taken in the phytocenoses of the given plant community; IV – species present in 60-80%; III – species present in 40-60%; II – species present in 20-40%, and I – species present in 0.0-20% of the pictures. Abundance was determined according to a modified six-degree scale by Braun-Blanquet, in which: + = a few specimens covering a small area, 0.1% on the average; 1 = the given species grows over 1-10% of the area, 5% on the average; 2 = the species covers 10-25%, 17.5% on the average; 3 = the species grows over 25-50%, 37.5% on the average; 4 = the species grows over 50-75%, 62.5% on the average; 5 = the species grows over 75-100% of the area, 87.5% on the average. The overgrowth index was calculated from the equation:

$$\text{coeffficient of cover index} = \frac{\text{sum of average values of the species overage}}{\text{number of releves for a given community x 100}}$$

Phytosociological units were determined on the basis of dominating species. This method is not consistent with the classical principles of the French-Swiss school, but it complies with the German school and with the real picture of vegetation in water bodies. Totally 20 phytosociological units were distinguished using a systematic arrangement and Matuszkiewicz (1982) nomenclature, with corrections according to Hartog and Segal (1964), Rejewski (1981) and Tomaszewicz (1979).

Maps of real vegetation in the lakes under study were prepared in 1 : 5 thousand scale. Phytocenoses of the littoral and of the shore zone vegetation were marked on the map (they are not presented in this paper due to editorial restrictions). The areas of individual phytocenoses were identified either directly on the lake (small up to 200 m^2) or indirectly in case of larger lakes by delineation of such zones on a bathymetric chart and their planimetric measurement (the bathymetric charts and data of the Institute of Inland Fisheries of Olsztyn–Kortowo were used).

In order to examine the synanthropization processes in the aquatic vegetation of the lakes under study, a modified phytoindication method was used (Rejewski 1981, Ciecierska 1994). Composition of the plant cover and the degree of anthropogenic changes were analysed. The method of Rejewski (1981) makes it possible to distinguish between two processes: the succession and the synanthropization. They develop in a similar way although they reflect different direction of changes. "Natural" succession results in more complicated systems, while synanthropization leads to simplified systems. The author of the paper made the supreme assumption that the lake, as an ecosystem, at the moment of origin is oligotrophic and the increase in trophy is a function of time.

The positions of reservoirs in both above mentioned processes are described by two negatively correlated ratios: the index of phytocenotic diversity (H) established according to the Shannon-Veaver function (treated as a specific measure of the aquatic ecosystem development path covered, the value of the ratio increases together with the progress of evolution and reaches the maximum value when the ecosystem reaches its maturity) and the index of colonization (Z) which determines the extent of the trophogenic layer available to macrophytes. The value of the isobath 2.5 m was assumed as constant because, as the studies by Olszewski (1971) indicated, the vegetation in eutrophic lakes is present down to the average depth of 2 m. The value of the isobath 2.5 m was accepted for practical reasons as it is most frequently marked on bathymetric charts.

$$H = -\sum ni / N \times \ln ni / N$$

$$Z = N / \text{isob. } 2.5 \text{ m}$$

where: H – index of phytocenotic diversity,
ni – area overgrown by the given plant community in per cents of the total phytolittoral area,
N – area of the phytolittoral taken as 100 %.

When we want to review the scope of synanthropization simplifications in the vegetation of a reservoir, we should always confront that scope with the current potential for a maximum achievement of its spatial structures (Rejewski, 1981). As a consequence, it is necessary to know the maximum value of the phytocenotic diversity index. This index tends to reach the highest value in the environment lacking factors limiting the possibilities of development of the vegetation in lakes, and its maximum value is reached in the theoretically situation when all plant groups in the littoral zone of a given reservoir are co-dominating, i.e. they occupy the same area.

$$H_{max} = \ln S$$

where: H_{max} – maximal value of the diversity index,
S – number of communities of which the given phytolittoral is composed.

The redundancy index (R) is the measure of differences between the potential and real (actual) degree of organization of the analyzed system (aquatic ecosystem).

$$R = 1 - H / H_{max}$$

As a consequence the measure of structural simplifications in the vegetation of lakes taking place under the influence of human pressure is provided by the so called synanthropization quotient-I_{syn} – ranging from 0 to infinity (Rejewski 1981).

$$I_{syn} = R / Z$$

The modification in Rejewski method was based on development of a new formula describing the anthropogenous changes in the vegetation of littoral of the lakes. It was necessary to define the maximum limit of the process of synantropization. In case of so defines a formula (I_{syn}) it was

TABLE 2. The variability ranges for synanthropization quotient and synanthrophization index.

L.p.	Groups of lakes according to degree of anthropogenic transformation	Volue of the synanthropization quotient index I_s	Value of the synanthropization index W_s
1	natural lakes	0.00–0.25	0.00–0.39
2	weakly synanthropic lakes	0.26–0.50	0.40–0.59
3	moderately synanthropic lakes	0.51–0.75	0.60–0.69
4	synanthropic lakes	0.75–0.99	0.70–0.79
5	anthropogenic lakes	≤ 1.00	0.80–1.00

impossible and unnecessary as the author of the method studied lakes located in forests with a low degree of trophic activity. It became important while studying the municipal lakes in the Masurian Lake District (Ciecierska 1994 – the majority of reservoirs was of hypertrophic nature). The synanthropization quotient (I_{syn}) was replaced by the index of synanthropization (W_s which is an exponential function) the values of which are within the range of 0-1.

$$W_s = \exp. (-H \times Z / H_{max}) \quad (W_s = e^{(-H \times Z / Hmax)})$$

In calculation of W_s the redundancy index (R) was resigned and replaced by the index of phytocenotic diversity (H / H_{max}).

New variability ranges were set for individual groups differing in the degree of human pressure (Table 2). The initial four groups of lakes are characterized by harmonious development while the fifth group (anthropogenic lakes) is among reservoirs with disharmonious development as a consequence of significant trophies. The limit values, after exceeding which reservoirs get into disharmonious development, were 1 for the quotient and 0.8 for index of synanthropization.

RESULTS

Totally 20 syntaxonomic units ranking as communities were distinguished; their syntaxonomic position and area occupied in particular lakes are presented in Table 3 (Tables 4, 5, 6).

TABLE 3. Percentage of the communities of aquatic plants and rushes in the phytolittoral of urban lakes in Ostróda.

Phytosociological units	Jakuba Lake	Kajkowskie Lake	Morliny Lake	Perskie Lake
Class: *Potamogetonetea* R.Tx. et Prsg.				
Order: *Potamogetonetalia* Koch 1926				
Alliance: *Potamogetonion* Koch 1926 em. Oberd. 1957				
1. *Potamogetonetum pectinati* Carstensen 1955	.	.	.	5.64
2. *Rannunculetum circinati* (Bennema et West. 1943) Segal 1965	.	0.03	13.76	.
3. *Elodeetum canadensis* (Ping. 1953) Pass. 1964	.	82.97	2.11	.
4. *Ceratophylletum demersi* Mild. 1956	.	.	9.28	.
5. *Potamogetonetum lucentis* Hueck 193	3.66	.	6.17	.
6. *Potamogetonetum perfoliati* Koch 1926 em. Pass. 1964	0.95	0.22	13.13	.
Alliance: *Nymphaeion* Oberd. 1957				
7. *Nupharo-Nymphaeetum albae* Tomaszewicz 1977	23.77	.	13.26	.
Class: *Phragmitetea* R.Tx. et Prsg 1942				
Order: *Phragmitetalia* Koch 1926				
Alliance: *Phragmition* Koch 1926				
8. *Scirpetum lacustris* (Allorge 1922) Chouard 1924	.	.	0.28	.
9. *Typhetum angustifoliae* (Allorge 1922) Soó 1927	16.53	0.05	3.86	.
10. *Sparganietum erecti* Roll 1938	0.37	.	0.10	0.21
11. *Eleocharitetum palustris* Schennikow 1919	.	0.11	0.01	.
12. *Phragmitetum* (Gams 1927) Schmale 1939	36.93	4.09	21.55	30.03
13. *Typhetum latifoliae* Soó 1927	2.19	1.62	.	48.20
14. *Acoretum calami* Kobendza 1948	7.17	.	5.76	9.73
15. *Glycerietum maximae* Hueck 1931	2.01	10.88	10.11	2.40
Alliance: *Magnocaricion* Koch 1926				
16. *Thelypteridi-Phragmitetum* Kuiper 1957	2.93	.	.	.
17. *Caricetum ripariae* Soó 1928	0.95	.	0.02	.
18. *Caricetum acutiformis* Sauer 1937	0.37	.	.	.
19. *Caricetum paniculatae* Wangerin 1916	.	.	.	3.81
20. *Caricetum gracilis* (Graebn. et Hueck 1931) R.Tx. 1937	2.19	0.03	.	.

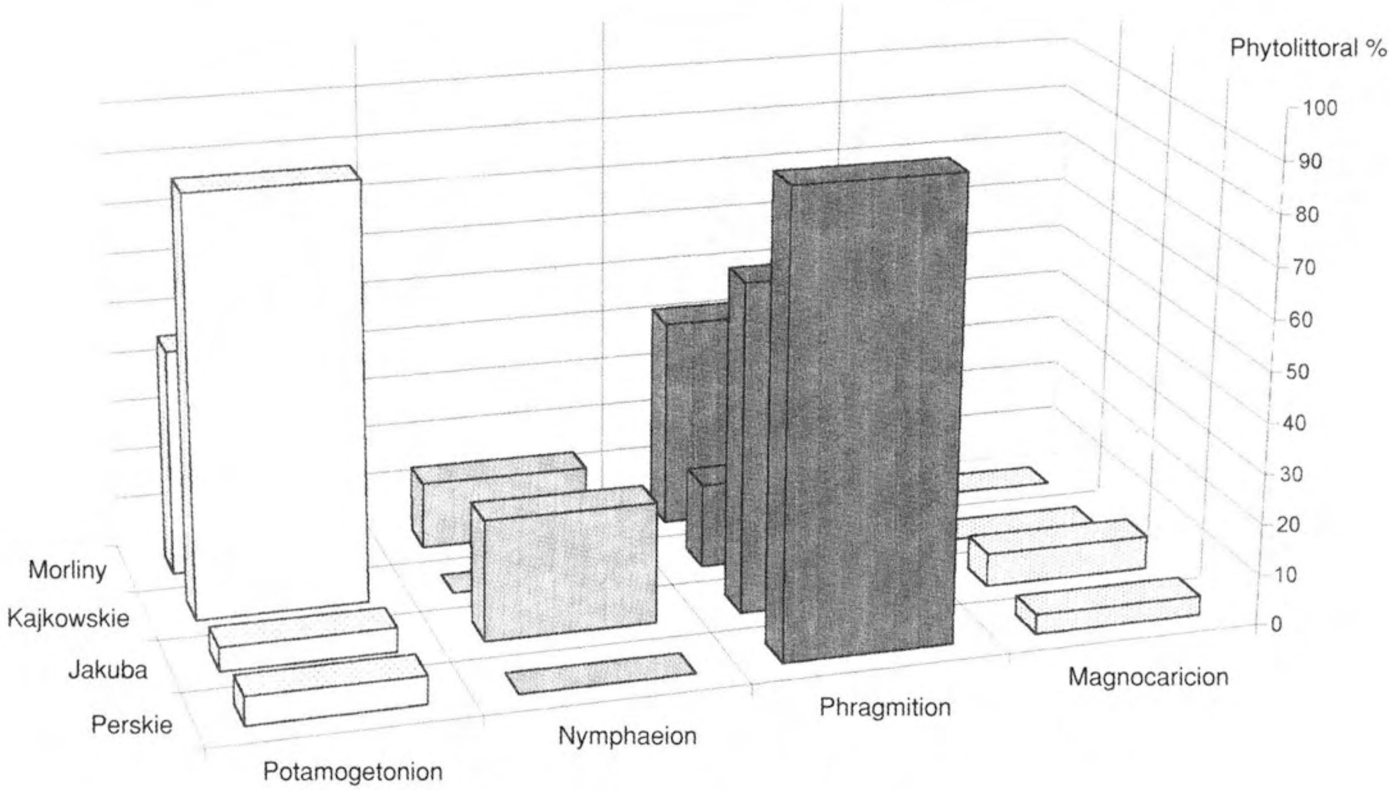

Fig. 2. Phytolittoral of urban lakes of Ostróda.

Adding up the areas of the phytocenoses, a picture of vegetation alliances: *Potamogetonion*, *Nymphaeion*, *Phragmition* and *Magnocaricion* has been obtained for each lake (Fig. 2).

In order to estimate the extent of anthropogenic changes induced in the lake littoral, synanthropization indices were calculated for the lakes under study (Table 7). According to the

TABLE 4. Communities of the class *Potamogetonetea*.

Community*	1	2	3	4	5	6	7
Number of releves	3	2	5	1	3	9	5
Cl. Potamogetonetea							
Potamogeton pectinatus L.	**III$^{3-4}$ 4583**	.	.	.	.	II^{1} 56	I^{+} 2
Ranunculus circinatus Sibth.	I^{1} 167	**II$^{3-4}$ 2750**	III^{+} 2	.	.	I^{+} 1	.
Elodea canadensis Rich	I^{+} 3	.	**V$^{3-5}$ 5750**	.	.	II^{+-1} 157	.
Ceratophyllum demersum L.	I^{+} 3	I^{+} 5	III^{+} 2	**I^{3} 3750**	I^{+} 3	II^{+} 1	I^{1} 250
Potamogeton lucens L.	.	.	.	.	**III^{4} 6250**	.	II^{+-1} 102
Potamogeton perfoliatus L.	.	I^{2} 875	III^{+-2} 753	I^{+} 10	.	**V$^{2-3}$ 3527**	I^{1} 250
Nuphar lutea (L.) Sibth. et sm.	.	I^{+} 5	I^{1} 100	I^{2} 1750	.	IV^{+-1} 71	**V$^{3-5}$ 6750**
Nypmhea alba L.	.	.	.	I^{2} 1750	.	I^{+} 1	II$^{2-3}$ 1100
Myriophyllum spicatum L.	.	I^{1} 250	III^{+-1} 173	.	.	I^{+} 1	.
Striatiotes aloides L.	.	.	I^{+} 2	.	.	I^{+} 1	.
Potamogeton crispus L.	.	.	.	I^{1} 500	.	I^{2} 194	.
Cl. Phragmitetea	.	.	.	.	.	.	.
Typha angustifolia L.	.	.	I^{+} 2	.	.	.	I^{1} 250
Phragmites austrialis (Cav.) Trin. ex Stueudel	.	.	I^{+} 2	.	.	.	I+ 2

* **1** – *Potamogetonetum pectinati* Carstensen 1955, **2** – *Ranunculetum circinati* (Bennema et West.1943) Segal 1965, **3** – *Elodeetum canadensis* (Ping. 1953) Pass. 1964, **4** – *Ceratophylletum demersi* Hild. 1956, **5** – *Potamogetonetum lucentis* Hueck 1931, **6** – *Potamogetonetum perfoliati* Koch 1926 em. Pass. 1964, **7** – *Nupharo-Nymphaetum albae* Tomasz. 1977.

TABLE 5. Communities of the alliance *Phragmition*.

Community*	1	2	3	4	5	6	7	8
Number of releves	1	3	3	2	4	5	4	8
Cl. Phragmitetea								
Scirpus lacustris L.	**I^{5} 8750**	.	.	.	I^{1} 125	.	I^{+} 3	.
Typha angustifolia L.	I^{+} 10	**III^{4} 6250**	.	.	II^{+} 3	I^{+} 2	I^{+} 3	.
Sparganium erectum Huds.	I^{1} 500	I^{2} 583	**III^{3-5} 5416**	.	II^{+-2} 440	.	.	.
Heleocharis palustris (L.) R. et Sch.	.	.	.	**II^{4} 6250**	.	.	.	I^{1} 63
Phragmites austrialis (Cav.) Trin. ex Stueudel	.	.	I^{+} 3	I^{+} 5	**IV^{3} 3750**	II^{+} 4	I^{1} 125	II^{+} 1
Typha latifolia L.	.	II^{+} 3	I^{1} 167	.	II^{+} 5	**V^{3-4} 4750**	I^{+} 3	II^{+-1} 64
Acorus calamus L.	.	I^{1} 167	I^{1} 167	.	I^{1} 125	II^{1} 100	**IV^{3-5} 6250**	IV^{+-2} 221
Glyceria maxima (Hartman) Holmberg	.	I^{+} 3	II^{1-2} 750	I^{2} 875	III^{1} 375	II^{+} 4	I^{2} 438	**V^{3-5} 6875**
Carex acutiformis Ehrh.	.	I^{+} 3	.	.	.	.	.	.
Carex gracilis Curt.	.	I^{+} 3	.	.	.	I^{+} 2	.	I^{+} 1
Alisma plantago-aquatica L.	.	.	I^{+} 3	.	.	II^{+} 4	I^{+} 3	I^{+} 1
Rumex hydrolapathum L.	.	.	I^{+} 3	.	.	II^{+} 4	.	I^{+} 1
Lysimachia thyrsiflora L.	.	.	.	I^{+} 5	.	.	.	.
Rorippa amphibia (L.) Besser	.	.	.	I^{+} 5	.	I^{+} 2	I^{+} 3	II^{+} 1
Veronica beccabunga L.	.	.	.	I^{+} 5	.	.	.	.
Cicuta virosa L.	.	.	.	.	I^{+} 3	.	.	II^{+} 1
Sium latifolium L.	.	.	.	.	I^{1} 125	.	.	I^{+} 1
Iris pseudacorus L.	.	.	.	.	I^{+} 3	.	.	.
Carex paniculata L.	.	.	.	.	.	I^{1} 100	I^{1} 125	.
Carex riparia Curt.	.	.	.	.	.	I^{1} 100	.	.
Glyceria fluitans (L.) R. Br.	.	.	.	.	.	I^{+} 2	.	I^{+} 1
Phalaris arundinacea L.	.	.	.	.	.	.	I^{1} 125	I^{+} 1
Cl. Potamogetonetea								
Ceratophyllum demersum L.	I^{+} 10	II^{+} 7	I^{1} 167	.	I^{+} 3	I^{+} 2	I^{1} 250	II^{1} 63
Potamogeton pectinatus L.	I^{+} 10	.	.	.	.	.	I^{1} 250	II^{+} 1
Nuphar lutea (L.) Sibth. et Sm.	I^{+} 10	.	I^{+} 3	.	.	I^{+} 2	I^{2} 438	.
Sagittaria sagittifolia L.	I^{+} 10	.	.	.	I^{1} 125	.	.	.
Myriophyllum spicatum L.	.	I^{1} 167	.	.	I^{+} 3	I^{1} 100	.	II^{1} 63
Potamogeton pectinatus L.	.	.	I^{+} 3	.	II^{+} 5	.	.	.
Hydrocharis morsus-ranae L.	.	.	I^{+} 3	.	.	I^{+} 2	II^{+-1} 28	II+ –1 64
Polygonum amphibium f. natans	.	.	.	I^{+} 5	.	.	.	.
Potamogeton lucens L.	.	.	.	.	I^{1} 25	.	.	.
Elodea canadensis Rich.	.	.	.	.	I^{+} 3	I^{2} 350	.	II^{1} 63
Ranunculus circinatus Sibth.	.	.	.	.	.	I^{1} 100	.	.
Nymphea alba L.	.	.	.	.	.	.	I^{2} 438	.
Accompanying species								
Epilobium hirsutum L.	.	II^{+} 7	.	I^{+} 5	I^{1} 125	II^{+} 4	I^{+} 3	IV^{+-3} 476
Lysimachia vulgaris L.	.	I^{+} 3	.	.	.	.	.	.
Lemna minor L.	.	I^{+} 3	.	I^{3} 1875	II^{1} 250	II^{1} 200	II^{+-1} 128	II^{2} 219
Spirodela polyrriza (L.) Schleiden	.	I^{+} 3	II^{+-1} 170	I^{1} 250	I^{+} 3	II^{1} 200	II^{+-1} 128	II^{2} 219
Mentha aquatica L.	.	.	II^{+-1} 170	I^{1} 250	I^{+} 3	.	.	I^{+} 1
Lycopus europaeus L.	.	.	.	I^{1} 250	.	I^{+} 2	I^{1} 125	IV^{+-1} 65
Agrostis stolonifera L.	.	.	.	I^{1} 250	.	.	I^{1} 125	II^{+-1} 64
Salix cinerea L.	.	.	.	.	.	I^{+} 2	.	I^{+} 1
Senecio paludosus L.	.	.	.	.	.	I^{3} 750	.	.
Alopecurus geniculatus L.	.	.	.	.	.	I^{+} 2	.	.
Bidens tripartitus L.	.	.	.	.	.	I^{+} 2	I^{+} 3	II^{+} 1
Polygonum amphibium f. terrestre	.	.	.	.	.	.	I^{+} 3	.
Epilobium palustre L.	.	.	.	.	.	.	I^{+} 3	I^{+} 1
Ranunculus scelertus L.	.	.	.	.	.	.	.	I^{+} 1
Galium palustre L.	.	.	.	.	.	.	.	I^{+} 1
Ranunculus repens L.	.	.	.	.	.	.	.	I^{+} 1
Lolium perenne L.	.	.	.	.	.	.	.	I^{+} 1
Polygonum aviculare L.	.	.	.	.	.	.	.	I^{+} 1
Solanum dulcamara L.	.	.	.	.	.	.	.	I^{+} 1

* **1** – *Scirpetum lacustris* (Allorge 1922) Chouard 1924, **2** – *Typhetum angustifoliae* (Allorge 1922) Soó 1927, **3** – *Sparganietum erecti* Roll 1938, **4** – *Eleocharitetum palustris* Sennikov 1919, **5** – *Phragmitetum* (Gams 1927) Schmale 1939, **6** – *Typhetum latifoliae* Soó 1927, **7** – *Acoretum calami* Kobendza 1948, **8** – *Glycerietum maximae* Hueck 1931.

TABLE 6. Communities of the alliance *Magnocaricion*.

Community*	1	2	3	4	5
Number of releves	1	3	1	2	3
Cl. Phragmitetea					
Thelyptheris palustris Schott	**I^5 8750**	.	.	I^2 1750	.
Carex riparia Curt.	I^1 500	**III^{4-5} 7917**	.	.	.
Carex acutiformis Ehrh.	.	.	**I^5 8750**	.	.
Carex paniculata L.	.	.	.	**II^{4-5} 7500**	.
Carex gracilis Curt.	.	.	.	.	**III^5 8750**
Scophularia umbrosa Dumort.	I^+ 10	.	.	.	.
Rorippa amphibia (L.) Besser	I^+ 10	.	.	.	.
Cicuta virosa L.	I^1 500	.	.	I^+ 5	I^+ 3
Rumex hydrolapathum L.	I^+ 10	.	.	II^+ 10	I^+ 3
Typha latifolia L.	.	.	I^+ 10	II^{1-3} 2125	.
Glyceria maxima (Hartman) Holmberg	.	II^{+-1} 170	.	II^{+-1} 255	.
Acorus calamus L.	.	I^+ 3	.	I^+ 5	I^1 167
Poa palustris L.	.	I^+ 3	.	.	I^2 583
Phalaris arundinacea L.	.	.	.	.	I^+ 3
Phragmites austrialis (Cav.) Trin. ex Stueudel	.	I^+ 3	I^1 500	I^+ 5	I^+ 3
Carex vesicaria L.	.	.	.	I^+ 5	.
Typha angustifolia L.	.	.	.	.	I^+ 3
Galium palustre L.	.	.	.	I^+ 5	.
Cl. Lemnetea					
Lemna minor L.	I^+ 10	II^{+-1} 170	I^1 500	II^{+-1} 255	III^+ 10
Spirodela polyrriza (L.) Schleiden	I^+ 10	II^2 1167	I^+ 10	II^{+-2} 880	III^+ 10
Cl. Molinio-Arrhenatheretea					
Lythrum salicaria L.	I^+ 10	.	.	.	.
Epilobium hirsutum L.	I^+ 10	II^+ 3	.	II^1 500	II^+ 7
Juncus effusus L.	.	.	.	II^1 500	.
Lothus corniculatus L.	.	.	.	I^+ 5	.
Cardamine pratensis L.	.	I^+ 3	.	I^+ 5	.
Epilobium palustre L.	I^+ 10	.	.	.	.
Holcus lanatus L.	.	I^+ 3	.	.	.
Cirsium oleraceum (L.) Scop.	.	I^+ 3	.	.	.
Cirsium palustre (L.) Scop.	.	.	.	.	I^+ 3
Dactylis glomerata L.	.	.	.	.	II^+ 7
Phleum pratense L.	.	.	.	.	I^+ 3
Scirpus silvaticus L.	.	.	.	.	II^+ 7
Ranunculus acris L.	.	I^1 63	.	.	II^+ 7
Deschampsia caespitosa (L.) Beauv.	.	.	.	.	I^1 167
Accompanying species					
Hydrocharis morsus-ranae L.	I^+ 10	.	.	.	.
Salix alba L.	I^+ 10	.	.	.	.
Solanum dulcamara L.	I^+ 10	.	.	II^+ 10	III^{+-1} 255
Lycopus europaeus L.	I^+ 10	.	.	.	.
Bidens tripartitus L.	I^2 1750	I^+ 3	.	.	.
Mentha aquatica L.	.	.	.	I^+ 5	.
Carex hirta L.	.	.	.	I^+ 5	.
Juncus inflexus L.	.	I^+ 3	.	.	.
Agrostis stolonifera L.	.	I^+ 3	.	.	.
Agrimonia eupatoria L.	.	.	.	.	I^+ 3
Equisetum arvense L.	.	.	.	.	II^+ 7
Elymus repens (L.) Gould	.	.	.	.	I^+ 3
Juncus articulatus L.	.	.	.	.	I^+ 3
Urtica dioica L.	.	I^+ 3	.	.	.
Salix cinerea L.	.	.	.	I^+ 5	.

* **1** – *Thelypteridi-Phragmitetum* Kuiper 1957, **2** – *Caricetum ripariae* Soó 1928, **3** – *Caricetum acutiformis* Sauer 1937, 4 – *Caricetum paniculatae* Wangerin 1916, **5** – *Caricetum gracilis* (Graebn. et Hueck 1931) R. Tx. 1937.

classification presented in the methods (Table 2), the urban lakes of Ostróda were classified (using the index of synanthropization) into three out of five groups: natural water bodies (Lake Morliny), synanthropic lakes (Lake Kajkowskie; these two lakes remain in the series of harmonic development), and anthropogenic water bodies (lakes Jakuba and Perskie; these two lakes are characterised by disharmonious development due to high lake trophy).

TABLE 7. Values of the indices characterising phytocenotic composition of the vegetation in urban lakes of Ostróda.

L.p.	Lake name	Area of 2.5 m isobath	Area of phytolittoral	Number of phytolittoral communities	Index of phytocenotic diversity	Index of max. phytocenotic diversity	Index of colonization	Synanthropization index	Anthropopression effect
		(ha)	(ha)	S	H	H_{max}	Z	W_s	
1	Morliny	9.30	12.06	15	2.19	2.71	1.30	0.35	natural
2	Kajkowskie	9.30	9.28	9	0.62	2.20	1.00	0.75	synanthropic
3	Jakuba	10.90	1.39	13	1.80	2.56	0.13	0.92	anthropogenic
4	Perskie	10.00	0.71	7	1.33	1.95	0.07	0.95	anthropogenic

DISCUSSION

The distinguished communities of aquatic and rush-belt plants are fairly common in Polish waters (Tomaszewicz 1979, Matuszkiewicz 1982).

Taking advantage of the value of the synanthropic indices, lakes Morliny and Kajkowskie were classified as belonging to the group of water bodies with the fitocenoses in a balanced state.

Morliny lake was included in the group of natural reservoirs where, independent of the development stage, the flora develops either without human pressure or such a degree of human pressure which is within the natural categories of influence of the basin and climate (Rejewski 1981). The majority of lakes in the area of Laski in Tuchola Forest (Rejewski 1981) and Wiktorowo lake situated among the agricultural landscape of southern Kujawy region (Samosiej 1987) belonged to that group. Śluza lake from the area of Laski is the most similar one as concerns the value of different ratios for the studied reservoir (S-14 of which 9 phytocenoses were present in both reservoirs, H – 2.02, H_{max} – 2.64, Z – 1.35, W_s – 0.35). On the other hand, the nearest surrounding of the reservoir, high banks in their majority occupied by meadows and cultivated fields is closest to the Wiktorowo lake.

Lake Morliny is located at the outskirts of Ostróda, it is not polluted from point sources, and has an almost natural shore zone (only 3% of this area are represented by anthropogenic communities). It is a lake with the least human impacts, mostly because it is not directly affected by the town. This lake is characterised by a well developed zone of submerged vegetation (58.4% of the whole phytolittoral; Fig. 2), composed mainly of the phytocenoses: *Ranunculetum circinati*, *Potamogetonum perfoliati* or *Nupharo-Nymphaeetum albae* (Table 3). Submerged vegetation is present to the depth of 3.5-4 m. The rush belt is composed mainly of the patches of *Phragmitetum* and *Glycerietum maximae.*

Lake Kajkowskie is a eutrophic, synanthropic water body, with the biocenotic systems on the verge of collapsing. This is reflected in the fact that although the zone of submerged vegetation is well developed, it is composed almost exclusively of *Elodea canadensis*. Mass appearance of this anthropological species suggests advanced anthropopression.

Many reservoirs in the group of synanthropic lakes were identified in Kujawy (Samosiej 1987), but they differed in developed phytolittoral both as concerns the number of phytocenoses and in the expanse of it.

According to the methods, the lakes for which the synanthropisation index was equal to or higher than 0.8 were classified as anthropogenic. These lakes were characterised by disharmonic development due to very high trophy. Hence, it is suggested to extend the term anthropogenic lake to include also hypertrophic water bodies, in which high levels of nutrients lead to lake degradation as an ecosystem. Of course it is possible to inhibit or reverse the evolutionary process of an aquatic ecosystem , according to the concept of allogenic succession (Margalef 1975, Rejewski 1981, and many others).

The two other water bodies of Ostróda, lakes Jakuba and Perskie, were included into the group of anthropogenic lakes. These lakes are characterised most of all by a well developed zone of emerged vegetation: in Lake Jakuba 65.2%, and in Lake Perskie 90.5% of the whole phytolittoral (Table 2, Fig. 2). These vegetation are represented most of all by the alliance *Phragmition* (high rushes and reed), composed of the phytocenoses: *Phragmitetum*, *Typhetum latifoliae* or *Typhetum angustifoliae*. Sedge rushes were poorly developed. They were present only in lakes Perskie and Jakuba. In the latter lake, sedge developed in supralittoral. This was the reason for the presence of many land species from the class *Molinio-Arrenatheretea* in the patches of *Caricetum* phytocenoses (Table 5).

Submerged vegetation was poor in both latter lakes: 4.7% of the submerged zone in Lake Jakuba and 5.6% in Lake Perskie. It was composed in both lakes of pond-weeds: *Potamogeton lucens*, *P. perfoliatus* and *P. pectinatus* (Table 3). The last species is usually characteristic of highly eutrophic waters. *Nupharo-Nymphaeetum* patches developed well only in Lake Jakuba, in a bay on the lake end opposite the town. They formed a zone of nympheids (*Nymphaeion*). *Nymphea* alba is connected with fertile habitats of shallow bays, in which thick organic sediments have accumulated (Tomaszewicz 1977, 1979). *Nyphar lutea* has a very wide ecological amplitude and forms phytocenoses in eutrophic habitats with mineral sediments and flowing water as well as in very shallow mesotrophic habitats with stagnant water. Samosiej (1987) also included a number of lakes in Kujawy into the group of anthropogenic reservoirs. Low residence ratio (from 0.28 to 0.51) and a small number of groups residing in the phytolittoral zone (2-7) were the common features for such lakes. Lubienieckie lake was the only exception with the flora consisting of 13 phytocenoses, which, however, did not form a zoned pattern and were of anthropogenic nature like e.g. *Elodeetum canadensis* or *Acoretum calami*. In Jakuba lake also 13 phytocenoses were recorded while in the lakes of Olsztyn: Trackie and Skanda, even 14 while the phytolittoral of those reservoirs has always been small (index of colonizacion was 0.40 and 0.41 respectively).

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OCENA STOPNIA SYNANTROPIZACJI ROŚLINNOŚCI JEZIOR MIEJSKICH W OSTRÓDZIE (POJEZIERZE IŁAWSKIE)

STRESZCZENIE

Dokonano analizy strukturalno-przestrzennych układów roślinności litoralu 4 jezior miejskich w Ostródzie: Jakuba, Morliny, Kajkowskie i Perskie. Badania fitosocjologiczne pozwoliły na wyróżnienie 20 jednostek fitosocjologicznych w randze zespołu z klas: *Potamogetonetea* i *Phragmitetea*. Rozmiary antropogenicznych zmian roślinności litoralu prześledzono wyliczając wartość wskaźnika synantropizacji, dla poszczególnych jezior. Jezioro Morliny zostało zaliczone do grupy zbiorników naturalnych i Jezioro Kajkowskie do grupy zbiorników synantropijnych (akweny te mieszczą się w szeregu rozwoju harmonijnego). Resztę jezior zaliczono do grupy antropogenicznych – charakteryzujących się rozwojem dysharmonijnym ze względu na duży poziom trofii. Wyniki te potwierdza powierzchniowy udział poszczególnych typów roślinności w zbiornikach.

SŁOWA KLUCZOWE: roślinność jezior, fitosocjologia, antropopresja, proces synantropizacji jezior, jeziora miejskie.