Teka Kom. Ochr. Kszt. Środ. Przyr. – OL PAN, 2013, 10, 274–283

THE EFFECT OF HUMAN IMPACT ON THE VEGETATION OF SMALL WATER BODIES IN AN AGRICULTURAL LANDSCAPE[1]

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Co-financed by National Fund
for Environmental Protection
and Water Management

Summary. Hydrobiological studies were carried out in the summer of 2010 on small water bodies of natural origin located in rural areas of the Wielkopolska region. The aim of the study was to determine the effect of human impact on the vegetation of the examined ponds. Flora as well as water and rush vegetation with reference to the physical-chemical parameters of water were investigated. A total of 42 plant species and 20 communities of aquatic and rush vegetation were found in eight studied water bodies. The ponds differed significantly both in terms of number of species (1 to 19), the number of phytocoenoses (1 to 9) and trophic conditions. The anthropogenic transformation in the direct catchment area of the ponds influenced the structure of vegetation. Based on the hydromacrophyte analysis the lowest diversity was found in the pond with the highest degree of anthropogenic transformation.

Key words: mid-field ponds, plant communities, rare community, frequency

INTRODUCTION

Human activity and its impact on the environment has existed for a long time and still increases within the area of Wielkopolska [Ratyńska 2001]. Changes in the natural environment include soil, hydrography, topoclimate, changes in land use and vegetation. Anthropopression affects the structure

[1] This study was supported by the KBN grant (Project number: N N305 042739).

of vegetation, which is directly or indirectly altered by human activity. Small water bodies make up a very precious natural element in the human-transformed landscape. These small and shallow reservoirs have an impact on the increase of agricultural biodiversity. Ponds are known to play an economic, social and ecotonal role, along with the surrounding vegetation they form a biogeochemical trap, together with mid-field stands of trees they create ecological corridors and finally they are a living place for various organisms, including rare and endangered species, and are valuable for agriculture (e.g. amphibians, insects). They also increase the local retention and play a landscape role, contributing to diversification of a monotonous agricultural landscape [Celewicz-Gołdyn *et al*. 2009]. However, in recent decades it has been found that the number of small water bodies in various Polish regions is decreasing [Paczuska and Paczuski 1997, Pieńkowski *et al*. 2004, Pieńkowski *et al*. 2010]. The disappearance of ponds is not only a Polish problem. This process has also been observed outside the country [Thyssen 2009]. The disappearance of field water bodies can be either natural or anthropogenic, however, the intensification of agriculture is one of the main factors. Ponds are destroyed by burying, plowing up to the edge of the pond and the increase of both mineral and organic fertilization which accelerates the process of eutrophication and finally the pond's overgrowing [Bielecka 2009].

Because of the role played by small water bodies in the agricultural landscape, they should be protected. A thorough investigation of the effect of human impact on small reservoirs in rural areas can help in developing a plan to protect them.

In order to determine the effect of human impact on the vegetation of small water bodies an examination of vegetation of ponds located in an agricultural catchment, and an analysis of the physical-chemical parameters that determined the grouping process of water bodies with different levels of trophic conditions (from mesotrophy to hypertrophy) were established.

STUDY AREA AND METHODS

In summer 2010 hydrobiological studies on natural small water bodies located in rural areas in four districts of the Wielkopolska region (western Poland) were conducted. Pond No. 1 was located near the village of Racot (district Kościan), No. 2 on the outskirts of the city Śmigiel (district Kościan), No. 3 in the village of Popowo Wonieskie (district Leszno), No. 4 in the village of Palędzie (Poznań district), No. 5 in the village of Modliszewko (District of Gniezno), No. 6 in the village of Sulejewo (district Leszno), No. 7 near the village of Rąbiń (district Kościan) and No. 8 in the village of Drzeczkowo (district Leszno) (Tab. 1). The basic physical parameters of water: visibility (Secchi disk), pH, electrolytic conductivity, temperature (Hanna HI 991301 meter) and oxygen saturation (field meter Elmetron CO-401) were measured directly in each pond. Moreover, water samples for analysis of chlorophyll *a*, hardness, nitrogen and phosphorus forms were also collected. Floristic inventory was made and plant communities within the basin of each pond were studied. Plant nomenclature was adopted from Mirek *et al*. [1995], phytosociological classification and severity, syngenesis and prevalence of communities were adopted from Brzeg and Wojterska [2001]. Laboratory analyses were carried out according to standard methods [Hermanowicz i in. 1999]. Trophic conditions were evaluated based on the indicators proposed by Carlson [1977].

Table 1. Location of particular water bodies

Pond	District	Geographic coordinate	
		N	E
No. 1	Kościan	52°3'36.74"	16°42'38.91"
No. 2	Kościan	52°1'1.84"	16°31'44.12"
No. 3	Leszno	51°57'23.89"	16°40'06.4"
No. 4	Poznań	52°22'3.47"	16°44'11.7"
No. 5	Gniezno	52°37'28.17"	17°36'35.9"
No. 6	Leszno	51°57'24.99"	16°38'17.11"
No. 7	Kościan	52°2'23.87"	16°51'54.69"
No. 8	Leszno	51°55'58.89"	16°39'42.31"

The studied ponds varied in size (0.05–1.6 ha), maximum depth (0.3–2.3 m) and the structure of vegetation. Based on the ratio TSI_{Tot} it was found that ponds differed mainly in respect to trophic conditions. Ponds No. 1 and 2 were mesotrophic, ponds No. 3–7 eutrophic and pond No. 8 was hypertrophic [Kuczyńska-Kippen *et al*. 2010]. Principal Component Analysis (PCA) was applied in order to determine which environmental parameters will be decisive for grouping ponds, differing in the trophic conditions of their waters.

Another aim of the study was to investigate whether differences in the number of plant communities between ponds in various districts were statistically significant. Correlation coefficients were calculated in order to determine the relationships between various environmental parameters with the total number of communities or number of communities representing particular ecological groups of plants.

RESULTS

A total of 42 plant species belonging to 20 families were recorded in the studied ponds. Plants were very unevenly distributed in particular water bodies, from one species in pond No. 8 to a maximum of 19 species in pond No. 4. Only one species – *Lemna minor* L. – appeared in six ponds and reached the highest frequency – 75%. *Typha latifolia* L. and *Phragmites australis* (Cav.) Trin. ex Steud. reached a frequency of 63%, four species (*Potamogeton crispus* L., *Ceratophyllum demersum* L., *Ceratophyllum submersum* L., *Typha angustifolia* L.) 38% and five other species (*Potamogeton pectinatus* L., *Sparganium erectum* L. em. Rchb., *Phalaris arundinacea* L., *Glyceria maxima* (Hartm.) Holmb. and *Rumex hydrolapathum* Huds.) 25%. The remaining 30 species occurred in only one water body. Analysis of flora in respect to ecological groups showed that rush macrophytes had the greatest participation, while pleustophytes and nymphaeids the lowest. In the group of 42 species, two species that are protected in Poland [Journal of Laws of 20 January 2012 No. 81] – *Nuphar lutea* and *Nymphaea alba*, were recorded, however, they occurred only as single specimens and had not built their own phytocenoses.

Table 2. Macrophyte associations and communities present in water bodies

Syntaxonomic units	A	B	C	1	2	3	4	5	6	7	8
Lemnetum minoris Soó 1927	-	NA	P	+	+	.	.	.	.	+	.
Lemnetum trisulcae (Kelhofer 1915) R.Knapp et Stoffers 1962	-	NA	C	+	.	.	.	.	.	.	.
Potametum lucentis Hueck 1931	I	NA	C	.	.	+	+	.	.	.	.
Potametum pectinati (Hueck 1931) Carstensen 1955	-	NA	C	.	.	.	+	+	.	.	.
Potametum perfoliati (W. Koch) Pass. 1964	-	NA	C	.	.	.	.	+	.	.	.
Ceratophylletum demersi Hild 1956	-	NA	P	.	+	.	+	.	.	+	.
Ceratophylletum submersi Soó 1928	V	NA	R	+	.	.	.	+	.	+	.
Ranunculetum circinati (Sauer 1937) Segal1965	I	NA	R	.	+	.	.	.	.	.	.
Polygonetum natantis Soó 1927 ex Brzeg et M.Wojterska 2001	-	NA	C	.	.	+	.	.	.	.	.
Scirpetum lacustris (Allorge 1922) Chouard 1924	-	NA	P	+	.	.	.	.	.	.	.
Typhetum angustifoliae Soó 1927 ex Pignatti 1953	-	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 Eggler1933 ex Kobendza 1948	-	X	P	.	.	.	.	.	.	+	.
Caricetum acutiformis Eggler 1933	-	NA	P	.	.	+	.	.	.	.	.
Oenantho aquaticae-Rorippetum amphibiae Lohmeyer 1950	-	NA	C	.	.	.	.	+	.	.	.
Eleocharitetum palustris Schennikov 1919 ex Ubrizsy 1948	-	NA	P	.	.	.	+	.	.	.	.
Phalaridetum arundinaceae Libbert 1931	-	NA	P	.	.	.	.	.	.	+	.
N phytocoenoses				5	5	3	5	4	3	9	1
N helophytes				2	2	1	2	1	2	6	1
N nymphaeids				-	-	1	-	-	-	-	-
N elodeids				1	2	1	3	3	-	2	-
N pleustophytes				2	1	-	-	-	1	1	-

A – degree of threat (V – possibly endangered community, I – communities of unidentified risk, /-/ – community not at risk or expanding); B – syngenesis (NA – natural auxochoric community, X – xenospontaneous community); C – frequency (P – common community, C – well spread community, R – rare community). Numbers 1–8 represent particular water bodies

The occurrence of 20 plant associations in the rank of the community (Tab. 2) was recorded in the examined ponds. Rush communities from the class *Phragmitetea australis* – 11 communities – were the most numerous. Only one community represented the class *Potametea*, alliance *Nymphaeion*, vegetation with floating leaves. In the same class, but alliance *Potamion pectinati*, six communities of submerged vegetation were recorded. The class *Lemnetea* was represented by two plant communities freely floating on the water surface. The investigated water bodies differed in respect to the number of plant communities. In pond No. 7 nine communities were found, while in pond No. 8 only one. In the remaining ponds the number of phytocoenoses ranged between 3 and 5. It should also be noted that none of the identified communities occurred in all ponds. From among the most frequently reported plant communities two rush communities – *Typhetum latifoliae* i *Phragmitetum communis* – occurred in 50% of water bodies. At the same time thirteen phytocoenoses occurred only in one pond (13% frequency). Phytocoenoses representing all ecological groups did not occur in any of the ponds. Only helophytes grew in all investigated reservoirs, while the remaining types: nymphaeids, elodeids and pleustophytes were found in ponds 1, 6 and 3, respectively.

Assessment of vegetation of the studied reservoirs based on syngenesis, frequency and protection status in the Wielkopolska region [acc. Brzeg and Wojterska 2001] showed that in the group of 20 diagnosed communities, 3 were in the status of endengered in the Wielkopolska region. *Potametum lucentis* and *Ranunculetum circinati*, which represent rare communities (R) within Wielkopolska, belong to communities of unidentified risk (I), while *Ceratophylletum submersi* is a community vulnerable to a reduction of its acreage and degenerative changes (V). The remaining plant communities in this area are common community (P) or well spread community (C). Only one community *Acoretum calami* was xenospontaneous (X), while the remaining are natural auxochoric communities (NA) (Tab. 2).

The results of statistical analyses revealed that significant differences in the number of communities between particular ponds located in various districts occurred (KW-H(3; 17) = 12.1776; $p < 0.01$). Most communities were found in ponds of the Kościan district (No. 1, No. 2 and No. 7) and the fewest communities in a pond in the Leszno district (No. 8) (Fig. 1). In order to determine which

Table 3. Correlations between number of communities (N c), number of helophytes (N h), number of elodeids (N e), number of nymphaeids (N n), number of pleustophytes (N p) and the physico-chemical parameters (nitrate – NO_3, nitrite – NO_2, ammonia – NH_4, dissolved inorganic nitrogen – DIN, conductivity – EC, dissolved organic matter – DOM, total phosphorus – TP)

Parameter	r	p
N c vs. NO_3	-0.483	0.0496
N c vs. NO_2	-0.503	0.0395
N e vs. NH_4	-0.646	0.0051
N e vs. NO_3	-0.500	0.0411
N e vs. DIN	-0.655	0.0043
N n vs. EC	-0.521	0.0318
N p vs. DOM	-0.618	0.0082
N h vs. TP	0.542	0.0246
N h vs. TRP	0.622	0.0076

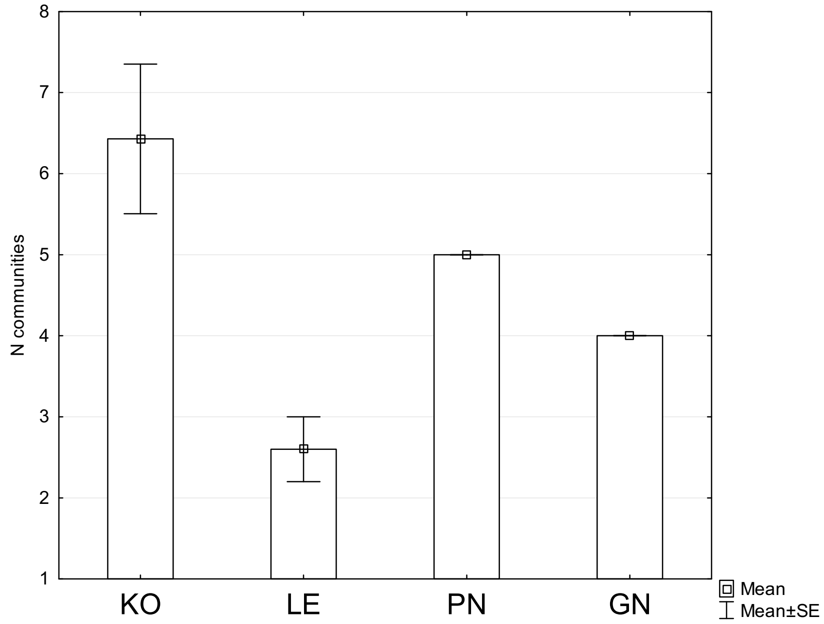

Fig. 1. Comparison of the number of communities between water in ponds of various districts: KO – Kościan district, LE – Leszno district, PN – Poznań district, GN – Gniezno district

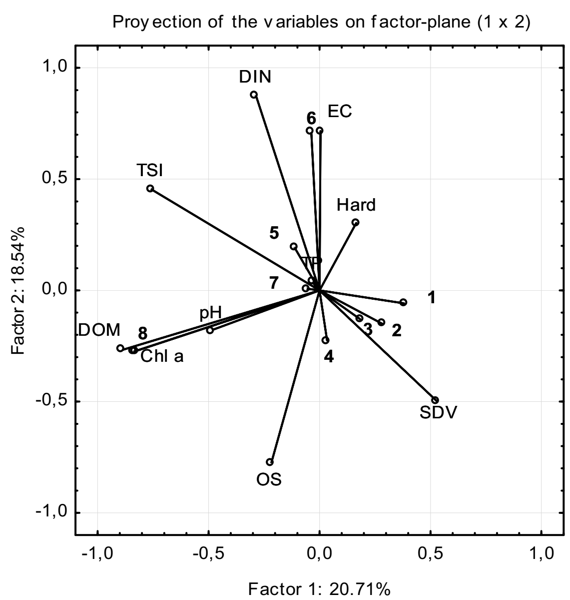

Fig. 2. PCA diagram showing the physico-chemical parameters affecting the distribution of various ponds due to the level of water fertility; Numbers 1–8 represent particular water bodies

of the parameters determined the grouping of various ponds due to the fertility of the water bodies the PCA analysis was performed. The water transparency in ponds No. 1–4 had the greatest impact on the severity of the trophic conditions according to the TSI_{Tot} index. These ponds negatively correlated with the index of the TSI, simultaneously. In turn, DOM and chlorophyll *a* concentration were the strongest factors for ponds No. 7 and 8 (Fig. 2).

Moreover, there was a negative correlation between the total number of communities, the number of plant phytocoenoses of elodeids, nymphaeids, pleustophytes and nitrogen compounds, water hardness, EC and DOM. The number of helophyte communities positively correlated with phosphorus (Tab. 3).

DISCUSSION

In the examined ponds 20 phytocoenoses representing rush and water vegetation were reported. This differentiation is of a medium phytocoenotic level for the field type of small water bodies found in the Wielkopolska region. This was also confirmed by studies carried out on 28 similar ponds located in the agricultural landscape of Wielkopolska, where the appearance of 37 communities was recorded [Nagengast 2009], as well as by studies conducted in farmland ponds surrounding Tarnowo Podgórne (Wielkopolska), where in 27 ponds the presence of 20 plant communities was recorded [Nagengast and Ostapiuk 2004]. In the group of studied water bodies, ponds in the Kościan district were least anthropogenically transformed. Two of them were of mesotrophic character and one was eutrophic. This is reflected in a greater phytocoenotic variety, so the largest number of communities was found here. However, in pond No. 8 only one community – phytocoenosis of *Phragmitetum communis* occurred. There were not even single individuals of aquatic plants recorded here. This pond was the most transformed reservoir – located in the village, on one side encased by a low wall, littered and hypertrophic. Although small reservoirs are often home to protected and rare species [Nicolet *et al*. 2004], only in one of the surveyed ponds were single individuals of two protected species *Nuphar lutea* and *Nymphaea alba* reported. They were found in pond No. 2, which was of mesotrophic character and was of relatively weak anthropogenic influence. An analysis of severity, syngenesis and prevalence of communities showed that out of all communities two – *Ceratophylletum submersi* and *Ranunculetum circinati* – are rare in Wielkopolska [Brzeg and Wojterska 2001]. They occurred in ponds of lower trophic conditions. Other phytocoenosis are frequent and common in the Wielkopolska region. The lack of a greater number of rare plant communities can attest to the negative impact of agricultural catchment.

The fact that in the investigated water bodies there was only one xenospontaneous community and the rest were of natural character emphasizes the phenomenon that the aquatic and rush vegetation is the most natural type of vegetation. Also, the number of communities itself is not a real measure of the diversity of vegetation since individual phytocoenosis in the analysed ponds are mainly single-species patches. This means that in these ponds phytocoenosis were floristically poorer compared to similar water bodies in other areas, such as the vicinity of Kołobrzeg [Bosiacka and Radziszewicz 2002] and around Tarnowo Podgórne [Nagengast and Ostapiuk 2004]. Poor floristic diversity often reflects increased human pressure. The growth of human impact in the catchment area of a reservoir causes a greater influx of nutrients which in turn leads to an impoverishment of macrophytes [Maślanko *et al*. 2011, Sikorska *et al*. 2011]. This principle has also been partly proved in the study area. The mesotrophic ponds (No. 1, 2) had the highest number of plant communities, while in the most transformed hypertrophic pond (No. 8) only one phytocoenosis was recorded. The only exception is pond. 7, where despite its high eutrophic conditions and strong anthropogenic impact, the highest number of communities – 9 – occurred. It is also the largest of the examined ponds with a mild decrease of the shoreline. Therefore, probably, rush species were able to build their phytocoenoses – six helophyte communities were found here among a total nine communities. Small patches of rush plant species, arranged in a mosaic way, occurred and this is a characteristic feature of small water reservoirs [Bosiadzka and Radziszewicz 2003]. *Ceratophylletum demersi*, occurring in this pond, is a community that reaches its optimum in highly fertilised waters [Kłosowski and Kłosowski 2001]. However, a smaller participation of *Ceratophylletum submersi* is most likely leftover from the time when the pond had lower trophic conditions.

The correlations found between the number of plant associations and certain environmental parameters also prove the influence of human impact on the degree of phytocoenotic differentiation. The increase in nitrite, nitrate, ammonia, EC or DOM reduces the number of phytocoenoses of nymphaeids, elodeids and pleustophytes (Tab. 3). The presence of ammonium ions in water is a result of agricultural pollution [Joniak 2009]. Also DOM may originate from the catchment area runoff. Only an increase in helophyte diversity was positively correlated with phosphorus. Rush plants are known to be independent of water transparency and an increase in nutrients can positively affect their growth.

CONCLUSIONS

During the examination a total of 42 plant species and 20 communities were found in the surveyed ponds. Both the majority of species and communities reached, however, a low level of frequency. It has also been shown that the number of communities – phytocoenotic diversification decreases with increasing human pressure.

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WPŁYW ANTROPOPRESJI NA ROŚLINNOŚĆ DROBNYCH ZBIORNIKÓW WODNYCH W KRAJOBRAZIE ROLNICZYM

Streszczenie. Latem 2010 prowadzono badania hydrobiologiczne w drobnych, naturalnego pochodzenia zbiornikach wodnych zlokalizowanych na terenach rolniczych Wielkopolski. Celem badań było określenie wpływu antropopresji na roślinność zbiornika. Badano florę oraz roślinność wodną i szuwarową na tle parametrów fizyczno-chemicznych wody. W badanych ośmiu oczkach odnotowano łącznie 42 gatunki roślin oraz 20 zbiorowisk roślin wodnych i szuwarowych. Zbiorniki znacznie różniły się między sobą zarówno liczbą gatunków (od 1 do 19), liczbą stwierdzonych fitocenoz (od 1 do 9), jak i trofią. Wykazano wpływ przekształceń antropogenicznych w zlewni bezpośredniej stawów na strukturę ich roślinności. Na podstawie analizy hydromakrofitów najmniejszą różnorodność stwierdzono w stawie o najwyższym stopniu przekształceń antropogenicznych.

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