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Numerical analysis of plant communities of tundra at the Vårsolbukta, Bellsund, Spitsbergen

ABSTRACT: This paper contains the results of phytosociological studies carried out on the model fragment of Spitsbergen tundra at Bellsund. In the area of 4800 m^2 19 plant communities have been distinguished through association analysis and these communities, in turn, have been compared according to cluster analysis. Also, ecological groups of species have been distinguished.

Key words: Arctic, Spitsbergen, plant communities, numerical classification

Introduction

Arctic phytocoenoses have specific role in the process of learning of the structure and functioning of plant communities. Tundra phytocoenoses belong to the least complex plant communities and therefore they are very suitable subject of mathematical modelling.

Spitsbergen, having a status of separate geobotanical province (Aleksandrova 1971, 1980), belongs to the best known Arctic areas. Additional reason which makes Spitsbergen so attractive as a research area is its special political status facilitating the scientific penetration of this archipelago.

The simplicity of organization of plant cover in Spitsbergen is manifested by:

— small number of vascular plant species forming communities (on Svalbard archipelago there are no more than 200 species of vascular plants);
— mono-stratum plant cover;
— predomination of the habitat — population interaction over interpopulation relations (Aleksandrova 1983).

The authors of papers dealing with plant communities of Spitsbergen published so far have used almost exclusively collection method and material processing applied by Braun-Blanquet school (Hadač 1946, Hofmann 1968, Gugnacka-Fiedor and Noryśkiewicz 1982, Dubiel and Olech 1985) or Scandinavian phytosociologists (Rönning 1964, Eurola 1968). In these researches typological collection of material was used and the original matrix of data was ordered intuitively, forming phytosociological tables showing distinguished types of communities and groups of species characteristic for them. As a result of these researches many plant communities were distinguished and most of them were suggested to be placed in the order *Salicetalia polaris — arcticae* (Hartmann 1980, Elvebakk 1985).

Many papers were devoted to the analysis of habitat dependency of the variety of Arctic vegetation. As most important abiotic factors determining the qualitative composition, domination structure and physionomy of plant communities in Spitsbergen were considered: permafrost (Eurola 1968, Gugnacka-Fiedor and Noryśkiewicz 1982, Rezniček and Svoboda 1982); hydrological regime (Eurola 1968, Sarul 1981, Gugnacka-Fiedor and Noryśkiewicz 1982, Brattbakk 1985); geological kind of the ground (Eurola 1968, Elvebakk 1982); pH of the soil (Elvebakk 1982, 1984, Rezniček and Svoboda 1982); variability of duration and thickness of snow cover (Eurola 1968, Gugnacka-Fiedor and Noryśkiewicz 1982, Rzętkowska 1987); nutrients availability (Eurola and Hakala 1977); topographic gradient (Elvebakk 1985, Rezniček and Svoboda 1982); wind activity (Gugnacka-Fiedor and Noryśkiewicz 1982, Rezniček and Svoboda 1982) and mechanical ground instability (Fabiszewski 1975).

Eurola (1968) gave the most exhaustive and detailed information concerning ecological similarity of species for Hornsund and Isfjord region. He had classified all collected species of vascular plants, mosses and lichens into 5 groups. He had distinguished groups of species of deflation tundra, lichen tundra, dry and fresh moss tundra and also a group of species typical of snow beds. The ecological groups of species suggested by Eurola (1968) are the result of application of monothetic classification procedure which does not ensure full exploitation of information included in the original set of data.

Short characteristics of most important plant species of Svalbard, informing mainly about their diagnostic value for communities distinguished by various authors are included in Hartmann's work (1980).

The most important goals of the present work are:
- to show the advantage of non-typological method of material collection and of numerical classification methods (association analysis and cluster analysis) used to distinguish and describe plant communities in the Arctic basing on model example of tundra at Bellsund;
- to present the distinguished plant communities against the background of chosen environmental factors, such as topography, exposure and ground quality;

— to group vascular plants in clusters, combining taxa of similar ecological requirements.

Investigated area

Botanic research covered a small (80 × 60 m) part of sea shore terrace situated at Varsolbukta, a part of Bellsund (Nordenskiöldland, West Spitsbergen) at the foot of Ingeborgfjellet (Fig. 1, Pl. 1). This terrace is built of metamorphic rocks of Hecla-Hoek formation and of quartzite sandstone (Flood, Nagy and Winsnes 1971). A large colony of Little Auk (Plautus alle) occurs some 600—800 m to the noth from the research area on the slopes of the Ingeborgfjellet. Bird excrements are washed out from their nesting places and fertilize the areas situated below.

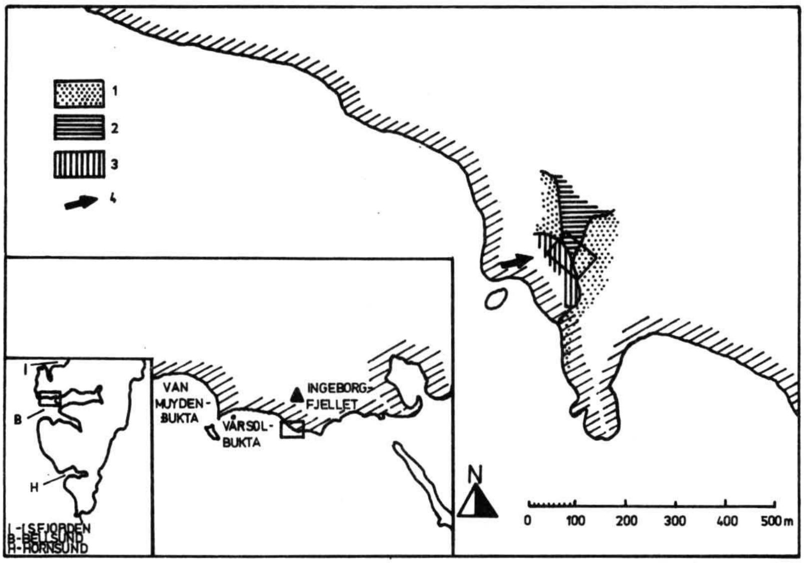


Fig. 1. Investigated area 1 — *Saxifraga oppositifolia* — *Cetraria delisei* community; 2 — *Tomentypnetum nitentis* Hofmann 1968; 3 — *Alpecurus alpinus* — *Poa arctica* community; 4 — the direction of topography projection. (Communities according to Brattbakk 1985).

The examined area lies at the border of two geobotanical zones — *Cassiope tetragona* zone and *Dryas octopetala* zone (Brattbakk 1986). Vegetation of the sea terrace surrounding Varsolbukta was charted by Brattbakk (1985) in scale 1:20000. The area analysed in the present paper comprises patches of 3 plant communities: of *Saxifraga oppositifolia* — *Cetraria delisei* community, *Tomentypnetum nitrentis* and of *Alopecurus alpinus* — *Poa arctica* community (Tab. 1).

Table 1

Species composition of the 19 distinguished plant communities

Community	6	8	5	4	7	3	15	1	10	11	12	16	2	9	13	14	17	18	19
Number of sampling squares	67	26	18	28	18	29	28	28	21	43	5	19	6	15	22	38	26	24	19
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Saxifraga flagellaris Willd.	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—
Silene acaulis (L.) Jacq.	2	—	—	—	—	—	1	1	1	2	—	—	—	—	—	—	—	—	—
Papaver dahlianum Nordh.	6	1	—	2	4	2	—	—	—	—	—	3	—	—	—	—	—	—	1
Saxifraga hieraciifolia W. et K.	7	1	3	4	—	1	—	2	2	—	—	—	—	—	—	—	—	—	—
Minuartia rubella (Wbg.) Hiern	4	3	1	6	—	2	—	4	1	—	—	—	—	—	—	—	—	—	—
Cardamine bellidifolia L.	—	—	1	2	—	1	1	2	—	—	1	—	—	—	—	—	—	—	—
Draba spp.[1]	67	26	18	28	18	29	—	28	—	—	—	—	6	—	—	—	—	—	—
Pedicularis hirsuta L.	7	11	2	6	—	2	—	—	—	1	—	—	1	—	—	—	—	—	—
Salix polaris Wg.	67	26	17	28	—	22	28	25	19	42	5	19	3	11	22	38	—	—	—
Polygonum viviparum L.	20	9	10	17	1	7	6	21	8	7	5	2	3	7	—	—	1	3	—
Saxifraga hirculus L.	19	7	7	16	2	1	1	5	4	6	—	2	1	1	—	2	—	—	1
Saxifraga nivalis L.	45	12	—	28	16	8	3	6	2	—	—	8	1	—	—	—	1	—	2
Saxifraga oppositifolia L.	59	20	11	18	17	15	5	21	10	11	3	12	2	—	5	1	—	6	4
Sagina intermedia Fenzl	41	19	11	25	8	8	3	12	1	1	—	8	—	1	—	1	2	2	3
Saxifraga caespitosa L.	67	—	15	19	18	18	7	28	9	5	2	10	—	5	3	5	4	15	10
Luzula confusa (Hartm.) Lindb.	50	19	6	22	6	19	20	2	21	—	—	15	1	4	13	12	15	5	5
Cerastium arcticum Lge.	54	22	14	28	12	21	12	28	20	29	3	9	6	11	22	—	9	3	8
Saxifraga cernua L.	20	2	14	12	6	14	4	26	9	25	5	1	6	10	6	8	17	22	7
Oxyria digyna (L.) Hill	6	7	3	6	—	6	7	8	9	12	1	1	6	15	10	3	17	1	5
Cerastium regelii Ostf.	1	—	2	1	—	4	1	1	—	2	1	—	—	1	2	1	5	24	—
Saxifraga rivularis L. + *Saxifraga hyperborea* R. Br.	—	—	2	2	1	10	8	2	4	5	1	2	—	3	14	28	23	19	11
Cochlearia officinalis L.	—	—	18	28	—	16	—	19	9	16	5	—	2	6	22	38	15	22	12

Table 1 — continued

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Poaceae spp.[2)]	—	—	—	—	—	29	28	15	20	38	4	—	5	15	19	22	22	15	12
Ranunculus pygmaeus Wahlenb.	—	—	—	—	—	3	2	2	—	—	1	—	1	15	1	1	26	—	—
Koenigia islandica L.	—	—	—	—	—	3	2	—	1	2	—	1	—	—	8	14	1	—	2
Stellaria crassipes Hult.	—	—	—	—	—	1	1	1	1	4	—	—	—	—	1	—	—	—	1
Equisetum spp.[3]	—	—	—	—	—	—	—	28	21	43	—	—	6	15	—	—	—	—	—
Ranunculus sulphureus Soland.	—	—	—	—	—	—	1	—	6	4	—	—	—	2	1	1	—	—	—
Minuartia biflora (L.) Sch. et Th.	—	—	—	—	—	—	1	—	—	—	—	—	—	3	—	—	1	—	—
Potentilla hyparctica Malte	—	—	—	—	—	—	—	—	1	—	—	1	—	—	—	—	—	—	—
Saxifraga foliolosa R. Br.	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	1	—
Chrysosplenium tetrandrum (N. Lund) Th. Fr.	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	—	—	—	2

[1)] *Draba alpina* L., *D.bellii* Holm., *D.gredinii* Ekman., *D.lactea* Adams., *D.norvegica* Gunn., *D.oblongata* R. Br., *D.subcapitata* Simm.

[2)] *Alopecurus alpinus* Sm. (wet places on the upper terrace — in the communities 14 and 15); *Festuca rubra* L. coll.; *F.baffinensis* Polunin (very dry, stony places on the upper terrace edge);*Poa alpina* L., *Poa arctica* R. Br. (fairly wet places on the slope); *Dupontia pelligera* Rupr. (very wet, mossy places on the lower terrace).

[3)] *Equisetum arvense* L., *E.scirpoides* Michx., *E.variegatum* Schleich.

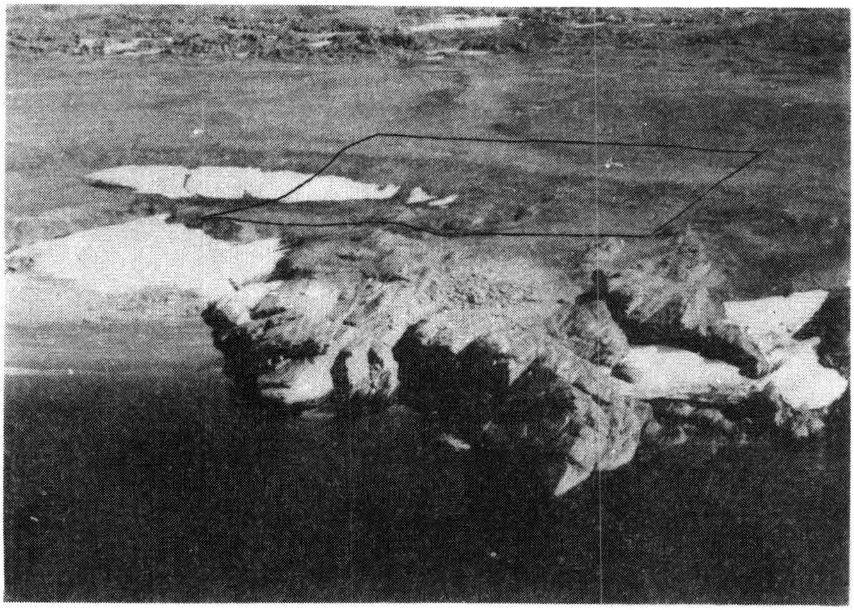


Plate 1

Investigated area — photo taken from helicopter on July 5th, 1985.

Looking for the research area the author tried to choose a fragment of tundra of maximal relief variability of different kinds of ground and types of vegetation.

Methods

The research area of 4800 m^2 was levelled with the use of theodolite. Altitude measurements in relation to the lowest point of the area were taken in the corners and in the middle of each of 192 squares (side length 5 m) which made up the research area. It enabled projection of topography and calculation of exposure of each fragment of the described area.

480 sample squares of the side of 36 cm were randomly chosen. The levelled fragment of the sea shore terrace was divided into 48 squares of the side of 10 m and in each of them 10 sample squares were chosen at random (coordinates were drawn at random). Each sample square was divided into 36 little squares of the side of 6 cm and in each of them the frequency of basal parts of sprouts of vascular plants was estimated. Maximal number (= 100%) could be reached by taxon whose presence was observed in 36 little squares of sample square. The coverage of the area with stones was estimated in the same way.

The thickness of the ground was measured with the use of scaled rod in the corners and in the middle of each sample square. The values of ground thickness presented in this paper are average values taken from 5 measurements. The amount of stones in the ground expressed as the degree to which the area was covered with stones in general agrees with the amount of stones calculated through depth measurements (Eurola 1968); different results when using both methods can be obtained when under the stratum of turf which is scarcely covered with stones a solid rock can be found. The application of both methods of measurements can show the impenetrable rock stratum in the ground that may affect the hydration of the examined fragment of tundra. Some pits were made in parts of the examined area clearly different in physiognomy.

Nomenclature of plants is based on the key of Rönning (1979).

All calculations and topography projections were performed on ZX Spectrum computer with the program written by the author.

Results

1. Association analysis and comparison of distinguished communities

a) Algorithm scheme

Using association analysis (Goodall 1973b, Kershaw 1974) 480 sample squares were divided into 19 subclasses — plant communities. As a stopping rule it was taken the smallest statistically significant value of sum from the first division. Dendrogram of association analysis is presented in Fig. 2; species composition of 19 communities is presented in Tab. 1.

Since association analysis, as a monothetic technique, does not demonstrate interrelations between the distinguished classes (Goodall 1973b) therefore a cluster analysis of the distinguished communities has been performed. Table 1 served as an original data matrix. Each element a_{ij} of this table, defining the number of community squares „j" in which taxon „i" was found was divided by total number of community squares „j" and multiplied by 100%. Using on such constancy matrix Czekanowski's similarity coefficients for each community has been calculated (percentage similarity: Goodall 1973a). On square basis (19 × 19) of the matrix of similarity coefficients there has been made a clusterization of distinguished community applying the method of weighed pair group (Anderberg 1973, Sneath and Sokal 1973, Kucharczyk 1982).

b) Characteristics of distinguished communities

Distinguished communities numbered from 1 to 19 were clustered in 3 groups (Fig. 3). The first group constituted dry moss tundra communities, the second one — communities of fresh grass tundra, the third one — wet moss tundra communities.

Communities of dry moss tundra occurred only in places where the ground was densely covered by stones (Fig. 4, Pl. 2). They occupied those fragments of

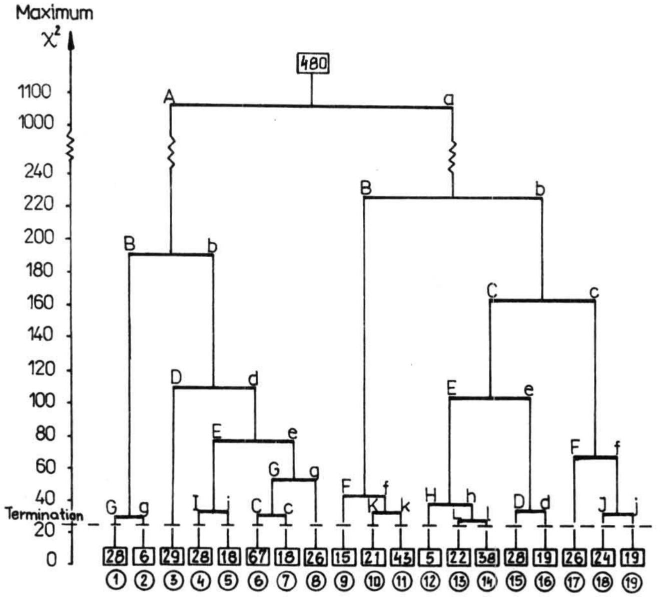


Fig. 2 Dendrogram presenting the classification of 480 sampling squares according to the method of association analysis. Letters denote taxa which were the basis for the division of particular class of squares into subclasses — with (large letter) or without (small letter) of particular taxon: A — *Draba* spp., B — *Equisetum* spp., C — *Salix polaris*, D — *Poaceae* spp., E — *Cochlearia officinalis*, F — *Ranunculus pygmaeus*, G — *Saxifraga caespitosa*, H — *Polygonum viviparum*, I — *Saxifraga nivalis*, J — *Cerastium regelii*, K — *Luzula confusa*, L — *Cerastium arcticum*. Numerals in square frames denote the number of squares of particular group (community), numerals in circles — the ordinal number of the community.

the examined area that were high and best exposed to the sun (Figs. 5 and 6). Extreme hydrological conditions prevail in the community 7 due to its situation and great abundance of stones. Lack of *Salix polaris* and *Oxyria digyna* can be here observed — although they occurred in other communities of dry moss tundra. Community 16 was also situated at the edge of upper terrace but milder conditions prevail here and *Salix polaris* occurred here with the constancy of 100%. In communities 7 and 16 *Papaver dahlianum* reached the highest constancy. The main feature differing slightly more humid communities 4 and 5 from more dry 6 and 8 was the presence of *Cochlearia officinalis* in 4 and 5 and their lack in 6 and 8. *Saxifraga hirculus* and *S. hieraciifolia* reached the highest constancy in communities 4 and 5. Communities 3 and 15 are floristically related to the fresh grass tundra communities.

Fresh grass tundra communities occupy the least stony fragments of the described area (Fig. 4, Pl. 2). Communities 10 and 11 are the richest in species; the community 10 is also privileged in terms of exposure (Figs. 4 and 6) — many plant species reached here higher constancy than in the community 11.

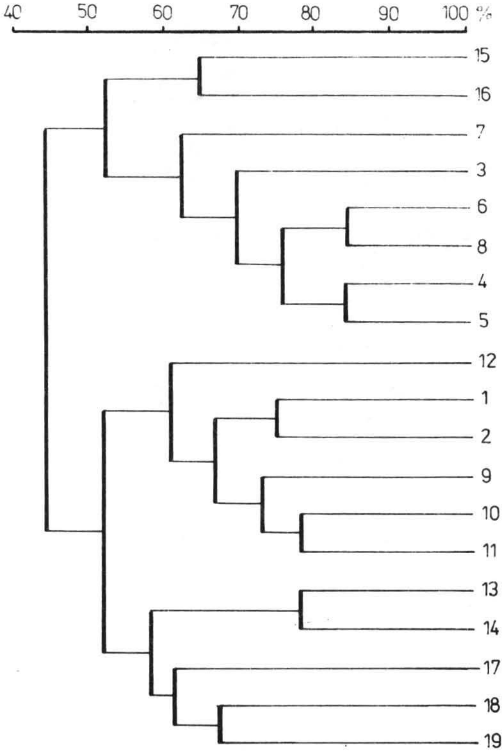


Fig. 3. Dendrogram of the affinities of the 19 distinguished communities.

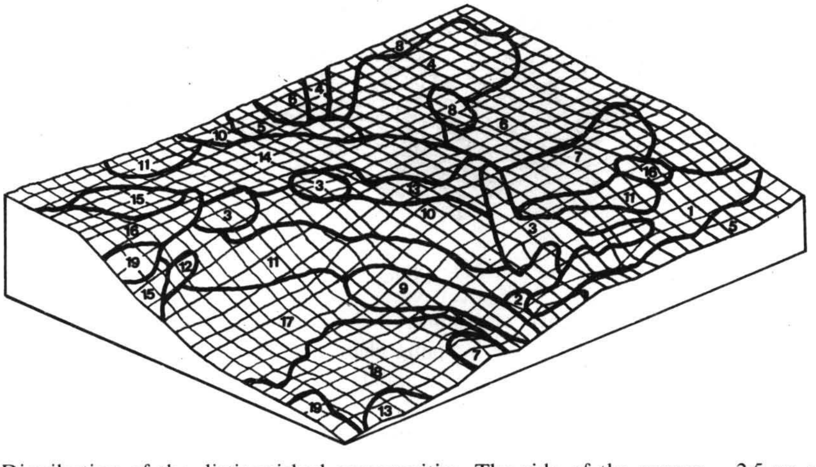
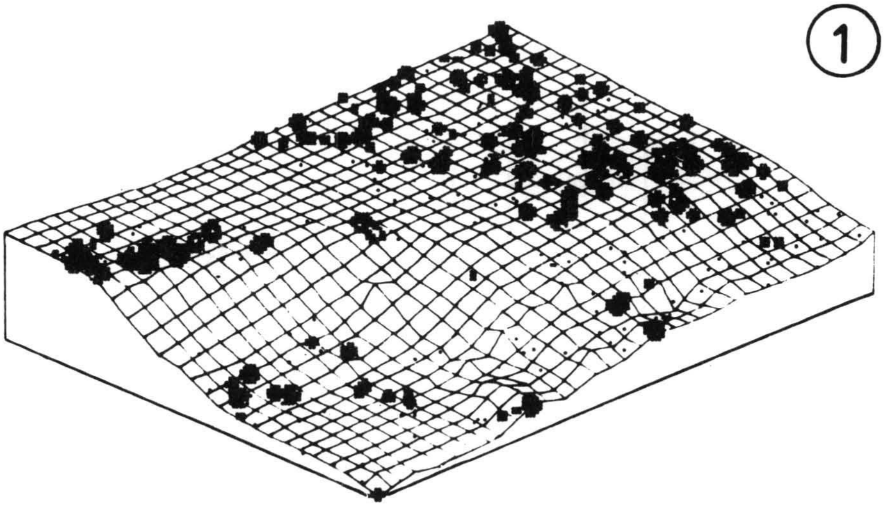


Fig. 4. Distribution of the distinguished communities. The side of the square =2.5 m; vertical dimension transformed according to the formula: $z' = 2z$.

1



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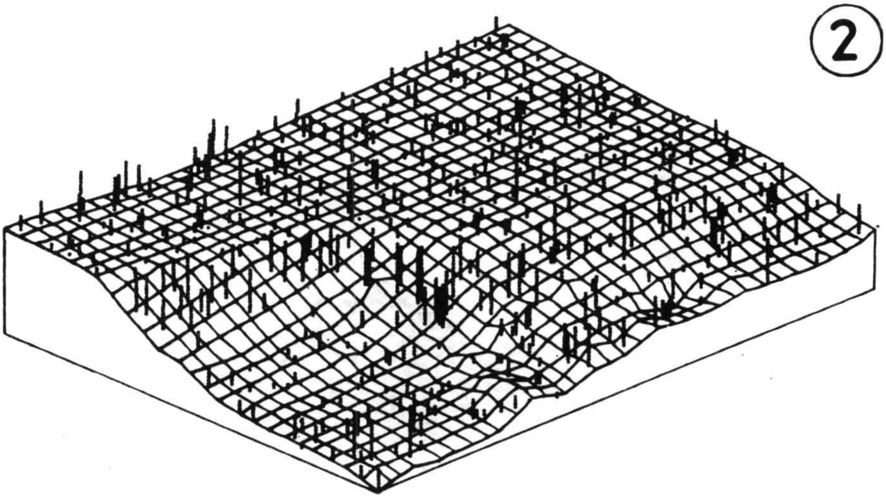


Plate 2

Fig. 1. Diversity of the ground cover with stones; the size of the circles corresponds to the intensity of this cover; the circles are put in the sampling place. Sampling squares without stones are not marked.

Fig. 2. Diversity of the depth of the ground in the investigated area; the size of the column put in the sampling place corresponds to this depth. Sampling squares with average depth of the ground = 0 are not marked.

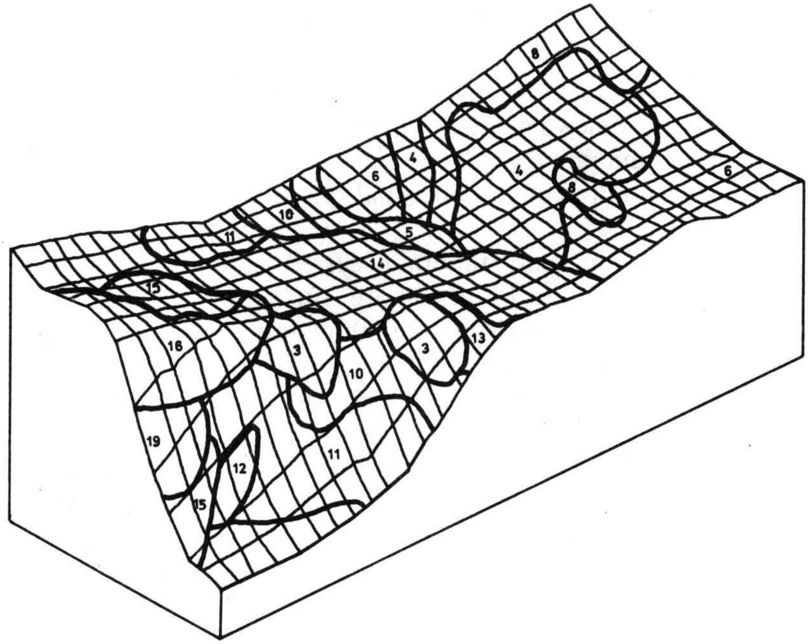


Fig. 5. Upper terrace communities. The side the square $=2.5$ m; vertical dimension transformed according to the formula: $z' = 0.1z^3$.

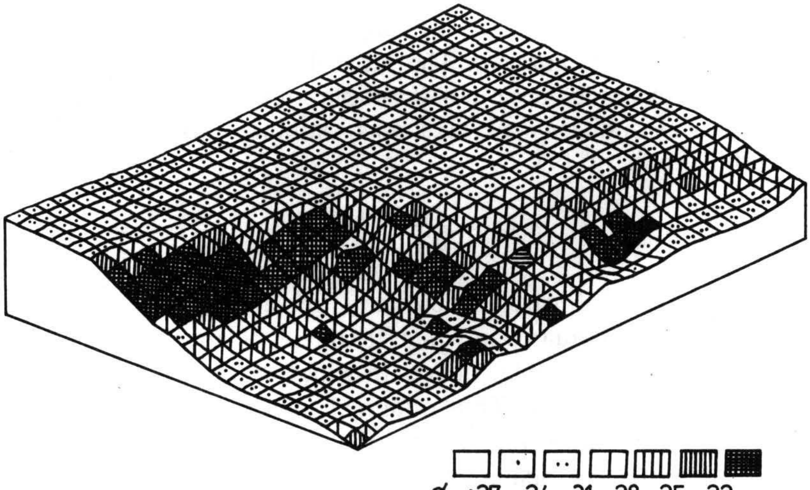


Fig. 6. The diversity of the exposition in the investigated area. α = the angle of sunrays incidence for each of 768 squares of the side of 2.5 m was calculated for June, 22nd. at non.

The species composition of the community 9 is similar to those of the snow bed (17) being, however, somewhat richer. On 5th of July snow cover was absent on the area of the community 9. Communities 1, 2 and 12 were transitional between dry moss tundra communities and typical communities of fresh grass tundra (10 and 11).

Communities of wet moss tundra occurred in local terrain depression (Figs. 4 and 5). Communities 13 and 14 are situated on the upper terrace; the community 13 was somewhat richer. On 5th of July snow bed (17) was almost entirely covered with snow whereas the remaining part of the examined area was free of the snow cover. The small angle at which sun rays fell on snow gathered at the foot of the slope did not favour quick melting of thick snow cover (Fig. 6). The community 18 characterized by the presence of *Cerastium regelii* occurred on lower terrace where waters flowing from the slopes stagnated. The outflow of these water was difficult because of the presence of impenetrable schists of Hecla-Hoek formation which occur in this part of the examined area. The community 19 which is not positively distinguished by any of taxa forming division basis in association analysis (Fig. 2) combines both the small number of extremely poor sample squares situated in the most stony fragments of the upper terrace and also those most humid ones, situated on the lower terrace.

2. Ecological groups of species

a) Algorithm scheme

The groups combining taxa of similar ecological requirements were obtained through cluster analysis. The table describing the occurrence of 32 taxa found in the examined area in 480 sample squares was used as an original matrix. Ecological similarity of taxa was estimated using Dice coefficient (Mirkin and Rozenberg 1983):

$$CD_{ij} = \frac{a - \min\ (b,\ c)}{a + \min\ (b,\ c)}$$

where: a — number of cases when taxa „i" and „j" were in common; b — number of sample squares in which taxon „i" occurred but taxon „j" was lacking; c — number of sample squares in which taxon „i" did not occur but where taxon „j" was observed. Thus obtained square (32 × 32) matrix of Dice coefficients was next transformed into the matrix of Euklidean distances between taxa within the space of these coefficients. Such transformation enables to take into consideration the relation between the compared pair of taxa and all others and it decreases all kinds of „noises" which can distort the picture of similarity of taxa compared (Mirkin and Rozenberg 1983). Basing on the matrix of Euclidean distances clusterization of taxa was made using weighted pair group method (Fig. 7).

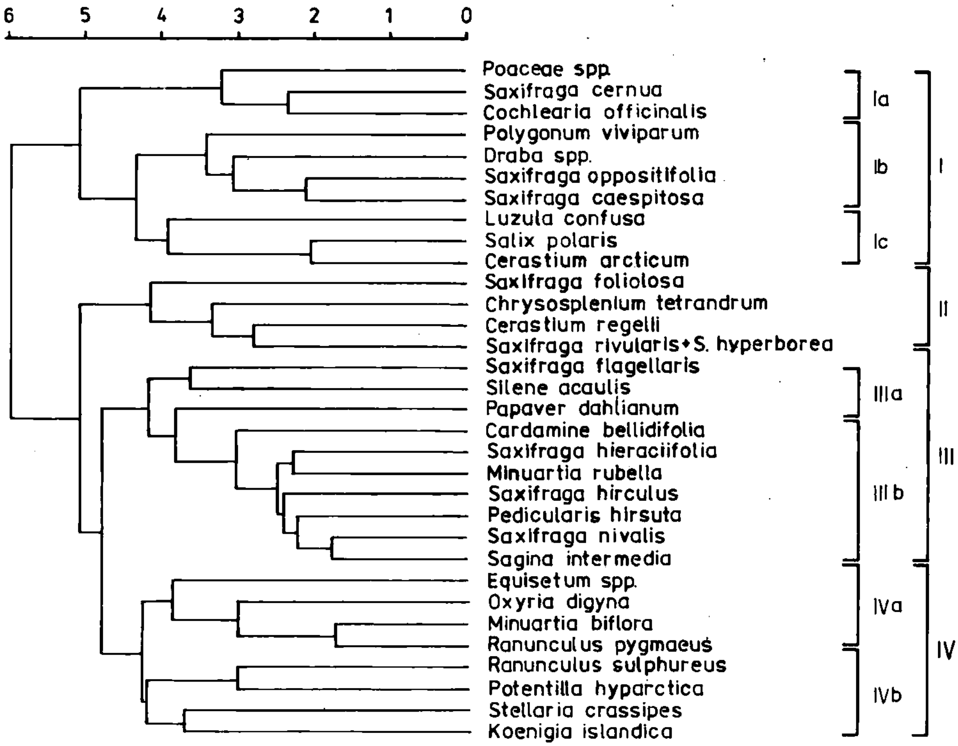


Fig. 7. Dendrogram presenting ecological groups of species.

b) Characteristics of the distinguish groups

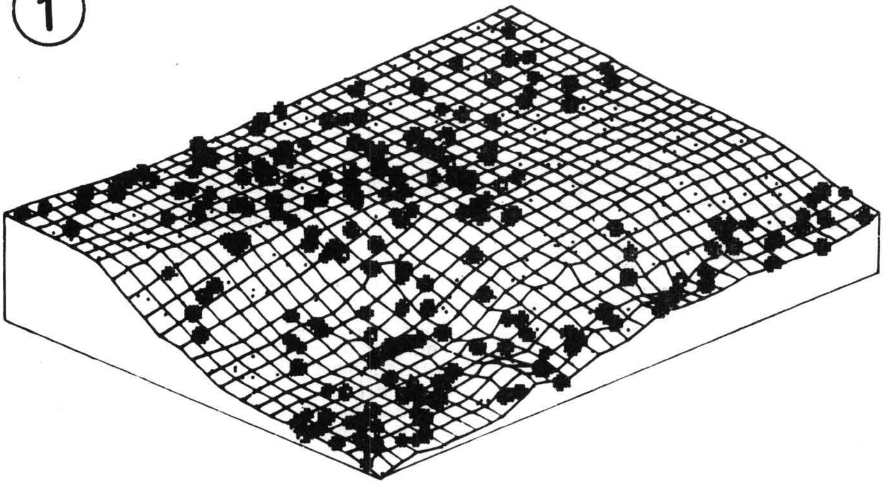
32 taxa which were found in the examined area were clustered into 4 groups (Fig. 7).

Group I is composed of taxa of wide ecological amplitude in the examined area. Sub-group Ia contains taxa occurring very commonly with the exception of extremely dry communities. The distribution of *Cochlearia officinalis*, a representative of this sub-group, is shown in Pl. 3, fig. 1. Taxa belonging to the sub-group Ib avoid wet places occurring in numbers in communities of very stony ground. The distribution of *Saxifraga oppositifolia* belonging to the sub-group Ib is presented in Pl. 3, fig. 2. Sub-group Ic is composed of taxa of widest ecological amplitude: *Luzula confusa* (Pl. 4, fig. 1), *Salix polaris* and *Cerastium arcticum.*

Taxa occurring exclusively in very wet places belong to group II. *Chrysosplenium tetrandrum* belonging to this group was found only in patches of the communities 13 and 19 situated at the edge of the lower terrace. Distribution of *Cerastium regelii*, another representative of this group, is shown on Pl. 4, fig. 2.

Group III is composed of species preferring dry habitats. At the edge of the upper terrace, in places especially exposed to winds, species from sub-group

1



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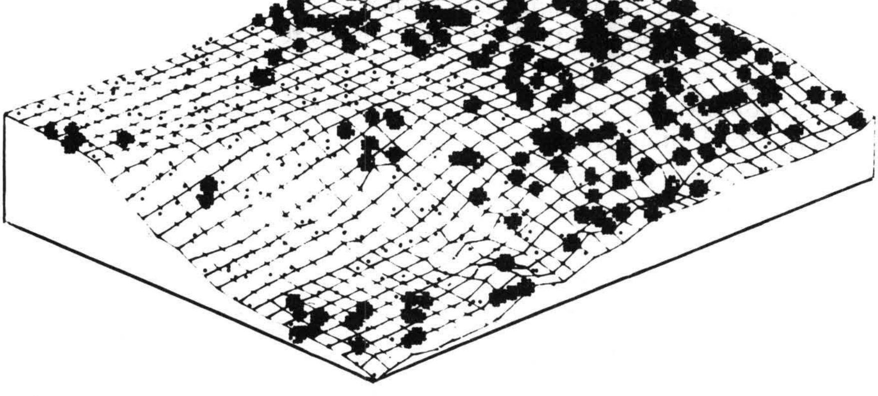
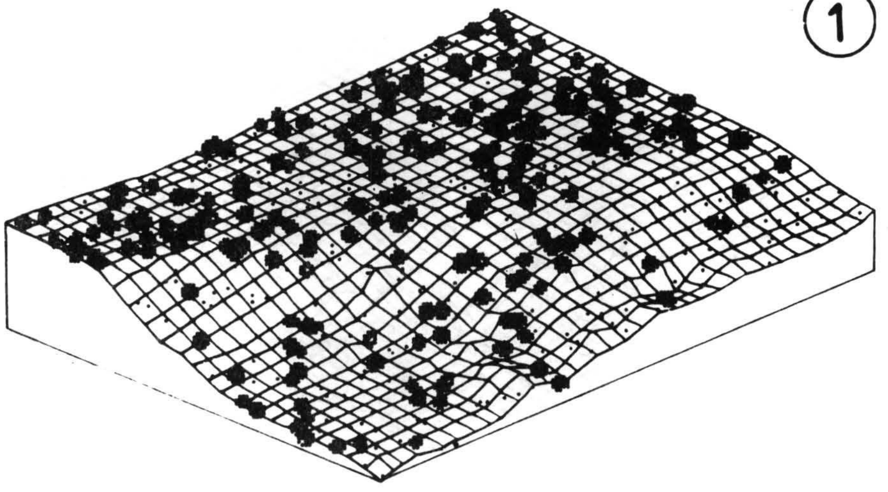


Plate 3

Fig. 1. The distribution of *Cochlearia officinalis*.

Fig. 2. The distribution of *Saxifraga oppositifolia*.



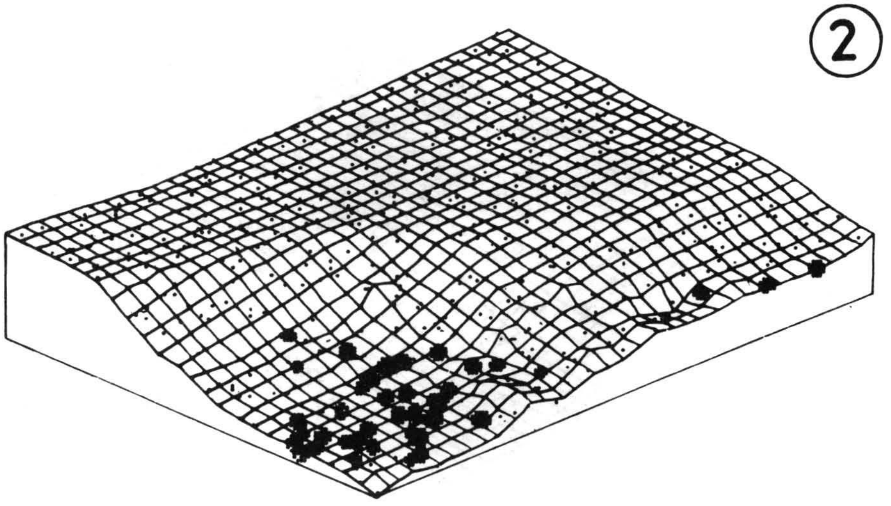


Plate 4

Fig. 1. The distribution of *Luzula confusa.*

Fig. 2. The distribution of *Cerastium regelii.*

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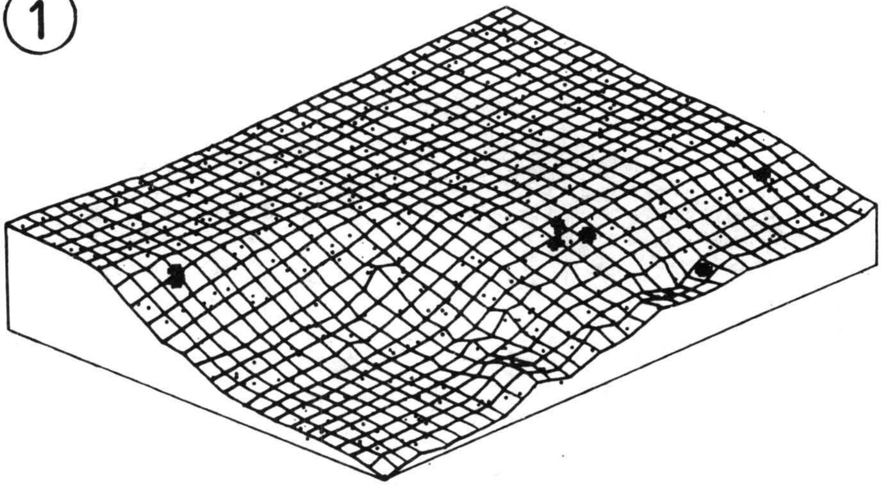

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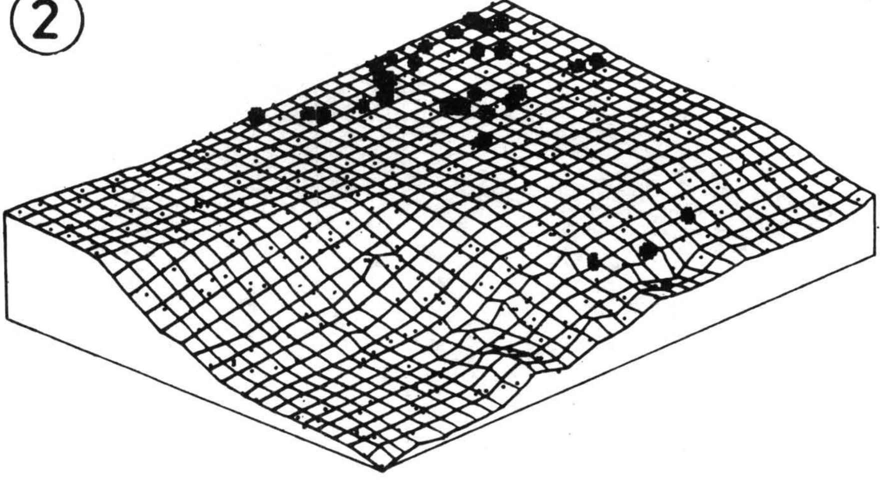
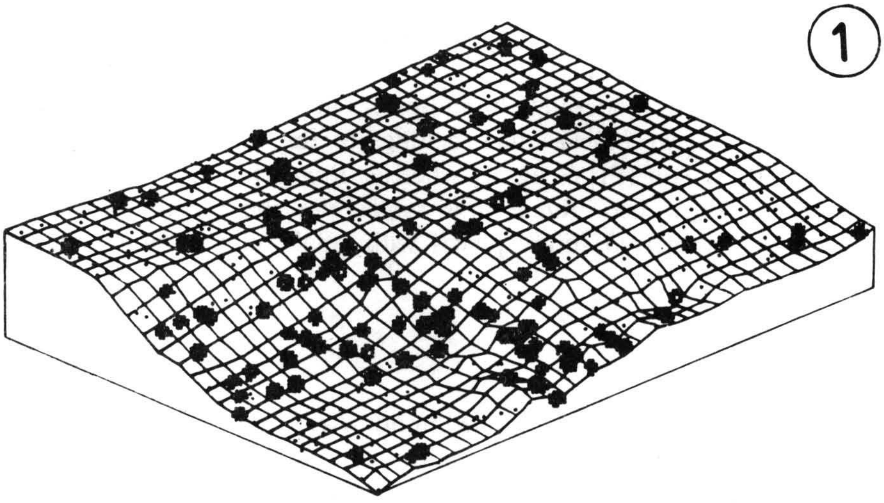


Plate 5

Fig. 1. The distribution of *Silene acaulis.*

Fig. 2. The distribution of *Pedicularis hirsuta.*



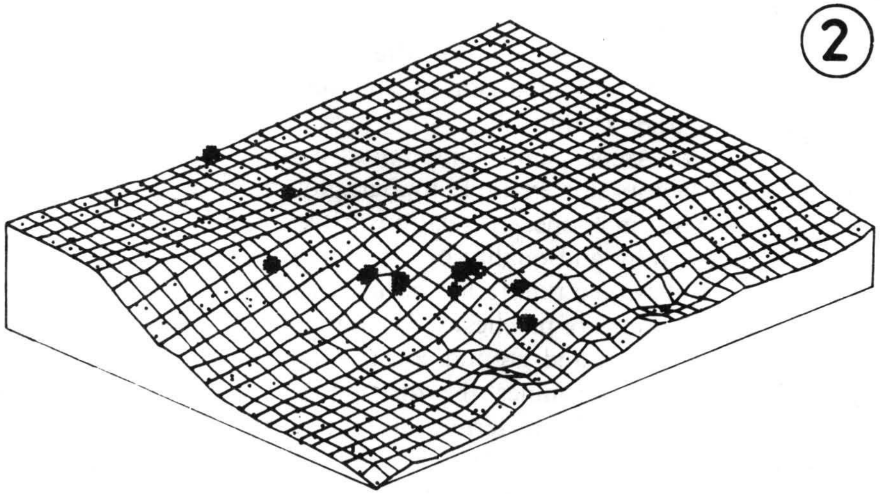


Plate 6

Fig. 1. Distribution of *Oxyria digyna.*

Fig. 2. Distribution of *Ranunculus sulphureus.*

IIIa can be found. *Papaver dahlianum* occupied the most stony habitats, *Silene acaulis* (Pl. 5, fig. 1) and *Saxifraga flagellaris* were found below the edge of the terrace. The species of the sub-group IIIb occurred in dry moss tundra communities (Pl. 5, fig. 2).

Taxa occurring in moderately humid places in the described area belong to the group IV. *Oxyria digyna* which belongs to the sub-group IVa preferred places with thick soil (Pl. 6, fig. 1) whereas *Ranunculus pygmaeus* occurred mainly in the snow bed. *Ranunculus sulphureus*, the representative of the sub-group IVb, preferred sunny places with small number of stones (Pl. 6, fig. 2).

Discussion

Association analysis widely applied in non-Arctic communities appeared to be valuable also in the case of tundra communities. Plant communities distinguished using this method can be easily interpreted in ecological terms. It appeared to be possible to distinguish plant communities taking into consideration vascular plants only. The application of association analysis in the first stage of regionalization procedure leads to considerable reduction of the amount of original data which is a prerequisite to use more precise classification methods such as cluster analysis. The use of cluster analysis algorithms enables the release of information „coded" in data matrix.

The scale of present research seriously differs from that of the former studies of Spitsbergen vegetation; moreover in this study only vascular plants were considered. Therefore the comparison of communities distinguished here with those described earlier is difficult.

The diversity of Arctic plant communities is the effect of cooperation of many ecological factors (for example topography, nutrients availability, microclimate) and also inter-species relations (Bliss 1956). In this work the influence of topography and quality of the ground on the formation of plant communities in Spitsbergen tundra has been presented. The shape, distribution and floristic compositions of patches of the communities distinguished here are the functions of the relief and ground construction (Fig. 4, Pl. 2, Tab. 1). The terrain configuration determines the distribution of snow-beds and those fragments of tundra which are termically favourable; it also determines the situation of places exposed to winds and defines also the intensity and direction of water flow which is one of three basic elements of water circulation, next to infiltration and evapotranspiration (Sarul 1981).

Abiotic factors mentioned above that are determined by topography shape, in turn, plant communities. Snow cover at the foot of the upper terrace of the examined area favouring the soil humidity, shortens on the other hand, the vegetation season and creates the conditions for the development of the community with *Ranunculus pygmaeus*. On locally raised places (the border of upper terrace) very poor communities occurred (7 and 16), composed of species resistent to the water shortage and winds (group IIIa). Water flowing from the upper terrace creates on the slope favourable conditions for the development of grass vegetation but its excess stagnates on the lower terrace creating there favourable conditions for rich development of hygrophilous species from the group II. The differences in the exposure of particular fragments of the examined area clearly influence the floristic composition of plant communities that can be seen on the example of patches of the communities 10 and 11 situated next to each other (Figs. 4 and 6, Tab. 1).

The amount of stones in the ground also influences the extent of radiation absorption and the rate of water penetration. The influence of the quality of the ground on its humidity and in consequence on the character of vegetation is reflected already at the stage of association analysis; the division of 480 sample squares into those in which *Draba* species occurred and those lacking them, is the approximately division into stony sample squares and non-stony ones (Figs. 2, 4, Pl. 2, Tab. 1).

Soil humidity depending both from topography and the ground structure is one of basic factors regulating the productivity of plant communities (Rezniček and Svoboda 1982). The elementary division of vegetation occupying Spitsbergen sea terraces is based on humidity gradient (Eurola 1968, Gugnacka-Fiedor and Noryśkiewicz 1982, Brattbakk 1985).

The distinguished ecological groups of species generally agree with the picture of ecological similarity of taxa proposed by Eurola (1968) for the areas situated at Isfjord and Hornsund. Essential differences appear in the case of some species only. According to Eurola (1968) *Ranunculus sulphureus* and *Cochlearia officinalis* are species typical of snow bed. In the present work *R. sulphureus* has been placed in the group IVb — of termophilous species whereas *Cochlearia officinalis* has been placed in the group Ia — of species of wide ecological amplitude, occurring everywhere with the exception of very dry places. *Saxifraga hieraciifolia* has been classified by Eurola (1968) to the group of wet moss tundra species whereas in the present work — to the dry moss tundra species (group IIIb). The above differences can be due to the somewhat different choice of habitats analyzed in both papers, or due to different method of data collectioning. The relations between vegetation and environment presented in studies based on the non-typological data collectioning are, in general, not so tight as one might conclude from researches based on typological method of data collectioning (Rozenberg 1984).

The present work concerns a small fragment of tundra at Bellsund, but similar ecological relations occur also in other parts of Spitsbergen (Eurola 1968, Eurola and Hakala 1977, Brattbakk 1985, 1986) which enables, *mutatis mutandis*, to refer the presented results to other regions of Svalbard.

The advantage of the present method of analysis and collectioning of data concerning the relations between species occurring in Spitsbergen can be seen when comparing the amount of work done by the present author and by Eurola (1968) to receive comparable information. The distance between most extreme phytosociological made by Eurola exceeds 140 km, whereas the same parameter in the present work does not exceed 100 m. Eurola (1968) had precisely examined 1450m^2 of tundra. The total surface which has been analyzed in detail in the present work amounts only to 66,2 m^2. Eurola has found 71 species of vascular plants, whereas 46 species have been recorded in the present work, out of which, due to the difficulties to *identifig in situ* some taxa on different developmental stages (*Draba, Equisetum, Saxifraga rivularis* s.l., *Poaceae*) only 28 were precisely analyzed. The high degree of representativeness of the area analyzed in this work (both in the relation to the diversity of plant communities and flora richness) is due to its particular situation. The fragment of tundra examined is situated at the border of two geobotanical zones (Brattbakk 1986) and is also very diversified in respect to topography, geomorphology etc. The reduction of phytocoenological research to the small but strongly diversified area enables a thorough examination of vegetation of the examined area and its relations with environmental factors. This can be done with relatively small effort.

It seems that the methods of material collectioning, data analysis and results presentation applied in the present work could be very useful in analysis of Spitsbergen vegetation, particularly in the case when the whole floristic diversity are taken into consideration and also when other abiotic factors like chemism, soil temperature, wind velocity etc. are considered.

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Streszczenie

W lipcu i w sierpniu 1985 roku prowadzone były badania fitosocjologiczne na modelowym fragmencie tundry spitsbergeńskiej, położonym nad Bellsundem. Badany teren (Rys. 1, Pl. 1) o powierzchni 4800 m^2 został zaniwelowany przy pomocy teodolitu, co umożliwiło wykonanie komputerowych projekcji topografii omawianego obszaru. Na badanym terenie rozmieszczono w sposób systematyczno-losowy 480 kwadratów próbnych o boku 36 cm. W każdym kwadracie ustalono ilościowość roślin naczyniowych oraz oceniano kamienistość podłoża.

Przy pomocy analizy asocjacji podzielono klasę 480 kwadratów próbnych na 19 podklas — zbiorowisk roślinnych (Rys. 2, Tab. 1). Zostały one następnie porównane przy użyciu metod analizy skupień (Rys. 3). Wyróżnione zbiorowiska skupiły się w trzech grupach. Pierwsza grupa to zbiorowiska suchej tundry mszystej, druga — zbiorowiska świeżej tundry trawiastej, w trzeciej zaś grupie znalazły się zbiorowiska wilgotnej tundry mszystej. Wyodrębnione zbiorowiska roślinne zostały ukazane na tle wybranych czynników środowiskowych (rzeźba terenu, kamienistość podłoża, ekspozycja; Rys. 4—6, Pl. 2).

Ekologiczne grupy gatunków roślin naczyniowych wyróżnione zostały przy pomocy analizy skupień. 32 znalezione na badanym obszarze taksony skupiły się w czterech grupach (Rys. 7). Grupę pierwszą tworzą taksony o szerokiej amplitudzie ekologicznej (Pl. 3; Pl. 4, rys. 1), grupę drugą — taksony występujące wyłącznie w miejscach bardzo wilgotnych (Pl. 4, rys. 2), w grupie trzeciej znalazły się gatunki preferujące suche siedliska (Pl. 5), a do czwartej grupy należą taksony zajmujące umiarkowanie wilgotne stanowiska na badanym obszarze (Pl. 6). Stwierdzono dużą zgodność wyróżnionych w tej pracy ekologicznych grup gatunków z danymi Euroli (1968).

Wykazano, że wyróżnione przy pomocy analizy asocjacji zbiorowiska roślinne dają się łatwo zinterpretować w kategoriach ekologicznych (pomimo uwzględnienia jedynie roślin naczyniowych).

Kształt, rozmieszczenie i skład florystyczny płatów zbiorowisk wyróżnionych w niniejszej pracy są funkcją reliefu i szkieletowości podłoża. Podstawowe czynniki abiotyczne środowiska — wilgotność, nasłonecznienie — determinowane są przez ukształtowanie terenu i kamienistość podłoża. Czynniki te kształtują z kolei oblicze zbiorowisk roślinnych.