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Potametum pectinati CARSTENSEN 1955 (*Potametea* CLASS) IN THE LIMNOCREN KARST SPRING. FIRST LOCATION IN POLAND

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Abstract. Natural water reservoirs in Europe are very valuable floristic sites. Among them, springs are very important for the preservation of the biodiversity of flora in Poland. The present paper presents a community of water plants that is new to limnocren karst springs in Poland – *Potametum pectinati* Carstensen 1955 from *Potametea* class. In Europe this community in limnocren karst springs has not been found so far. The paper presents the floristic composition and the ecological requirements of this association.

Key words: water vegetation, karst , distribution, phytosociology, Central Europe

INTRODUCTION

Natural water reservoirs in Poland are very valuable floristic sites. Among them, karst springs are very important for the preservation of the biodiversity of flora in Poland [e.g., Spałek and Horska-Schwarz 2009, Spałek and Proćków 2011, Spałek *et al.* 2011]. Physical and chemical properties of the soil, its quality, and the general mineralization and physical properties of water are the main factors influencing the proper development of aquatic plant communities. Each community and each species in this community has its own habitat preferences that ifluence the overall environmental conditions. But the selection of a habitat by a species is one of the least-known ecological processes [Krebs 1994]. It is generally assumed that the choice of habitat depends mainly on the ecological amplitude of a plant community. It therefore seems desirable to study ecosystems at the level of microhabitats, in order to identify factors that limit the development or range of plant communities. Given that the quality of microhabitats, especially in aquatic environments, changes easily under strong human pressure, it can be assumed that in most cases the factors limiting the occurrence of certain species include heavier pollution, a change in the chemical content of the water, lower pH, higher water salinity, less dissolved oxygen or more nutrients in water, the eutrophication of waters, or a decrease in habitat richness. Limnocren (from Greek: *limno* – lake, *cren* – spring) is a type of spring in which water coming out of the ground is accumulated in a basin, creating a stagnant water reservoir and a water jet coming out of it. This type of spring looks like a small pond or temporary reservoir, but it is characterized by specific site conditions: relatively low and constant temperature of water (as a result of water coming out of the ground) and reservoir stability compared to spring, small temporary reservoirs [e.g., Gibert *at al.* 1994, Botosaneanu 1998, Laukötter 2000].

Potametum pectinati Carstensen 1955 was first described in Germany [Carstensen 1955]. This association occurs in various types of standing (more rarely flowing) eutrophic waters on muddy or sandy ground, among others in oxbow lakes, ponds, lakes, canals, open-pit mines [Carstensen 1955, Hilbig 1971, Ot'ahel'ová 1995, Schubert *et al.* 1995, Matuszkiewicz 2005, Šumberová 2011]. According to some authors, *Potamogeton pectinatus* does not create its own association, but rather a community [e.g., Oberdorfer 1977, Schratt 1993, Pott 1995, Rodwell 2000]. *Potametum pectinati* in limnocren karst springs has not been found so far.

Phytocoenoses of this association occur in scattered localities throughout Poland [e.g., Tomaszewicz 1979, Tomaszewicz and Kłosowski 1985, Borysiak and Ratyńska 1986, Wojtaszek 1989, Kwiatkowska-Farbiś and Wrzesień 1996, Falkowski and Solis 2003, Spałek 2004b, 2005, Falkowski and Nowicka-Falkowska 2006], although the characteristic species of *Potamogeton pectinatus* association occurs throughout the country [Zając and Zając (eds.) 2001, Zalewska-Gałosz 2001]. This association is characterized by a wide ecological amplitude and usually develops in eutrophic or mesotrophic standing waters, more rarely in slow-flowing waters on the mineral or mineral-humus grounds. Water depth in the sites where it occurs rarely exceeds 1 m, and the water pH is alkaline or neutral [Tomaszewicz 1979, Matuszkiewicz 2005].

The aim of the study was to present the current distribution, floristic composition and the ecological requirements of *Potametum pectinati* in limnocren karst springs in Poland.

MATHERIALS AND METHODS

Fieldwork was conducted during growth seasons in 2014–2016. The *Potametum pectinati* community was studied using the methods of the Zurich-Montpellier School of Phytosociology [Braun-Blanquet 1964]. Its phytosociological nomenclature and syntaxonomical appendix are based on Oberdorfer [1994]. The species names of vascular plants are given according to Mirek *et al.* [2002].

Assessment of the physical and chemical properties of the habitat was carried out during the fieldwork. The pH of the water was measured in the spring at depths of 0–20 and 20–40 cm, and in the zone of the outflow at a depth of 0–20 cm. The assessment of the physical and chemical properties of the habitat was determined in the fieldwork, when the pH of water was measured in the spring at depths of 0–20 cm and 20–40 cm, and in the zone of the outflow to the Oder River at a depth of 0–20 cm. Measurements of conductivity, the temperature of water and the O_2 content of the water were taken at the depth of 0–20 cm at the spring and at the zone of its outflow to the river with a CX 401 Elmetron multipurpose measuring device. Samples of water at a depth of 0–20 cm and samples of the bottom sediments were collected from the spring and from the outflow to the Oder River. Laboratory tests consisted of: an analysis of water, which included measurement of the CO_2 content (mg/dm^3), general alkalinity (measured by titration), SO_4^{2-} (mg/dm^3) (measured by the turbidimetric method), NO_3^-, Cl^-, NH_4^+, PO_4^{3-} – (mg/dm^3) (measured by the colorimetric method with a Slandi LF 2004 spectrophotometer), and an analysis of the bottom sediments, which included the identification of pH in the water extract (measured by the potentiometric method used in soil sciences) and the $CaCO_3$ content (mg/dm^3) (measured by the calicimeter – pressure method).

RESULTS

For the first time in Poland, *Potametum pectinati* phytocoenoses were found in a limnocren karst spring with an area of approximately 0.5 ha near the town of Krapkowice in south-western Poland – geographical coordinates 50 30.888 N, 17 57. 325 E, (Fig. 1). Phytocoenoses of this association occupy small areas, usually between 5 to 20 m^2. In most patches, the community is characterized by a single-layered and, less frequently, a double-layered structure. The double layer is dominated by *Potamogeton pectinatus* (Table 1). From 3 to 6 (on average, 5) taxa were recorded in these patches. In total, 6 plant species were recorded in the association's phytocoenoses.

Potametum pectinati occurs within an irregularly shaped shallow limnocrene karst spring, located in the distal part of the flood terrace of the Oder River. The zone of outflow of underground waters can be classified as the type occurring at the edge of a valley lying in the direct zone of the flood waters [Staśko 1984]. Alkaline sediments (pH 8.03) occur in the substratum, but sediments with a lower pH value (7.73) occur in the spring's outflow zone towards the Oder River. The reaction of this substratum shows that the nutrients are characterized by limited mobility. Laboratory analyses showed that the bottom sediments in the spring zone were abundant in calcium (44038.45 ppm Ca/kg), iron (5843.50 ppm Fe/kg), aluminum (3400.5 ppm Al/kg), and magnesium (1138 ppm Mg/kg). The remaining compounds

Fig. 1. Locality of *Potametum pectinati* Carstensen 1955 in the limnocren karst spring in Poland

Table 1. *Potametum pectinati* Carstensen 1955 in the limnocren karst spring in Poland

Relevé number	1	2	3	4	5
Date: year	2014	2015	2015	2016	2016
month	06	07	07	07	07
day	28	22	22	11	11
Cover of herb layer, %	70	65	80	80	75
Area of relevé, m^2	8	10	10	10	10
Number of species in relevé	5	5	6	3	6
Ch. *Potametum pectinati* *Potamogeton pectinatus*	2	3	3	3	3
Ch. *Potametea*					
Callitriche stagnalis	1	1	1	1	1
Callitriche hamulata	+	1	1	1	+
Callitriche verna	+	+	+	•	+
Berula erecta fo. *submersa*	+	•	+	•	+
Veronica beccabunga fo. *submersa*	•	+	+	•	+

Explanation: Ch. – characteristic species

occurred in smaller concentrations below 1 g/kg (K > Zn > Na > Pb > Ni > Cu > Cd). The sediments in the outflow zone towards the Oder River were characterized by lower concentrations of macroelements (Fig. 2) and heavy metals (Fig. 3). We found the waters to be mineralized at a level of 750 mg/dm^3, a higher level than was found during studies conducted in 1978–83 [Staśko 1984]. High mineralization and contents of sulfates, calcium, and magnesium showed that the water leaches

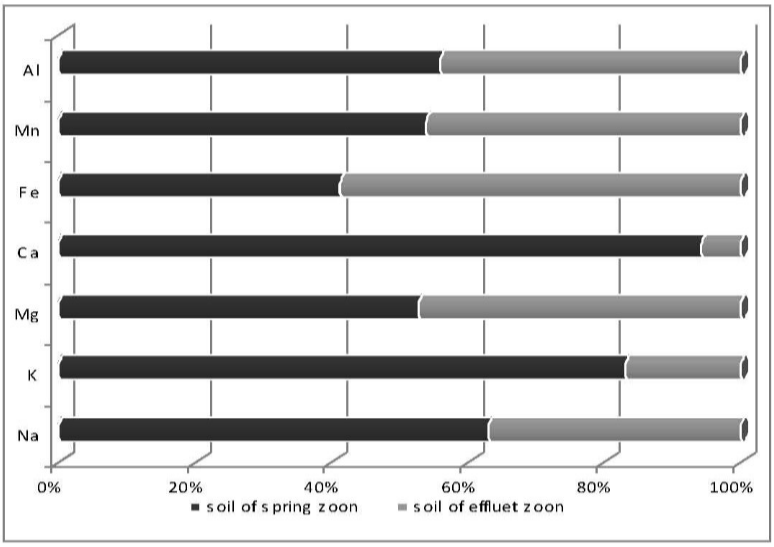

Fig. 2. The ratio of concentrations of macroelements in the sediments in the spring zone to their concentrations in the sediments in the outflow zone

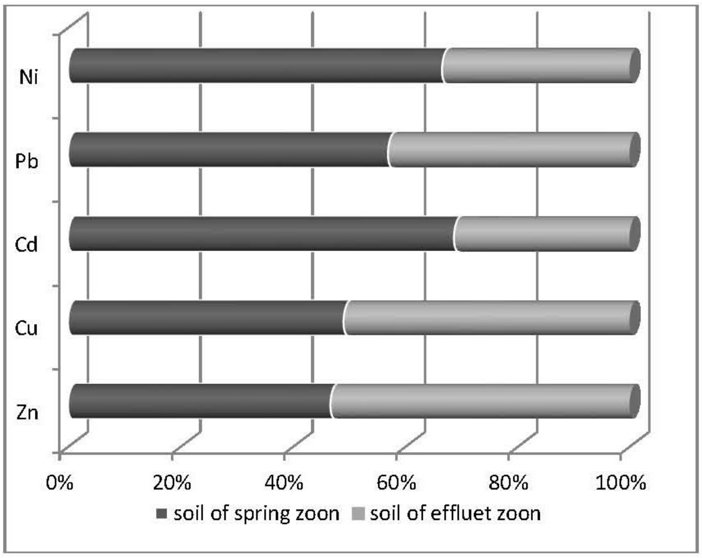

Fig. 3. The ratio of concentrations of heavy metals in the sediments in the spring zone to their concentrations in the sediments in the outflow zone

Table 2. Quality of habitat

Water	mg/dm^3												mg/dm^3		
	Na	K	Mg	Ca	Fe	Mn	Al	Zn	Cu	Cd	Pb	Ni	SO_4	NO_3	NH_4
Spring	8.01	1.24	19.41	93.85	0.02	-	0.25	-	0.02	-	-	-	102.71	34.48	0.10
Outflow zone	8.33	1.11	17.63	92.29	-	-	0.10	0.57	3.42	0.29	0.29	0.57	102.39	34.11	0.03
Sediments	mg/kg												mg/dm^3		
	Na	K	Mg	Ca	Fe	Mn	Al	Zn	Cu	Cd	Pb	Ni	SO_4	NO_3	NH_4
Spring	91.95	925.21	1130.00	44038.45	5843.50	292.02	3400.50	194.22	20.31	0.63	57.27	30.35	-	-	-
Outflow zone	53.95	186.32	1016.00	2631.12	8286.00	248.70	2674.50	221.67	21.11	0.28	43.31	15.25	-	-	-
Plants of *Potametum pectinati*	mg/kg												mg/dm^3		
	Na	K	Mg	Ca	Fe	Mn	Al	Zn	Cu	Cd	Pb	Ni	SO_4	NO_3	NH_4
Spring	17039.50	34803.85	3140.00	11724.65	1040.00	115.80	1700.00	622.40	40.50	-	64.40	37.00	-	-	-

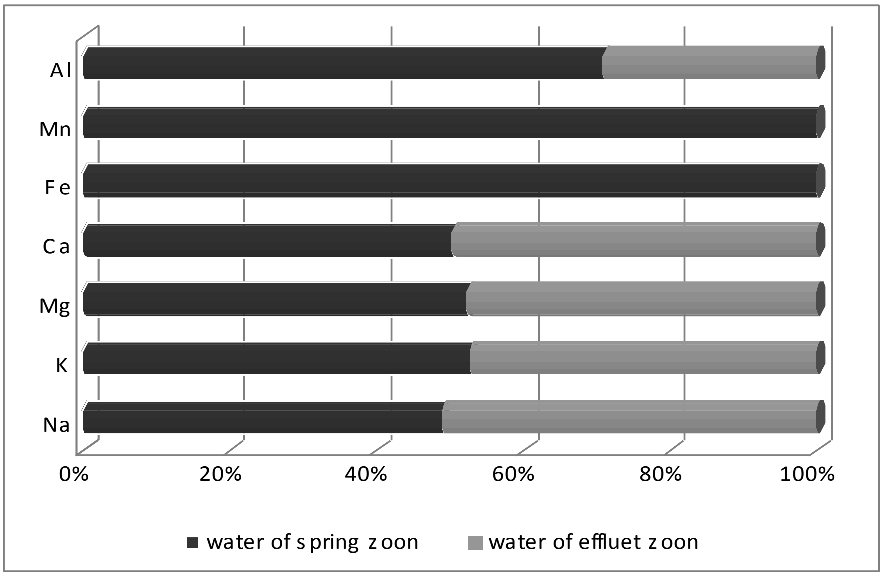

Fig. 4. The ratio of concentrations of macroelements in water in the spring zone to their concentrations in waters in the outflow zone

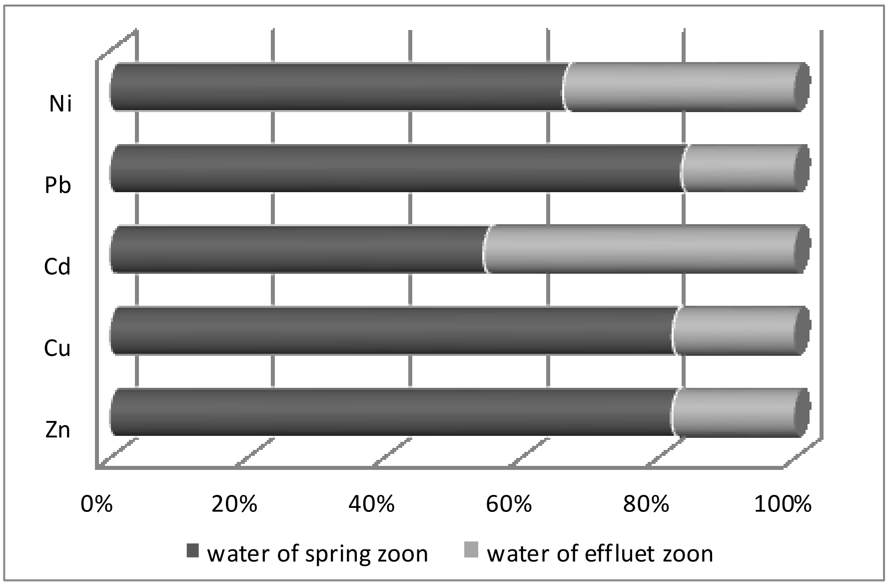

Fig. 5. The ratio of concentrations of heavy metals in water in the spring zone to their concentrations in waters in the outflow zone

calcites and dolomites at the rent of the substrate. The water we analyzed showed a slightly alkaline reaction, with the pH varying from 7.16 in the spring to 7.2 in the outflow zone. These waters were well oxygenated and the dissolved oxygen was relatively high, at 12.8 mg O_2/dm^3, around the spring, but lower in the outflow zone, at 8.27 mg O_2/dm^3. The water temperature around the spring (at the depths 0–20 and 20–40 cm) was 9.6ºC, but 9.7ºC (0–20 cm under the water level) in the outflow zone. The literature [Staśko 1984, 1992] suggests a relatively narrow range of changes in water temperature in the spring of about 1ºC. Temperatures ranged from 9.4 to 10.4ºC.

Water in the limnocrene karst spring where *Potametum pectinati* occurred is characterized by medium-level mineralization, but is rich in dissolved compounds, containing significant concentrations of macroelements, especially of calcium (93.85 mg Ca/dm^3), magnesium (19.41 mg Mg/dm^3), sodium (8.01 mg Na/dm^3), and potassium (1.24 mg K/dm^3). The remaining elements, such as aluminum (0.25 mg Al/dm^3), iron (0.02 mg Fe/dm^3), copper (0.015 µg/dm^3), zinc (0.002 µg Zn/dm^3), lead (0.0014 µg Pb/dm^3), nickel (0.0011 µg Ni/dm^3), and cadmium (0.0003 µg Cd/dm^3), occurred in trace quantities (Table 2). Our studies showed that the outflowing water had a chemical composition similar to that of the water around the spring (Fig. 4), but slightly more enriched in nutrients, namely, nitrates (from 34.1 to 34.48 mg NO_3/dm^3), phosphates (from 0.02 to 0.03 mg PO_4/dm^3) and ammonia (from 0.03 to 0.1 mg NH_4/dm^3). Small increases in indices of salinity, such as the content of sulfates (from 102.39 to 103.71 mg SO_4/dm^3) and chlorides (from 31.0 to 33.16 mg Cl/dm^3), was also noted (Fig. 5).

DISCUSSION

The condition of *Potametum pectinati* within the studied habitat may constitute evidence of highly adaptive abilities and this community's good adjustment to natural conditions. Our studies showed that the water habitat undergoes relatively small changes in its main physical and chemical parameters. Its chemical composition was similar to that found in earlier studies of the water at this spring [Staśko 1984, 1992]. The concentrations of Cl, Mg, and Ca that we found were in the same range of values. Na and K were characterized by slightly higher concentrations, with an increase at the level of 1% mval, but the greatest difference was recorded in the concentration of SO_4 in the tested water, with an increase of more than 20% mval. It also seems that physical properties of water, such as pH and temperature, which have remained constant for more than 24 years, are important for the proper development of *Potametum pectinati*.

The richness of the habitat and the chemical properties of the water indicate that this community requires relatively high concentrations of nutrients. We assume that an acid reaction in the water and substrate, a lower level of habitat richness, or greater variation in physical and chemical parameters would have led to a different development pattern for *Potametum pectinatii*. Therefore the factor limiting the range and proper development of this community be radical change the physical and chemical properties of the habitat.

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Potametum Pectinati CARSTENSEN 1955 (KLASA *Potametea*) W LIMNOKRENOWYM ŹRÓDLE KRASOWYM. PIERWSZE STWIERDZENIE W POLSCE

Streszczenie. Naturalne zbiorniki wodne są w Europie bardzo cennymi obszarami pod względem florystycznym. Wśród nich ważne dla zachowania różnorodności biologicznej flory w Polsce są źródła. Niniejsza praca przedstawia pierwsze w Polsce stanowisko *Potametum pectinati* Carstensen 1955 z klasy *Potametea* w limnokrenowym źródle krasowym. Dotychczas zespól ten nie był notowany w tego typu siedlisku w Europie. W artykule przedstawiono skład florystyczny i wymagania ekologiczne tego zespołu.

Słowa kluczowe: zbiorowisko wodne, kras, rozmieszczenie, fitosocjologia, Europa Środkowa