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On the Ecological Requirements of *Chara delicatula* Agardh

Wymagania ekologiczne *Chara delicatula* Agardh

Экологические требования *Chara delicatula* Agardh

INTRODUCTION

Of all the *Characeae*, only *Chara delicatula* Agardh and *Nitella flexilis* Agardh are indicators of oligotrophic processes in lakes (2, 3, 7). In spite of its clearly individual cytogenetic and ecological features, *Ch. delicatula* is not always considered as a separate species and is even classified together with *Ch. fragilis* Desv. into a common species *Ch. globularis* Thuill. (4, 20). On one hand, according to the latest investigations carried out by Guerlesquin (5), *Ch. delicatula* has a number of chromosomes $x=6, 7$, $n=14, 24$ or even 40 (42). Its largest chromosome number is found in the karyoecotypes of various habitats. *Ch fragilis*, on the other hand, has a variable number of chromosomes $x=6, 7$ (8), $n=16, 18$ up to 20, 24, 28 and 32. Karyoecotypes from diversely different ecological habitats have a variable numerical value. The former species grows in oligotrophic lakes and it is characteristic of the association *Isoeto-Lobelietum* in *Lobelia* lakes occurring within the lake districts near the Baltic Sea (2, 3, 10, 19). The latter species has a wide ecological amplitude and is common in different types of eutrophic lakes and small water basins. Morphological differences between the two species are also distinct. Therefore, even poorly developed forms of *Ch. fragilis* cannot be taken for *Ch. delicatula* plants.

MATERIAL AND METHODS

The phytosociological and ecological material for this study was collected from the lakes of North-western and Eastern Poland in 1967—1971. In the area of Western

Pomerania the material came from the environs of Bobolice (the lakes Pniewo and Piekiełko) in the Koszalin District, of Miastko (the lakes Piasek and Bobiecińskie Wielkie I) in the Miastko District and from the environs of Bytów (the lakes Gubisz and Jeleń) in the Bytów District. In Gdańsk Pomerania only the lakes Chojnackie and Kamienne, situated in the Kartuzy District, were investigated. In these lakes in addition to *Ch. delicatula* and the more rarely occuring *Nitella flexilis* there also occur three syecies of vascular plants (*Lobelia dortmanna, Litorella uniflora, Isoetes lacustris*) which are indicators of low content of nutrients and CaO. Detailed hydrochemical reports on a group of these lakes has been made (17, 18).

Also, three lakes from the Łęczna and Włodawa Lake District, in which *Ch. delicatula* occurs abundantly, were taken into consideration namely, Lakes Piaseczno, Kleszczów and Czarne Sosnowieckie.

MAIN PHISICO-CHEMICAL PROPERTIES OF WATERS

In *Lobelia* lakes, S z m a l (17—18) has established that two physical parameters are essential for the penetration of light which is necessary for photosynthesis. These parameters are 1) water transparency, and 2) bottom water temperature. Water transparency which is so important for the peneration of light necessary for photosynthesis, is greatest in deep lakes with limpid waters and sandy bottoms. These two parameters, as it is seen from investigatons on the effect of light and temperature upon the growth and abundant formation of gametangia n *Chara fragilis*, clearly restrict the occurrence of this species at great depths. In the case of *Ch. delicatula* this relationship is identical.

The highest transparency (over 4 m) was found in Lake Jeleń near Bytów and the lowest transparency (l. lm) was found in Lake Chojnackie. The lowest bottom water temperature (4.5°C) was in Lake Piekiełko near Bobolice. Of the chemical factors in Lobelia lakes, the amount of chemical oxygen demand (COD) in mg/l O_2 should be mentioned. In seven lakes these values were low. Only in Lake Kamienne did they fall within the range of 8.8—12.9 mg/l O_2. There was a distinct correlation between the concentration of carbonate, CaO concentration and *pH*. Some lakes had a high concentration of K-ion and at times of Cl-ion a relatively low value of carbonate in these lake waters would be 0.8—5 mg/l CaO.

In the Łęczna and Włodawa Lake District the values of physico-chemical factors were slightly different. Since they corresponded at different depths; Lakes Czarne Sosnowieckie and Kleszczów belong to shallow mesotrophis lakes. The highest transparency was in Lake Piaseczno (7.10 m). The minimum concentration of oxygen was also established for Lake Piaseczno; it amounted to 4.4 mg/l on the 8th of September, 1967. The average *pH* values in this lake were about 7.0. Lower *pH* values (6.5 and 6.6) were found in all bottom water layers. The *pH* value was within 6.1—7.0 in dystrophic lakes as for instance, in Lake Orchówek near Włodawa in

which *Ch. delicatula* grows. At certain times during the summer in Lake Kleszczów a very high *pH* (8.5—10.0) was found at a depth of 0.5—1.0 m. The water hardness was 1.91 for Lake Piaseczno and 2.77 for Lake Kleszców (8, 12).

Statistical analysis of the results obtained showed a directly proportional relation between the content of O_2 and *pH* in the upper water layers (13). The values of electric conductivity depended upon the temperature and depth of a lake. The lowest values of electric conductivity were found in the bottom water layers of the Lake Piaseczno (241 uS). These values in the surface layers in this lake amounted only to 198 uS.

RESULTS

The most favourable conditions for the development of *Chara delicatula* occurs in oligotrophic or highly mesotrophic lakes. In Northern Poland the species is found in *Lobelia* lakes in the association *Isoëto-Lobelietum* which is an association from the order *Litorelletalia*, developing only in both types of lakes: *Ch. delicatula* is a characteristic species of this association and it reaches a low rate of constancy (I, II) in it. Here *Ch. delicatula* is often accompanied by *Nitella flexilis*. In Southern and Eastern Poland where similar associations are absent, *Ch. delicatula* grows in oligotrophic or mesotrophic lakes with limpid water, and very rarely in pit hollows in intermediate peat bogs.

I. *Ch. delicatula* occurs in numbers in *Lobelia* lakes which are not linked with rivers. It grows most abundantly at a depth of 0.1—0.5 (1) m on a sandy bottom of the littoral in the leeward zone. It appears almost always with *Lobelia dortmanna* and *Isoëtes lacustris*. *Nitella flexilis*, *Juncus bulbosus* and *Litorella uniflora* may occur in smaller number. In winter, *N. flexilis* oospores easely become frozen and lose their germination capacity, this results in disappearance of this species, especially in shallow lakes. The oospores of *Ch. delicatula* growing at greater depths are not frozen. The plants of *Ch. delicatula* from oligotrophic lakes grow up to 15 (20) cm in length. They are not incrusted on the surface. The uppermost cells of stems are strongly elongated. The formation of antheridia and oogonia in a hundred of the examined specimens attains a variable value of 45—60%. This phenomenon has been observed in most of the investigated *Lobelia* lakes. It takes place at a low concentration of carbonates and at acid reaction in the meta- and hypolimnion. Such conditions previal in the lakes of the so-called „Suchary" type as, for instance, in the Lakes Piekiełko, Chojnackie and Kamienne in where this species grows most abudantly. The plants from a depth of 2 m form gametangia in 35% and below 4—5 m they are sterile. In *Ch. delicatula* the formation of gametan-

gia takes place from the end of May till the half of August. In the sallow littoral of Lake Kamienne forma *bulbillifera* occurs very frequently. The types of similar oligotrophic and mesotrophic habitats are known from the area of Northern Germany and Denmark (11, 15).

II. In Lake Piaseczno well developed specimens of *Ch. delicatula* grow in the association *Nitelletum flexilis* Corillion 1957 (8) and there, similarly as in Lake Kleszczów, forma *bulbillifera* is found. It develops on a sandy bottom of the littoral in limpid water at a depth of about 0.5 m. In the lakes of poor transparency *Ch. delicatula* does not grow deep on a sandy bottom and forma *bulbillifera* does not develop at all (9). In Lake Piaseczno, which is a deep lake and the deepest water transparency occurs at 7.10 m, specimens of *Ch. delicatula* are found at a depth of 5 m. It may, therefore, be assumed that only penetration of light into great depths in this lake explains the development of the species at these depths. The species attains the optimum of its development at a low *pH* value and a low rate of electric conductivity. In this lake both factors clearly depend upon the low content of Ca, Mg and K-ion in mg/l. The above relationships were presented in the description of the associations and ecology of *Characeae* from the Łęczna and Włodawa Lake District (8). The concentration of Fe and P (PO_4-ion) is variable and fluctuates within 0.220—0.6 mg/l for Fe-ion (for the Lakes Kleszczów and Czarne Sosnowickie) and 0.020—0.025 mg/l P or PO_4-ion (for the Lakes Piaseczno and Kleszczów). This makes it possible to maintain good oligotrophic canditions of waters in Lake Piaseczno and to advance the oligothropis process in the mesotrophic Lake Czarne Sosnowieckie. The values of *pH* in the Lake Czarne Sosnowieckie are always close to 6.8. In the Lake Piaseczno, Kleszczów and Czarne Sosnowieckie *Ch. delicatula* has large internodes and with branchlets and stipulodes ending sharply. These are very typical characteristics of this species. Their uppermost cells are elongated and they end in a spine. The stipulodes undergo strong reproduction. In a dense stands the stems are delicate, thin and usually sterile. In specimens collected from Lake Piaseczno the precipitate of calcium carbonate was not found on the surface of their cortical cells.

Ch. delicatula frequently grows in dense stands and may even cover considerable areas. In the most shallow zone of the littoral it is accompanied by *Heleocharis acicularis, H. palustris* and more rarely by *Elodea canadensis.* In a deeper zone there increases the number of accompanying species mainly, *Elodea canadensis, Myriophyllum alterniflorum, Potamogeton lucens, P. natans* and *P. perfoliatus.* Among these vascular plants *Ch. fragilis* and *N. flexilis* occur in small numbers. Below a depth of 5 m where vascular plants are absent, only individual specimens of *Ch. delicatula* are found. In Lakes Kleszczów and Czarne Sosnowieckie floristic

relationships in the littoral zone are similar to those in Lake Piaseczno. In these lakes there also occurs abundantly with *Ch. delicatula, Batrachium circinatum, Ceratophyllum demersum* and *Schoenoplectus lacustris.* Of the *Characeae, Ch. fragilis, N. flexilis* and *N. syncarpa* var. *thuilleri* A. B r. are found. These two localities are in the association *Myriophylletum alterniflori,* or, in its poorly developed facies. The largest number of species occurring together with *Ch. delicatula* are to be found in the Lakes Czarne Sosnowickie and Kleszczów in which the sandy littoral is well developed and eutrophic conditions are unfavourable. In both these lakes *Ch. delicatula* does not grow densely. The sudden appearance of microscopic algae at the western and eastern banks in late summer diminishes the water transparency and intensifies the processes of decay. This phenomenon increases the eutrophic process. As a result of this, *Ch. delicatula* is crowded out by *Ch. fragilis,* an eutrophic species. The intensive formation of oogonia and antheridia takes place at a higher temperature from the end of May to the end of July. If the temperature of water is exceptionally low in these months, the process of gametangia formation will be prolonged until the end of August. These results are true for both species. Until now they have been known only for *Ch. fragilis* (6, 11).

CONCLUSIONS

1. *Ch. delicatula* is a species of definite autoecology in spite of the fact that its karyoecotypes have a different number of chromosomes.

2. *Ch. delicatula* is not a frequent species in the area of Central and Eastern Europe. As a species of oligotrophic and highly mesotrophic lakes it occurs most abundantly in the areas of the Baltic Lake District. Its concentrated distribution of localities is restricted to post-glacial *Lobelia* lakes (Western and Gdańsk Pomerania). In Eastern Poland (the Łęczna and Włodawa Lake District) it grows also in quantity in three oligotrophic and mesotrophic lakes in which the usual and characteristic associated species of *Lobelia* lakes are absent.

3. *Ch. delicatula* grows in deep lakes with high water transparency, low concentration of carbonates and low *pH value.* A high concentration of Cl-ion decreases the dynamic development of *Ch. delicatula* and its accompanying species *N. flexilis.* Under such conditions *Ch. fragilis* tolerant of Cl-ion surplus becomes predominant. The optimum values of carbonate concentration in waters of *Lobelia* lakes are within 0.8—4.2 and 5 mg/l $CaCO_3$ in the Lake Gubisz. The value of *pH* depends upon the concentration of carbonates. A high concentration of carbonates and Cl-ion is a factor restricting the growth and development of *Ch. delicatula.*

4. Under unfavourable ecological conditions this species does not form the organs of sexual reproduction but only bulbils (forma *bulbillifera).*

5. The ecological requirements of *Ch. delicatula* in the oligotrophic lakes of a "Suchary" type and in mesotrophic lakes are similar to the requidements *N. flexilis*. Both of these *Characeae*, as well as *Isoëtes lacustris* and *Lobelia dortmanna*, belong to the characteristic species of the *Isoëto-Lobelietum* association (3, 19).

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STRESZCZENIE

W grupie ramienic (*Characeae*) tylko *Chara delicatula* Agardh i *Nitella flexilis* Agardh rosną w jeziorach oligotroficznych i skrajnie mezotroficznych. Na Pomorzu Zachodnim i Gdańskim występują w jeziorach lobeliowych w zespole *Isoëto-Lobelietum* wraz z *Isoëtes lacustris* i *Lobelia dortmanna*. *Ch. delicatula* i *N. flexilis* należą do gatunków charakterystycznych tego zespołu. Na Pojezierzu Łęczyńsko-Włodawskim rosną w podobnych typach jezior w zespole *Myriophylletum alterniflori*. Główne czynniki określające autoekologiczne wymagania *Ch. delicatula* to podstawowe parametry jezior oligotroficznych i mezotroficznych, jak duża widoczność, niskie wartości *pH*, twardość wody i mała zawartość związków pokarmowych (15—21). W jeziorach oligotroficznych *Ch. delicatula* tworzy rozmnóżki służące do rozmnażania wegetatywnego (forma *bulbillifera*).

РЕЗЮМЕ

В семействе *Characeae* только *Chara delicatula* Agardh и *Nitella flexilis* Agardh растут в олиготрофных и крайне мезотрофных озерах. На Западном и Гданьском Поморьях выступают в олиготрофных озерах в ассоциации *Isoëto-Lobelietum* вместе с *Isoëtes lacustris* и *Lobelia dortmanna*. *Ch. delicatula* и *N. flexilis* принадлежат к характерным видам этой ассоциации. На Ленчиньско-Влодавском поозерье в озерах подобного типа растут в ассоциации *Myriophylletum alterniflori*. Главные факторы, определяющие автоэкологические требования *Ch. delicatula* — это основные параметры олиготрофных и мезотрофных озер: хорошая прозрачность, низкое *pH*, твердость воды и небольшое содержание кормовых соединений (15—21). В олиготрофных озерах *Ch. delicatula* образует выводковые тельца, служащие для вегетативного размножения (forma *bulbillifera*).