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Can Reed Stands Be Good Indicators of Environmental Conditions of the Lake Littoral? A Synecological Investigation of *Phragmites australis* - Dominated Phytocoenoses

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Abstract

A comparative analysis of three regional groups of phytocoenoses dominated by *Phragmites australis* was undertaken in order to find if they reveal any interregional differentiation in the habitat (water and substratum) conditions and if the differences are followed by floristic composition. A group of 60 phytocoenoses studied in mesotrophic and (mostly) eutrophic lakes of midwestern Poland were compared to two groups investigated in moderately nutrient-rich lakes of northeastern Poland (32 phytocoenoses) and nutrient-poor lakes of northern Poland (20 phytocoenoses). Statistical analyses revealed significant habitat differences. Although the groups of phytocoenoses were studied in different regions and different types of water bodies, they occupied habitats poor in bioavailable forms of nutrients in water and organic matter content and sodium in the substratum, which is inconsistent with the general opinion concerning the reed community as indicative for the high trophy level of lakes. Floristic differences among the studied groups of phytocoenoses are not significant in phytocoenotic terms and relate more to the type of lakes than to established habitat differences. This might suggest that the habitat-forming power of *Phragmites australis* is the main factor to influence habitat properties.

Keywords: *Phragmitetum australis, Phragmites australis*, ecological differentiation, habitat, synecology, macrophytes

Introduction

Based on synecological research, a distinct linkage between plant communities – basic elements of vegetation – and their habitats was clearly established. Moreover, detailed characteristics of habitats occupied by rushes and aquatic vegetation allowed describing the bioindicator value of particular macrophyte communities in relation to water and substratum properties [1-10]. Although physical and chemical measurements provide quantitative data on the presence and levels of nutrients and other parameters, they do not give exact information on their effects on living organisms [11]. Plant assemblages might be more sensitive bioindicators than species since the ecological amplitudes of communities are narrower than those of individual species the communities consist of [12].

The common reed association (*Phragmitetum australis* (Gams 1927) Schmale 1939) belongs to the most common assemblages among macrophyte vegetation as its characteristic species, *Phragmites australis* (Cav.) Trin ex Steudel, is widely spread in the world. Ecological characteristics of this plant on an autecological, population and genetic level has been provided by many authors [13-18]. Synecological studies on reed association has been carried out so far in north-eastern and northern [3,8] as well as mid-western regions of Poland [9,10,19]. It was

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also stated that some communities belonging to so called azonal vegetation (such as aquatic vegetation) might reveal internal ecological differentiation when appearing in various ecosystems or regions expressed in both floristic composition and habitat conditions [2,12].

The aim of the present paper was comparative, habitat and floristic analysis of three groups of phytocoenoses built by *Phragmites australis* studied in different regions of Poland. The question of interest was whether macrophyte assemblage of wide ecological amplitude, such as common reed association, can be an indicator of environmental conditions.

Material and Methods

The subject of the study were habitats of 112 phytocoenoses built by *Phragmites australis* (in terms of phytosociology: association *Phragmitetum australis*, class *Phragmitetea* R.Tx. et Prsg 1942, alliance *Phragmition* Koch 1926) investigated in different types of lakes and in three regions of Poland. 60 phytocoenoses forming the first group were examined by the author of this paper in mesotrophic and eutrophic lakes of the Wielkopolska region (N=60, Wielkopolskie Lakeland, midwestern Poland). Acquired results (floristic composition and detailed habitat characteristics regarding 15 water and 12 substratum parameters) were compared to those obtained by Kłosowski [3] in mesotrophic and eutrophic lakes of the Masurian and Pomerania Lakelands (N=32 phytocoenoses, north-eastern Poland) and Szańkowski [8] in mostly oligotrophic lobelia lakes of the Pomerania region (N=20 phytocoenoses, northern Poland).

In each studied phytocoenose the mid-European Braun-Blanquet method of phytosociological relevés was applied in order to establish species composition and cover. In each phytocoenose samples of water were collected from the central part and at an intermediate depth. Samples of substratum were collected from the root-rhizome zone (according to Kłosowski [3]). Physico-chemical determinations were made immediately after sampling. The same methods were applied to each group of phytocoenoses. Determinations were verified on the basis of the ionic balance of water. The following properties were considered: water samples – pH, colour, chemical oxygen demand (COD-$KMnO_4$), ammonia nitrogen, nitrate nitrogen, soluble phosphates, sulphates, chlorides, dissolved silica, calcium, total hardness, carbonate hardness, sodium, potassium, total iron; substratum samples – pH, organic matter content, hydration, total nitrogen (Kjeldahl nitrogen), nitrate nitrogen, total phosphorus, sulphates, dissolved silica, calcium, sodium, potassium, total iron. Results were represented for all the groups of phytocoenoses by the whole range of values and so called mid – mean, which unlike the arithmetic mean is much less affected by the extreme values at large scatter of results and is a good representation of the typical values. The mid-mean was calculated after rejection of the most extreme values.

Statistical significance of the comparison was tested by the ANOVA Kruskall-Wallis H test. The hypothesis of the lack of statistically significant habitat differentiation among the groups under study was tested. The H test was followed by the Dunn posteriori test in order to find out between which regional groups of phytocoenoses statistically significant habitat differences appeared. Non-parametrical analysis was dictated by the inconsistency between the empirical distributions of abundance and the normal one (based on the Shapiro-Wilk test). In the statistical tests the concentrations of H^+ ions instead of pH were taken into account. Statistica software was applied. In order to compare analysed three regional groups of phytocoenoses with respect to all of the investigated parameters of habitats (separately for the water and substratum properties) values were standardized and trait lines were drawn [1, 5].

Floristic differences among the studied groups of phytocoenoses were listed in the present study and discussed in the context of the habitat differentiation and trophic status of lakes. Phytosociological nomenclature followed Matuszkiewicz [12].

Results

The Water and Substratum Properties of Habitats Occupied by *Phragmites australis*-Dominated Phytocoenoses in Different Regions

The results of the comparison of the water and substratum habitats occupied by the analyzed three regional groups of phytocoenoses are contained in Table 1. In the case of water properties, habitats studied in mid-western Poland revealed small amounts of nutrients (ammonia nitrogen, nitrate nitrogen, dissolved phosphates). The trait line characterizing this group of phytocoenoses (Fig. 1a) visibly indicates the lowest values of nitrate nitrogen among the studied groups. On the other hand, habitats examined in midwestern Poland were rich in dissolved organic mater (as indicated by COD-$KMnO_4$) and extremely rich in sulphates, chlorides, calcium, sodium and potassium which was also indicated by a high total hardness value. As far as calcium, hardness, colour and COD are taken into account, waters examined in lobelia lakes were extremely poor, which could be considered as the typical feature of such kind of lakes. It is clearly shown in Fig. 1a that the trait line representing this group of habitats is shifted farthest down with the exception of high H^+ ion concentration indicating the lowest values of pH. Values of such water properties, as colour, COD, calcium, total hardness, indicated intermediate trophic status of lakes in northeastern Poland where the third group of phytocoenoses was studied.

In case of the substratum properties, habitats investigated within midwestern Poland revealed the highest concentrations of organic matter (as indicated also by hydration), total nitrogen and total phosphorus in comparison to those of northern and northeastern regions (Table 1). With respect to the above-mentioned properties, the latter groups of phytocoenoses are similar to each other

Table 1. Characteristics of the habitats occupied by groups of *Phragmites australis*-dominated phytocoenoses studied in different geographical regions of Poland. Group 1 – phytocoenoses studied in northern Poland (lobelia lakes, N=20, based on Szańkowski [8]), group 2 – phytocoenoses studied in northeastern Poland (mesotrophic and eutrophic lakes, N= 32, based on Kłosowski [3]), group 3 – phytocoenoses studied in midwestern Poland (mesotrophic and eutrophic lakes, N=60, the author's own investigations). Mid-means and ranges of values. Statistical significance of differences in the ANOVA Kruskall-Wallis H test: ** p<0,01; *** p<0,001; hypothesis of the lack of significant difference rejected at p>0,05.

Property	Group of phytocoenoses		
	1	2	3
Water			
Colour (mg Pt L^{-1})***	6.9	18.2	26.2
	0 – 64	7 – 49	9 –50
COD (mg O_2 L^{-1})***	5.999	10.689	12.177
	2.63 – 21.87	6.28 – 43.43	7.80 – 36.60
NH_4^+ (mg L^{-1})***	0.208	0.289	0.171
	0.05-0.72	0.00 – 2.70	0.00 – 0.60
NO_3^- (mg L^{-1})***	0.034	0.046	0[1]
	0.02 - 0.05	0.00 – 0.16	0.00 – 0.61
PO_4^{3-} (mg L^{-1})**	0.023	0.049	0.020
	0.01 - 0.05	0.00 – 0.54	0.00 – 4.10
SO_4^{2-} (mg L^{-1})***	14.20	13.79	85.27
	1.0 – 38.0	2.6 – 29.2	0.0 – 140.0
Cl^- (mg L^{-1})***	6.62	10.89	71.90
	3.5 – 17.4	2.8 –17.7	8.0 – 154.0
SiO_2 (mg L^{-1})***	0.12	3.97	1.68
	0.04 – 0.3	0.4 – 22.8	0.0 – 16.0
Ca^{+2} (mg L^{-1})***	3.31	41.24	70.97
	1.3 – 10.2	19.2 – 67.2	2.9 – 171.0
Total hardness (mval L^{-1})***	0.51	4.15	5.25
	0.2 – 1.3	1.5 – 7.9	0.4 – 9.5
Carbonate hardness (mval L^{-1})***	0.34	3.28	2.69
	0.1 – 1.1	1.2 – 4.5	0.4 – 7.8
Na^+ (mg L^{-1})***	7.38	5.06	25.22
	2.9 - 12.2	3.0 – 7.8	1.8 – 61.0
K^+ (mg L^{-1})***	0.92	1.70	9.96
	0.6 – 2.1	0.8 – 2.7	0.6 – 55.7
Total Fe (mg L^{-1})***	0.093	0.193	0.104
	0.00 – 0.36	0.07 – 0.87	0.02 – 0.89
pH***	7.09	8.16	7.68
	6.0 - 7.6	7.1 – 8.7	6.5 – 9.0
Substratum			
Hydration (%)***	23.39	33.81	51.70
	17.3 – 68.2	16.3 – 85.7	6.5 – 94.4

Table 1 continues on next page...

Org. matter cont. (%) p>0,05	3.77	5.26	10.34
	0.8 – 21.5	0.6 – 54.5	0.30 – 89.1
Tot N (g kg $^{-1}$ dw[2])***	0.445	1.224	2.056
	0.14 – 4.76	0.21 – 11.37	0.10 – 33.42
NO_3^- (g kg $^{-1}$ dw) ***	0.013	0.012	0[1]
	0.00 – 0.02	0.00 – 0.33	0.00 – 0.03
Total P (g PO_4^{3-} kg $^{-1}$ dw)***	0.138	0.256	0.885
	0.03 – 0.24	0.03 – 0.74	0.09 – 5.64
SO_4^{2-} (g kg $^{-1}$ dw)***	0.12	1.20	0.63
	0.0 – 1.0	0.3 – 5.2	0.0 – 26.5
SiO_2 (g kg $^{-1}$ dw)***	0.02	0.24	0.06
	0.0 – 0.1	0.0 – 1.0	0.0 – 0.9
Ca^{+2} (g kg $^{-1}$ dw)***	0.07	33.14	14.57
	0.0 – 0.6	0.8 – 245.0	0.3 – 236.0
Na^+ (g kg $^{-1}$ dw) p>0,05	0.165	0.146	0.129
	0.08 – 0.31	0.04 – 0.67	0.02 – 0.99
K^+ (g kg $^{-1}$ dw)***	0.062	0.143	0.206
	0.03 – 0.75	0.06 – 1.92	0.04 – 1.86
Total Fe (g kg $^{-1}$ dw)***	0.137	0.946	1.734
	0.00 – 0.58	0.26 – 7.86	0.38 – 15.76
pH***	5.78	7.23	7.07
	5.1 – 6.3	6.3 – 7.9	6.2 – 7.9

[1]"zero" values - below detection sensitivity,[2]dw - dry weight

as shown in Fig.1b. Significantly higher concentrations of potassium and iron were also observed in the group of habitats from midwestern Poland. As long as the majority of properties are taken into consideration, the trait line representing the group of habitats studied in lobelia lakes is shifted farthest down indicating significant poverty of the substratum. However, H^+ concentration reveals the highest value indicating the lowest pH among all the groups under study. In the case of sulphates, silica and calcium, substrata examined in mesotrophic and eutrophic lakes of northeastern Poland revealed the highest concentrations. With respect to those properties, habitats from midwestern Poland represented an intermediate resourcefulness (Table 1, Fig. 1b).

The ANOVA Kruskall-Wallis H test revealed statistically significant habitat differentiation among the groups of phytocoenoses under study in the case of all the water properties and the majority of the substratum ones (Table 1). Due to the Dunn posteriori test ($p<0.05$) that followed the Kruskall-Wallis H test, among the water properties ammonia nitrogen and dissolved phosphates revealed no statistically significant differences between habitats from lobelia lakes and those from lakes of higher trophical status examined in midwestern and northeastern Poland. Such properties as colour, dissolved silica, calcium, carbonate hardness and pH differentiated all the groups of phytocoenoses from each other.

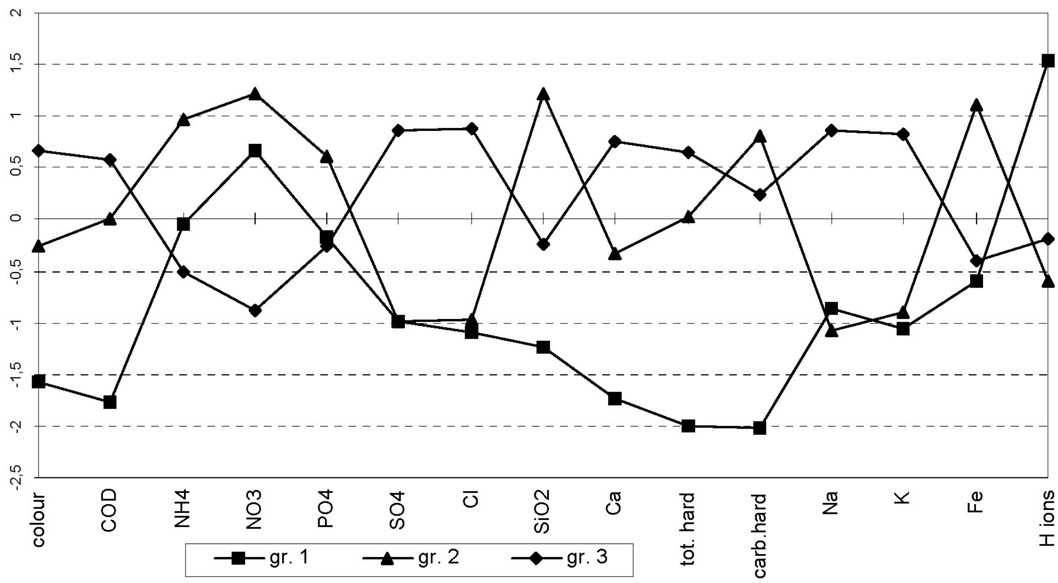
Among properties of the substratum no statistical differentiation (the Kruskall-Wallis H test) among all the groups of habitats was observed in the case of organic matter content and concentration of sodium (Table 1). In the case of hydration significant differences were found between habitats from northeastern and midwestern Poland and between those from lobelia lakes in northern Poland and more fertilized, mesotrophic and eutrophic lakes in northeastern Poland (the Dunn test, $p<0.05$). In the case of total phosphorus, sulphates and total iron concentrations in the substratum all the groups of habitats differed significantly from each other.

Floristic Composition of *Phragmites australis*-Dominated Phytocoenoses in Different Regions

The above-described habitat differentiation was associated with some minor differences in floristic composition and structure among the three groups of phytocoenoses. It seems to be noteworthy that the established differences were rather qualitative (different number of species) than quantitative (small differences in abundance of particular species). In all studied phytocoenoses *Phrag-*

mites australis sharply dominated over the rest of the species and shaped the patch physiognomy. In general, floristic differences between the groups of phytocoenoses studied in mesotrophic and eutrophic lakes of midwestern and northeastern Poland were less significant than those between these two groups and the group from lobelia lakes of northern Poland. Basic difference referred to the presence or absence as well as – at least in some cases - phytosociological constancy of species, mainly representatives of the *Phragmitetea* class and *Phragmition* alliance. However, such differences were also to be observed in the group of accompanying species. The highest number of species was noted in midwestern Poland (56), and the lowest one in lobelia lakes (28). By contrast to northern regions of Poland, in midwestern Poland *Typha angustifolia* L., revealed significantly high constancy as it occurred in 50% of phytocoenoses although its abundance in each phytocoenose was insignificant. On the other hand, in lobelia lakes *Lobelia dortmanna* L. and other representatives of the *Littorelletea uniflorae* Br.-Bl. et R. Tx. 1943 class were present among accompanying species in phytocoenoses built by *Phragmites australis.*

A



B

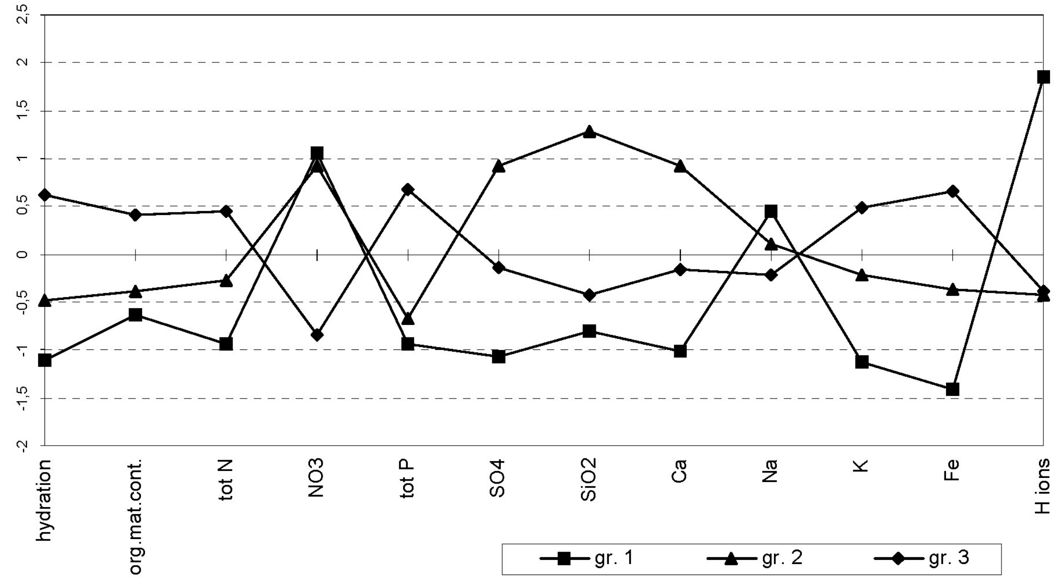


Fig. 1. The water (a) and substratum (b) properties in the habitats occupied by groups of Phragmites australis-dominated phytocoenoses studied in different geographical regions of Poland. Gr. 1 (group 1) – phytocoenoses studied in northern Poland (lobelia lakes, N=20, based on Szańkowski [8]), gr. 2 (group 2) – phytocoenoses studied in northeastern Poland (mesotrophic and eutrophic lakes, N= 32, based on Kłosowski [3]), gr. 3 (group 3) – phytocoenoses studied in midwestern Poland (mesotrophic and eutrophic lakes, N=60, the author's own investigations). Trait lines based on standardized mid-means.

Discussion

In the present study habitat and some minor floristic differences were found between three groups of *Phragmites australis*-dominated phytocoenoses studied in different types of lakes and in three different regions of Poland. Therefore, it might be assumed that the common reed association (*Phragmitetum australis*) reveals to a certain degree an internal ecological differentiation on a geographical scale. So far, this phenomenon has been described by Kłosowski [4] in the case of rare aquatic communities studied in northeastern Poland. On the contrary, studies of the internal differentiation of *Phragmitetum australis* on a local scale carried out in 30 lakes within midwestern Poland did not reveal such results [9,19].

However, floristic differences stated here seem to be more dependent on the type of water body than the habitat properties. Since these differences are rather insignificant in phytocoenotical terms, they can not be responsible for habitat differences, on one hand, and similarities, on the other, among the groups of phytocoenoses. Thus *Phragmites australis*, species building and dominating the studied phytocoenoses, might be a factor influencing the water and substratum properties as the habitat forming and stabilizing effect of emergent macrophytes (such as *Phragmites australis* or *Typha angustifolia*) on littoral habitats against water movement caused by wave action or sediment resuspension [15,16,19-21].

Although the groups of phytocoenoses under comparison revealed statistically significant differentiation with respect to the majority of the water and substratum properties, some habitat similarities, such as small amounts of nutrients in waters and low organic matter content in substrata, allow concerning the studied reed association to have a certain bioindicator value in relation to the phytolittoral habitats of lakes. However, such an indicator value as shown in this study might be unexpected since the presence of reed community in a lake is usually understood as a reaction to ongoing eutrophication. Further investigations on the seasonal variability of the habitats inhabited by the reed community and its influence on particular habitat parameters seem to be required. However, there is still a limited number of detailed habitat data on macrophyte vegetation. Only in a few research institutes are synecological studies on the rushes and aquatic plant assemblages regarding a wide variety of the habitat parameters being carried out [5 and authors cited there], although such characteristics seems to be desirable from a practical point of view. Undertaking such a comparison as provided in this study on a larger geographical scale might have cognitive and applicable results.

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