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Occurence of algae on tundra soils in Oscar II Land, Spitsbergen

ABSTRACT: 104 algal taxa (31 blue-green algae, 48 diatoms and 25 green algae) were identified from 18 stands of tundra soils in the Kaffiöyra Plain (Oscar II Land, NW Spitsbergen). Basing on numerical analysis by the reciprocal averaging method and on hierarchic classification based on „distinguishing species", two groups of stands were distinguished: moist and wet ones characterized by diatoms, and dry and drying ones characterized by blue-green algae.

K e y w o r d s : Arctic, Spitsbergen, blue-greens, diatoms, desmids, wet biotops.

Introduction

Program of geobotanical studies was an objects of 8th Toruń Polar Expedition (Spitsbergen'89). An important part of this program focused on a study of species composition and role of algae in various of plant formations in tundra of marine terraces in the Kaffiöyra Plain. Initial studies on algal flora had already been carried out in previous Toruń Polar Expeditions (Oleksowicz 1984, Plichta and Luścińska 1988).

Ecological importance of terrestrial algae has been appreciated for a long time. A particular role in soil building processes is ascribed to blue-green algae, which can colonize habitats extremely poor in biogens. Thanks to their ability to assimilate atmospheric nitrogen (Steward 1971) blue-green algae can act as pioneer organisms (Cameron *et al.* 1978) by enriching substratum with biogenous substances, indispensable for the development of other more demading organisms.

Range and methods

The present work contains analysis of species composition of algae sampled in late July and early August 1989 from stands in the Kaffiöyra Plain. The samples were taken mostly from wet areas associated with poorly permeable surface ground layers of some marine terraces as well as with microrelief of a ground surface and with periglacial structures. They appear most frequently

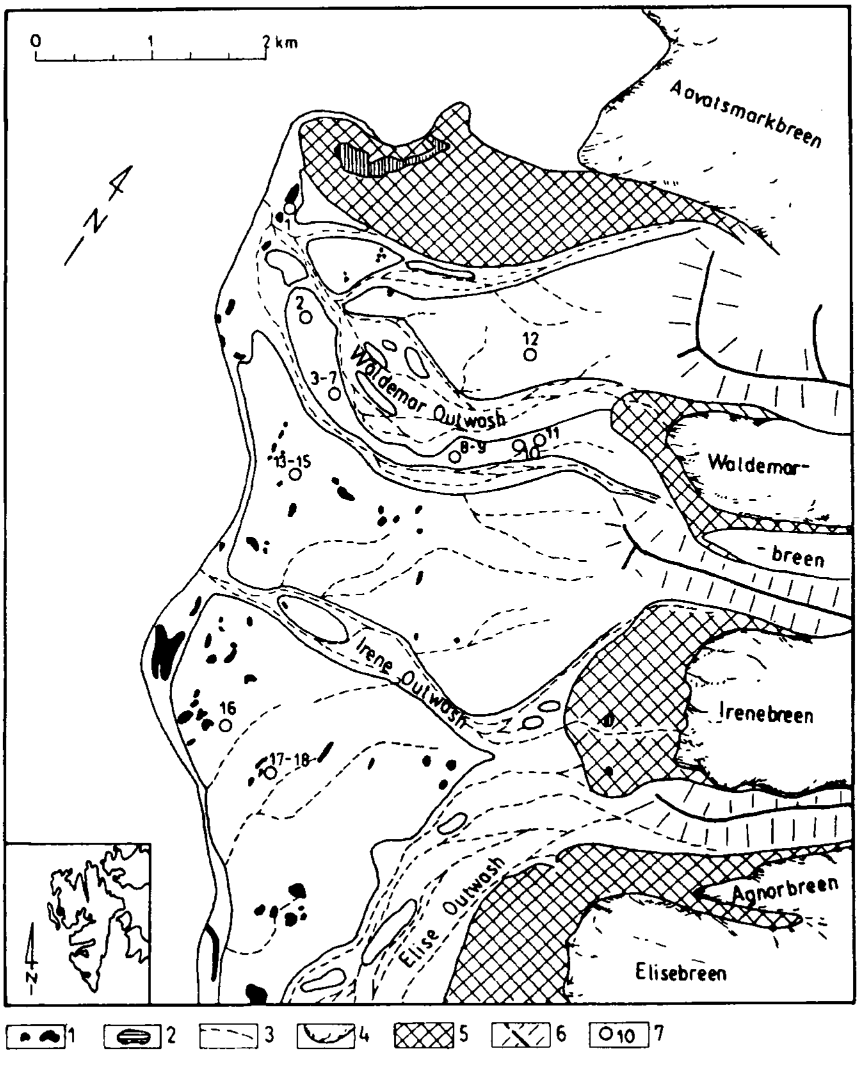

Fig. 1. Location of the studied area and distribution of the stand in the Kaffiöyra
1 – inland lakes, 2 – coastal lakes, 3 – rivuletes, 4 – glaciers, 5 – moraines, 6 – mountains, 7 – stands.

Table 1

Description of stands

Stand	Type of soils	Type of vegetation	Plant communities
1	Gelic Regosols	snow-bed tundra	*Cochlearia groenlandica* – *Drepanocladus revolvens*
2	" Gleysols	lichen tundra	*Cetraria delisei* – *Luzula confusa*
3	" "	dry moss tundra	*Saxifraga oppositifolia* – *Drepanocladus revolvens*
4	" "	snow-bed tundra	*Drepanocladus fluitans* – *Deschampsia alpina*
5	" "	" " "	*Drepanocladus intermedius* – *Scorpidium turgescens*
6	Gelic Cambisols	dry moss tundra	*Saxifraga oppositifolia* – *Drepanocladus revolvens*
7	" "	" " "	" " " "
8	" "	fresh moss tundra	*Salix polaris* – *Drepanocladus revolvens*
9	" "	" " "	" " " "
10	" "	" " "	" " " "
11	Rankers	snow-bed tundra	*Deschampsia alpina* – *Juncus biglumis*
12	Gelic Cambisols	" " "	" " " "
13	" Gleysols	" " "	" " " "
14	" "	" " "	" " " "
15	" "	" " "	" " " "
16	" "	" " "	" " " "
17	Gelic Lithosols " Cambisols	" " "	" " " "
18	" "	" " "	" " " "

at the beginning of summer, just after the snow cover disappears. An important role in the maintenance of those areas is played by permafrost, which retards infiltration of precipitation and of melt waters. As an active layer gets thicker, a ground surface becomes gradually drier and the wet areas are more limited. In full summer they occur most frequently only on flat terrace surfaces in watershed areas or at foot of terrace scarps (Szczepanik *unpubl.*). Samples come from wet areas on all terraces, from the youngest accumulative one to the oldest accumulative-abrasive ones at foot of the Prinz Heinrich and Grǻfjellet massifs. Some samples were taken from rubble springs at foot mountain slopes in rubble zone, additionally supplied with precipitation and water from melting snow patches. Types of arctic soil were identified using the soil map of the studied area (Sinkiewicz and Plichta 1987), and the plant communities by means of actual vegetation map (*unpubl.*) and the distinguished types of tundra (Gugnacka—Fiedor and Noryśkiewicz 1982) (Fig. 1, Table 1).

Studies of the algal flora in the Kaffiöyra Plain were designed by Dr Andrzej Oleksowicz, who died in September 1989 on his way back from the 8th Toruń Polar Expedition. Results presented in this paper concern a part of the material he collected, the remaining one will be an object of the another study.

Identified algae and bryophytes from samples were analyzed by the reciprocal averaging method (RA; Hill and Gauch 1980) applying the indirect gradient analysis with use of program DECORANA (Hill 1979), and then by the hierarchic classification method basing on „distinguishing species" with the use of program TWINSPAN (Hill, lc.).

The object of those studies was to define a species composition of algae and bryophytes on selected types of tundra soil in the Kaffiöyra Plain and to find out to what extent particular taxa or taxonomic groups of plants are associated with stands of various moisture and trophic conditions, and so be able to characterize various habitats by their species composition.

Results

In 18 samples fixed in formalin 104 taxa of algae (Figs 2—9) and 30 taxa of bryophytes were identified. The most numerous group of algae was formed by diatoms (48 taxa), blue-green algae were the second (31 taxa), and the least numerous were green algae (25 taxa, mainly Desmidiales). Among bryophytes there were 28 taxa of mosses and two species of Hepaticae (identified by W. Gugnacka—Fiedor). Different numbers of algal taxa were found in different samples, thus *e.g.* in the sample 3 only one species was found, the blue-green alga *Nostoc commune*, forming large wrinkled thalli on nearly dry substratum. The largest number of taxa (45 identified algae) were enclosed in the sample 17, where diatoms were predominant.

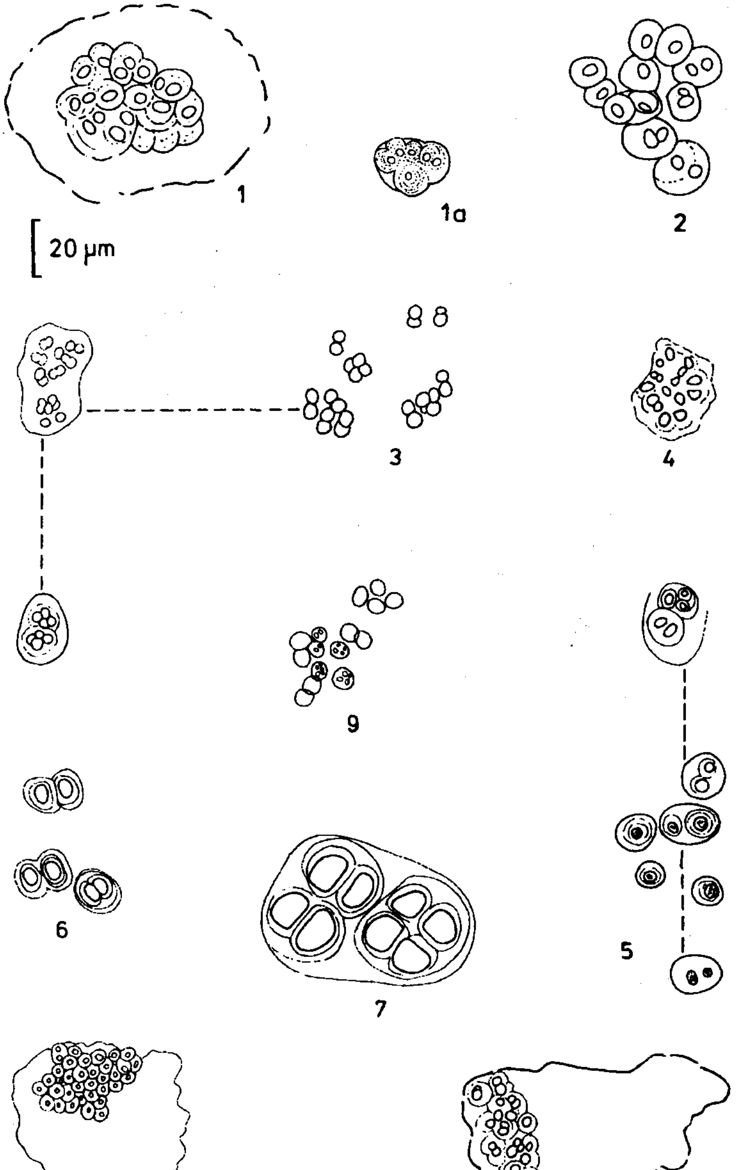

Fig. 2. Cyanophyta – blue-greens, in parentheses – number of stands
1 *Gleocapsa alpina* Näg.emend.Brand. (2,5,6,7,8,9,13), la *G.alpina* – nannocytes, 2 *G. kützingiana* Näg. (2,6,7,8,13,15,16), 3 *G. minor* (Kütz.) Hollerb. (4,6,8,13,15,16), 4 *G.* cf. *bituminosa* (Boy) Kütz.(15), 5 *G. montana* Kütz. (1,5), 6 *G. decorticans* (A.Braun) P.Richt. (1), 7 *G. turgida* (Kütz .) Hollerb. (4,5,6,7,8,9,10,13,14,15,16,17), 8 *G. punctata* Näg. (1), 9 *Chlorogloea* cf. *microcistidoides* Geit. (15), 10 *Microcystis* cf. *parietina* (Näg.) Elenkin (5).

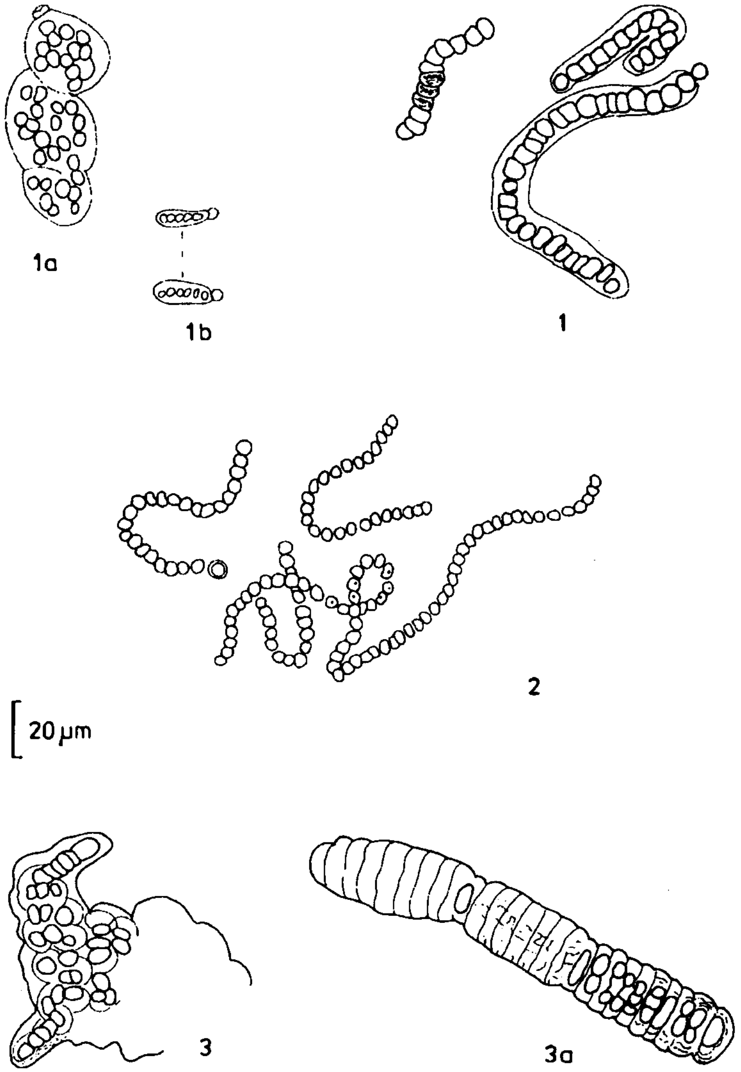

Fig. 3. Cyanophyta – blue-greens, in parentheses – number of stands
1, 1a, 1b *Nostoc commune* Vaucher (1,2,3,5,6,7,8,9,10,13,15,16), 1a and b – hormogonium, 2 *N. paludosum* Kütz. (2,9), 3 *Stigonema mamillosum* (Lyngb.)Ag. (8,9), 3a *S. mamillosum* – hormogonium

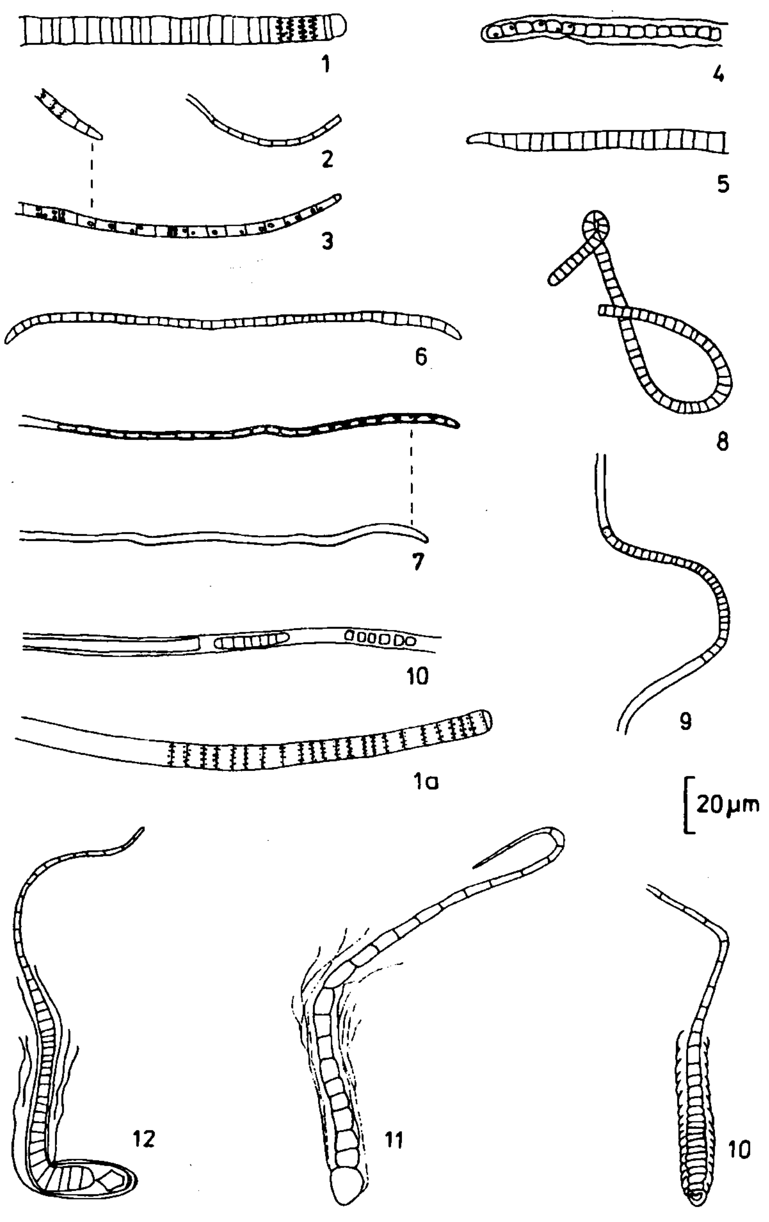

Fig. 4. Cyanophyta — blue-greens, in parentheses — number of stands
1 and 1a *Ocillatoria irrigua* (Kütz.)Gom. (7,11,13,14,17), 2 *Lyngbya* sp. (C) (15), 3 *Oscillatoria geminata* (Men.)Gom. (11), 4 non determined blue-green alga (1), 5 *Oscillatoria cortiana* (Men.)Gom. (2), 6 *O. laetevirens* (Crouan)Gom. (6), 7 *Oscillatoria* sp.(A) (4,5,7,9,13,15,16), 8 *G. rupicola* Hansg.(4), 9 *Lyngbya* sp. (A) (2,4,5,6,7,13), 10 *Lyngbya* sp (B) (5,8,15,18), 11 — 13 *Calothrix* cf. *parietina* (Näg.) Thur. (1,4,5,6,7,8,9,13,15)

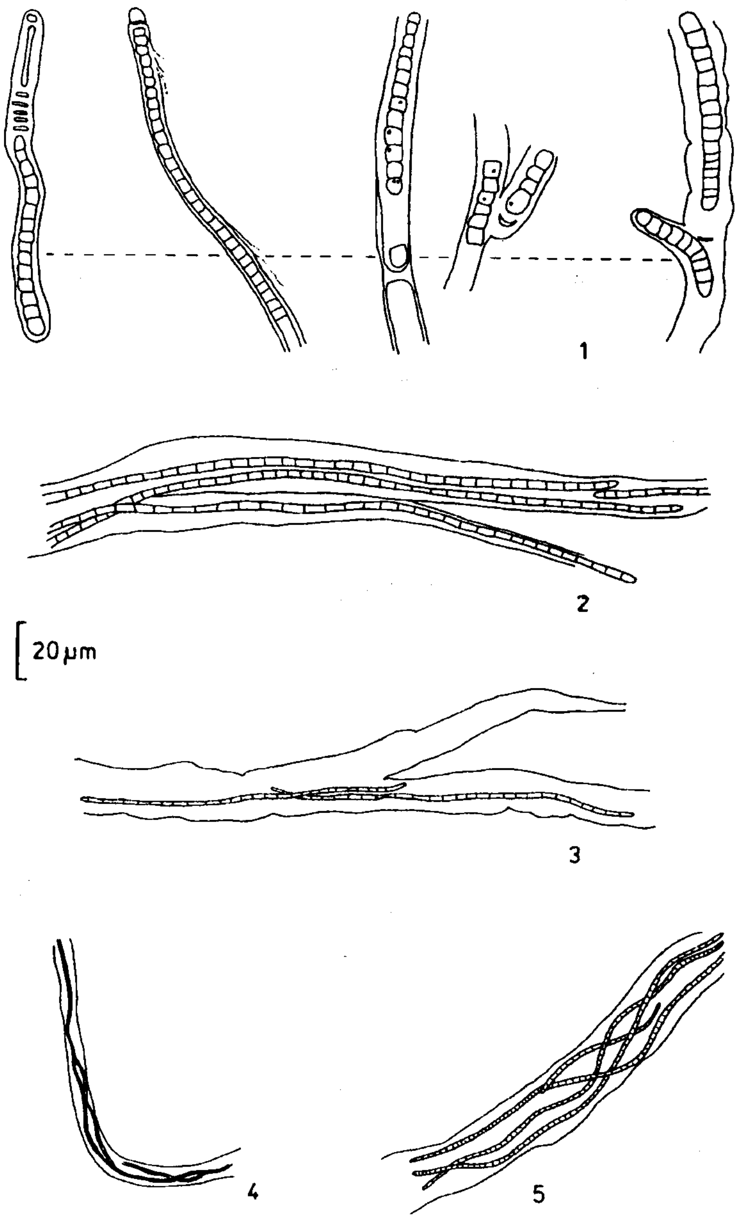

Fig. 5. Cyanophyta – blue-greens, in perentheses – number of stands
1 *Tolypothrix tenuis* Kütz. f. *terrestris* Boye-Petersen (2,9,10,17), 2 *Schizothrix friesii* (Ag.)Gom. (7,9,10), 3–5 *S. lardacea* (Cesati)Gom. (2,6,7,8,9,10,15,16)

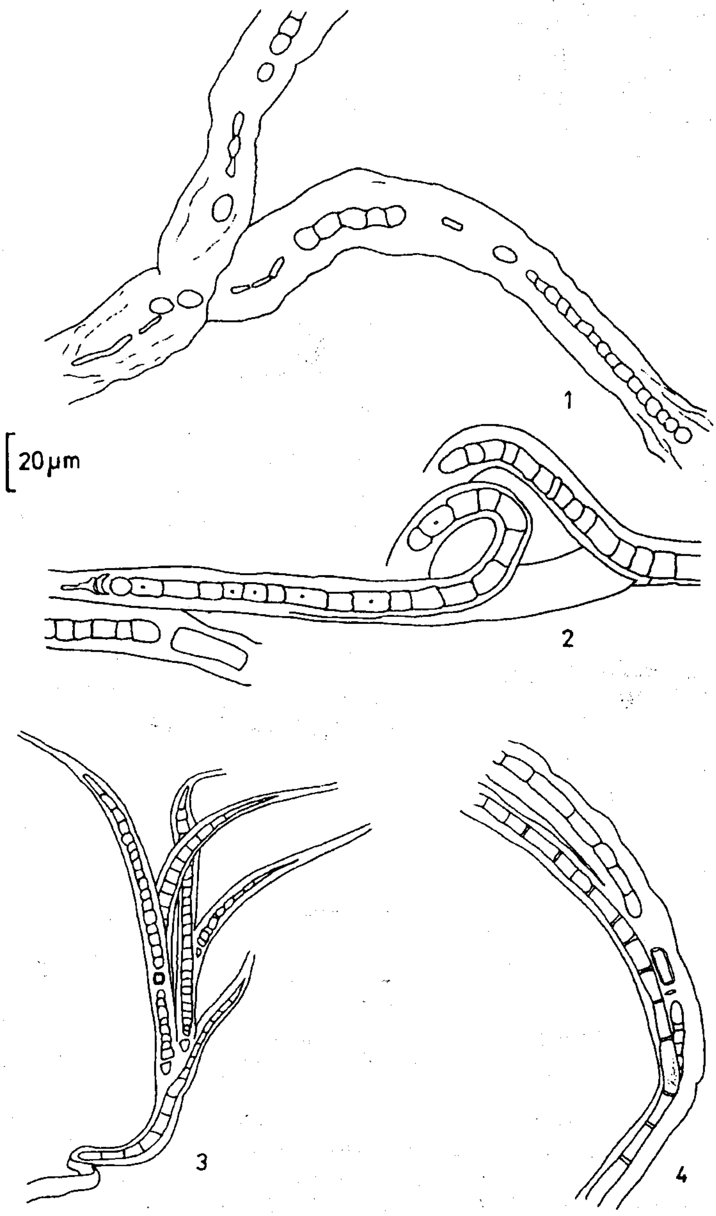

Fig. 6. Cyanophyta – blue-greens, in parentheses – number of stands
1 *Scytonema crustaceum* Ag. (5,6,7,8,9,13), 2 *S. ocellatum* Lyngb. (7,17), 3 *Dichothrix* cf. *fusca* F.E.Fritsch (7,8,9,13,17), 4 *Scytonema tolypotrichoides* Kütz. (6,9,17)

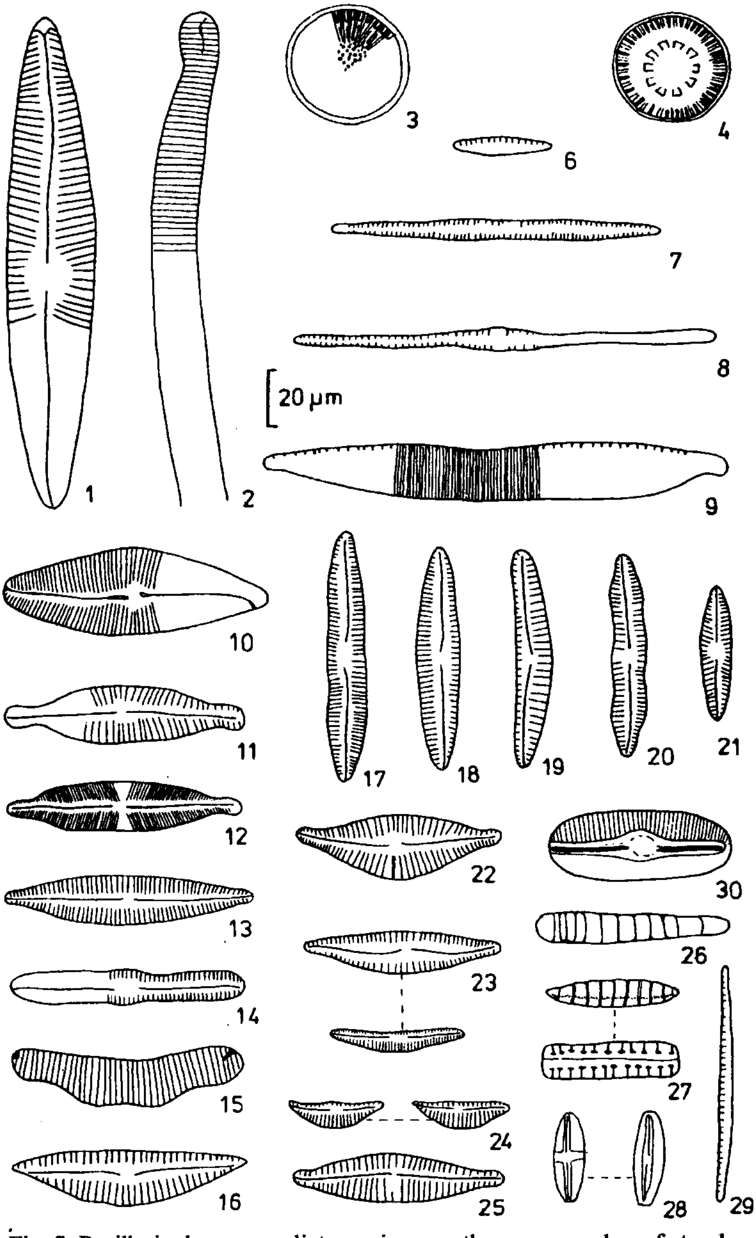

Fig. 7. Bacillariophyceae — diatoms, in parentheses — number of stands
1 *Navicula radiosa* Kütz. (8,12,13), 2 *Eunotia pseudopectinalis* Hust. (13,17), 3 *Cyclotella bodanica* Ehr. (1), 4 *C. antigua* W.Sm. (12,13,14,15,17,18), 6 *Nitzschia pusilla* Grunov (1,4,8,11,12,13,14,17, 18), 7 *Fragilaria alpestris* Krasske (11,13,14,17), 8 *Synedra rumpens* Kütz. v. *scotica* Grunov (1), 9 *Hantzschia amphioxys* (Ehr.) W.Smith (8,11,13), 10 *Achnanthes flexella* (Kütz)Brun. (11,12,13,14, 17,18), 11 *Navicula cryptocephala* Kütz. (11), 12 *Stauroneis agrestis* Petersen (11), 13 *Navicula halophila* (Grun.)Cleve (4,12,13,14,15,17,18), 14 *Caloneis silicula* (Ehr.)Cleve (8,13,17,18), 15 *Eunotia bigibba* Kütz. (18), 16 *Cymbella elginensis* Kramer (15,17), 17,18 *C. norvegica* Grunov (12, 13,14,15,17,18), 19 *C. norvegica* v. *lapponica* Cleve-Euler (1,4,8,10,11,12,13,14,15,17,18), 20 Cymbella cf. *sinuata* Greg. (4,12,13,14,15,18), 21 *Navicula* sp. (2,13,15,17), 22 *Cymbella designata* Kramer (13,14,17,18). 23 *C. delicatula* Kütz. (4,8,10,11,12,13,14,15,17,18,), 24 *C. minuta* Hilse ex Rabenh. (11,17,18), 25 *Gomphonema parvulum* Kütz. (17,18), 26 *Meridion circulare* Ag. (1,4,8,11), 27 *Denticula elegans* Kütz. (1,4,10,12,13,14,15,17,18), 28 *Stauroneis* sp. (11,12,13,15,18), 29 *Nitzschia paleacea* Grun. (8,14), 30 *Diploneis boldtiana* Cleve (1,8,13,17)

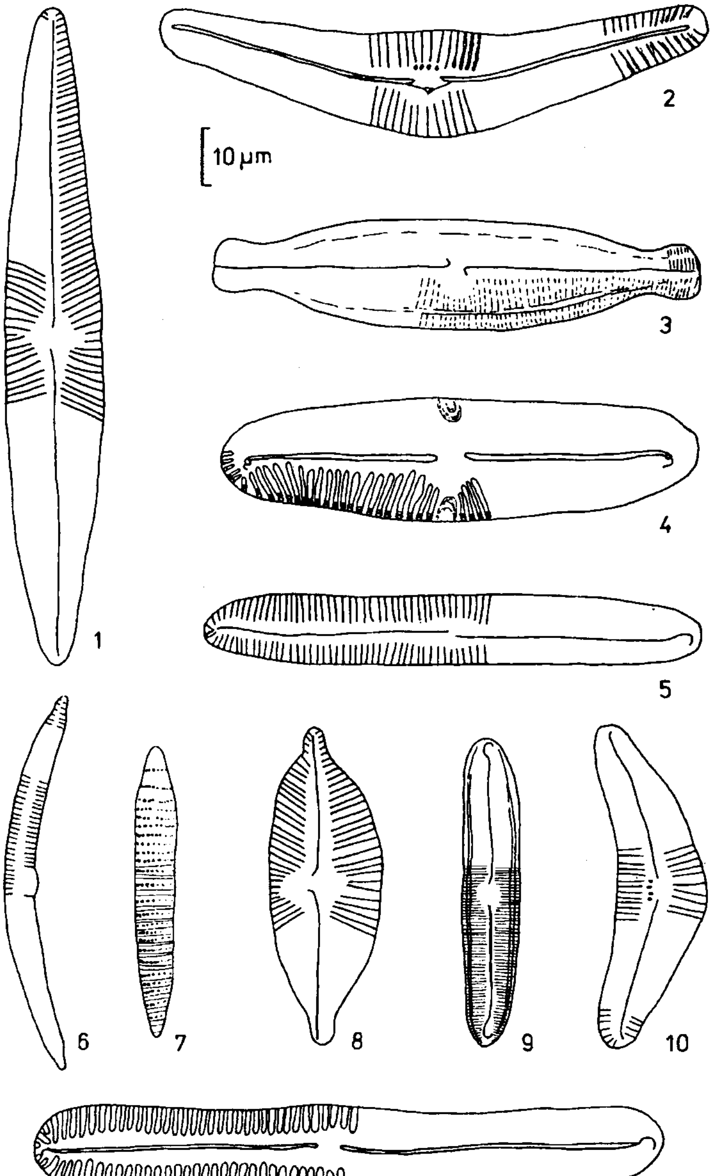

Fig. 8. Bacillariophyceae – diatoms, in parentheses – number of stands
1 *Navicula hasta* Pantocsek (4,12,13), 2 *Cymbella poxima* Reimes (1,12,14,17,18), 3 *Neidium affine* (Ehr.)Pruff. (8,14,17), 4 *Pinnularia divergens* W. Smith (8,14,17), 5 *P. viridis* (Nitzsch.)Ehr. (1,8,11,12), 6 *Ceratoneis arcus* (Ehr.) Kütz. (1,4,8,11,12,17,18), 7 *Nitzschia amphibia* f.*amphibia* Grunov (1,4,8,10,12,13,14,17,18), 8 *Cymbella cuspidata* Kütz. (8,11,17,18), 9 *Caloneis alpestris* (Grunov)Cleve (17), 10 *Cymbella cymbiformis* (Kütz.)V.H. (1,4,8,10,11,12,13,14,15,18), 11 *Pinnularia macilenta* (Ehr.)Ehr. (13)

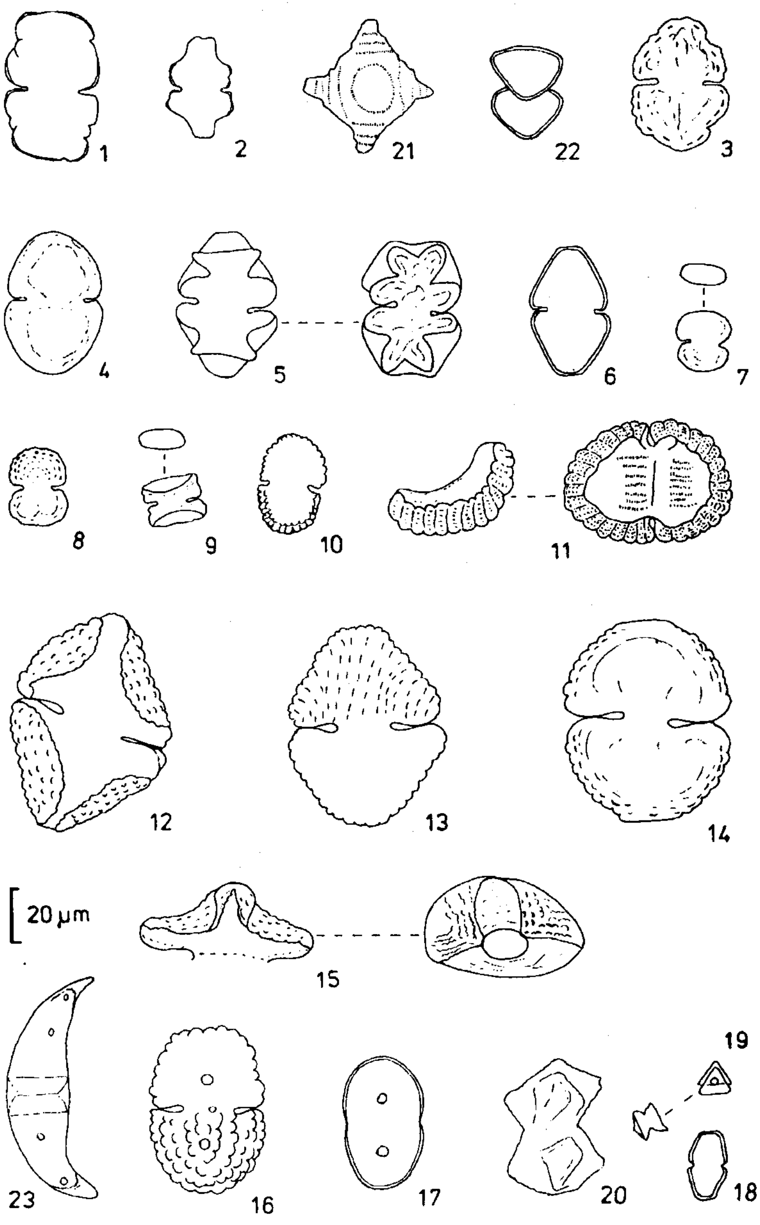

Fig. 9. Desmidiales – desmids, in parentheses – number of stands
1 *Cosmarium holmiense* Lund v. *integrum* Lund (6,8,9,13,17,18), 2 *C. pokornyanum* (Grun.)W. et G.S.West (8,9), 3 *Cosmarium* sp.(D) (13), 4 *C. microsphinctum* Nordst. (9,17), 5 *Cosmarium* sp. (C) (13,16), 6 *C. pseudopiramidatum* Lund. (14), 7 *C. bioculatum* (Bréb.) ex Ralfs (7,13), 8 *C. punctulatum* v. *supunctulatum* (Bréb.)Pal.–Mordv. (5,6,7,8,9,10,11,14,17,18), 9 *C.* cf. *pseudobroomei* Wille, forma (5,6,7,8,9,13,14,17,18), 10 *C. speciosum* v. *simplex* Nords. (7,13), 11 *C. speciosum* Lund. (7,8,9,10,13,15,17,18), 12 *C. hornavanense* Gutw. v. *dubovianum* (Lutkem.)Růž., forma (17,18), 13 *C. botrytis* Men. v. *subtumidum* Wittr. (18), 14 *C. obtusatum* Schmidle (10,14,17,18), 15 *Cosmarium* sp. (A) (10,13), 16 *Cosmarium* sp. (B) (6,7,8,9,10), 17 *Actinotaenium curtum* (Bréb.)Teil. v. *maius* Wille (6,7,10,17), 18 *C. anceps* v. *anceps* Lund. (9,17), 19 *Staurastrum clepsydra* Nord. v. *sibiricum* (Borge) West f. *trigona* (8,9), 20 *Cosmoastrum punctulatum* (Bréb.)Pal.–Mordv. v. *kiellmanii* (Bréb.)Pal.–Mordv. (17), 21 *Staurastrum* cf. *hexacerum* (Ehr.)Wittr. (8,17), 23 *Closterium leibleinii* Kütz. v. *minimum* Schmidle (10,14)

Generally speaking, more diversity in species was found in stands with stagnant water, long to dry, whereas in small drying or dried up pools a number of taxa was small. There, too, blue-green algae usually predominated, and among them the most abundant were the large thalli of *Nostoc commune*. Filaments of this alga, like those of *Tolypothrix* or *Schizothrix*, were surrounded with a very thick layer of jelly (Figs 2 – 1, 3 – 1, 2, 3, 5 – 1, 3, 6 – 1). Jelly envelopes of soil blue-green algae were often coloured; it follows from Fott's (1959) and Kol's (1968, *after* Kawecka 1986) studies that the red pigment in algal envelopes constitutes probably a filter protecting a cell assimilation apparatus from harmful ultraviolet radiation. Diatoms from soil samples would have been also adapted to living in terms of frequent drying up of seasonal pools. They either occurred in a jelly of blue-green algae or produced themselves a tangle of jelly-like styluses (diatoms of the genus *Cymbella*) and tubules, which protected them from desiccation. These extreme conditions caused frequent occurrence in some species of desmids of concave cell walls (Figs 9 – 5, 9, 12, 15). Similar cells were observed by Palamar – Mordvintseva (1975) and Oleksowicz (1984), who described them as developmental anomalies occurring under frequent changes in habitat.

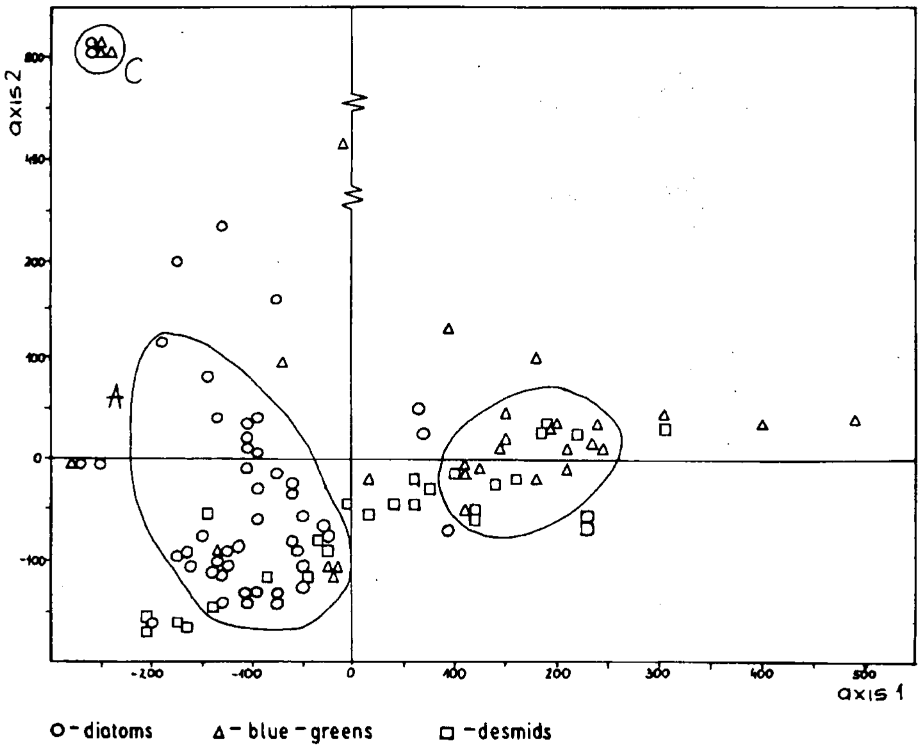

Fig. 10. Distribution of taxa groups of algae according to the main gradient in DECORANA program

It follows from a comparison of the species composition by the reciprocal averaging method (Fig. 10) that blue-green algae and diatoms in the studied stands characterize fairly well two distinct types of habitats (Fig. 10A and B). The factor dividing the algae into two groups, distinctly differentiated on either side of the axis, may have been both the presence of water and the concentration of biogenous salts in a substratum. Blue-green algae, being better adapted to desiccation, can live under protracted drought conditions; they can also colinize sites devoid of mineral nitrogen compounds. Greater requirements of diatoms with reference to both water biogenous salts place them on the other side of the graph axis. Distinctly separate group of algae (Fig. 10C), situated far from the graf axis, is constituted by planktonic diatoms: *Melosira granulata, Cyclotella bodanica, Synedra rumpens v. scotica* and blue-greens: *Gleocapsa punctata* and *G. decorticans*. A behaviour of desmid species is different from that of blue-green algae and diatoms: they are scattered on either side of the dividing axis (Fig. 10) among diatoms and blue-green algae. This confirms the opinion expressed by Oleksowicz (1987) on a low indicatory value of this systematic group.

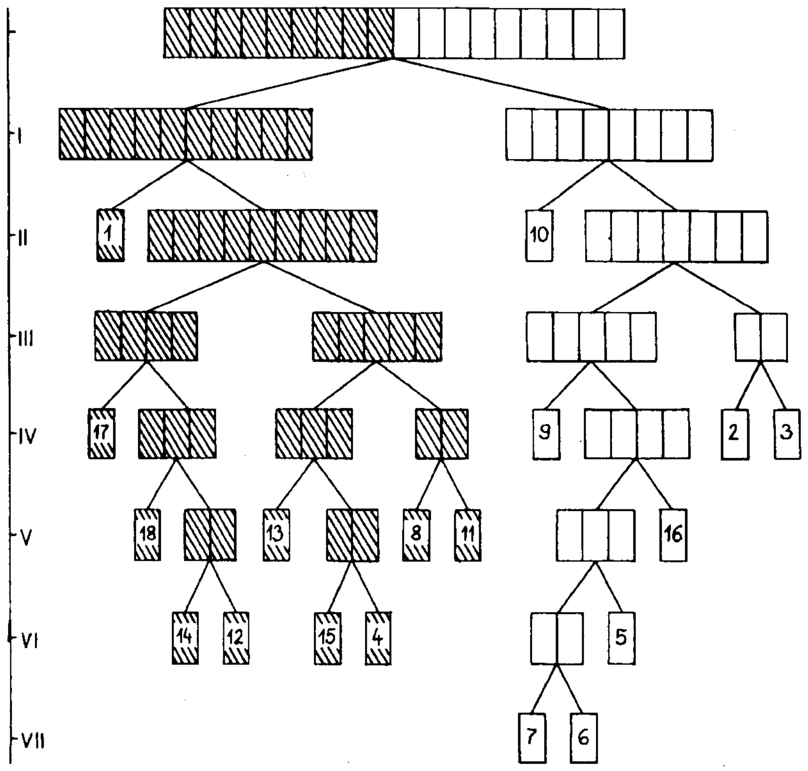

Fig. 11. Dendrogram of samples ordering according of the hierarchical classification in TWINSPAN program; I – VII – division levels, 1–18 – number of samples

Also the dendrogram made by the hierarchic classification method basing on „distinguishing species" (Fig. 11) divides the stands already at a first level into two groups characterized by the following species:

1 – *Navicula halophila, Cymbella norvegica v. lapponica, Nitzschia pusilla* and *Denticula elegans*

2 – *Schizothrix friessi.*

It comparing a distribution of samples that contain algae only with those containing algae and bryophytes, it seems obvious that bryophytes, while constituting an ecological niche for algae, characterize rather poorly the distinguished habitats. Stand 1 (Fig. 12) is definitely distinct with numerous diatom species. It is regulary flooded with sea water at high tides. Stand 11 situated in spring area is distinguished at a second level of division; it contains

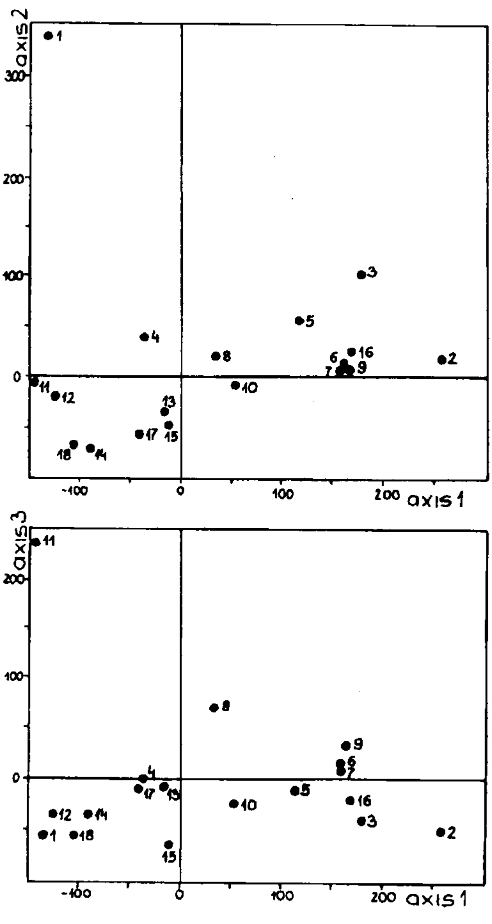

Fig. 12. Distribution of samples obtained along main gradient axes 1,2,3 distinguished by DECORANA program; 1 – 18 – number of samples

a large number of filaments of green algae of the genus *Zygnema* and is characterized probably by the highest biogenous salt content in water. It is also sheltered from cold winds and well exposed to insolation. On account of these climatic factors it is to be characterized with high temperature of a ground surface.

Except for those two stands distinguished for different reasons, the remaining ones accumulate near the dividing axis; it is possible to distinguish a group of stands with diatoms (left side of the graph) and a group of stands with blue-green algae (right side of the graph).

Conclusions

The algal flora in tundra soils of the Kaffiöyra Plain is rich and diversified, being the evidence of numerous ecological niches, where individual species find favourable conditions for their development. Algological studies carried out so far in this area (Oleksowicz 1984, Plichta and Luścińska 1988) have demonstrated that the most important among the tundra soil algae are the blue-green ones. They often predominate in given stand, *e.g. Nostoc commune* which forms large brown thalli on a drying up substratum. A significance of blue-greens is expressed by production of large amounts of biomass in spite of extreme conditions, thus enriching a substratum with, among other things, carbon and nitrogen compounds, and so participating in soil building processes (Plichta and Luścińska, lc.). Remaining algal taxa, though taxonomically and ecologically diversified, do not produce significant biomass unter those conditions. Habitats where water stagnates longer or permanently are colonized mainly by diatoms and green algae of the order Zygnematales, while habitats regulary drying or dry, dependent solely on precipitation water, contain mainly blue-green algae on a soil surface.

Considering results of the above analyses, the stands have been divided into two well distinguished groups: lastingly moist and apparently wet with predominant diatoms or Zygnematales (stands: 1, 10–12, 14, 17, 18) and drying up stands with predominant, even mass occurrence, of blue-green algae (2, 3, 5–7, 9, 13, 15, 16).

It can be assumed therefore that these are the blue-green algae that on account of their biology and morphology as well as large amount of biomass production, play a pioneer role in soil building processes, particularly in areas where extreme conditions prevent development of other organisms.

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Streszczenie

Materiał do badań glonów gleb tundrowych niziny Kaffiöyra zbierano podczas Ósmej Toruńskiej Wyprawy Polarnej Spitsbergen'89. Próby pobierano przeważnie z obszarów podmokłych niektórych teras morskich (fig. 1, tab. 1) na przełomie lipca i sierpnia 1989 roku. Z 18 stanowisk oznaczono 104 taksony glonów (31 sinic, 48 okrzemek i 25 sprzężnic) (fig. 2—9), które następnie analizowano metodą wzajemnego uśredniania z zastosowaniem pośredniej analizy gradientowej przy użyciu programu DECORANA (fig. 10), a następnie metodą klasyfikacji hierarchicznej na podstawie „gatunków wyróżniających" przy użyciu programu TWINSPAN (fig. 11). Analiza składu gatunkowego glonów z badanych stanowisk pozwala na wyróżnienie dwu wyraźnych grup siedlisk: suchych i szybko schnących charakteryzowanych przez sinice oraz wilgotnych i wodnych charakteryzowanych przez okrzemki lub Zygnematales (fig. 12).