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WATER AND RUSH PLANT COMMUNITIES IN THE WARTA RIVER OXBOWS: BIODIVERSITY AND HABITAT REQUIREMENTS[1]

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Summary. In the summer of 2007 and 2008, hydrobiological studies were conducted in 18 oxbow lakes located on both sides of the Warta River, on the Rogalinek-Czmoniec section. The entire test section of the Warta ice-marginal valley is located in areas protected under Nature 2000 Rogalin Warta Valley (Rogalińska Dolina Warty) and Rogalin Refuge (Ostoja Rogalińska) as well as Rogalin Landscape Park (Rogaliński Park Krajobrazowy). The oxbows lakes differed in size, depth, visibility, trophic conditions, a type of the immediate catchment area (forest, field) and they were located at different distances from the river. The aim of the studies was to determine the diversity and habitat requirements of aquatic and rush communities in oxbow lakes on both sides of the Warta River.

The research revealed a large phytocoenotic diversity in the analysed reservoirs. In total, there were 35 communities belonging to all ecotypes. It also showed differences in vegetation between the right- and left-side reservoirs, resulting from different catchment characteristics. Statistical analyses showed negative correlations between the number of elodeid, nymphaeid and helophyte communities, and a concentration of NO_2. There were single correlations with the size and depth of reservoirs and the highest phytocoenotic diversity in oxbow lakes with weaker trophic conditions. Rare and very rare communities in the Wielkopolska region also occurred which emphasizes the precious environmental character of the reservoirs studied.

Key words: mid-field ponds, hydromacrophyte communities, rare communities, frequency

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INTRODUCTION

River valleys are wildlife corridors that are refuges for many organisms, while oxbows are a very important part thereof [Dembowska and Napiórkowski 2012].

Oxbows is a common name for meander lakes, less known as river lakes [Choiński 2000] located in river valleys and being remains of old riverbeds [Choiński 1995]. These usually small reservoirs can be permanently or temporarily connected with river channel or completely separated from it. Oxbow lakes are formed both naturally and artificially [Jezierska-Madziar 2005]. Natural oxbows emerge after a meander is cut off from the main river, while artificial ones result from regulation of river flows [Jezierska-Madziar 2005]. Regardless of how they are formed, the common features of these reservoirs include a small area, medium depth and the fact that morphometric parameters show seasonal variations [Dawidek and Turczyński 2006].

Due to the depth, which usually does not exceed a few meters, thermal stratification does not develop in them and hence there are no epilimnion, metalimnion and hipolimnion zones. The entire surface of oxbow lakes is often covered with vegetation, which further complicates the separation of pelagic and littoral zones [Wilk-Woźniak 2012].

Oxbow lakes have also different types of immediate catchments and varying degrees of anthropogenic transformation. However, contact with the river or lack thereof is the factor that most differentiates horseshoe shaped lakes and affects the physico--chemical parameters of water, the structure of organisms and the rate of fouling. Results of numerous studies indicate that the species composition of organisms is determined mainly by hydrological periods: potamophase – a river valley is flooded with water, or limnophase – an oxbow lake is isolated from the flow of the river [Wojciechowska and Pasztaleniec 2006]. High water caused an increase in gross primary production and zooplankton species richness also in Brazilian oxbow lakes [Sampaio and López 2000].

Practically the same communities occur in oxbow lakes and eutrophic glacial lakes, and less often in mesotrophic lakes. Zonal vegetation system can be observed in medium deep river lakes [Podbielkowski and Tomaszewicz 1996], while in smaller ponds, phytocoenoses form a mosaic of plant communities [Gołdyn *et al*. 2005]. Despite their small surface and depth, vegetation may be more diversified in oxbows than in lakes [Lorens 2006].

Since oxbow vegetation may be subject to disturbance, depending on many abiotic factors [Gołdyn *et al*. 2005], the aim of the studies was to determine the diversity and habitat requirements of aquatic and rush communities in the Warta River oxbow lakes. The intention of the authors was to conduct a phytosociological inventory, to determine the frequency of communities and to show the relationship between the number of plant communities and physico-chemical parameters of water and morphometric parameters of reservoirs, such as depth, size or overshading of water surface. The distance of an oxbow from the river channel and the location of a reservoir (which may relate to contact with the river or lack thereof) are important factors that affect the functioning of the oxbow lake. One of the study objectives was to compare the diversity of vegetation in oxbow lakes located on two opposite sides of the Warta River.

STUDY AREA AND METHODS

The study area is a section of ice-marginal valley of the Warta River which lies entirely in the area covered by various forms of environmental protection: Nature 2000 PLH300012 Rogalin Warta Valley and PLB300017 Rogalin Refuge, Rogalin Landscape Park. In the Rogalin Warta Valley, forests cover nearly 48%, arable land – 25% and meadows and pastures – about 23% of the area. There are 16 habitat types listed in Annex I to Council Directive 92/43/EEC. The largest area is occupied by riparian oak, elm and ash forests (91F0 *Ficario-Ulmetum*), extensively used lowland and mountain hay meadows (6510 *Arrhenatherion elatioris*) and habitats that are the object of the studies – oxbow lakes and natural eutrophic water reservoirs with *Nympheion* and *Potamion* communities (3150). Hundreds of old protected oak trees (natural monuments) grow in the Rogalin Landscape Park.

The study area covers about 900 hectares, i.e. about 25% of the Rogalin Warta Valley [Stachnowicz 2009]. In the summer of 2007 and 2008, hydrobiological research was conducted in 18 Warta River oxbow lakes. The oxbows were located on both sides of the river over a distance of approximately 20 km from Rogalinek to Czmoniec village. The test reservoirs differed in size (from 0.018 to 5.75 ha), depth (from 0.4 to 3.5 m), visibility (from 0.1 to 1.6 m), trophic conditions of water, distance from the river (from 112 to 523 m), a type of immediate catchment (forest, field) and location. In the group of eight oxbows located on the right bank of the Warta River, all had immediate agricultural catchments, whereas four of the left-bank reservoirs had forest catchments and six – agricultural catchments.

Electrolytic conductivity EC, visibility SDV, oxygen saturation O_2, maximum depth and pH were measured in each reservoir. In addition, water samples were collected from each reservoir for chemical analyses (TP, DIN, DOM, hard, Chl *a*). These analyses were carried out following standard methods as reported in Hermanowicz *et al.* [1999]. Test results concerning physico-chemical parameters of oxbow water pointed to their high trophic level. Among the eighteen reservoirs studied, only two (no. 7 and 14) were slightly eutrophic, while the others were eutrophic [Joniak 2007, 2009a].

An inventory of aquatic and rush communities was conducted in each reservoir. Phytosociological releves were taken using the Braun-Blanquet's method [1951], while phytosociological classification, prevalence and risks in the Wielkopolska region were adopted after Brzeg and Wojterska [2001]. The shading of water surface was also investigated, determining the percentage of trees or shrubs surrounding reservoir banks (100% – trees or shrubs all around the edge of the pond, 0% – no trees or bushes at the edge of the reservoir) and the percent coverage of water surface by vegetation.

Correlation coefficients were calculated to determine whether there were any dependencies between the total number of communities or the number of communities in particular ecotypes of plants, and various parameters.

RESULTS

In the test oxbows, a total of 35 communities were reported: 8 of the *Lemnetea* class, 10 of the *Potametea* class (3 of the *Nymphaeion* alliance and 7 of the *Potamion* alliance) and 17 communities of the *Phragmitetea* class (Tab. 1). The frequency of occurrence of each association was very different. *Lemno-Spirodeletum polyrrhizae* which occurred in 15 of the 18 reservoirs reached the highest frequency – 83%, then *Ceratophylletum demersi* – 67% and *Nymphaeo albae-Nupharetum luteae* and *Phalaridetum arundinaceae* – 56%. Analysing the different ecotypes of plants, it was found that phytocoenoses of pleustophytes occurred in all of the oxbow lakes (100%), helophytes in 17 (94%), elodeids in 12 (66%) and nymphaeids in 10 oxbow lakes (56%).

The analysis of differences in vegetation structure between the right- and left-bank oxbows ($p > 0.05$) did not show statistically significant differences. However, the oxbows differed in the number and type of plant communities. The number of communities was higher in the left-bank reservoirs (29) than on the right-bank (23). Out of the 35 plant communities observed in all studied oxbow lakes, 17 phytocoenoses were common to oxbows on both sides of the river, 6 grew only in the right-bank waters and 12 phytocoenoses were characteristic of the left-bank oxbow lakes. *Potamion* communities were dominant in the group of phytocoenoses in the left-bank oxbow lakes, which significantly increased the syntaxonomic diversity of this group of river lakes. As for individual oxbows, the number of communities in a reservoir ranged from 3 to 13 on the right side and from 2 to 21 on the left side, while the average number of phytocoenoses in the reservoirs on both sides of the river was almost equal (7.5 and 6.9). Most communities – 21 – were reported in a reservoir located on the left side of the Warta River (no. 14) (Tab. 2). Not only the total number of communities, but also the number of rush vegetation communities (helophytes) in relation to the number of aquatic vegetation communities (elodeids, nymphaeids and pleustophytes) were different in individual oxbows. Rush phytocoenoses prevailed in five right-bank reservoirs, aquatic in two, while both vegetation types were of equal quantity in one pond. However, aquatic phytocoenoses were dominant in five oxbow lakes on the left side of the river, rush vegetation communities in two, while the number of aquatic and rush vegetation communities was the same in three reservoirs.

Ten plant communities typical of the habitat 3150 (oxbow lakes and natural eutrophic reservoirs with Nymphaeion and Potamion communities) were found in the test oxbow lakes, while all ten communities from this group were recorded in the left-bank reservoirs and only three in the right-bank ponds (Tab. 2).

Table 1. Macrophyte associations and communities present in water bodies

Syntaxonomic units	A	B	C	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Lemno-Spirodeletum polyrrhizae W. Koch 1954 ex Th. Müller et Görs 1960	-	NA	P	+	+	+	.	+	+	.	+	+	+	+	+	+	+	+	+	.	+
Lemnetum minoris Soó 1927	-	NA	P	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.
Lemnetum trisulcae (Kelhofer 1915) R.Knapp et Stoffers 1962	-	NA	C	.	.	.	.	.	.	+	+	.	.	+	.	.	+	.	.	.	.
Lemno-Hydrocharitetum morsus-ranae (Oberd. 1957) Pass. 1978	I	N	C	.	+	+	+	.	.	+	+	.	.	.	+	.	.	+	+	.	.
Wolffietum arrhizae (Bennema *et al*. 1943) Miyawaki et J. Tx. 1960	V	NA	R	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	+	.
Riccietum fluitantis Slavnić 1956 em. R. Tx. 1974	V	NA	R	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Lemno-Utricularietum vulgaris Soó 1928 ex 1947	I	NA	C	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.
Stratiotetum aloidis (Nowiński 1930) Miljan 1933	V	N	C	.	.	.	+	.	.	.	.	.	.	.	+	.	+	.	.	.	.
Potametum pectinati (Hueck 1931) Carstensen 1955	-	NA	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Ceratophylletum demersi Hild 1956	-	NA	P	+	+	.	+	+	+	+	.	+	.	.	+	.	+	+	+	.	+
Myriophylletum spicati Soó 1927 ex Podbielkowski et Tomaszewicz 1978	I	N	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Ranunculetum circinati (Sauer 1937) Segal 1965	I	NA	R	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.	.	.
Elodeetum canadensis Eggler 1933	-	X	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Potametum compressi Tomaszewicz 1979 nom. Inval.	E	NP	RR	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Myriophylletum verticillati Gaudet 1924	I	NA	R	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	+	.	.
Nymphaeo albae-Nupharetum luteae Nowiński 1928 nom. mut. propos	V	NP	C	+	+	+	+	.	+	+	.	+	.	.	+	.	+	.	+	.	.
Potametum natantis Soó 1927 ex Podbielkowski et Tomaszewicz 1978	-	NA	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Polygonetum natantis Soó 1927 ex Brzeg et M.Wojterska 2001	-	NA	C	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Scirpetum lacustris (Allorge 1922) Chouard 1924	-	NA	P	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.
Typhetum latifoliae Soó 1927 ex Lang 1973	-	NA	P	.	+	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.

Sparganietum erecti Roll 1938	-	NA	P	+	+	·	·	+	+	·	·	·	·	·	·	·	+	·	+	·	·
Phragmitetum communis (W.Koch 1926) Schmale 1939	-	NA	P	·	·	+	+	·	·	+	·	·	+	·	·	·	+	·	+	+	+
Glycerietum maximae (Allorge 1922) Hueck 1931	-	NA	P	+	+	·	+	+	+	·	·	·	+	·	·	+	·	·	·	·	·
Acoretum calami Eggler 1933 ex Kobendza 1948	-	X	P	·	·	·	+	·	·	+	+	·	·	·	+	·	+	·	·	·	·
Cicuto-Caricetum pseudocyperi Boer et Sissingh in Boer 1942	V	NP	C	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Iridetum pseudacori Eggler 1933 ex Brzeg et M.Wojterska 2001	I	NA	P	·	·	·	+	·	+	·	·	·	+	·	·	·	·	·	·	·	·
Caricetum ripariae Soó 1928	-	NA	P	·	·	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·
Oenantho aquaticae-Rorippetum amphibiae Lohmeyer 1950	-	NA	C	·	·	·	+	·	·	·	·	·	·	·	·	·	·	·	·	·	·
Sagittario-Sparganietum emersi R.Tx.1953	I	NP	R	·	+	+	+	·	·	·	·	+	·	·	·	·	·	·	+	·	·
Butometum umbellati Konczak 1968	-	NA	C	·	+	·	·	·	·	·	+	+	·	·	·	·	+	·	·	·	·
Eleocharitetum palustris Schennikov 1919 ex Ubrizsy 1948	-	NA	P	·	·	·	+	·	·	·	·	·	·	+	·	·	+	·	+	·	·
Phalaridetum arundinaceae Libbert 1931	-	NA	P	+	·	·	+	+	+	+	+	+	·	·	+	+	+	·	·	·	·
Caricetum elate W.Koch 1926	I	N	P	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Glycerietum fluitantis (Nowiński 1928) Wilzek 1935	-	NA	C	·	·	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	·
Leersietum oryzoidis Krause in R.Tx.1955 ex Pass.1957	E	NA	RR	·	·	·	·	·	·	·	·	·	·	·	·	·	+	·	+	·	·
Number of helophyte communities				3	5	2	9	3	5	3	3	3	3	1	2	2	9	0	7	1	1
Number of nymphaeid communities				1	1	1	1	0	1	1	0	1	0	0	1	0	3	0	1	0	0
Number of elodeid communities				1	1	0	1	1	1	2	0	1	0	0	2	0	6	1	2	0	1
Number of pleustophyte communities				1	2	2	2	1	2	4	3	1	2	2	3	1	3	2	2	1	1
Total number of communities				6	9	5	13	5	9	10	6	6	5	3	8	3	21	3	12	2	3

A – vulnerability level (E – directly endangered community, V – possibly endangered community, I – no data on vulnerability, /-/ – not endangered community); B – syngenesis (N – natural community, NA – natural auxochoric community, NP – natural perdochoric community, X – xenospontaneous community); C – frequency (P – common community, C – well spread community, R – rare community, RR - very rare community). Numbers 1–18 represent particular oxbows (1–7 and 13 right-bank, 8–12 and 14–18 left-bank)

Table 2. Syntaxonomic diversity of oxbows situated at two sides of the Warta River: R – right-side and L – left-side

Syntaxonomic parameter	Oxbows		
	R	L	total
Number of not endangered communities	14	17	20
Number of communities of no data on vulnerability	5	7	8
Number of possibly endangered communities	4	3	5
Number of directly endangered communities	0	2	2
Number of natural auxochoric communities	17	20	25
Number of natural perdochoric communities	3	3	4
Number of natural communities	2	4	4
Number of xenospontaneous communities	1	2	2
Number of common communities	12	12	14
Number of well spread communities	7	11	14
Number of rare communities	3	4	5
Number of very rare communities	0	2	2
Total number of communities	23	29	35
Number of differentiating communities	6	12	18
The mean number of communities in the oxbow	7.5	6.9	7.1
The maximum number of communities in the oxbow	13	21	21
The minimum number of communities in the oxbow	3	2	2
Number of communities with *Nympheion* and *Potamion* characteristic for 3150 habitat	3	10	10
Number of helophyte communities	13	14	17
Number of pleustophyte communities	7	5	8
Number of nymphaeid communities	1	3	3
Number of elodeid communities	2	7	7

Table 3. Correlation coefficient between frequency of plant communities occurrence and morphometric parameters of a water body: tree – overshading of oxbow caused by tree or shrub belt around the pond; depth – depth of oxbow; size – surface size of oxbow

Parameters			r	p
Lemnetum trisulcae	vs.	tree	-0.5357	p = 0.022
Acoretum calami	vs.	tree	-0.4724	p = 0.048
Phalaridetum arundinaceae	vs.	tree	-0.5905	p = 0.010
Nymphaeo albae-Nupharetum luteae	vs.	depth	0.4692	p = 0.049
Ceratophylletum demersi	vs.	depth	0.6289	p = 0.005
Glycerietum maximae	vs.	size	-0.5746	p = 0.013

It should be noted that ten communities at risk in the Wielkopolska region were found in the studied oxbow lakes, including two: *Potametum compressi* and *Leersietum oryzoidis* in imminent danger of extinction. These communities are simultaneously very rare in Wielkopolska [Brzeg and Wojterska 2001]. In addition, five rare communities were identified (Tab. 2). The analysis of syngenesis of identified communities showed that the vast majority – 33 – are natural phyto-coenoses and only two are xenospontaneous – *Elodeetum canadensis* and *Acoretum calami* (Tab. 2).

Dependence of the occurrence of plant communities on the morphometric properties of a reservoir (depth and surface), the overshading of water surface by a line of trees growing on the edge as well as pleustophytes and nymphaeids covering water surface was also determined. It was found that *Lemnetum trisulcae*, *Acoretum calami* and *Phalaridetum arundinaceae* were sensitive to shading, and that deeper water conditions were favourable for the development of *Ceratophylletum demersi* and *Nymphaeo albae-Nupharetum luteae*. The only negative correlation concerned the relationship between the size of an oxbow and the presence of *Glycerietum maximae* (Tab. 3).

Table 4. Correlation coefficient between frequency of plant communities occurrence and concentration of NO_2

Parameters	r	p
Number of elodeid communities vs. NO_2	-0.8461	p = 0.000
Number of nymphaeid communities vs. NO_2	-0.771	p = 0.000
Number of helophyte communities vs. NO_2	-0.5393	p = 0.021

A statistical analysis of the variability of physico-chemical parameters in water zones occupied by plant communities showed negative correlations between the number of helophyte, nymphaeid and elodeid communities, and a concentration of NO_2 (Tab. 4).

DISCUSSION

As a result of the detailed inventory carried out in the studied oxbow lakes, 35 plant associations were found, including 18 communities of aquatic vegetation and 17 communities of rush vegetation. Comparing the results with other studies, it is clear that the Warta River oxbows are characterized by large phytocoenotic diversity. For example, in oxbow lakes in the Bug River valley – one of the few places in Europe that still have their original character [Chmielewski *et al.* 2006], 28 communities in 7 (large-surface) reservoirs were found [Lorens 2006].

Plant associations found in the studied oxbow lakes are phytocoenoses characteristic of eutrophic reservoirs [Podbielkowski and Tomaszewicz 1996, Kłosowski and Kłosowski 2001]. Physico-chemical parameters of waters showed that only two oxbow lakes (no. 7 and 14) were slightly eutrophic and the others were eutrophic [Joniak 2007, 2009a]. In the studied oxbow lakes, their trophic status was reflected in their phytocoenotic diversity.

Most syntaxa were identified in two slightly eutrophic (no. 7 and 14) and two eutrophic oxbows (no. 4 and 16). Ten phytocoenoses were found in reservoir no. 7 and as many as 21 in pond no. 14. It is true that successively 13 and 12 communities occurred in oxbow lakes no. 4 and 16, but they were dominated by rush vegetation (helophytes) which accounted for 70% and 58% of the communities. Despite good visibility in excess of 1 m [Joniak 2007, 2009a], only one community of submerged plants was found in reservoir no. 4 and only two in reservoir no. 16. However, aquatic vegetation (elodeids, nymphaeids, pleustophytes) prevailed in slightly eutrophic oxbow lakes (no. 7 and 14) and accounted for 70% and 57 % of the total number of communities. This reflects the impact of the degree of reservoir eutrophication on the development of underwater vegetation, resulting from a deeper penetration of light in reservoirs of lower trophic status [Joniak 2009b].

In the oxbow lakes studied, the incidence of individual communities was very different. *Lemno-Spirodeletum polyrrhizae* occurred in 15 out of 18 reservoirs, reaching the highest frequency among the identified communities (83%), *Ceratophylletum demersi* was found in 12 oxbow lakes (67%), while *Nymphaeo albae-Nupharetum luteae* and *Phalaridetum arundinaceae* in 10 oxbow lakes (56%). Very frequent occurrence of *Lemno-Spirodeletum polyrrhizae*, *Ceratophylletum demersi* and *Nymphaeo albae-Nupharetum luteae* is typical of oxbows [Janauer and Stetak 2003]. Species that build these phytocoenoses: *Spirodela polyrrhiza* (L.) Schleid., *Ceratophyllum demersum* L. and *Nuphar lutea* (L.) Sibth.& Sm. prefer standing water bodies, including oxbow lakes [Tomaszewicz 1999, Kłosowski and Kłosowski 2001, Janauer and Stetak 2003].

Catchment has a very large impact on the trophic conditions in a reservoir and consequently on different aquatic organisms. The strength of this effect is largely dependent on land use within the catchment area – i.e. its type [Kajak 2001]. Since the types of the immediate catchments of the analysed oxbows differed between the two banks of the Warta River (oxbow lakes located on the right bank had immediate agricultural catchments, whereas on the left side of the river, four reservoirs had forest catchments and six – agricultural catchments), differences in vegetation structure between reservoirs on both sides were also expected. More communities and twice more distinctive phytocoenoses were found in the left-bank reservoirs. The dominance of communities from the *Potamion* alliance significantly increased the syntaxonomic diversity of these oxbows. In the right-bank oxbow lakes, there were only two phytocoenoses of submerged plants, while in the left-bank reservoirs – as many as seven. Aquatic communities were more dominant than rush vegetation communities in more ponds also on the left bank of the Warta River. This may indicate that more favourable conditions – better visibility and weaker trophic conditions [Joniak 2007, 2009a] – for the development of submerged plants are in the ponds on the left side of the Warta River, while good transparency and poor trophic conditions are conducive to an increase in the diversity of elodeids [Scheffer 2001].

The diversity of aquatic and rush vegetation depends on many factors. Morphometric parameters of a reservoir and physico-chemical properties of water are among those of major importance. One of the study objectives was to demonstrate the correlation between the number of plant communities and physico--chemical parameters of water and morphometric properties of a reservoir, such as depth, size or shading of water surface. Statistical analyses showed negative correlations between the number of helophyte, nymphaeide and elodeid communities, and a concentration of NO_2. As is well known, the direction of change of nitrogen compounds is conditioned by the level of oxygenation [Kajak 2001]. The correlation with nitrites, which are unstable compounds, resulting from oxidation disorders or reduction, indicates very active nitrogen transformation processes in waters occupied by plant communities. It is worth noting that a high level of correlation ($r > 0.75$) prevailed in elodeid communities, followed by nymphaeide and helophyte communities. The dependences were weak in semiaquatic rush systems. This kind of gradient biochemical activity of water in environmental areas involved in various reservoir zones suggests the key significance of light as a factor that regulates the availability of microhabitats and the biocoenotic complexity of microstructures „macrophyte – periphyton" [Kuczyńska--Kippen and Nagengast 2006].

Analysing vegetation in 20 oxbow lakes of the Tisza River, researchers expected a positive correlation between the number of species and the size of oxbows. The results, however, indicated a lack of significant relationship [Janauer *et al*. 2012]. An increase in a reservoir area neither increased the number of aquatic vegetation communities in the Warta River. There was only one negative correlation between the size of oxbows and the rush community – *Glycerietum maximae*. This is probably due to the impact of the phytocoenosis on the shallowing of reservoirs [Tomaszewicz 1979, Matuszkiewicz 2007].

Light is the main determinant of vegetation abundance. Shading may affect their development. The analysis of the impact of shading of oxbows by a line of trees and shrubs surrounding the reservoirs showed that with increasing shading, the number of *Acoretum calami, Phalaridetum arundinaceae* and *Lemnetum trisulcae* communities decreased. The first two communities are helophytes which prefer open areas of meadows and alluvial terraces, and therefore shading is not conducive to their development. The last correlation is surprising, because duckweed occurs both in full sunlight and in the shade [Wołek 1974], while *Lemna trisulca L.* is a species highly resistant to lack of light [Bornkamm 1963 after Wołek 1974].

In addition to the assessment of correlations between the occurrence of plant communities and the size and shading of reservoirs, their dependence on the depth of oxbow lakes was also analysed. Such correlation was found for the second and third most common communities *Ceratophylletum demersi* and *Nymphaeo albae-Nupharetum luteae*. These communities were more numerous in deeper oxbow lakes. *Ceratophylletum demersi* and *Nymphaeo albae-Nupharetum luteae* occurred together in 50% of the test reservoirs. The depth of the occurrence of submerged plants is primarily correlated with visibility [Canfield *et al*. 1985, Caffrey *et al*. 2007]. In the studied reservoirs, hornwort occurred in oxbow lakes where visibility ranged from 0.25 to 1.6 m [Joniak 2007, 2009a]. It is also known that the plant tolerates relatively well highly eutrophic water of low transparency. As hornwort has no roots, in the case of decreasing water clarity, it occurs in water column or even swims near the surface [Casper and Krausch 1981]. *Nymphaeo albae-Nupharetum luteae* was present in the same range of visibility, but visibility is not important to nymphaeids as long as their leaves reach the surface. Aerenchyma that withstands a certain hydrostatic pressure [Lampert and Sommer 2001] may be a factor in the occurrence of nymphaeids in large reservoirs.

Furthermore, the presence of communities in the study area that are rare or very rare in the Wielkopolska region, in the vast majority, natural communities and communities characteristic of the habitat 3150 – oxbow lakes and natural eutrophic water reservoirs with the *Nymphaeion* and *Potamion* communities, indicates that the investigated oxbow lakes are valuable natural objects that increase biodiversity in the River Warta valley. To preserve such valuable objects, it is necessary to protect them. The test reservoirs are already protected, because they are located in Nature 2000 sites. Unfortunately, this form of protection does not protect the oxbows against the anthropogenic influence (littering, fishing) and lowering water level, i.e. factors that cause their disappearance.

CONCLUSIONS

The test oxbow lakes are characterized by large phytocoenotic diversity. Thirty-five phytocoenoses were found in the eighteen test reservoirs. The studies also showed differences in the structure of vegetation in the right- and left-bank reservoirs, resulting from diverse characteristics of catchments of both groups of oxbows. The statistical analyses showed negative correlations between the number of elodeid, nymphaeid and helophyte communities, and a concentration of NO_2. It also showed single correlations with the size and depth of reservoirs and the highest phytocoenotic diversity in oxbow lakes with poorer trophic conditions. The rare and very rare communities reported highlight the valuable natural character of these reservoirs.

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ZBIOROWISKA ROŚLINNOŚCI WODNEJ I SZUWAROWEJ W STARORZECZACH RZEKI WARTY: RÓŻNORODNOŚĆ I WYMAGANIA SIEDLISKOWE

Streszczenie. Latem 2007 i 2008 roku prowadzono badania hydrobiologiczne w 18 starorzeczach zlokalizowanych po obu stronach rzeki Warty na odcinku od Rogalinka do wsi Czmoniec. Badany fragment pradoliny Warty w całości zlokalizowany jest na obszarach chronionych Natura 2000: Rogalińska Dolina Warty i Ostoja Rogalińska oraz Rogalińskiego Parku Krajobrazowego. Starorzecza miały różną powierzchnię, głębokość, widzialność, trofię wody, położone były w różnej odległości od koryta rzeki i różniły się rodzajem zlewni bezpośredniej (leśna, rolna). Celem badań było określenie różnorodności oraz wymagań siedliskowych zbiorowisk roślinności wodnej i szuwarowej w starorzeczach po obu stronach rzeki Warty.

W wyniku badań stwierdzono dużą różnorodność fitocenotyczną w analizowanych zbiornikach. Łącznie odnotowano 35 zbiorowisk należących do wszystkich typów ekologicznych. Wykazano także różnice w roślinności pomiędzy prawo- i lewobrzeżnymi zbiornikami, co związane było ze zróżnicowanym charakterem zlewni. Analizy statystyczne wykazały ujemne korelacje pomiędzy liczbą zbiorowisk elodeidów, nymfeidów i helofitów a koncentracją NO_2. Wykazano pojedyncze korelacje z wielkością i głębokością zbiorników oraz największe zróżnicowanie fitocenotyczne w starorzeczach o słabszej trofii. Odnotowano także zbiorowiska rzadkie i bardzo rzadkie na terenie Wielkopolski, które podkreślają cenny przyrodniczo charakter badanych zbiorników.

Słowa kluczowe: stawy śródpolne, zbiorowiska hydromakrofitów, rzadkie zbiorowiska, frekwencja