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New records of *Chara connivens* P. Salzmann ex A. Braun 1835 – an extremely rare and protected species in Polish brackish waters

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Abstract

The stonewort *Chara connivens* was rediscovered in the Vistula Lagoon in 2011, almost 35 years after its last record. In 2012, the species was recorded for the first time in the Szczecin Lagoon. *Chara connivens* occurred at shallow (0.5–1.2 m) sandy-muddy and muddy bottoms of small embayments. In the Vistula Lagoon, the stonewort was represented by single small specimens, while in the Szczecin Lagoon, it formed dense and extensive patches.

Keywords: *Chara*; rare species; Vistula Lagoon; Szczecin Lagoon; Baltic

Introduction

Charophytes are a group of macroscopic green algae represented by 314 species [1] assigned to the family Characeae within the phylum Chlorophyta; alternatively, they are treated as a separate phylum, the Charophyta [2]. The occurrence of most of the Characeae species in Europe is limited to clear, freshwater lakes of low fertility [3–8]. In response to increasing trophic status and the associated light limitation, many charophytes have therefore become rare, and are treated as sensitive bioindicators of water quality [6,9]. Although the number of sites with abundant charophyte vegetation has decreased, these macroalgae are widely distributed in different types of aquatic environments throughout the world. Due to their ability for ion regulation and osmotic adjustment, a set of charophyte species, commonly known from freshwaters, can occur in brackish coastal lagoons, as shown for the Baltic Sea [10].

In brackish waters, charophytes experience changes in osmotic pressure and mineral composition [7]. A brackish environment unique on a global scale is the Baltic Sea, the world's largest brackish water body [11]. The variety of the Baltic coast types gives rise to diverse and specific biocoenoses. Among submerged algae, a number of freshwater and brackish charophyte species were identified to represent five out of six genera within the family of Characeae [10]. Among the rarest brackish charophytes, *Chara connivens* P. Salzmann ex A. Braun 1835 exemplifies those species whose distribution has been reported to have greatly declined [12,13].

Chara connivens is widely distributed, with records known from Europe, Africa and Northern Asia [6,12,14–16]. Within Europe, *C. connivens* was recorded in the western European maritime regions, along the coasts of the Mediterranean and the Baltic Sea, and in inland saline waters of central and southern Europe [4,6,12]. In Poland, historical records of the species are available for the Gulf of Gdańsk [4] and for the Vistula Lagoon [17]. Currently, *C. connivens* has a status of a strictly protected species. In the "Red list of plants and fungi in Poland", published in 2006 [18], the species was assigned to the category Ex, i.e., extinct or probably extinct species.

The present paper reports new records of *C. connivens* from the Vistula and the Szczecin Lagoons. The Vistula Lagoon observation is a rediscovery of *C. connivens* after almost 35 years of the previous record, while in the Szczecin Lagoon this species has never been noted so far.

Material and methods

The occurrence of *C. connivens* was evidenced in the Polish parts of the Vistula and Szczecin Lagoons (Fig. 1) during the vegetation studies performed on 6 July 2011 in the Vistula Lagoon and on 31 July and 14 August 2012 in the Szczecin Lagoon. The distribution and species composition of aquatic vegetation was determined by direct observations and from samples collected with an anchor. Additionally, in the Vistula

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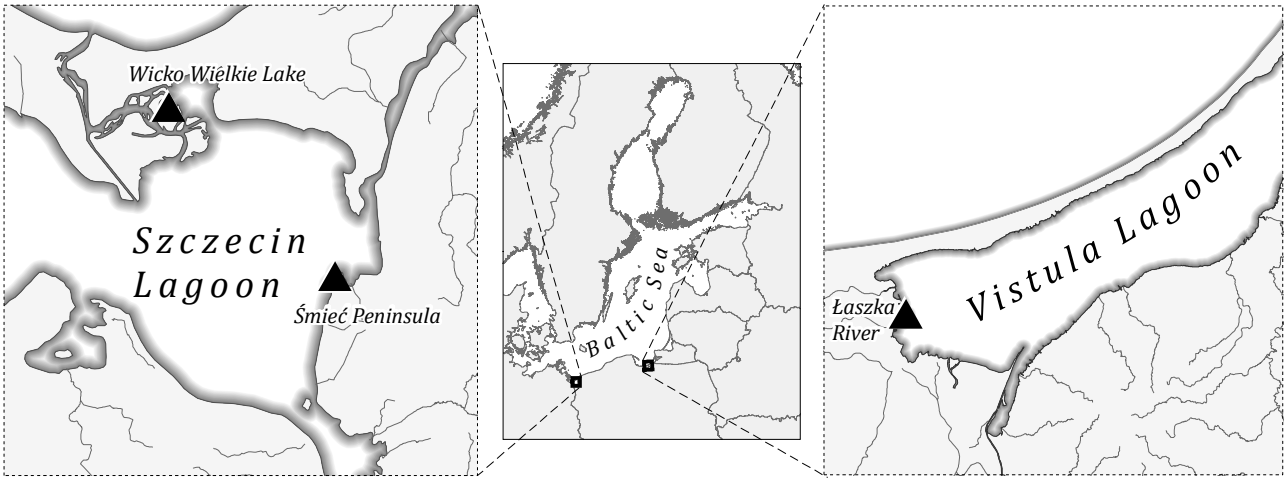

Fig. 1 Sites of *C. connivens* occurrence in the Szczecin and Vistula Lagoons.

Lagoon the floristic data collection was supplemented with measurements of water conductivity and temperature taken with a portable CTD probe.

Results and discussion

Characteristics of individuals

Chara connivens [syn. *Chara globularis* f. *connivens* (P. Salzmann ex A. Braun) R.D. Wood 1962] is a small alga, usually up to 15 cm long, rarely longer (25–50 cm) [4,12,13,15,19]. The slightly encrusted and slender thalli are delicate green and lustrous [4]. Sterile specimens of *C. connivens* are very similar to those of *C. globularis* Thuill. [15] due to presence of triplostichous stem cortex (usually isostichous or prime cells slightly larger than the secondaries) with lacking or rudimentary spine cells [4] and two rows of rudimentary stipulodes (uppers slightly larger than lowers or all imperceptible).

The features important in distinguishing the two species include the branchlets (6–10 in a whorl composed of 6–13 segments each, out of which the terminal 1–2 celled segment is ecorticate) which in *C. connivens* are strongly incurved in fertile male specimens, often also in fertile female individuals [4,6,12,15]. This feature is marked on the photographs of individuals from the Szczecin (Fig. 2) and Vistula (Fig. 3) Lagoons. Additionally, the axial internodes are very long, up to 6 times as long as the branchlets [12]; this was observed in our collections (Fig. 3). The most important distinguishing trait is that *C. connivens* is dioecious, while *C. globularis* is monoecious. In *C. connivens*, antheridia and oogonia develop at the lowermost 1–4 and 1–3 branchlet nodes, respectively [4]. The red solitary antheridia of up to 1 mm in diameter in *C. connivens* are larger than those in *C. globularis* [12,16]. The oogonia are up to 1.1 mm long and the oospores are dark. The specimens collected in the two lagoons showed the characters described above, typical of the vegetative thallus parts of *C. connivens*. In addition, besides sterile specimens, both lagoons yielded fertile male specimens which were more abundant in the Szczecin Lagoon (Fig. 2), where fertile female individuals were found as well.

Characteristics of *Chara connivens* sites

On 6 July 2011, *C. connivens* was found in the western part of the Vistula Lagoon (Fig. 1), on sandy mud at a depth of 1.1 m. The area was partially isolated by abundant monospecific assemblages of emergent vegetation, particularly *Phragmites australis* (Cav.) Steud. and *Schoenoplectus lacustris* (L.) Palla. As the site is shallow and the water dynamics is low, the water column temperature was high (19.5°C). The site is located 2 km away from the nearest river mouth; the riverine inflow resulted in low salinity (0.8 psu). The water was transparent down to the bottom; however, it was not possible to examine the submerged vegetation distribution from the shipboard as the bottom was densely covered by the filamentous green algae *Cladophora* sp., *Oedogonium* sp. and *Rhizoclonium riparium* (Roth) Harvey (those accounted for 90% of the biological material collected). The site supported a high diversity of macrophyte species occurring as single and small-sized specimens. They were dominated by *Potamogeton pusillus* L. (scoring 3 in the cover-abundance scale), young specimens of *Sparganium emersum* Rehmann (3) and *Stuckenia pectinata* (L.) Børner (2). Stoneworts such as *Chara tomentosa* L., *C. contraria* A. Braun ex Kützing, and *C. globularis* co-occurred in small quantities (1). *Chara connivens* was assigned to the category of the least numerous species (r), along with *C. aspera* Detharding ex Willdenow, *Ceratophyllum demersum* L., *Myriophyllum spicatum* L., *Zannichellia palustris* L. and *Nitellopsis obtusa* (N.A. Desvaux) J. Groves. In the 1970s, single specimens of *C. connivens* were reported from the same area by Pliński et al. [17].

In 2012, two sites supporting *C. connivens* were identified in the Szczecin Lagoon. The first site (visited on 31 July) was located in a small cove in the western part of Wicko Wielkie Lake, the other site (visited on 14 August) was situated off the western shore of the Śmieć Peninsula (Fig. 1). The first site, with muddy and sandy-muddy bottom and an average depth lower than 1 m was virtually entirely vegetated by a dense patch of elodeids represented by *Potamogeton perfoliatus* L., *Stuckenia pectinata*, *Potamogeton crispus* L., *Elodea canadensis* Michx., *Ceratophyllum demersum* and *Myriophyllum spicatum*. *Chara connivens* formed dense patches in the southern and south-western parts of the cove,

Fig. 2 A male *C. connivens* collected in the Szczecin Lagoon. 1 – main axis (stem) with triplostichous isostichous cortex; 2 – a node with a double whorl of rudimentary stipulodes; 3 – a male gametangium (antheridium) only, showing the dioecious character; 4 – an incurved branchlet; 5 – an ecorticate terminal segment of the branchlet.

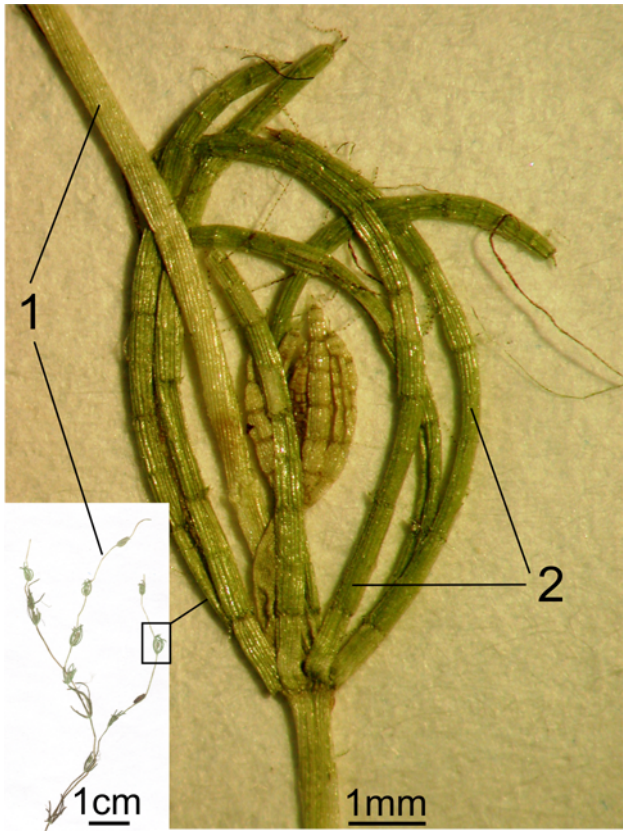

Fig. 3 A *C. connivens* specimen from the Vistula Lagoon. 1 – an internode of the main axis (stem), usually longer than branchlets; 2 – an incurved sterile branchlet. The specimen's thalli are delicately green and lustrous as described by Dąmbska [4].

at a depth of 0.5–1.2 m, frequently in a close proximity to the shore and the reed belt. The area covered by *C. connivens* was about 750 m long and up to a few tens of meters wide. Single specimens were encountered as admixtures to other elodeids throughout the cove. The site supported both male and female individuals, the first being distinctly more abundant (at a 3:1 ratio). The male specimens occurred throughout the depth range, the females were present at larger depths (about 1 m) only. When growing abundantly, *C. connivens* forms a community that, in terms of phytosociological attempt to vegetation study [20], is classified as *Charetum conniventis* Velayos et al. 1989 association, with *C. connivens* to be both diagnostic and dominant species [19]. In the cited work, *Charetum conniventis* was classified within I category of threat – vague threat, no threat [19].

The other site was a shallow (depth of about 1 m), muddy embayment, distinctly set off from the Szczecin Lagoon by the course of the shoreline and a dense, wide belt of *P. australis*. The shores were lined by patches of nympheids (*Nuphar lutea* L., *Nymphaea alba* L., *Hydrocharis morsus-ranae* L.) and pleuston species (*Lemna minor* L., *L. gibba* L., *L. trisulca* L.) The central part of the embayment supported an assemblage consisting of *Stratiotes aloides* L. accompanied by *Elodea canadensis*, *Myriophyllum spicatum*, and covered densely by *Lemna trisulca*. The easternmost part of the embayment was found to host a few scattered patches of *C. connivens* – exclusively female individuals.

This paper provides information on new stands of *C. connivens*, an extremely rare and protected stonewort species which has been, for many years, considered to be extinct. Interestingly, following the investigations reported here, the species was found in other localities in both lagoons in 2012 [19]. The cited authors suggested that the species' distribution in Poland can be wider (not only coastal but also saline inland waters) and proposed to change the category of threat of *C. connivens*, species formerly considered as extinct, to LC category – the least concern species. In our opinion such a significant shift in category of threat is disputable and premature due to the very few records. Nevertheless, similar conclusions on a possibly wider distribution of the species have been recently drawn for the Estonian and Swedish coastal waters [21,22].

The fact that *C. connivens* was rediscovered in the Vistula Lagoon (eutrophicated water body), might have resulted from the natural ability of charophytes to survive in unfavorable environmental conditions, probably via their oospore bank in the sediments. Under favorable conditions, oospores can germinate even after decades [23]. During the last few years water column phosphorus concentrations in the Vistula Lagoon have declined [24]. It is known that under lower phosphorus concentrations and improved light

conditions charophythes recover their meadows [25]. New sites of charophytes, like in the case of Szczecin Lagoon, can be established not only through vast floristic studies but, interestingly, also by animals, particularly by birds distributing oospores over considerable distances in their intestinal tracks [7].

Considering the findings presented in this paper, it can be concluded that *C. connivens* requires further field studies. Since both Vistula and Szczecin Lagoons still experience a strong anthropogenic pressure (eutrophication), it is essential to identify the species' distribution for its preservation and potential conservation actions.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: designing and performing field studies: PB, AW; species identification: PB, AW, MP, IB; photographs: MP, AW; writing of the manuscript: PB, MP, AW, IB.

Competing interests

No competing interests have been declared.

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