POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 28(1): 31–42, Y. 2013

STRUCTURE VARIABILITY OF *CHARA TOMENTOSA L.* SPECIMEN ON STANDS OF DIVERSE HABITAT CONDITIONS

Ewa Hirsz-Siwicka

Chamber of Natural Sciences
Sopot High School

K e y w o r d s: ecology of stoneworts, structure of population, *Chara tomentosa*, Pojezierze Mazurskie.

A b s t r a c t

Chara tomentosa is a species placed on the red list of endangered algae in Poland. However, its ecology is still barely known. The aim of the study was to advance this knowledge through determination of the variability of *Chara tomentosa* specimen between the stands of varied habitat properties. The structure of the specimen was tested in six lake populations of *Chara tomentosa* in Pojezierze Mazurskie (Mazurskie Lake District). A total length and biomass of the specimen as well as its habit and reproductive potential were determined in each of them. In the habitats rich in calcium, nitrogen and phosphorus, long (52–74 cm), of high biomass (0.6–1.2 g), extensively branched (2 branches on average) specimens of high reproductive potential (1.5–3.2 generative branches) occurred. Whereas, in the habitats poorer in the said elements small (29–42 cm), light (0.5 g) usually weakly branched specimens of low reproductive potential (0.5 generative branches) occurred.

ZMIENNOŚĆ STRUKTURY OSOBNIKA *CHARA TOMENTOSA* L. NA STANOWISKACH O ZRÓŻNICOWANYCH WARUNKACH SIEDLISKOWYCH

Ewa Hirsz-Siwicka

Katedra Nauk Przyrodniczych
Sopocka Szkoła Wyższa

S ł o w a k l u c z o w e: ekologia ramienic, struktura populacji, *Chara tomentosa*, Pojezierze Mazurskie.

Address: Ewa Hirsz-Siwicka, Sopot High School, ul. Rzemieślnicza 5, 81-855 Sopot, Poland, phone: +48 (58) 550 78 80, e-mail: ewahirsz@vp.pl

Abstrakt

Chara tomentosa jest gatunkiem umieszczonym na czerwonej liście glonów zagrożonych w Polsce, jednak jego ekologia jest nadal słabo poznana. Celem pracy było pogłębienie tej wiedzy poprzez określenie zmienności cech osobnika *Chara tomentosa* między stanowiskami o zróżnicowanych właściwościach siedliskowych. Strukturę osobnika zbadano w 6 jeziornych populacjach *Chara tomentosa* na Pojezierzu Mazurskim. W każdej z nich określono całkowitą długość i biomasę osobnika oraz jego pokrój i potencjał reprodukcyjny. Na siedliskach bogatych w wapń azot i fosfor występowały długie (52–74 cm), o wysokiej masie (0,6–1,2 g), mocno rozgałęzione (średnio 2 odgałęzienia) osobniki o silnym potencjale reprodukcyjnym (1,5–3,2 odgałęzień generatywnych), natomiast na siedliskach uboższych w te pierwiastki były one niewielkie (29–42 cm), lekkie (0,5 g), zazwyczaj słabo rozgałęzione i o słabym potencjale reprodukcyjnym (0,5 odgałęzień generatywnych) okazy.

Introduction

As a consequence of a negative influence of habitat factors, extinction of many charetea is reported. A high content of phosphorus (FORSBERG 1964, KOHLER et al. 1971) or light deficiency (BLINDOW 1988, 1992a, 1992b, COOPS and DOEF 1996) is believed to be one of the causes. Extinction of charetea has been noticed, inter alia, in Sweden (BLINDOW 1991), Finland (RINTANEN 1996), Holand (SIMONS and NAT 1996) and in Poland, where e.g. in Lake Mikołajskie, phytomass of charophyta in comparison to biomass of remaining macrophytes decreased from 60% in 1963 to 24% in 1980 and in the years 1980–1990, charophyta were completely eliminated (OZIMEK 1992).

Undoubtedly, a number of endangered species from *Characeae* of the same colony reflects inconvenient conditions of life for charophyta. All 33 taxa found in Poland (DĄMBSKA 1964, RINGER 1972) are on the red list of endangered algae (SIEMIŃSKA 2006). *Chara tomentosa* L. 1753 is one of them. Earlier, it was a taxon of an undetermined group of risk (SIEMIŃSKA 1992), currently is included in the group of rare species (SIEMIŃSKA 2006). However, there is insufficient information on this topic.

Thus, it is worth to advance the knowledge on this subject, inter alia, by determining optimal habitat conditions for development of this species. They may be depicted on the basis of individual variability of *Chara tomentosa* (MIGULA 1898, 1900, DĄMBSKA, KARPIŃSKI 1954, DĄMBSKA 1964, KRAUSE 1976, 1997). According to FALIŃSKA (1974, 1996) and ANDRZEJEWSKA (1983) diversity of individuals within one species results from the influence of abiotic and biotic environment (or it may be genetically influenced). Thus, it is a good indication of living conditions of the population.

Methods of experiments

Methods of experiments on the structure of a specimen

Field experiments were held in August in 2001 in the following lakes: Neliwa Lake (53° 22' N; 19° 52' E), Jełguń Lake (53° 39' N; 20° 32' E), Majcz Wielki Lake (53° 47' N; 21° 27' E), Krutyńskie Lake (53° 42' N; 21° 25' E) and in 2002 in Redykajny Lake (53° 49' N; 20° 25' E) and Kołowin Lake (53° 44' N; 21° 24' E). In each of the lakes, one stand was selected in the sites, where species *Chara tomentosa* occurred and formed a large, well visible patch in the environment[1].

In the first half of August, within the range of one population, five samples of plants of 0.1 m2 surface area were taken at random at the depth of 0.5 m. From among the above 5 samples, 6 specimens of *Chara tomentosa* were selected during species segregation (6 specimens * 5 samples = 30 individuals from a particular population) in order to examine individual properties (length, dry biomass and habit). Their total length and length of the third internode of a pseudo-stem (from the bottom of a thallus) and size of the longest pseudo-leaf growing out of the third internode were measured when dry. Next, stoneworts were dried in the temperature of 105°C for 3 hours. After drying, the biomass of the whole specimen was determined with accuracy up to 0.01 g. The habit was estimated on the basis of two above-mentioned properties: length of an internode and a pseudo-leaf as well as the number of long branches (over 5 cm). Number of branches with reproductive organs (oogonia and antheridia) was an additional feature taken into consideration.

Methods of experiments on habitat conditions

The analyses of habitat conditions of the researched stands were carried out in August 2001 and 2002. One surface sample of a 5-centimetres layer of sediments was taken from the best-developed area of population of *Chara tomentosa* from each lake, on the basis of which, properties of over-sedimentary water were determined. The samples of sediments were taken with the use of a tube sampler Kajak type of 52 mm diameter.

Over-sedimentary water was obtained by decanting a layer of water over sediments. In this water, nitrogen (nitrate and total), phosphorus (phosphatic and total) as well as calcium were determined. The analyses were carried out according to the methods set out by HERMANOWICZ et al. (1998). Calcium was

[1] permit number: OŚR/OIII/6638/67/00, OŚR/OIII/6636/69/01.

measured by the use of sodium versenate compared to calcite. Nitrate nitrogen was determined with phenol-disulphonic acid (435 nm), Kjeldahl nitrogen – with the distillation method; total nitrogen was calculated as a sum of Kjeldahl and nitrate nitrogen. Phosphoric phosphorus was determined with ammonium molybdenum and tin chloride(II) (650 nm); total phosphorus – was determined after mineralization with sulphur acid and amonium persulfate.

Statistical analysis of research results

Statistical analysis of the collected material was carried out with the use of Statistica 6.0 application.

Substantial hypothesis on significance of diversity of *Chara tomentosa* specimens in regard of length, dry biomass, habit and reproductive potential between the lakes, was verified by a non-parametric equivalent of analysis of variation – that is by Kruskal-Wallis test and next by a non-parametric U test (Mann Whitney) at the significance level calculated from Bonferroni correction $\alpha = \alpha/m$, where m = number of compared samples (ŁOMNICKI 1995, STANISZ 1998).

Relation between properties of a specimen and chemical properties of water was expressed by the use of Spearman correlation coefficient at the level of significance $p < 0.05$ (GUILFORD 1960, ŁOMNICKI 1995, STANISZ 1998).

Results

Chemical properties of water

The tested stands were characterised by different habitat conditions. In Kołowin, Jełguń and Neliwa lakes higher concentration of calcium in water (approx. 49–71 mg dm^{-3}) than in the remaining water bodies (under 45 mg dm^{-3}) was reported. The first group of lakes was also characterised by a slightly higher content of biogenic elements, especially total nitrogen (0.96–1.43 mg dm^{-3}). On the basis of these differences, two types of water reservoirs were distinguished. The first one including Kołowin Lake, Jełguń Lake, Neliwa Lake characterised by a higher concentration of calcium and bio genes and the second, including Majcz Wielki Lake, Krutyńskie Lake and Redykajny Lake, where the content of the tested elements was slightly higher (Table 1).

Table 1

Chemical properties of water on the experimental stands

Specification	Calcium [mg dm^{-3}]	P-PO_4 [mg dm^{-3}]	Total P [mg dm^{-3}]	N-NO_3 [mg dm^{-3}]	Total N [mg dm^{-3}]
Kołowin Lake	71.4	n.r.	0.10	0.10	1.22
Jełguń Lake	48.6	n.r.	0.25	0.14	1.43
Neliwa Lake	61.4	n.r.	0.25	0.14	0.96
Majcz W. Lake	45.0	n.r.	0.11	0.08	0.86
Krutyńskie Lake	42.8	n.r.	0.10	0.10	0.94
Redykajny Lake	35.0	n.r.	0.09	0.05	0.94

n.r. – not reported

Plant material

Diverse architecture of *Chara tomentosa* specimen as well as its reproductive potential between local populations was analysed in the study.

In case of dry biomass, the highest average values (0.6–1.2 g) are reported among specimens from Kołowin Lake, Jełguń Lake and Neliwa Lake; slightly lighter specimens, on average 0.5 g, occur in the remaining water bodies (Figure 1). Differences, which are statistically significant are visible between the above-mentioned two groups of lakes (Mann-Whitney U test, $p<0{,}001$) – Figure 1.

In regard of the number of long branches, stoneworts are less diverse. Specimens with the highest plant mass from Kołowin Lake, Jełguń Lake and Neliwa Lake, as well as Krutyńskie Lake average have 2 branches (Figure 1). In the remaining two water bodies, specimens have only one branch or do not have any (Figure 1). Differences, which are statistically significant, are visible between the above-mentioned two groups of lakes (Mann-Whitney U test, $p<0.001$).

The strongest stoneworts with the highest biomass have the longest thalli (on average 52–74 cm) of long internodes (on average 7.2–7.6 cm) and pseudo-leaves (on average 3–4 cm) in Kołowin Lake, Jełguń Lake and Neliwa Lake. Stoneworts occurring in three remaining reservoirs, that is Krutyńskie Lake, Majcz W. Lake and Redykajny Lake, have the lowest values among the researched length properties. Their pseudo-stems reach 29–42 cm on average, an internode does not exceed 5.5 cm and pseudo-leaves approximately 2 cm (Figure 2). Statistical differences become visible between the length of particular properties of a specimen from two above-mentioned groups of reservoirs (U Mann-Whitney test, $p<0.001$).

The most impressive stoneworts, which form populations in Kołowin Lake, Jełguń Lake and Neliwa Lake have the biggest number of branches with reproductive organs (1.5–3.2 branches on average). Specimens from Redykajny

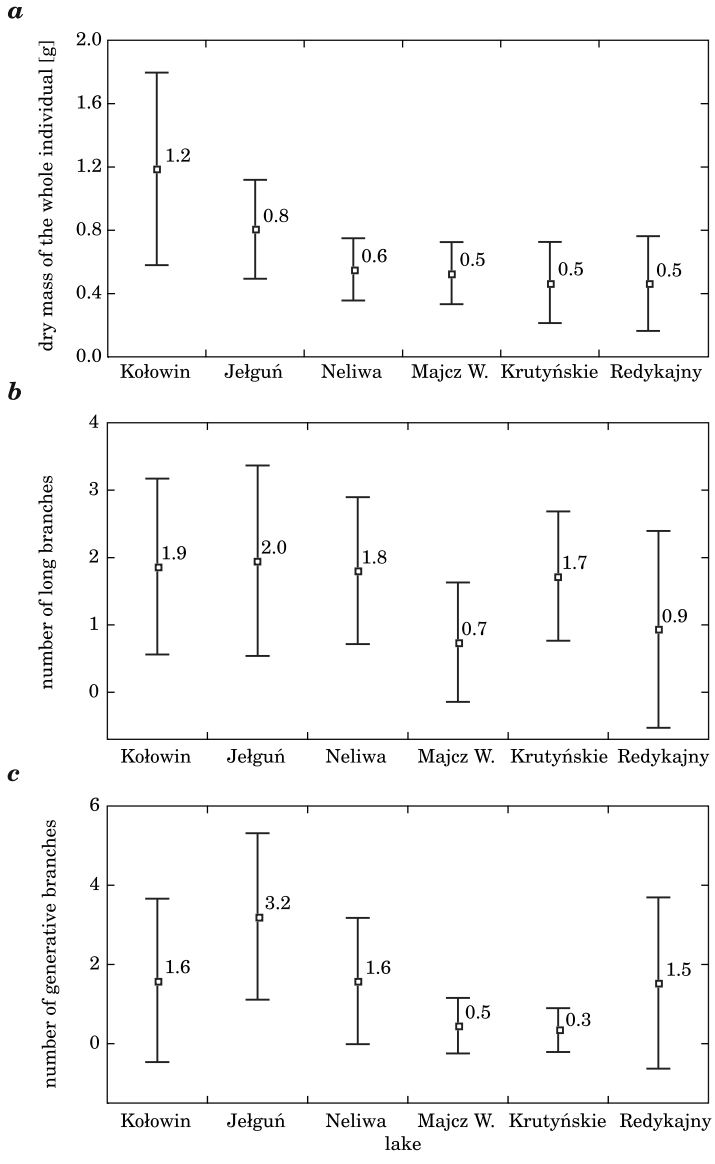

Fig. 1. Diversity of plant biomass, habit and reproductive potential *Chara tomentosa* specimen

Lake are similar in regard of the above. Thalli from remaining populations occurring in Krutyńskie Lake and Majcz W. Lake have considerably less generative branches (on average less than 0.5 branch) – Figure 1. Significant statistical differences occur between the above-mentioned values (U Mann-Whitney test, $p<0.001$).

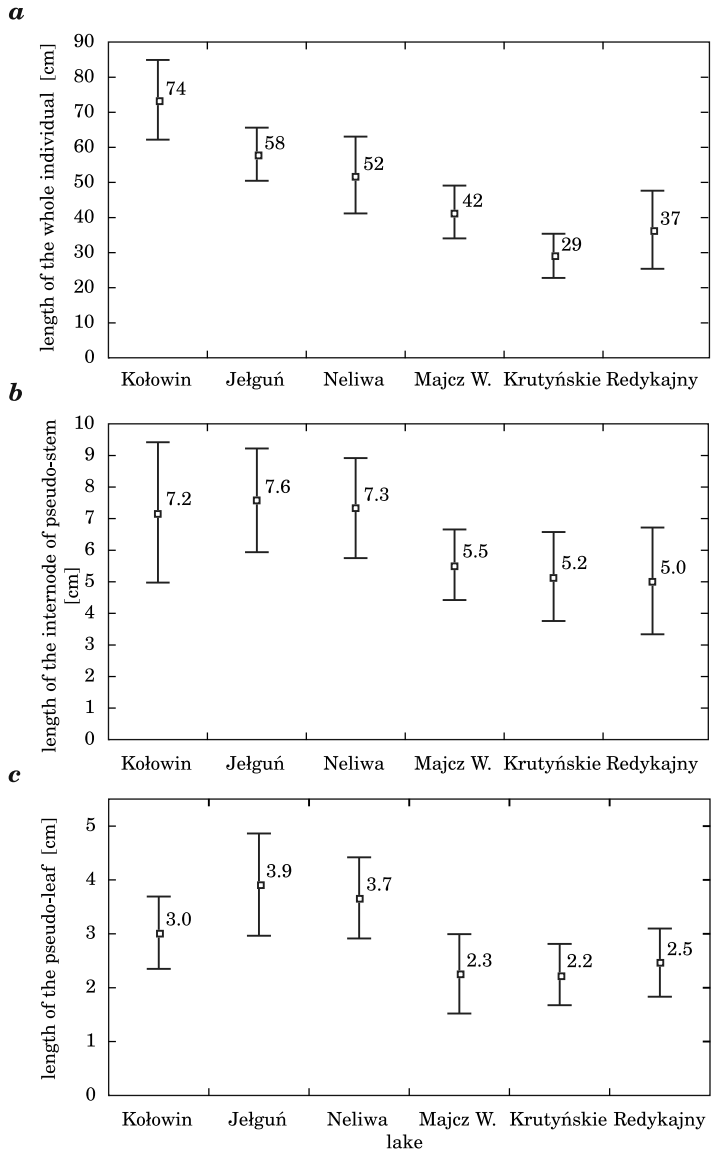

Fig. 2. Diversity of properties lenght of *Chara tomentosa* specimen

When considering values of all examined properties and degree of their relationship, it may be stated that branched thalli of the highest biomass the longest pseudo-stems, their internodes as well as pseudo-leaves and usually of the strongest reproductive potential, occur in the populations of Kołowin Lake, Jełguń Lake and Neliwa Lake. Shorter and lighter specimens, with lower number of branches and lower number of generative branches are reported

mainly in the populations of Krutyńskie Lake, Majcz W. Lake and Redykajny Lake (Figure 1, 2).

Undoubtedly, diverse habitat conditions, which occur in the researched stands influence the variability of structure of *Chara tomentosa* specimen. These places are characterised mainly by different chemical composition of water within a patch (Table 1). It mainly concerns concentration of calcium, nitrogen and phosphorus. These properties are related to different degrees with the properties of the researched taxa.

Dry biomass, length and degree of branching of a specimen prove significantly statistical correlations with calcium occurring in water. These relations are of an average strength (Spearman test rs = 0.26–0.76, $p<0.05$). The above properties of a stonewort are correlated similarly (Spearman test rs = 0.32–0.66, $p<0.05$) with all tested forms of nitrogen occurring in water, whereas considerably weaker with phosphorus (Spearman test rs = 0.11–0.26, $p«0.05$) – Table 2. All these correlations are directly proportional. Thus, relatively long specimens of considerable dry biomass and strongly branched thalli occur on the stands rich in calcium and in biogenic elements (N, P). Such specimens grow in Kołowin Lake, Jełguń Lake and Neliwa Lake. Lower, less branched specimens of low biomass occur on the stands of lower content of calcium and phosphorus as well as nitrogen (Table 1 and Figure 1, Table 2 and Figure 2).

Table 2

Relations between properties of *Chara tomentosa* specimen and chemical properties of water

Specification	Spearman's rank correlation Marked correlations are essential with $p < 0.05$		
	t.l.	d.m.	n. of b.
Calcium	0.76	0.45	0.26
Total P	0.26	0.11	0.18
$N\text{-}NO_3$	0.55	0.32	0.35
Total N	0.66	0.44	0.32

t.l. – total length of individual
d.m. – dry mass of the whole individual
n. of b. – number of long branches

Discussion

Chara tomentosa specimens from particular local populations considerably differ with the size structure. Long, "heavy", intensely branched stoneworts occur most frequently in populations from stands rich in nitrogen, phosphorus and calcium (Kołowin, Jełguń, Neliwa lakes) while short, light, weakly branched specimens grow on the habitats of slightly poorer content of the said elements (Majcz W., Krutyń, Redykajny lakes). Abiotic and biotic environ-

ment, which influence the speed of growth and development of a plant may affect the variability of the specimen within the species as FALIŃSKA (1974, 1983, 1990, 1996, 2002) and ANDRZEJEWSKA (1983) suggest. Thus, specimens living in the conditions which fully satisfy their life requirements are bigger and their architecture is more complicated as in case of the first group of the researched stands, whereas, populations occurring in inconvenient environmental conditions are basically formed by smaller, less developed specimens, what may be noticed in the second group of water bodies. Diversity of the structure of a specimen's size affected by diverse environmental conditions is known from SYMONIDES research (1974) based on *Spergula vernalis*. Specimens of this taxon are of small sizes on barren, dune sands and of considerably bigger proportions on the soils rich in water and humus. *Myosotis palustris* (FALIŃSKA 1979) attain considerable sizes in advantageous conditions of life as well.

Among "heavy" *Chara tomentosa* specimens, which form populations in Kołowin, Jełguń and Neliwa lakes, high reproductive potential is reported as well. Home range and nutritional requirements, as well as participating in reproduction depend on biomass of a specimen (ANDRZEJEWSKA, FALIŃSKA 1983). Thus, the more biomass plant organisms collect the bigger chances they have to propagate (FALIŃSKA 2002). It is also confirmed by the research on stoneworts conducted by BONIS et al. (1993) as well as GRILLAS and BATTEDOU (1998), which concern relations between weight of plants and the number of propagules produced by it.

Stands, on which *Chara tomentosa* populations occur, show similarities in relation to the water hardness and its reaction, while they are characterised by different calcium and biogenic elements content (nitrogen, phosphorus). Two last factors may influence the individual variability of the researched species. Therefore, correlations between the amount of calcium, phosphorus and nitrogen and particular properties of stoneworts were determined in own researches. During research on these relations, it must be considered that the analysis of habitats was carried out in the peak of the growing season and some of the above-mentioned elements had been already collected from water or sediments by developing stoneworts. Thus, the presented correlations may be slightly weaker than real.

In habitats of hard water, calcium cations often accompany hydrogen carbonate anions, which are the main source of inorganic carbon in the process of photosynthesis at submerged macrophytes (LÖWENHAUPT 1956, SMART, BARKO 1986, KUFEL, KUFEL 2002). Moreover, stoneworts prove higher relationship with hydrogen carbonates than vascular plants. An experiment carried out by VAN DEN BERG et al. illustrates it very well (2002). In this experiment, *Chara aspera* proved considerably higher speed of photosynthesis

in a wide range of hydrogen carbonates concentration than *Potamogenton pectinatus*. Therefore, on the "hard" water stand, richer in calcium (Kołowin, Jełguń, Neliwa lakes) stoneworts show higher speed of photosynthesis and simultaneously high plant biomass. Additionally, their "weight" increases with the increase of thallus inlay with calcium carbonate (calcite), which precipitates during uptake of carbon by plants in the process of photosynthesis (VAN DEN BERG et al. 2002).

Phosphorus content in water is positively correlated with properties of *Chara tomentosa* specimen, thus, the higher concentration of this element the better developed the specimen is. FORSBERG'S research (1964) does not confirm it, as he believes that phosphorus limits development of stoneworts. HUTCHINSON (1975), as well, states that this group of plants develops the best in waters of low content of this element. However, the experiment carried out by BLINDOW (1988) on two species of stoneworts: *Chara hispida* and *Chara tomentosa* does not show a negative influence of phosphorus on their growth even at the concentration of 1000 $\mu g\ l^{-1}$. Moreover, no disturbances in the development of *Chara connivens* and *Chara major* at the concentration of phosphoric phosphorus within the range of 9–1009 $\mu g\ l^{-1}$ was reported (SIMONS et al. 1994). What is more, KRÓLIKOWSKA (1997) reported the highest biomass of *Chara tomentosa* and *Chara aculeolata* in Łuknajno Lake, in the places frequently visited by swans. Water fertilized by droppings of these birds may stimulate growth of plants biomass even when their biomass is decreased by preying. Thus, high concentration of phosphorus, in this case, positively influences development of *Chara tomentosa* specimen.

Properties of the researched taxon, in relation to nitrogen forms, show similar relation. The highest nitrate nitrogen concentration the biggest specimens are reported. Partially, it is confirmed by research results carried out in Dutch lake Botshol, where the concentration of nitrate nitrogen within the range 5.3–20.3 $g\ l^{-1}$ triggers development of *Chara connivens* and *Chara major* (SIMONS et al. 1994).

Conclusion

Long and strongly branched specimens of high biomass and strong reproductive potential occur in the habitats rich in calcium, nitrogen and phosphorus. Shorter, lighter, often not branched specimens grow in the places poorer in the above-mentioned elements.

Translated by EMILIA MNICH

Accepted for print 18.01.2013

Reference

ANDRZEJEWSKA L., FALIŃSKA K. 1983. *Struktura wielkości osobników w populacji*. Wiad. Ekol., 29: 3–31.

BLINDOW I. 1988. *Phosphoru toxicity in Chara*. Aquat. Bot., 32: 393–395.

BLINDOW I. 1991. *Reasons for the decline of Charophytes in eutrophicated lake in Scania* (*Sweden*). Bull. Soc. Bot. Fr., 95: 138.

BLINDOW I. 1992a. *Decline of charophytes diurng eutrophication: comparison with angiosperms*. Freshwat. Biol., 28: 9–14.

BLINDOW I. 1992b. *Long – and short – term dynamics of submerged macrophytes in two shallow eutrophic lakes*. Freshwat. Biol., 28: 15–27.

BONIS A., GRILLAS P., VAN WIJCK C., LEPART J. 1993. *The effect of salinity on the reproduction of coastal submerged macrophytes in experimental communities*. J. Veg. Sci., 4: 461–468.

COOPS H., DOEF R. W. 1996. *Submerged vegetation development in two shallow, eutrophic lakes*. Hydrobiologia, 340: 115–120.

DĄMBSKA I., KARPIŃSKI J. 1954. *Ramienice – klucz do oznaczania gatunków krajowych*. PWN, Warszawa.

DĄMBSKA I. 1964. *Charophyta – Ramienice*. PWN, Warszawa.

FALIŃSKA K. 1974. *Reakcja populacji roślinnych na zróżnicowanie ekosystemów oraz układów ekotonowych*. Wiad. Ekol., 20: 356–376.

FALIŃSKA K. 1979. *Modifications of plant populations in forest ecosystems and their ecotones*. Pol. ecol. Stud., 5: 89–150.

FALIŃSKA K., PIROŻNIKOW E. 1983. *Ecological structure of Geranium robertianum* L. *populations uder natural conditions and in the garden*. Ecol. pol., 31: 93–121.

FALIŃSKA K. 1990. *Osobnik, populacja, fitocenoza*. PWN, Warszawa.

FALIŃSKA K. 1996. *Ekologia roślin*. PWN, Warszawa.

FALIŃSKA K. 2002. *Przewodnik do badań biologii populacji roślinnych*. PWN, Warszawa.

FORSBERG C. 1964. *Phosphorus a maximum factor in the growth of Characeae*. Nature, 201: 517–518.

GRILLAS P., BATTEDOU G. 1998. *Effects of the date of flooding on the biomass, species composition and seed production of submerged macrophyte beds in temporary marshes in the Camargue* (S. France). [In:] *Wetlands for the Future. Proceedings of the INTECOL International Wetland Conference*, Eds. A.J. McComb, J.A. Davis, Perth, September 1996, pp. 207–218.

GUILFORD J.P. 1960. *Podstawowe metody statystyczne w psychologii i pedagogice*. PWN, Warszawa.

HUTCHINSON G.E. 1975. *A treatise on Limnology, Limnological Botany*, Vol. III. Wiley, New York, pp. 660.

KOHLER A., VOLLRATH H., BEISL E. 1971. *Zur Verbreitung, Vergesellschaftung und Ökologie der Gefäss – Makrophyten im Fliessgewässer Moosach*. Arch. Hydrobiol., 69: 333–365.

KRAUSE W. 1976. *Characeen aus Bayern*. Ber. Bayer. Bot. Ges., 47: 229–257.

KRAUSE W. 1997. Charales (Charophyceae). [In:] Süswasserflora von Mitteleuropa. Gustav Fischer, Jena Stuttgart Lübeck Ulm, pp. 202.

KRÓLIKOWSKA J. 1997. *Eutrophication processes in a shallow, macrophyte – dominated lake – species differentiation, biomass and the distribution of submerged macrophytes in Lake Łuknajno* (*Poland*). Hydrobiologia, 342/343: 411–416.

KUFEL L., KUFEL I. 2002. *Chara beds acting as nutrient sinks in shallow lakes – a review*. Aquat. Bot., 72: 249–260.

HERMANOWICZ W., DOJLIDO J., DOŻAŃSKA W., KOZIOROWSKI B., ZERBE J. 1998. *Fizyczno-chemiczne badanie wody i ścieków*. Arkady, Warszawa.

LÖWENHAUPT B. 1956. *The transport calcium and other cations in submerged aquatic plants*. Biol. Rev., 31: 371–395.

ŁOMNICKI A. 1995. *Wprowadzenie do statystyki dla przyrodników*. PWN, Warszawa, pp. 242.

MIGULA M. 1898. *Characearum europaearum*. *Eduard Kummer*, Leipzig, pp. 88–93.

MIGULA M. 1900. *Die Characeen – Deutschlands, Oesterreichs und der Schweiz*. *Eduard Kummer*, Leipzig: pp. 386–418.

OZIMEK T. 1992. *Makrofity zanurzone i ich relacje z glonami w jeziorach o wysokiej trofii*. Wiad. Ekol., 38: 13–34.

RINGER Z. 1972. *Rośliny Bałtyku*. Państwowe Zakłady Wydawnictw Szkolnych, Warszawa, pp. 149.

RINTANEN T. 1996. *Changes in the flora and vegetation of 113 Finnish lakes during 40 years*. Ann. Bot. Fenn., 33: 101–122.

SIEMIŃSKA J. 1992. *Czerwona lista glonów zagrożonych w Polsce*. [W:] *Lista roślin zagrożonych w Polsce*. Red. K. Zarzycki, W. Wojewoda, Y. Heinrich. Instytut Botaniki im. W. Szafera, PAN, Kraków, pp. 21–22.

SIEMIŃSKA J. 2006. *Czerwona lista glonów zagrożonych w Polsce*. [W:] *Lista roślin zagrożonych w Polsce*. Red. Y. Mirek. Instytut Botaniki im. W. Szafera, PAN, Kraków, pp. 7–19.

SIMONS J., OHM M., DAALDER R., BOERS P., RIP W. 1994. *Restoration of Botshol* (*The Netherlands*) *by reduction of external nutrient load: recovery of a Characean community dominated by Chara connivens*. Hydrobiologia, 275/276: 243–253.

SIMONS J., NAT E. 1996. *Past and present distribution of stoneworts* (*Characeae*) *in The Netherlands*. Hydrobiologia, 340: 127–135.

SMART R.M., BARKO J.W. 1986. *Effects of water chemistry on aquatic plants: growth and photosynthesis of Myriophyllum spicatum* L. Tech. Rep. A – 86 – 2, Environmental Laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, MS, pp. 34.

STANISZ A. 1998. *Przystępnym kurs statystyki w oparciu o program STATISTICA PL. Na przykładach z medycyny*. StatSoff Polska, Kraków, pp. 362.

SYMONIDES E. 1974. *Populations of Spergula vernalis Willd. on dunes in the Toruń basin*. Ekol. pol., 22: 379–416.

VAN DEN BERG M., COOPS H., SIMONS J., PILON J. 2002. *A compararative study of the use of inorganic carbon resources by Chara aspera and Potamogeton pectinatus*. Aquat. Bot., 72: 219–233.