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Distribution and abundance of stoneworts (Charales) in the Kashubian Lakeland (NW Poland) – data collected so far and some implications

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Abstract: This work contains a list of currently known stands of 13 Charales species occurring in 63 lakes in the Kashubian Lakeland. *Chara fragilis* and *Chara tomentosa* most often grow in hard-water lakes, whereas *Chara delicatula* and *Nitella flexilis* can be found in soft-water lakes. The biggest number of stands is situated in the middle and southern parts of the Lakeland, i.e. in the area of terminal moraines and outwash plains from the latest glaciation. In the Kashubian Lakeland over half of the lakes with Charales are burdened with various effects of human pressure: 30% of the lakes are heavily exploited for recreation purposes; 20% of them undergo the process of eutrophication as a result of arable farming in their catchments; and 15% are under threat of humification. In an era of transformations caused by human intervention in ecosystems, the analysis of their flora's condition is as important as the evaluation of physical and chemical features of water bodies.

Key words: Charales, *Chara*, *Nitella*, distribution, Kashubian Lakeland

1. Introduction

The Kashubian Lakeland is situated in the north-west of Poland (Fig. 1) in the area of the latest (Baltic) glaciation. It covers about 3000 km^2 and includes almost 600 lakes (including only those with an area of more than 1 ha). It is one of the regions of Poland characterized by the highest lake density, i.e. the ratio between the area of lakes and the area of the region (Augustowski 1979). All the trophic types of lakes occur in this area: oligotrophic, α, β-mesotrophic, eutrophic and dystrophic. Oligo-, meso- and distrophic lakes are relatively numerous, while the remaining ones are less abundant. Lakes of the Kashubian Lakeland differ not only in terms of trophy but also water hardness, i.e. the content of dissolved salts, especially calcium (Piotrowska 1977; Szmeja 1998).

In the area under study the distribution and population abundance of stoneworts were not examined in detail. The information concerning this group of plants comes mainly from studies on other issues. A lot of attention was devoted to the flora of oligo- and mesotrophic soft-water lakes with isoetids such as *Lobelia dortmanna* L., *Isoëtes lacustris* L., *Littorella uniflora* (L.) Asch. (Krawiecowa 1954; Dąmbska 1965; Szmeja 1980, 1996; Szmeja & Clement 1990) and Bryophyta (Gos *et al*. 1998; Gos & Banaś 1999). However, hard-water lakes with charophytes were described much less frequently (Dąmbska 1955, 1959). The water in the latter group of lakes contains a fairly large amount of calcium carbonate, which results in its neutral or alkaline pH and its high electrolytic conductivity. Taking macrophytes into consideration, the coexistence of Charales and Cormophyta is the common feature of the vegetation in hard-water lakes (Dąmbska 1966; Szmeja 2000). Nowadays there is an urgent need for making a complete inventory of these lakes and their flora. It should be mentioned that stoneworts occur in fresh, brackish and salt waters, e.g. in bays of the Baltic Sea, both stagnant and flowing. They can be found not only in water bodies, but also in rivers and flood control ditches. They occur both in soft- and hard-water lakes of various nutrient levels. However, they are particularly numerous in hard-water lakes (Krause 1997).

In the Kashubian Lakeland, like in other regions of Poland and Europe, stoneworts are becoming a rare group of water plants, above all, due to their high susceptibility to various forms of human pressure on lakes.

There are 34 species of Charales in Poland (Gąbka & Pełechaty 2004). All of them are on the list of threatened plants in Poland (Siemińska *et al.* 2006), and 20 species are protected.

The aim of this work is to present the list of the currently known stands of stoneworts (lakes with this group of species) in the Kashubian Lakeland and to estimate the population abundance on the basis of information collected until 2005. In the future, these data can be used to analyse range structures and dynamic tendencies of Charales populations in this part of Poland or Europe.

2. Methods

The list of stands was compiled on the basis of works published after 1950, herbaria, the author's own research results and data collected in the Department of Plant Ecology of Gdańsk University between 1995 and 2005. A given species' stand is a lake. As far as lakes consisting of more than one basin are concerned, a separate basin is considered as a stand. Lake names were taken from the Catalogue of Polish Lakes (Choiński 1991) and maps with a scale of 1: 100 000. Some unnamed water bodies which had been included in the Catalogue were given names used by local inhabitants and put in quotation marks. After each lake name, its number in the Catalogue was given in brackets in order to simplify the location of stands. The borders of the Kashubian Lakeland were adopted from Augustowski (1979).

In total 63 lakes were included in the list, more than half of them being visited between 1995 and 2005. Data concerning population size of individual species, i.e. their abundance in a lake, were only presented for lakes visited by the author herself. The following scale of population abundance in a lake (in a stand) was used: (s) sparse – individuals are scattered and do not form aggregations; (n) numerous – a big number of individuals forming clusters; (m) massive – very large numbers of individuals in extensive aggregations in many places in the littoral zone.

3. Results and discussion

Stonewort stands are scattered in the whole area of the Kashubian Lakeland (Fig. 1). In the northern part of the region there are many soft-water lakes, whereas in the central and south-western parts hard-water ones dominate. In total 13 species were found in the Kashubian Lakeland, including 9 species of the genus *Chara*, 3 of the genus *Nitella* and 1 of the genus *Nitellopsis*. They constitute almost half (40%) of the number of these plant species in Poland. The following ones belong to the most common species: *Nitella flexilis* (26 stands), *Chara tomentosa* (24), *C. delicatula* (21) and *C. fragilis* (20). Two species (*Nitella flexilis* and *C. delicatula*) occur in soft-water lakes together with isoetids. Most stands of these species were found in lobelia lakes (77% and 57%, respectively), in isoetid patches or in the deep littoral zone together with bryophytes. The remaining Charales most often grow in hard-water lakes and form their own aggregations or clusters with Cormophyta. As far as hard-water lakes are concerned, *C. tomentosa* (24 stands) occurs most often. *C. aspera* (11), *C. rudis* (9), *C. contraria* (6), *Nitellopsis obtusa* (5) and *C. intermedia* (4) are less often found. *Nitella mucronata* (2), *N. opaca*, *C. hispida* and *C. polyacantha* (1) are rare.

Stonewort stands connected with lobelia lakes, where stoneworts grow together with isoetids, and in the deep littoral zone with bryophytes, are especially precious. In Poland, communities with such a structure occur exclusively in Pomerania, most of them being situated in the Kashubian Lakeland. Stands of *Nitella opaca* and *C. polyacantha*, extremely rare species throughout the country as they are, are also precious (see Gąbka & Pełechaty 2003).

So far, an initial analysis of the abundance of half (64) of 131 stonewort populations presented on the list (see Appendix) has been carried out. Small populations, formed by sparse individuals, represent one third of this number. In the remaining (70%) populations stoneworts are numerous or occur in massive numbers.

Lakes with stoneworts are subject to various forms of human pressure. Agriculture, urbanisation of lake shores, inclusion of lakes in drainage systems of peatlands, and developing tourism and recreation facilities exert a significant influence on the species diversity of this plant group as well as on the population abundance of individual species. It is estimated that 30% of lakes with stoneworts are heavily exploited for recreation purposes, 20% undergo the process of eutrophication due to arable farming in their catchments, and 15% are under threat of humification.

This human-induced pressure on lakes where stoneworts can be found may result in the extinction of their populations. In many populations in the Kashubian Lakeland regression is in progress, i.e. their density decreases and population home ranges move to shallow waters (Bociąg 2000). The disappearance of stoneworts in the processes of lake eutrophication and humification was recorded in scientific literature (incl. Ozimek & Kowalczewski 1984; Blindow 1992; Bociąg 2000). These plants are commonly considered to be sensitive to habitat changes. They have become an increasingly rarer group of plants, which was confirmed in the studies of lakes in Poland (Polakowski *et al.* 1973; Ozimek & Kowalczewski 1984), Germany (Schmidt 1981), south-western Sweden and Norway (Henriksen *et al.* 1988).

The Environment Minister's Regulation from 2004 (L.J. 04 N°168, pos. 1764) is the legal basis for the full

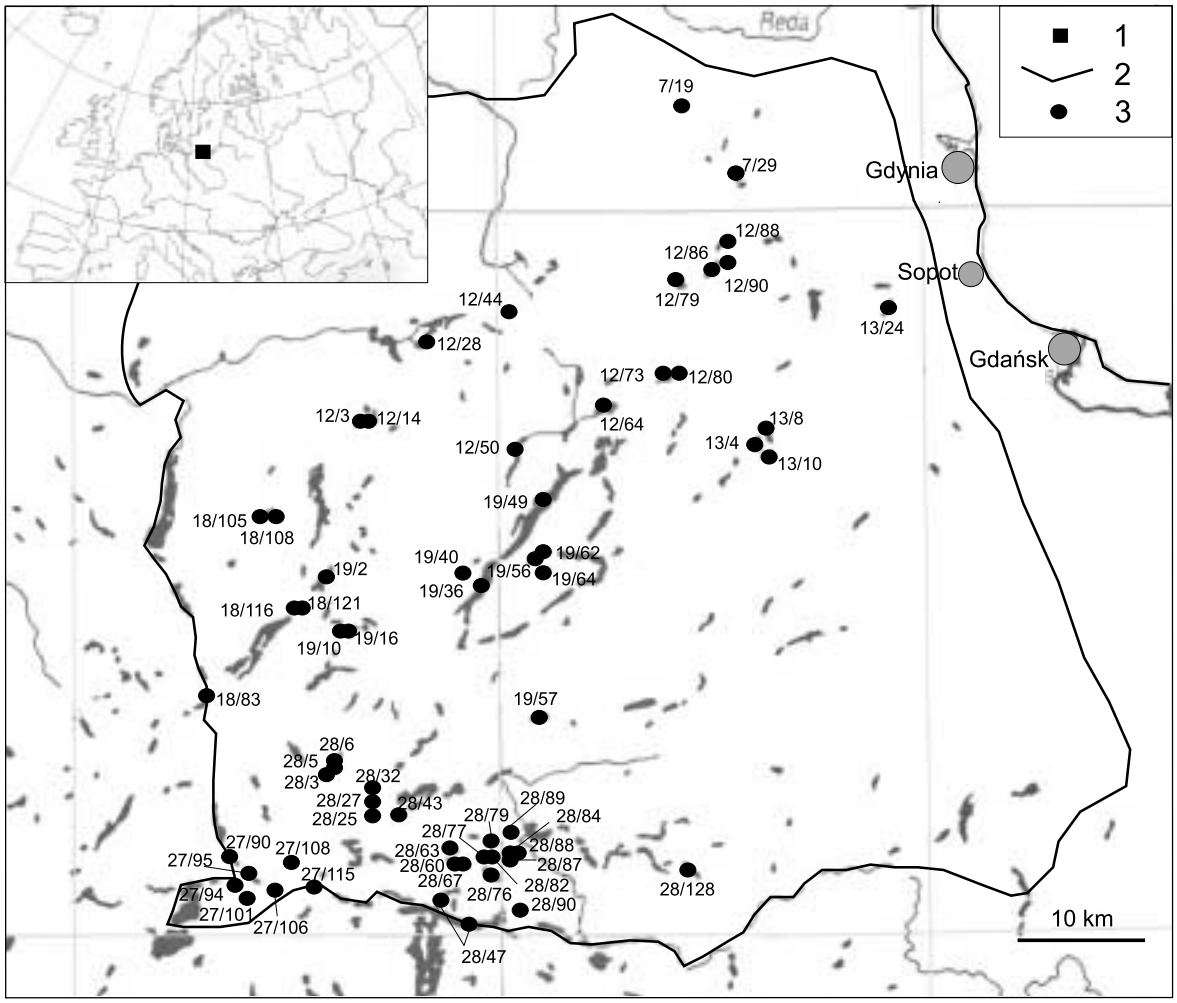

Fig. 1. Stands of stoneworts and location of the Kashubian Lakeland
Explanations: 1 – location of the Kashubian Lakeland; 2 – borders of the Lakeland (from Augustowski 1979); 3 – lakes: 7/19 Ustarbowskie; 7/29 Bieszkowickie; 12/3 Miemino; 12/14 Długie; 12/28 Junno; 12/44 Kamienne; 12/50 Wielkie; 12/64 Łapalickie; 12/73 Białe; 12/79 Otalżyno; 12/80 Czarne; 12/86 Wycztok (Wysoka); 12/88 Kamień; 12/90 Brzeżonko; 13/4 Sitno; 13/8 Głębokie; 13/10 Karlikowskie; 13/24 Wysockie; 18/83 Glinowskie; 18/105 Chojnackie; 18/108 Warleńskie; 18/116 Moczadło; 18/121 Kczewo; 19/2 Węgorzyno, 19/10 Unnamed, W of Lake Ostrowickie; 19/16 Ostrowickie; 19/36 Raduńskie Górne; 19/40 'Żuromińskie'; 19/49 Raduńskie Dolne; 19/56 Bukrzyno Małe; 19/57 Dobrogoszcz; 19/62 Bukrzyno Duże; 19/64 Kamionka; 27/90 Małe Sarnowicze; 27/94 Krampe; 27/95 Wielkie Sarnowicze; 27/101 Radolino; 27/106 Duży Zbełk; 27/108 (N part) Unnamed, S of Lake Trawiki; 27/108 (S part) Unnamed, SW of Lake Trawiki; 27/115 Słone; 28/128 Duże; 28/3 Skrzynki Duże; 28/5 Skrzynki Małe; 28/6 Karpno; 28/25 Płocice; 28/27 Kułkówko; 28/32 Wielkie Płocice; 28/43 Sominko; 28/47 (N part) Gołuń; 28/47 (NE part) Jelenie; 28/60 Kramsko Małe; 28/63 Kramsko Duże; 28/67 Białe near Wąglikowice; 28/76 Strupino; 28/77 Mieliste; 28/79 Długie near Juszki; 28/82 Głęboczko; 28/84 Wielkie Oczko (Duże Oczko); 28/87 Małe Oczko; 28/88 Zakrzewie; 28/89 Drzędno; 28/90 Kotel

protection of 20 stonewort species in Poland including *Nitella opaca* and *Chara polyacantha*, which occur in the Kashubian Lakeland. According to the Habitat Directive, 'hardwater oligo- and mesotrophic lakes with underwater stonewort mats', i.e. lakes in which large stonewort populations occur, should be protected (Piotrowicz 2004). At present, in the Kashubian Lakeland no lake with submerged vegetation dominated by stoneworts is a reserve. Such lakes are not within the network of protected areas Natura 2000 either. Undoubtedly, this results from the insufficient knowledge of this group of lakes in the region.

In the Kashubian Lakeland stoneworts from 30 lakes were reported up to 1980. After 2000, as a result of the research into lake flora which began at that time, the number of lakes increased to 63. The list of these lakes is still incomplete. This research is still in progress in this region and it is going to be continued.

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Appendix: A list of stands of stoneworts (Charales) in the Kashubian Lakeland (NW Poland)

Nitella flexilis (L.) Agardh

Lakes: Białe (12/72) Gałka 2004 m; Bieszkowickie (7/29) Szańkowski 1998; Brzeżonko (12/90) Dąmbska 1965; Czarne (12/80) Gałka 2004 c; Długie (12/14) uam 1955, Dąmbska 1959; Dobrogoszcz (19/57) Szańkowski 1998; Drzędno (28/89) Szmeja 1980; Wielkie Oczko (28/84) Szmeja 1980; Glinowskie (18/83) Dąmbska 1959; Głęboczko (28/82) Szmeja 1980; Kamienne (12/44) uam 1959; Kamień (12/88) uam 1955, Dąmbska 1959, 1965, ug 1995 s; Karlikowskie (13/10) Szańkowski 1998, aut. 2002 s.; "Kczewo" (18/121) Dąmbska 1965; Małe Oczko (28/27) Szmeja 1980; Miemino (12/3) Dąmbska 1965, aut. 2004 not found; Moczadło (18/116) aut. 1998 s; Otalżyno (12/79) Dąmbska 1965, Szańkowski 1998; Sitno (13/4) uam 1959; Skrzynki Duże (28/3) aut. 1998, 2003 n; Ustarbowskie (7/19) uam 1955, Dąmbska 1955, 1959, 1965, 1966, ug 1995 s; Warleńskie (18/108) uam 1955; Wysockie (13/24) uam 1955, Dąmbska 1963, aut. 2005 not found; Wycztok (12/86) Dąmbska 1965, 1966, aut. 1997 s; Zakrzewie (28/88) Szmeja 1980, ug 1995, aut. 2002 n; "Żuromińskie" (19/40) aut. 2000 s.

Nitella mucronata A.Br.

Lakes: Biale (12/73) Gałka 2004 s; Male Oczko (28/87) Szmeja 1980.

Nitella opaca Agardh

Lake Gleboczko (28/82) Szmeja 1975 unpd.

Nitellopsis obtusa (Desvaux) J. Groves

Lakes: Bukrzyno Małe (19/56) aut. 2003 n; Bukrzyno Duże (19/62) aut. 2003 n; Raduńskie Dolne (19/49) aut. 2005 n; Raduńskie Górne (19/36) Bociąg, Arendt 2005 n; Wielkie Płocice (28/32) aut 2003.

Chara aspera (Deth.) Willd.

Lakes: Białe (12/73) Bociąg 2000, Gałka 2004 n; Białe near Wąglikowice (28/67) Szmeja 1976 unpd.; Głębokie (13/8) uam 1955, Dąmbska 1955; Kamienne (12/44) uam 1959; Kotel (28/90) Szmeja 1976 unpd., aut. 1997 m, Gąbka 2004 unpd.; Kramsko Małe (28/60) Szmeja 1975 unpd., aut. 2001, Balcewicz 2004 n; Łapalickie (12/64) uam 1955, Dąmbska 1959; Ostrowickie (19/16) Balcewicz 2004; Sitno (13/4) uam 1959; Strupino (28/76) Szmeja 1976 unpd.; Wielkie Płocice (28/32) Balcewicz 2004.

Chara contraria Kütz.

Lakes: Dobrogoszcz (19/57) Szańkowski 1998; Gołuń (part 28/47) Gąbka 2004 unpd.; Kramsko Małe (28/60) Szmeja 1976 unpd., aut 2001, Balcewicz 2004 n; Mieliste (28/77) Szmeja 1976 unpd.; Raduńskie Dolne (19/49) aut 2005 n; Raduńskie Górne (19/36): Bociąg, Arendt 2005 n.

Chara delicatula Ag.

Lakes: Białe (12/73) Bociąg 2000, Gałka 2004 n; Chojnackie (18/105) Karczmarz 1973; Czarne (12/80) Gałka 2004 s; Dobrogoszcz (19/57) Szańkowski 1998, ug 1995, aut 2001 m; Drzędno (28/89) Szmeja 1980; Glinowskie (18/83): uam 1961; Głęboczko (28/82) Szmeja 1980, Szańkowski 1998, Gąbka 2004 unpd.; Junno (12/28) aut 2001 m; Kamienne (12/44) Karczmarz 1973; Karlikowskie (13/10) ug 1995, Szańkowski 1998; Kotel (28/90) Gąbka 2004, unpd.; Kramsko Małe (28/60) Balcewicz 2004; Małe Oczko (28/87) Szmeja 1980, Gąbka 2004 unpd.; Mieliste (28/77) Balcewicz 2004; Sitno (13/4) uam; Skrzynki Duże (28/3) aut 1998, 2004 n; Sominko (28/43) aut 2003; Wielkie Oczko (28/84) Szmeja 1980; Wielkie Płocice (28/32) Balcewicz 2004; Zakrzewie (28/88) Szmeja 1980, aut 2002 m, Gąbka 2004 unpd.; "Żuromińskie" (19/40) aut 2000 s.

Chara fragilis Desvaux

Lakes: Białe (12/73) Bociąg 2000, Gałka 2005 m; Czarne (12/80) Bociąg 2000, Gałka 2005 s; Długie near Juszki (28/79) Szmeja 1976 unpd.; Duże (28/128) Gąbka 2004, unpd.; Głęboczko (28/82) Szmeja 1975 unpd.; Gołuń (part 28/47) Gąbka 2004 unpd.; Jelenie (part 28/47) Gąbka 2004 unpd.; Junno (12/28) aut 2001 m; Kotel (28/90) Szmeja 1976 unpd., aut 1997 n, Gąbka 2004 unpd.; Krampe (27/94) aut 2003 n; Kramsko Duże (28/63) Balcewicz 2004; Radolino (27/101) aut 1996, 2005 m; Raduńskie Dolne (19/49) aut 2005 n; Raduńskie Górne (19/36) Bociąg, Arendt 2005 n; Skrzynki Duże (28/3) aut 1998, 2003 n; Strupino (28/76) aut 2002 s; Unnamed W of Lake Ostrowickie (19/10) aut 2002; Węgorzyno (19/2) uam 1955, Dąmbska 1955, 1959; Wielkie (12/50) uam 1955, Dąmbska 1955, 1959; Wielkie Płocice (28/32) Balcewicz 2004;

Chara hispida L.

LakeMieliste (28/77) Szmeja 1975 unpd.

Chara intermedia A.Br.

Lakes: Mieliste (28/77) Szmeja 1976 unpd.; Strupino (28/76) Szmeja 1976 unpd.; Unnamed S of Lake Trawiki (27/108, N part) aut 2003 n; Unnamed SW of Lake Trawiki (27/108, S part) aut 2003 n.

Chara polyacantha A.Br.

LakeWielkie Płocice (28/32) Balcewicz 2004.

Chara rudis A. Br.

Lakes: Długie near Juszki (28/79) Szmeja 1976 unpd.; Drzędno (28/89) Szmeja 1975 unpd.; Kotel (28/90) aut 1997 m, Gąbka 2004 unpd.; Kramsko Małe (28/60) Szmeja 1975 unpd., aut 2001 n; Mieliste (28/77) Szmeja 1976 unpd., Balcewicz 2004 n; Płocice (28/25) Balcewicz 2004; Radolino (27/101) aut 1996 m; Unnamed S of Lake Trawiki (27/108, N part) aut 2003 n; Wielkie Płocice (28/32) Balcewicz 2004.

Chara tomentosa L.

Lakes: Białe near Wąglikowice (28/67) Szmeja 1976 unpd.; Bukrzyno Duże (19/62) aut 2003 s; Bukrzyno Małe (19/56) aut 2003 n; Duży Zbełk (27/106) aut 2003 m; Głęboczko (28/82) Szmeja 1975 unpd.; Kamionka (19/64) aut 2003 s; Karpno (28/6) aut 2003 s; Kotel (28/90) aut 1997 n; Krampe (27/94) aut 2003 n; Kramsko Duże (28/63) Szmeja 1975 unpd.; Kramsko Małe (28/60) Szmeja 1975 unpd., Balcewicz 2004 n; Kułkówko (28/27) Balcewicz 2004; Małe Sarnowicze (27/90) aut 2003 n; Ostrowickie (19/16) Balcewicz 2004 n; Płocice (28/25) Balcewicz 2004; Raduńskie Dolne (19/49) aut 2005 s; Skrzynki Małe (28/5) aut 2003 n; Słone (27/115) aut 2002 s; Sominko (28/43) Balcewicz 2004 n; Strupino (28/76) Szmeja 1976 unpd.; Unnamed S of Lake Trawiki (27/108, N part) aut 2003 n; Unnamed SW of Lake Trawiki (27/108, S part) aut 2003 n; Wielkie Płocice (28/32) Balcewicz 2004 n; Wielkie Sarnowicze (27/95) Balcewicz 2004 n.

Explanations: Lake number from the work by Choiński (1991), 'Catalogue of Polish Lakes', was given in brackets; s – sparse, n – numerous, m – massive; uam: herbarium 'Polish stoneworts', prof. Izabela Dąmbska's collection, data were made available by the Department of Hydrobiology, Adam Mickiewicz University in Poznań; ug: data collected in the Department of Plant Ecology, University of Gdańsk; aut: author's data; unpublished data – unpd.