Eco-geographical relations of the Bjørnøya vascular flora, Svalbard

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A renewed survey of the flora of Bjørnøya (74° 31'N) has yielded a total of 54 native vascular species. Details of their distribution are provided by local maps and vertical frequency tabulations. Soil preferences of species and various plant communities are outlined. The general climate and microthermal conditions of the prevailing vegetation place Bjørnøya as a pronouncedly maritime part of the Svalbard archipelago, supporting mainly hygrophilous and chionophilous plant communitites and species. Only half of the island's vascular species persist at elevations above 200 m a.s.l., corresponding to a heat sum of July and August below approximately 190 Degree-Days. Ice-cored peat mounds coated by *Rhacomitrium lanuginosum* were discovered on plateaux above 400 m elevation.

The impact of the Vistula glaciation is discussed in view of Quaternary evidence from the Barents Sea area. Probably only one third of the present vascular flora could endure full-glacial conditions in possible ice-free cliffs on the coast of Bjørnøya.

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1. Introduction

Since the floristic survey published by Engelskjøn & Schweitzer (1970) of the vascular flora of Bjørnøya (Bear Island), Svalbard, little botanical work was done until 1983, when the present author joined an expedition of Tromsø Museum to Bjørnøya, 9 to 28 August.

New observations of the flora and vegetation during this stay make up the foundation of the present treatment. An outline of the plant communities of Bjørnøya is provided, and the thermal and edaphic conditions are related to the development of vegetation and plant distributions within the island. Notes on altitudinal belts are included, as well as notes on the discovery of *Rhacomitrium lanuginosum* peat mounds at approximately 400 m above sea level on the southern mountain plateaux of the island.

Distribution maps are given for the 54 native vascular species.

Brattbakk (1984) visited the island to study the potential of the vegetation for reindeer grazing. He contributed an interesting floristic novelty, *Saxifraga foliolosa* R. Br.

The taxonomy and nomenclature of Svalbard vascular plants are still ambiguous for several genera, such as *Draba, Dupontia, Festuca, Potentilla*, and *Puccinellia* s. lat. I generally adopt preliminary results from an ongoing cytotaxonomical study of vascular plant species from Bjørnøya and Spitsbergen (Engelskjøn & Schweitzer 1970; Engelskjøn 1979, and unpublished results).

The nomenclature of bryophyte species follows Arnell (1956) and Nyholm (1954—69), and of lichens, Santesson (1984) and Walker (1985).

2. The climate of Bjørnøya

The meteorological station is situated on the N coast, at 74°31'N, 19°E, 15 m above sea level. The extensive northern plain of the island undulates between 15 and 50 m a.s.l. This relief causes only insignificant deviations from the prevailing maritime climate observed at the station. Mountains to the SE and S reach altitudes from 410 to 535 m a.s.l., and temperatures there are lower owing to the vertical temperature gradient and orographic cloud formation (Steffensen 1969, 1982). The thermal climate of Bjørnøya is shown in Table 1 and compared with other North Atlantic, Arctic stations. Due to inconsistency of the observation material, two sets of mean monthly temperatures are presented. One is for the period 1946—65 and is continuous, with a few breaks of homogeneity due to moving of stations (Steffensen 1969). The other is the Standard normal series (1931—60) with interpolations of breaks during World War II. Differences between these series reflect a secular decline of temperatures at the end of the 1950s, which lasted up to the late 1960s, e.g. on the island of Jan Mayen (Steffensen 1969, pp. 266—267).

Complex phenomena such as secular climatic change could not be dealt with here, although an analysis would be of interest in relation to distribution and performance of North Atlantic, Arctic vegetation.

Some derived parameters of ecological significance are listed in Table 2 for the same Arctic stations. Heat sums were calculated as Degree-Days, June—September (DD—4) and July—August (DD—2), all based on the 1946—65 period.

Cloudiness and mean annual precipitation are summarized for the period up to 1965, annual sunshine hours are given when available, and wind chill and cooling power calculated according to the formulae of Siple & Passel (1945) and Vinje (1962).

A special feature of Bjørnøya and other Arctic islands is the foggy summer. The number of days with fog occurring at 7, 13, or 19 C.E.T. is given in Table 3A for the months June—September. We see that Hopen is most frequented by Arctic seafog. A closer study of the original tables (Steffensen 1969, Table II) reveals that Bjørnøya tends to have foggy and overcast days concentrated to July and August, which is also reflected in the low number of annual sunshine hours. The figures from Isfjord Radio on the W coast of Spitsbergen indicate a more favourable radiation climate.

Bjørnøya compared with North Norway (Table 3B) shows a much higher fog incidence than Vardø, which is also exposed to drifting fog from the Barents Sea.

The thermal regimen of Bjørnøya is comparable to that of Jan Mayen, but is less oceanic with regard to annual amplitude of temperature and total precipitation. Hopen is cooler than Bjørnøya throughout the year, whereas Isfjord Radio experiences slightly higher July tempera-

Table 1. Average monthly air temperatures, annual means, and amplitudes (A) for Bjørnøya and some other Norwegian Arctic stations. Data compiled from Steffensen (1969). °C.

Station	N Lat.	Long.	Altitude m a.s.l.	Observation period	J	F	M	A	M	J	J	A	S	O	N	D	Year	A
Bjørnøya	74°31′	19°01′E	15	1931—60	- 5.7	- 6.9	- 7.2	- 5.4	- 1.3	2.0	4.5	5.0	3.0	0.4	- 2.0	- 3.9	- 1.5	12.2
				1946—65	- 6.8	- 6.9	- 7.5	- 5.2	- 1.4	1.8	4.2	4.3	3.0	0.5	- 2.4	- 5.3	- 1.8	11.8
Jan Mayen	70°56′	8°40′W	12	1931—60	- 4.0	- 5.2	- 4.8	- 3.5	- 0.5	2.4	5.2	5.5	3.9	0.9	- 1.2	- 3.0	- 0.3	10.7
				1946—65	- 3.8	- 4.8	- 5.1	- 3.4	- 0.6	2.0	4.6	5.4	3.5	1.2	- 1.6	- 3.5	- 0.5	10.5
Hopen	76°30′	25°04′E	7	1946—65	- 12.3	- 12.1	- 13.5	- 10.1	- 4.8	- 0.4	2.0	2.2	0.9	- 2.1	- 6.2	- 10.0	- 5.5	15.7
Isfjord Radio	78°04′	13°38′E	7	1931—60	- 9.2	- 10.2	- 11.7	- 9.1	- 3.2	1.8	4.9	4.4	1.3	- 2.9	- 5.9	- 7.5	- 3.9	16.6
				1946—65	- 10.9	- 11.2	- 12.1	- 8.8	- 3.3	1.7	4.5	4.2	1.1	- 2.7	- 6.2	- 9.0	- 4.4	16.6

Table 2. Some basic and derived climatological parameters from Bjørnøya and some other Norwegian Arctic stations. Data compiled from Steffensen (1969) and Andresen (1979). Comparable, 1946–65 20 year means. Wind chill/cooling power computed according to Siple & Passel (1945) and Vinje (1962).

Station	Precipitation mm	Degree-Days June—Sept. DD-4	Degree-Days July-August DD-2	Sunshine hours, annual	Clear days, June—Sept.	Overcast days, June—Sept.	Wind chill/cooling power June	Wind chill/cooling power July	Wind chill/cooling power August
Bjørnøya	357	405	265	613*	1.7	93.3	898/32	822/29	835/30
Jan Mayen	698	475	310	1)	1.1	86.4	856/29	780/27	758/26
Hopen	368	145	130	2)	3.6	88.4	875/28	822/26	807/26
Isfjord Radio	378	355	270	1066**	4	73	876/30	804/28	823/29

* 1960—65 1) No record; mean cloud cover 6.7 octas
** 1956—65 2) No record; mean cloud cover 6 octas

Table 3. Fog conditions on Bjørnøya and some other Norwegian Arctic and hemi-Arctic stations. 1946—65 means.

A) Cases of fog as number of days through June—September with fog at specified hours. Data from Steffensen (1969).

Station	At 07	At 13	At 19
Bjørnøya	19.3	14.6	17.9
Jan Mayen	16.8	12.7	12.2
Hopen	19.6	17.1	20.0
Isfjord Radio	7.1	4.9	6.6

B) Monthly fog frequency: Percentage of days with cases of fog at Bjørnøya and at Vardø, East Finnmark, North Norway.

Station	June	July	August	September
Bjørnøya	14	24	22	11
Vardø	4	5	7	1

tures than Bjørnøya. Other stations in Spitsbergen are not compared in detail here, but inner Isfjord (Longyearbyen) has higher summer averages and maxima than Isfjord Radio, and less fog.

The heat sums for June—September and July—August (Table 2) place Bjørnøya in a position between Jan Mayen and Isfjord Radio, whereas Hopen is much cooler than most other stations.

The indices of wind chill and cooling power entered in the same table reflect the combined cold and wind stress on animals and plants. We note that Bjørnøya has a more pronounced exposure to this factor than the other Arctic stations considered during the summer months. However, Semlja Frantsa Josifa, at nearly 82° N, has an even less favourable thermal climate (Müller 1982), as have Kong Karls Land and Sjuøyane in the far north and east in the most sea ice frequented parts of Svalbard (Norsk Polarinstitutt, unpublished observations).

The annual precipitation on Bjørnøya is below 400 mm like in most Arctic regions. High humidity of the ground and vegetation cover is maintained by the low temperatures and heavy cloud cover, and fog precipitation is also considerable.

Accordingly, Bjørnøya has a maritime Arctic climate with low temperatures and humid conditions. At comparable latitudes in the North Atlantic this climatic oceanity is only surpassed by Jan Mayen.

3. The vertical temperature gradient

Data from radiosonde ascents between 10 and 22 August 1983 were utilized to estimate the air temperatures at higher levels of Bjørnøya. The upper air soundings start from the meteorological station and are performed regularly at 1200 and 2400 hrs. G.M.T. The air temperature decreases linearly with altitude, but stratification and inversions occur at various levels. The first of these so-called significant levels is usually crossed between 950 and 850 mb air pressure, which corresponds to 500—1300 m above sea level. The temperatures t_1 and t_2 at levels H_1 and H_2 are inherent in the simplified barometric formula:

$$H_2 = 1600 \cdot \frac{P_2 - P_1}{P_2 + P_1} (1 + 0.004 \frac{t_1 + t_2}{2})$$

(Blüthgen & Weischet 1980)

Here, P_1 and t_1 are air pressure and temperature at the station, P_2 and t_2 at the lowest significant altitude level as explained above. The vertical temperature gradient is then given by

$$\Delta = \frac{t_1 - t_2}{0.01\, H_2} \quad (^0C/100\,m)$$

For successive days, the average Δ was computed as 0.66°/100 m at 1200 hrs. G.M.T., varying between 0.15° and 0.93°. These two extreme values occurred in connection with a cyclone passage with hurricane windspeeds.

The same value, 0.66°/100 m, varying between 0.47° and 0.88°, was obtained from night ascents at 2400 hrs. G.M.T.

In view of the relatively uniform weather conditions on Bjørnøya during the summer months, 0.65°/100 m is considered a realistic estimate for the vertical temperature gradient in the growing season. This value is also the WMO standard for temperature reductions. Because the island is unprotected from the general air circulation over the Barents Sea, the local summit effect (Eide 1945) is not expected to lower air temperatures much.

The temperatures at about 450 m on Miseryfjellet and Hambergfjell were calculated from this vertical gradient (Table 4). It is noted that the temperatures on the mountains of Bjørnøya are lower than at Hopen Radio, two degrees of latitude to the north, but still higher than in extreme Arctic environments, e.g. Semlja Frantsa Josifa or Severnaja Semlja (Tables in Müller 1982).

4. Outline of the vegetation on Bjørnøya

A short description of the terrestrial vegetation of Bjørnøya is provided to relate the local ecological conditions, and to compare with other Arctic areas.

Phytosociological analyses were only made at a reference site on the N coast (Fig. 1), but I visited most parts of the island during altogether six weeks in 1967 and 1983, recording the main plant communitites. Cryptogams were collected from representative sites, totalling 220 samples of mosses, 35 of liverworts, 150 of lichens, and a few of terrestrial algae. Assistance with the determination of some samples was provided by specialists mentioned in the *Acknowledgments*. I could also draw on ecological notes by Summerhayes & Elton (1923), Hanssen & Holmboe (1925), Bertram & Lack (1938), Rønning (1959), and Brattbakk (1984). Ecological comments were also given by Berggren (1875) and Lynge (1926) in works on the bryo- and lichenflora of Bjørnøya.

The available map of Bjørnøya (Norsk Polarinstitutt 1944) does not display the microtopography, and the only photocoverage consists of oblique pictures on file in the Norwegian Polar Research Institute. These photograms do not show the high ground because of orographic fog during the flight. Vertical aerial photos of a large scale will be needed for quantitative vegetation mapping of the island.

Bedrock and soil

The geological map (Fig. 2) is reproduced from Worsley & Edwards (1976) and based on the mapping by Horn & Orvin (1928). The bedrock varies considerably as to chemical composition. Table 6 shows soil chemical parameters of weathering material derived from three main groups of sedimentary rocks:

I. Carbonatites and marls. — 1. Older and Younger Dolomite (Hecla Hoek), 2. Tetradium limestone, 3. Landnørdingsvika and Kapp Kåre formations (='Ambigua limestone and marl'), 4. Kapp Dunér formation ('Fusulina limestone and dolomite', cf. Siedlecka (1975)), 5. Hambergfjellet formation ('Cora limestone'), 6. Miseryfjellet formation ('Spirifer limestone').

II. Intermediate sediments with some calcite. — 1. Sandstone within the Miseryfjellet formation, 2. Kapp Hanna formation ('Yellow sandstone'), 3. Triassic shales, partly with limestone concretions.

Table 4. Thermal conditions (air temperatures and heat sums) on the high ground of Bjørnøya, 450 m a.s.l. 1946—65 means. Temperature reductions based on the meteorological station 15 m a.s.l. and gradient 0.65° C/100 m.
DD-4: Degree-Days, June—September. DD-2: Degree-Days, July—August.

Parameter	Altitude m a.s.l.	10—22 August, 1983	Monthly means June	July	August	September	Mean of June—September
Mean temperature	15	4.3	1.8	4.2	4.3	3.0	3.3
	450	1.5	- 1.0	1.4	1.5	0.2	0.5
Mean maximum	15	5.4	3.7	6.5	6.2	4.7	5.3
	450	2.5	0.9	3.7	3.4	1.9	2.5
Mean minimum	15	3.2	0.2	2.5	2.7	1.5	1.7
	450	0.3	- 2.6	- 0.3	- 0.1	- 1.4	- 1.1
Heat sums	15	—	55	130	135	90	(DD-4=405, DD-2=265)
	450	—	- 30	45	45	5	(DD-4=65, DD-2=90)

Table 5. Air and vegetation temperatures and some other meteorological parameters, reference site at Herwighamna, N coast of Bjørnøya, 5—8 m a.s.l. 10—22 August 1983.

Main weather situation	Mean temperature °C	Air	Vegetation category and aspect: Humid plain (1), 2° E	Lichen slope (31), 20° SE	Terrace (34), 10° SE	Cloud cover octas	Mean windspeed m s⁻¹
Clear, sunny days (n=4)	Diurnal	4.2	5.5	9.5	7	4	4
	Maximum	5.4	9	21.5	16		
	Minimum	3.0	2	1	1.5		
Partly overcast days (n=5)	Diurnal	4.0	5.5	6	5.5	5	6
	Maximum	4.8	8	13.5	10.5		
	Minimum	3.1	2	1	1.5		
Heavily overcast, rainy or foggy days (n=4)	Diurnal	4.7	5	5.5	5	8	7
	Maximum	6.2	7	7	7.5		
	Minimum	3.5	4	3.5	3.5		
Entire period (n=13)	Diurnal	4.3	5.5	7	6	6	6
	Maximum	5.4	8	14	11		
	Minimum	3.2	2.5	2	2		

III. Silicic sediments poor in calcite. — 1. Rødvika and Nordkapp formations ('Ursa sandstone' or 'Kulm'). 2. Sandstones within the Kapp Kåre formation.

The carbonatites of group I yield alkaline lithosol with a high content of Ca (Table 6). This explains why most of the eutrophic species are concentrated in the lime-rich southern third of the island, as well as below Miseryfjellet, and on the northern coast.

The soils of rock group II are less well represented and may be influenced by seaspray and organic deposition. A sandstone within the 'Spirifer limestone', originally a redeposited desert sand (Siedlecka 1975), weathers easily. Its vegetation, however, is windworn and sparse, although pH is 7.1 (Table 6). The Triassic shales on the summits of Miseryfjellet have not been analysed. Their barrenness may be caused by mechanical instability.

Fig. 1. The reference site for vegetational and microthermal studies near Gravodden, north coast of Bjørnøya. 1, 35: Square numbers of first and last end of vegetation transect, cf. Fig. 3.
9 August 1983.

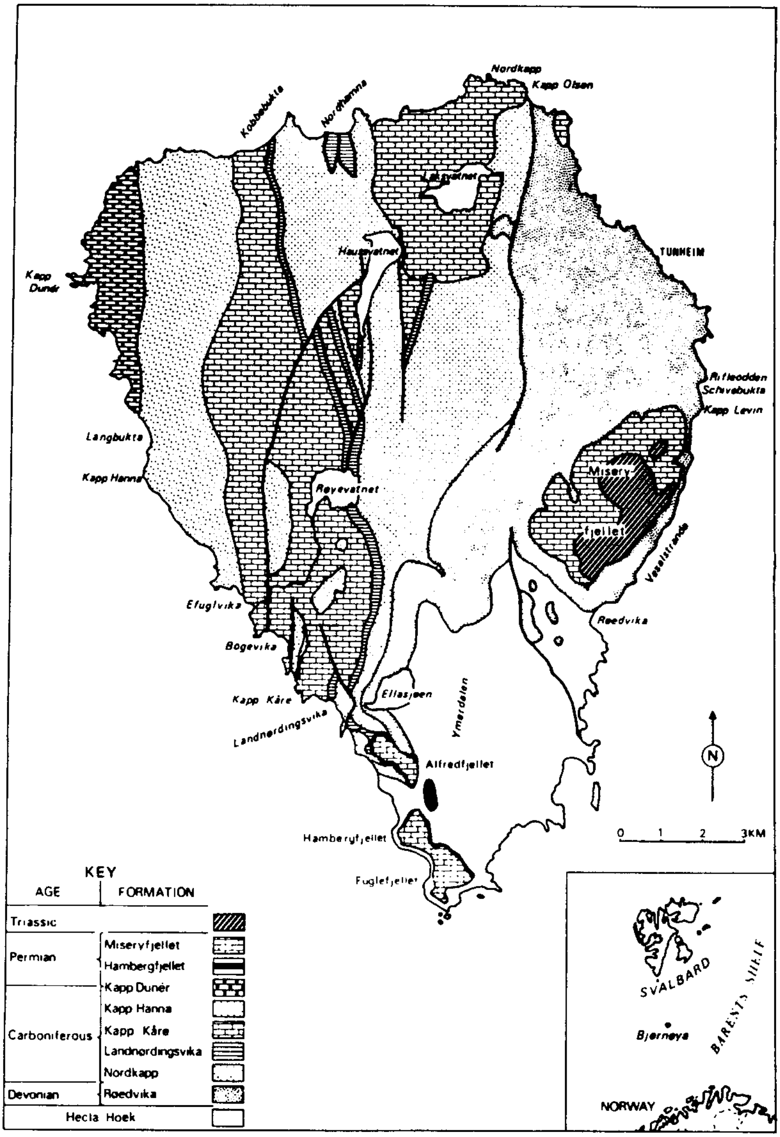
Lithosol of the Nordkapp formation ('Ursa sandstone') is slightly acid and very poor in lime. The intercalated shaly layers cause the sandstone to break up into coarse blockfields or stone polygons which support scattered moss and lichen turfs, the so-called 'soil cadaver' (Keilhau 1831). Another sandstone within the Kapp Kåre formation (Table 6) produces an equally acid and lime-poor lithosol, which is more fine-grained and supports some vegetation. The studies of Elvebakk (1982) from Spitsbergen show similar bedrock/vegetation interrelations.

The maritime influence on soils

Table 6 also shows that some soils are high in Na, which is presumably caused by sea-spray. This is the case on the coastal brink which is exposed to breaking waves, and where local winds may carry seafoam up to 170 m a.s.l. even in calm weather (Brattbakk 1984, p. 13).

The seabird rookeries on Bjørnøya are among the largest in the northern hemisphere (Norderhaug et al. 1977). Bird manure contributes to enrichment of N and P, and the seabirds also

Fig. 2. Geological sketch map of Bjørnøya. Reproduced from Worsley & Edwards (1976), by permission.



drop shells and carcasses. Especially the polar gulls and skuas affect the vegetation by trampling and moss plucking. The bird influence around the large rookeries of Fuglefjell and Hambergfjell is traced more than one km away from the coast. The zone of ornithogenic influence is readily seen from the distribution map of *Cochlearia groenlandica* (Section 7, map 38).

The influence of permafrost

Horn & Orvin (1928, p. 12) observed ground thawing down to approximately 0.75 m in the summer. Below this level permafrost continues down to 60—70 m. Fleetwood et al. (1974) indicate unfrozen ground below lake bottoms, but the permafrost causes waterlogging in the surface sediments. Extensive areas on the northern plain of Bjørnøya are studded with ponds and muddy polygon fields. The central sandstone areas have a better drainage, but solifluction slopes develop on shaly layers i.a. in Sigjorddalen W of Miseryfjellet.

The limestone and dolomite hills in the

Table 6. Weathering soils on Bjørnøya. pH values and some elemental analyses.

	Main bedrock derivation (cf. text)	Texture and vegetation	pH	Ca-AL mg/100 g	CaO %	Mg-AL mg/100 g	K-AL mg/100 g	P-AL mg/100 g	Na mg/100 g
I	Spirifer limestone in the Station area	Coarse gravel, ahumic, with *Saxifraga oppositifolia*	8.0	355	2.10	22	4.5	0.5	26
	Spirifer limestone S of Station area	Coarse gravel, humic, below mesotrophic moss turf	6.9	58	0.58	18	4.6	3.0	—
II	Arenite within limestone, Kapp Posadowsky	Fine, sandy detritus with windworn *Stereocaulon* sp., on the brink	7.1	5.0	0.14	11	6.1	5.5	—
	Arenite within limestone, Kapp Posadowsky	Fine, sandy detritus below *Schistidium maritimum* cushions, on the brink	6.7	—	—	—	—	—	13
	Arenite, Kapp Hanna formation	Fine, sandy detritus below *Trentepohlia* algal mat, on the brink	7.4	—		—	—	—	40
III	Ursa sandstone SW of Station area	Gravel and cryoturbated loam, sparse vegetation	6.6	4.0	0.07	12	1.7	0.4	—
	Ursa sandstone SW of Station area	Gravel and cryoturbated loam, sparse vegetation	6.3	2.0	0.04	12	1.8	0.3	—
	Arenite, outlet of Pølsa	Reddish sand, with *Luzula arcuata* and *Silene acaulis*	6.8	2.0	0.03	6.2	2.1	0.1	—

— : Not analysed.

southern part of the island are better drained and less influenced by cryoturbation.

A particular development of permafrost was discovered on the plateaux of Hambergfjell and Fuglefjell, i.e. palsa-like mounds cored by ice and coated by *Rhacomitrium lanuginosum* peat (Section 6).

Karst phenomena

Runoff is directed by the rivers Lakselva and Engelskelva in the north, Russelva and Jordbruelva in the south. Limestone ground causes subterranean drainage in the vicinity of Lakselva, Jordbruelva, and upper Ymerdalen. Contrary to the topographical map, part of the Ymerdalen river is subterranean and disappears in a karst hole W of Antarcticfjellet, to well up in a gorge 1.4 km farther down. Protected and well-drained dolines are seen in the limestone areas, and they support special plant communitites (Table 7, C.2).

Wind abrasion

Windworn vegetation is seen on the calcareous sandstone plains of the Kapp Hanna formation, in the pass between Hambergfjellet and Alfredfjellet, and on the splintered shales covering the upper slopes of Miseryfjellet. Winter conditions have not been studied, but snow abrasion may be an important ecological factor on exposed crests, whereas the river gorges and dolines are more protected.

A vegetational gradient on the N coast

The composition of vegetation was studied in relation to hydrology, exposure and microclimate at a reference site near Gravodden, W of the Bjørnøya meteorological station (Fig. 1). Vegetation was analysed along a 35 m long strip running ESE-WNW from a mossy plain 5 m a.s.l., crossing a blockfield with protected fruticose lichen, grass and herb communitites, and ending on a wind-exposed terrace 8 m a.s.l.

The first 10 m of the transect (Fig. 3) are uniform *Drepanocladus uncinatus-Brachythecium glaciale* carpets with scattered vascular species such as *Koenigia islandica, Phippsia algida,* and *Saxifraga rivularis*. Then 15 m of stony ground follow with few vasculars and several chionophilous lichens. The species content changes from square 27 onwards, as is seen from the coverage of *Festuca rubra, Poa pratensis* ssp. *alpigena, Oxyria digyna, Saxifraga caespitosa,* and cushions of *Cetraria islandica* and *Cladina mitis*. The end of the transect at square 35 is a wind-exposed and well-drained terrace with i.a. *Draba norvegica, Rhacomitrium lanuginosum,* and *Ochrolechia frigida*.

This transect shows three main developments of the Bjørnøya vegetation:

1) Poorly drained moss carpet communities.
2) Well-drained and wind-protected lichen heaths with several vascular plant species.
3) Wind-abraded summit or terrace vegetation.

This standard profile is well developed in the S slope of Kikutkollen close to the Bjørnøya Radio station, 30—50 m a.s.l. (Fig. 4).

A provisional classification of the vegetation of Bjørnøya

Extensive areas of Bjørnøya support mainly non-vascular communities, where grasses, herbs and dwarf willows are insignificant. However, some vascular species are even found in extreme cryptogamic communities.

A classification of vegetation may be founded on a combination of physiognomical, floristic, and ecological criteria. The ecological factors of bedrock, marine influence, frost action, hydrology, and wind exposure must be considered in particular.

Main groups of communities can be arranged in this way, and some sociations (Dahl 1957, p. 60) can be defined by the criterium of dominance. A grouping into associations is desirable by syntaxonomic methods. The present provisional classification (Table 7) is based on ecological features and the occurrence of Dominant and characteristic species (D), Characteristic, but not dominant species (C) and Frequent, but ubiquitous species (F). Floristic similarities and differences are often blurred out in the Bjørnøya vegetation because several ubiquitous species are dominant, e.g. *Cochlearia groenlandica, Saxifraga caespitosa,* and *Cetraria delisei*.

Table 7. A provisional outline of the terrestrial vegetation of Bjornoya.
D: Dominant and characteristic species, C: Characteristic but not very numerous species, F: Frequent and ubiquitous species.

A. STRONGLY MARINE INFLUENCED COMMUNITIES

1. Shore communities

1.1. *Puccinellia phryganodes* community
- D *Puccinellia phryganodes*
- F *Festuca rubra*
- F *Cochlearia groenlandica*
- C *Schistidium maritimum*
- C *Verrucaria ceuthocarpa*
- C *Verrucaria maura*

1.2. *Stellaria humifusa* community
- C *Stellaria humifusa*
- C *Carex subspathacea*
- F *Saxifraga rivularis*
- F *Drepanocladus uncinatus*

2. Bird rookery communities

2.1. *Cochlearia groenlandica* community
- D *Cochlearia groenlandica*
- D *Drepanocladus uncinatus*
- C *Prasiola crispa*
- C *Xanthoria sorediata*

2.2. *Festuca rubra* community
- D *Festuca rubra*
- F *Cochlearia groenlandica*
- C *Poa pratensis* ssp. *alpigena*
- C *Puccinellia phryganodes*

B. MODERATELY MARINE INFLUENCED COMMUNITIES

1. *Saxifraga rivularis* community
- D *Saxifraga rivularis*
- F *Phippsia algida*
- F *Koenigia islandica*
- F *Oxyria digyna*
- F *Cochlearia groenlandica*
- F *Saxifraga caespitosa*
- D *Brachythecium glaciale*
- D *Drepanocladus uncinatus*
- C *Cephaloziella* aff. *arctica*
- D *Lecidea vernalis*
- C *Leciophysma arctophilum*
- F *Pertusaria* spp.
- F *Psoroma hypnorum*

2. *Chrysosplenium tetrandrum* community
- C *Chrysosplenium tetrandrum*
- F *Oxyria digyna*
- F *Cardamine nymanii*
- C *Saxifraga caespitosa*
- F *Saxifraga cernua*
- F *Saxifraga hirculus*
- C *Brachythecium salebrosum*
- C *Cinclidium arcticum*
- C *Climacium dendroides*
- F *Drepanocladus uncinatus*
- C *Drepanocladus vernicosus*
- C *Plagiomnium ellipticum*
- C *Philonotis fontana*
- C *Rhytidiadelphus squarrosus*
- C *Tortula ruralis*
- C *Marchantia polymorpha*
- C *Peltigera membranacea*

3. *Sedum rosea* ssp. *arcticum* community
- D *Sedum rosea*
- F *Cochlearia groenlandica*
- F *Draba norvegica*

C. INLAND COMMUNITIES, WELL-DRAINED

1. Chionophobous communities

1.1. *Papaver dahlianum* community (Bedrock group I)
- C *Papaver dahlianum*
- D *Saxifraga oppositifolia*
- C *Arabis alpina*
- C *Draba alpina*
- F *Cerastium arcticum*
- F *Saxifraga caespitosa*
- D *Lecidea ramulosa*
- C *Fulgensia bracteata*
- C *Lecanora epibryon*
- C *Caloplaca cerina*

1.2. *Silene acaulis* community (Bedrock group II)
- D *Silene acaulis*
- F *Festuca vivipara*
- F *Cerastium arcticum*
- F *Draba norvegica*
- F *Saxifraga caespitosa*
- F *Saxifraga oppositifolia*
- F *Cetraria delisei*
- F *Ochrolechia frigida*

(continued)

1.3. *Luzula arcuata* community (Bedrock group III)
- D *Luzula arcuata*
- D *Festuca vivipara*
- F *Salix herbacea*
- D *Rhacomitrium lanuginosum*
- D *Alectoria nigricans*
- D *Sphaerophorus globosus*
- F *Cetraria delisei*

2. Intermediately exposed communities

2.1. *Salix polaris* community (Bedrock group I)
- D *Salix polaris*
- C *Equisetum scirpoides*
- C *Poa alpina*
- C *Polygonum viviparum*
- C *Ranunculus pygmaeus*
- C *Salix reticulata*
- F *Oxyria digyna*
- F *Saxifraga cernua*
- F *Drepanocladus uncinatus*
- C *Orthothecium chryseum*
- C *Timmia austriaca*
- C *Tomenthypnum nitens*
- C *Toninia lobulata*

2.2. *Salix herbacea* community (Bedrock groups II and III)
- D *Salix herbacea*
- C *Cerastium cerastoides*
- F *Oxyria digyna*
- F *Saxifraga cernua*
- D *Brachythecium reflexum*
- D *Kiæria glacialis*
- C *Conostomum tetragonum*
- F *Drepanocladus uncinatus*
- D *Cladina mitis*
- D *Cladonia ecmocyna*
- D *Cladonia stricta*
- C *Peltigera kristinsonii*
- C *Peltigera rufescens*
- C *Stereocaulon alpinum*

2.3. *Taraxacum cymbifolium* community (Bedrock group II)
- D *Taraxacum cymbifolium*
- D *Oxyria digyna*
- C *Sedum rosea* ssp. *arcticum*
- F *Festuca rubra*
- F *Salix herbacea*
- F *Saxifraga cernua*

D. INLAND COMMUNITIES, SEASONALLY FLUSHED

1. *Phippsia concinna* community (Bedrock group I)
- D *Phippsia concinna*
- C *Equisetum variegatum*
- C *Juncus biglumis*
- C *Alopecurus alpinus*
- C *Saxifraga hirculus*
- C *Saxifraga tenuis*
- F *Koenigia islandica*
- F *Sagina intermedia*
- F *Cerastium regelii*
- F *Ranunculus sulphureus*
- C *Bryum cryophilum*
- D *Scorpidium turgescens*
- F *Lecidea ramulosa*

2. *Phippsia algida* community (Bedrock group II)
- D *Phippsia algida*
- F *Koenigia islandica*
- F *Sagina intermedia*
- F *Cerastium regelii*
- F *Ranunculus sulphureus*
- F *Drepanocladus uncinatus*
- F *Hygrohypnum* spp.

3. *Deschampsia alpina* community (Bedrock group III)
- D *Deschampsia alpina*
- D *Festuca vivipara*
- F *Equisetum arvense*
- F *Ranunculus sulphureus*
- F *Polytrichum alpinum*
- C *Solorina crocea*

E. INLAND COMMUNITIES, WATER-LOGGED

1. *Dupontia* community (Eutrophic/mesotrophic)
- D *Dupontia psilosantha*
- C *Calamagrostis neglecta*
- C *Cardamine nymanii*
- C *Hippuris vulgaris*
- C *Ranunculus hyperboreus*
- F *Calliergon stramineum*
- F *Drepanocladus intermedius*
- F *Drepanocladus badius*
- F *Meesea triquetra*
- F *Paludella squarrosa*

2. *Arctophila* community (Mesotrophic/oligotrophic)
- D *Arctophila fulva*
- F *Dupontia psilosantha*
- F *Ranunculus hyperboreus*
- D *Brachythecium glaciale*
- D *Calliergon giganteum*
- D *Calliergon sarmentosum*
- F *Drepanocladus fluitans*
- F *Sphagnum lindbergii*
- F *Sphagnum riparium*

(continued)

F. VARIOUS NON-CLASSIFIED COMMUNITIES

i. Nearly non-vascular *Rhacomitrium lanuginosum* community, montane

D	*Rhacomitrium lanuginosum*	D	*Cetraria nivalis*
D	*Aulacomnium turgidum*	F	*Cetraria islandica*
F	*Tortula norvegica*	F	*Sphaerophorus globosus*
F	*Tortula ruralis*	C	*Placopsis gelida* (on stones)

ii. Nearly non-vascular *Drepanocladus exannulatus* community

D	*Drepanocladus exannulatus*	C	*Sphagnum lindbergii*
D	*Drepanocladus fluitans*	C	*Sphagnum squarrosum*
D	*Calliergon sarmentosum*	C	*Leptoglossum lobatum*
C	*Koenigia islandica*	C	*Mitrula gracilis*

iii. Shale screes on summits of Miseryfjellet

D	*Cochlearia groenlandica*	F	*Saxifraga cernua*
F	*Poa alpina*	F	*Saxifraga rivularis*
F	*Cerastium regelii*	D	*Rhacomitrium fasciculare*

iv. Sandstone blockfields and crags in the interior of Bjørnøya

D	*Andreaea rupestris* s. lat.	C	*Parmelia omphalodes*
D	*Dicranoweisia crispula*	C	*Parmelia saxatilis*
F	*Rhacomitrium lanuginosum*	D	*Umbilicaria arctica*
C	*Gymnomitrium coralloides*	C	*Umbilicaria cylindrica*
C	*Cladonia bellidiflora*	C	*Umbilicaria proboscidea*
F	*Cladonia coccifera*	C	*Umbilicaria torrefacta*

v. Limestone boulders and crags in the interior of Bjørnøya

C	*Saxifraga oppositifolia*	C	*Caloplaca cerina*
C	*Encalypta* spp.	C	*Lecanora epibryon*
C	*Hypnum revolutum*	C	*Physcia muscigena*
C	*Pseudoleskeella* spp.	C	*Placynthium asperellum*
C	*Schistidium apocarpum*		

vi. Late thawing or temporarily flooded bryophyte turf snow-beds, nearly non-vascular

C	*Conostomum tetragonum*	C	*Kiaeria glacialis*
F	*Drepanocladus uncinatus*	C	*Polytrichum* spp.
C	*Gymnomitrium* spp.		

Regional comparisons

The vegetation of Bjørnøya may be compared with that of other Arctic and Oroarctic regions adjacent to the Barents Sea. Spitsbergen is best investigated in this respect, and Brattbakk (1983, 1984) recognizes the Sphaerophoro-Rhacomitrietum lanuginosi as similarly developed on the western coast of Spitsbergen. There are also ecogeographical relations to the *Cladina mitis*-zone as defined by Eurola (1968) from coastal tracts of Spitsbergen. Limestone plains of Bjørnøya support communities with *Saxifraga oppositifolia* and *Cetraria delisei*, which are similar to coastal communities of Prins Karls Forland (Summerhayes & Elton 1923) and Brøggerhalvøya on the western coast of Spitsbergen (Brattbakk 1981). The bryophyte carpet communities resemble those described from Jan Mayen (Russell & Wellington 1940; Lid 1964), especially with regard to the dominance of *Brachythecium* spp. and chionophilous vascular species.

5. Thermal conditions of the vegetation

Vegetation temperatures were monitored from 10 to 22 August 1983 by hourly PT 100 thermistor readings charted on a Grant writer at the reference site W of the Bjørnøya meteorological station (Fig. 1). For discussion of temperature measuring methodology, see Walton (1984). The instruments worked without failure throughout the period, and the registration covers various representative weather situations (Table 5).

Diurnal means of superficial vegetation temperatures as well as average maxima and minima are summarized from three representative plant

Fig. 3. Vegetation transect, Bjørnøya: North coast, between Tobiesenelva and Gravodden, 5—8 m above sea level. Coverage according to Hult—Sernander's scale (▬ : 1 — █ : 5).

communities along the transect shown in Figs. 1 and 3.

Square no. 1 is on a humid, freely exposed plain with carpets of *Drepanocladus uncinatus, Brachythecium glaciale, Bryum nitidulum* and *Cephaloziella* aff. *arctica*, and with *Phippsia algida* and *Saxifraga rivularis* as the only vascular species of importance. It belongs to the *Saxifraga rivularis* community (Table 7, B.1).

Square no. 31 is in a SE facing slope with well-developed fruticose lichen cushions *(Cetraria islandica and Cladina mitis), Poa pratensis ssp. alpigena, and Oxyria digyna*. It is related to the *Salix herbacea* community (Table 7, C.2.2), but no *Salix* occurred in the immediate vicinity.

Square no. 34 is on an exposed sandstone terrace with scattered moss and lichen turfs, bordering on a wind-swept *Sedum rosea* community.

The summary of microthermal conditions (Table 5) shows the low diurnal temperature amplitude of square no. 1, irrespective of the weather situation. The average temperature for the entire period was 5.5°, and average maxima did not exceed 9°.

Square no. 31 had a mean superficial vegetation temperature of 7° and an average maximum of 14°. The highest temperature recorded during a calm and sunny period was 27.5°.

Square no. 34 had lower averages and maxima, which may be caused by a less sunward aspect and exposure to wind chill.

The thermal conditions in these plant communities recall observations from other Arctic areas (cf. Gjessing & Øvstedal 1976). Water saturation is a main factor controlling the superficial temperature, and the former is dependent on aspect, slope, and drainage. Sun heating is most effective in square no. 31, which is favourably exposed and wind-protected. The vegetation temperatures on Bjørnøya were recorded as generally low and not on average exceeding the ambient air temperature by more than 1—2°. This is ascribed to the low direct sun radiation (Table 2) and the generally humid conditions. On foggy summer days, vegetation temperatures are levelled, irrespective of slope, aspect, and drainage. Recalling the summer fog frequency (Table 3A, B), Bjørnøya is evidently not suitable for vascular species having high temperature demands for growth and reproduction. Lignified species such as *Salix herbacea, S. polaris* and *S. reticulata* mainly grow in sheltered and south-facing places, and only in the low-lying areas (cf. Section 6).

However, the low temperatures may be compensated for by a long growing season, but this seems to promote mainly the cryptogamic vegetation. In this respect Bjørnøya may be compared with Jan Mayen (Lid 1964) and the SW coast of Spitsbergen (Triloff 1944; Eurola 1968). Parts of Bjørnøya have a slightly more favourable local climate, e.g. the southern slopes of Miseryfjellet, the valley at Kvalrossbukta, and the Ymerdalen valley, judged from the local development of

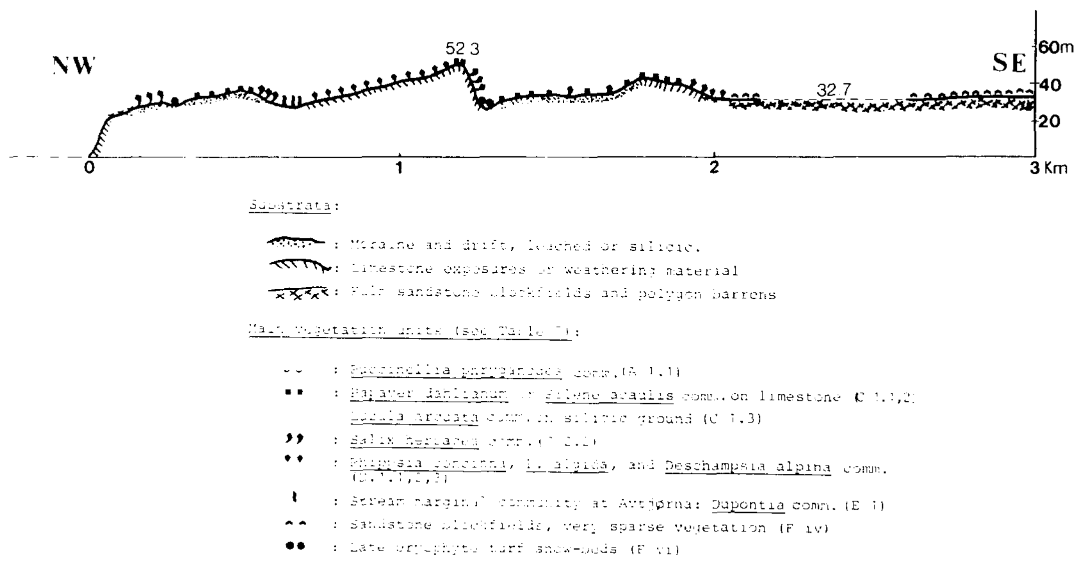


Fig. 4. Generalized profile on the northern plain of Bjørnøya from the brink east of Kapp Posadowsky, passing southeast over Kikutkollen (52.3 m a.s.l.) to Lomvatnet (32.7 m a.s.l.).

Table 8. Vascular species occurring at higher elevations on Bjørnøya °: Sterile specimens only.

Altitude m a.s.l.	Skuld	Hambergfjell	Fuglefjell
454	*Cerastium regelii*		
	Cochlearia groenlandica		
	Saxifraga caespitosa		
452	*Phippsia algida*		
440	*Cerastium arcticum*	*Phippsia algida*	
	Saxifraga cernua	*Ranunculus hyperboreus*°	
	Saxifraga rivularis	*Cochlearia groenlandica*	
		Saxifraga rivularis	
430		*Saxifraga caespitosa*	
410			*Phippsia algida*
			Cochlearia groenlandica
			Festuca rubra°
400	*Poa alpina*	*Oxyria digyna*	*Poa pratensis* ssp. *alpigena*°
380		*Poa alpina*	
350	*Ranunculus sulphureus*	*Cerastium regelii*	
320			*Saxifraga nivalis*
310			*Saxifraga oppositifolia*
300		*Draba alpina*	
		Draba norvegica	
290		*Phippsia concinna*	
250	*Deschampsia alpina*		
	Festuca vivipara		
	Salix herbacea		
	Salix polaris		
220	*Sagina intermedia*		
	Saxifraga tenuis		
200	*Ranunculus pygmaeus*		

vegetation. These are the habitats of plant communities and species which are absent from the monotonous and water-logged northern plain, e.g. *Arabis alpina*, *Saxifraga aizoides*, and *Taraxacum cymbifolium*.

6. Vertical floristic belts

Altitude limits of vascular species

Table 8 summarizes the altitudinal distribution of 25 species which were observed between 200 and 454 m a.s.l. on the mountains of Bjørnøya. Most probably some of them will also be found on a higher altitude when the summits of Urd (535 m) and Verdandi (462 m) become explored. Marking with a ° notifies sterile plants only. This does not apply to *Cardamine nymanii* and *Cerastium regelii* which do not usually flower on Bjørnøya.

It is noted that the dwarf willows, *Salix herbacea* and *S. polaris*, do not ascend above 250 m a.s.l. on Bjørnøya. This is a considerable downward displacement from the Finnmark coast, where both species reach over 800 m a.s.l. (Dahl 1934), and still more from interior North Scandinavia where they ascend to at least 1600 m (Engelskjøn 1986 unpublished). The third lignified species on the island, *Salix reticulata*, ascends to 80 m a.s.l.

Table 9 relates the vertical distribution to heat sums, calculated as Degree-Days for June—September or July—August.

About half of the Bjørnøya species persist and reproduce at the 200 m level, which corresponds to DD-2 = 190. The remaining species are confined to lower hills, valleys and plains. Some of them are hydrophytes, e.g. *Arctophila fulva* and *Hippuris vulgaris*, whereas others may be absent from the summits for thermal reasons, e.g. *Salix reticulata*, *Cerastium cerastoides*, *Saxifraga aizoides*, and *Taraxacum cymbifolium*.

Table 9. Heat sums (as Degree-Days) at various elevations on Bjørnøya, related to uppermost occurrences of vascular plant species. DD-4: Degree-Days, June—September. DD-2: Degree-Days, July—August. °: Sterile specimens only.

Altitude m a.s.l.	DD-4	DD-2	Upper altitudinal limit of vascular species
535	-5	60	Floristic content unknown
450	65	90	*Cerastium arcticum, C. regelii, Cochlearia groenlandica, Phippsia algida, Saxifraga caespitosa, S. cernua, S. rivularis Oxyria digyna, Poa alpina*
350	140	130	*Ranunculus sulphureus Draba alpina, D. norvegica, Phippsia concinna, Saxifraga nivalis, S. oppositifolia*
250	220	170	*Deschampsia alpina, Festuca vivipara, Salix herbacea, S. polaris Cardamine nymanii, Saxifraga hirculus°, S. tenuis, Sagina intermedia, Silene acaulis°*
200	260	190	*Arabis alpina, Papaver dahlianum, Ranunculus pygmaeus*
⋮	⋮	⋮	
30	400	260	54 native species at low levels

Formation of peat mounds on the high ground of Bjørnøya

During the 1983 expedition, Mr. Sigbjørn Dunfjeld and the present author visited the summit plateau of Hambergfjell. We came across an extensive area of 1—3 m high, peat covered and ice-cored hillocks (Figs. 5, 6). *Rhacomitrium lanuginosum* is the main bryophyte species making up the peaty coat of these ice mounds, which are very similar to palsas (Svensson 1964; Lundquist 1969). The Hambergfjell field measures approximately 0.4 × 0.3 km and is situated somewhat inside the margins of the sheer precipices to the SW, between 400 and 440 m a.s.l. The largest mounds measure up to 20 × 5 × 3 m. The peaty mantle is 0.3 to 0.5 m thick and covers ice lenses (Fig. 6) which rest on Spirifer limestone pavements of the old plateau surface. No silty or clayey sediments were seen inside the mounds.

Dark brown peat is exposed by erosion on many of the larger, partly collapsed structures. *Rhacomitrium* stems are recognizable also in the deepest peat layer. On intact surfaces the cryptogamic cover consists of *Rhacomitrium lanuginosum, Drepanocladus uncinatus, Aulacomnium palustre, A. turgidum, Cetraria nivalis,* and *Sphaerophorus globosus.* It is mainly non-vascular, but did support some fungi, even the large *Lepista polygoni.* Between the mounds are water-soaked moss carpets of *Calliergon sarmentosum, Drepanocladus uncinatus,* and *Hygrohypnum alpestre,* and of vascular species, *Phippsia algida, Saxifraga rivularis,* and *Cochlearia groenlandica* seedlings, as well as the hygrophilous fungi *Galerina pumila* and *Leptoglossum lobatum.*

Proceeding to Alfredfjell (410 m a.s.l.) we found a smaller area with similar peat mounds (Figs. 7, 8). They cover the top of the mountain, and eroded peat is exposed in terraces on its NW side. I suppose these structures are ice-cored, but time was too short for excavation.

Ways of formation of the Bjørnøya peat mounds

Several factors contribute to create ice-cored mounds of the kind described (Seppälä 1976).

1) Low annual mean temperature,
2) a sufficiently high water saturation of the ground,
3) thermal isolation by peat during summer thaw,
4) cyclic erosion and regeneration courses.

The mean annual temperature at the 450 m level on Bjørnøya is about -5° (Table 4). Precipitation

Fig. 5. Peat mounds up to 3 m high on the summit plateau of Hambergfjell, approximately 430 m a.s.l. 16 August 1983.

Fig. 6. Detail of ice core in mound shown on Fig. 5. Scale (I) carved into ice, 20 cm high. 16 August 1983.

Fig. 7. Peat mounds on the summit of Fuglefjell, 410 m a.s.l., looking north towards Miseryfjellet (535 m a.s.l.) and the northern low ground of Bjørnøya.
16 August 1983.

Fig. 8. Eroded *Rhacomitrium lanuginosum* peat terraces on Fuglefjell, probably ice-cored. The section is 3 m high.
16 August 1983.

is liable to be trapped in absorbent moss hummocks, the growth of which is enhanced by the stability of the plateau and the bird manuring. Situated above very large bird rookeries (Fig. 10, Section 8), the plateaux are exposed to steady dropping of manure, feather, fish bones, and shells. However, the plateaux are not breeding sites, which would lead to overdunging and trampling.

Although *Rhacomitrium lanuginosum* is a frugal species (Jalas 1955) it grows vigorously with the mentioned bird manuring, and a comparable growth at bird rookeries has not been described elsewhere in the North Atlantic Arctic (cf. Steindórsson 1945; Elvebakk 1979; Brattbakk 1983). Nor have I seen descriptions of *Rhacomitrium*-coated palsas (cf. Datkiewicz 1967; French 1971; Hambrey & Swett 1980; Vorren 1972). Peat accumulations on Spitsbergen, described by Låg (1980), may be compared with the Bjørnøya occurrences.

Peat mounds were not observed on the low ground of Bjørnøya. Manuring is less in the interior of the island, and the seasonal thermal fluctuations may be less suitable for formation of such structures.

It seems that the high ground of Bjørnøya is the only place in the North Atlantic where such structures have developed at a large scale. Their time of formation is unknown, and it would be desirable to have them surveyed and dated.

7. Specific distribution patterns within the island

The following record of horizontal and vertical distributions of the vascular species of Bjørnøya is founded on accumulated information from field work in 1967 (cf. Engelskjøn & Schweitzer 1970) and in 1983.

Two species are new to the island: *Alchemilla glomerulans* and *Saxifraga foliolosa*. The first numeral in the species headings corresponds to numbers of distribution maps (1—54), which also include a tabulation of vertical distribution. The number in brackets gives the number of stations known of the species on Bjørnøya. Introduced species are enumerated after the 54 supposedly native species.

1. *Equisetum arvense* L. (62).

Frequent in various parts of the island, especially on the N coast, reaching the altitude limit 130 m a.s.l. on the plain W of Miseryfjellet.

The species is indifferent to bedrock and even grows in Ursa sandstone blockfields, but requires seasonal flooding and shelter from wind abrasion.

Characteristic of *Cetraria delisei—Drepanocladus uncinatus* and *Oxyria—Saxifraga cernua* communities, or associating with *Deschampsia alpina* (Table 7, D.3), but also in the most species-rich, eutrophic moss carpet communities.

2. *Equisetum scirpoides* Rich. (12).

The two records from the N coast (Engelskjøn & Schweitzer 1970, Map 16) must be excluded, because my recent revision of the material (TROM) proved these collections to be gracile modifications of *E. variegatum*. Accordingly, *E. scirpoides* is confined to the S half of the island, ascending to 100 m a.s.l. on the S slope of Miseryfjellet.

It grows on well-drained, licheniferous bryophyte turfs with a silty subsoil, often associated with *Salix polaris*.

3. *Equisetum variegatum* Schleich. (19).

Localized to the N and S parts, from 10 to 130 m a.s.l. Preferentially in the carbonatite areas; on flooded or cryoturbated lithosol with a thin bryophyte turf, but also in nearly non-vascular *Drepanocladus uncinatus* carpets in the Kulm areas.

4. *Juncus biglumis* L. (16).

Scattered and partly overlooked; most frequent in the western pond areas but now also found in three places in the interior. Its vertical range is from 20 m on the brink to 50 m a.s.l. at Gåsvatna in Ymerdalen.

Confined to level, cryoturbated, silty patches with a short bryophyte or cyanophycean crust, associated with *Phippsia concinna*, *Koenigia islandica*, *Sagina intermedia*, and *Cerastium regelii* (Table 7, D.1).

5. *Luzula arcuata* (Wg.) Sw. ssp. *arcuata* (56).

Locally frequent in the interior, more sparsely near the brink. The upper limit of only 150 m a.s.l. is reached at Mefaringen W of Miseryfjellet.

Associated with sandstone lithosol and avoiding carbonatites, but once found together with the eutrophic *Silene acaulis* (Table 6, bedrock III.2).

L. arcuata is a characteristic species in the vegetation of polygon fields and boulder areas, often occurring on small sandstone outcrops within limestone areas (Table 7, C 1.3).

6. *Alopecurus alpinus* Sm. (9).

Restricted to the S half of the island, from 35 m at Røyevatn to 150 m a.s.l. in Ymerdalen. Five new localities were found in 1983, the total being nine. The clones, carrying a few culms, grow centrifugally on flooded, eutrophic moss carpet communities with *Hygrohypnum* spp., *Drepanocladus intermedius*, *Phippsia concinna*, *Dupontia psilosantha*, and *Ranunculus sulphureus*.

7. *Calamagrostis neglecta* (Ehrh.) G. M.S. (26).

By ponds and rivers, especially on the N coast, ascending to 52 m a.s.l. at Krillvatn in the SE. New finds were made at Ellasjøen and in the interior.

Characteristic of peaty banks, often associated with *Dupontia psilosantha*. Culms are sparse and do not appear until mid-August.

8. *Arctophila fulva* (Trin.) Rupr. (17).

A hydrophyte growing in brooks and lakes, up to 100 m a.s.l. in a pond E of Grautauget on the interior plateau.

Exacting as to hydrology, it seems independent of bedrock. Extensive stands were discovered in the Kulm area around Storlona, upper Engelskelv watercourse. Here it brims the ponds, in open water as well as in soaked *Calliergon sarmentosum* carpets with few other vascular species.

Culms are rare (cf. Engelskjøn & Schweitzer 1970).

9. *Dupontia psilosantha* Rupr. (44).

Previously overlooked due to its often sterile state, now recorded from 12 new stations on the S half of Bjørnøya, including the uppermost one at Dipilen, 103 m a.s.l.

The species was found in several places in the interior Kulm areas, but seems to prefer slightly bird-influenced places on the brink.

Recorded from a variety of moss carpet communities ranging from *Sphagnum riparium* and *Calliergon sarmentosum* on the oligotrophic, to *Paludella squarrosa* and *Drepanocladus intermedius* on the eutrophic side (Table 7, E).

10. *Deschampsia alpina* (L.) R. & S. (70).

Frequent in the polygon areas inside the brink and ascending to the mountains: 250 m on Skuld and approximately 300 m a.s.l. between Verdandi and Skuld (Brattbakk 1984).

The species appears indifferent as to bedrock, but requires flooding or cryoturbation, such as in the centre of polygon field communities, associating with *Festuca vivipara*, encircled by *Rhacomitrium lanuginosum* turfs (Table 7, D.3).

11. *Poa alpina* L. var. *vivipara* L. (60).

Concentrated in limestone areas at various levels, ascending to 400 m on Skuld and 380 m a.s.l. on Hambergfjell.

The species has definitely eutrophic demands, but occurs on intermediate, pelitic shales on the summits of Miseryfjellet.

The vegetative development is best in protected herb communities along brook trails.

12. *Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit. (33).

Locally common in some sections of the coast and other moderately bird-influnced places, to 230 m below the Ymerdalen kittiwake rookery and to 400 m a.s.l. on the Fuglefjell plateau. Usually in luxuriant grass vegetation, but also in eroded peat on the brink. Sterile at the altitude limit, elsewhere flowering in August.

13. *Puccinellia phryganodes* (Trin.) Scribn. & Merr. (39).

Dispersed on the lower coastal brinks. Being a principally littoral species (Table 7, A 1.1), it ascends only to 30 m a.s.l.

In moss carpet communities, usually as vegetative, stoloniferous clones, but developing tufts with few stolons and flowering culms when growing on silty, well-drained brink sites.

14. *Phippsia algida* (Sol.) R. Br. (112).

One of the species having the most stations on Bjørnøya, including the mountain plateaux: Skuld 452 m, Hambergfjell 430—440 m, and Fuglefjell 410 m a.s.l. Although occurring within the Kulm barrens, it has a certain eutrophic preference.

The high frequency of *P. algida* seems related to the numerous available habitats with flooded mineral soil or moss carpets (Table 7, D.2).

15. *Phippsia concinna* (Th. Fr.) Lindeb. (32).

Less common than the preceding *Phippsia* and confined to open, cryoturbated patches of carbonate-containing subsoil, especially the red Ambigua marl, the Hecla Hoek limestone, and Spirifer limestone. Mainly on the 30 and 100 m plains, but extending to 290 m a.s.l. in the pass between Hambergfjell and Fuglefjell.

P. concinna is numerous in eutrophic habitats, accompanied by exacting species such as *Juncus biglumis* and *Saxifraga hirculus* (Table 7, D.1).

16. *Festuca rubra* L. (102).

Common in most sections of the brink, under bird cliffs, on skua hummocks in the interior, as well as in non-manured limestone bluffs.

Concentrated in low-lying areas, but ascending to 400 m a.s.l. on Fuglefjell. Avoiding the Kulm areas, if not promoted by bird manure. In polar gull areas it forms carpets without culms (Table 7, A 2.2).

17. *Festuca vivipara* (L.) Sm. (63).

Dispersed over the island, including the interior, but less common to the W and S. Vertically, it reaches 250 m a.s.l. on Miseryfjellet.

Equally common in the limestone and Kulm areas, but avoids manured situations. *F. vivipara* is a specialist of gravelly, cryoturbated habitats, often associating with *Luzula arcuata*, *Deschampsia alpina*, and *Cerastium regelii* (Table 7, C1. 2,3, D. 3).

Culm development is not regular and usually takes place from the end of July.

18. *Carex lachenalii* Schkuhr (4).

No new finds were made of this restricted species, which has four stations below 50 m a.s.l.

The northern group of localities at Lakselva was unchanged since 1967. The tufts, partly sterile, were intact in 1983 as then. The best developed plants were flowering in mid-August in a community of *Drepanocladus uncinatus*, *Festuca rubra*, *Salix polaris*, *Polygonum viviparum*, *Cerastium regelii*, and *Ranunculus pygmaeus*.

19. *Carex subspathacea* Wormsk. (3).

Discovered on one spot in 1967, two new stations were added in 1983: NW coast, river bed N of Hira, 23 m a.s.l. in a *Drepanocladus uncinatus* carpet; and NE coast, Framnes, NE side of tarn 18.0 m a.s.l., covering 10 × 6 m within a wet, littorally influenced *Drepanocladus uncinatus* carpet. It was still growing at Lusbekken on the N coast, 6—8 m a.s.l. The species seems to occur only in the sterile state on Bjørnøya.

20. *Salix herbacea* L. (117).

Extensively distributed and ascending to 250 m a.s.l. on Skuld, dispersed also in the barren Kulm sandstone areas, but clearly avoiding the bird-influenced sites at the southern end of the island. *S. herbacea* also enters the limestone areas, associating even with *Saxifraga oppositifolia* on Spirifer limestone on the northern coast, but tends to become replaced by *S. polaris* on this substratum.

21. *Salix polaris* Wg. (80).

Concentrated within the carbonatite areas and locally common, reaching the same altitude limit as *S. herbacea*, 250 m a.s.l., on Skuld. Preferably in bryophyte communities, e.g. of *Drepanocladus uncinatus*, *D. intermedius*, *Oncophorus* spp., *Tomenthypnum nitens*, *Timmia austriaca*, and *Orthothecium chryseum*.

S. herbacea × *polaris*

Often met with in mixed growths of the parent species or with one of them (cf. Engelskjøn & Schweitzer 1970). Hybrid clones have their separate signature on the *S. polaris* map (21).

22. *Salix reticulata* L. (21).

A restricted species which is fairly common on dolomite around Ellasjøen; elsewhere only as small clones on local limestone outcrops. Its highest occurrence is 80 m a.s.l., in the floristically rich area to the S of Miseryfjellet.

S. reticulata prefers eutrophic peat in protected situations and is often associating with *S. polaris*.

23. *Koenigia islandica* L. (45).

Several new stations were found during the late summer of 1983 in the NW and central part of Bjørnøya. It grows mainly in the low-lying plains, reaching 130 m a.s.l. at Kollerskardet, W of Miseryfjellet.

A specialist of flooded or springy communities, *Koenigia* may be the only vascular plant species in floating *Calliergon-Drepanocladus* moss carpets by pools and lakes (Table 7, F ii).

24. *Oxyria digyna* (L.) Hill (108).

Frequent all over the island, concentrated in the luxuriant herb communities, and ascending to 400 m a.s.l. in the bird-influenced moss carpets on Hambergfjell.

Oxyria also occurs on barren polygon ground and in seasonally flooded *Cetraria delisei* communities.

25. *Polygonum viviparum* L. (63).

Dispersed in most parts of the island, reaching 150 m a.s.l. on the N plateau of Miseryfjellet. Preferring eutrophic ground and rare in the sandstone areas.

26. *Sagina intermedia* Fenzl (58).

Dispersed and locally frequent up to 220 m a.s.l. on the NW and W sides of the Miseryfjellet plateau.

Tolerating cryoturbation and bird trampling, the species may be numerous in the central part of limy detritus polygons, as well as in moss carpet communities on the brink.

27. *Cerastium arcticum* Lge. (118).

Widespread, with a high number of recorded stations, although preferring eutrophic habitats. It is met with regularly at high levels, reaching 440 m a.s.l. on Skuld.

A character species of dolomite and limestone barrens, it is best developed in bryophyte peat, seldom missing in skua hummocks and other local peat mounds.

A glabrescent biotype of *C. arcticum* was found S of Ellasjøen at 80 m a.s.l.

C. arcticum × *regelii*

Intermediate clones which may be this hybrid combination were found at Kikutkollen, 35 m, and on the N side of Lakselva, 15 m a.s.l., in both places with the supposed parent species, cf. Rønning (1959, p. 24).

28. *Cerastium cerastoides* (L.) Britton (12).

This species, of very local distribution on the island, was found at new localities in the Spirifer limestone area on the N coast and around the W end of Ellasjøen on the SW coast, reaching 45 m a.s.l. on Kikutkollen. Seems restricted to a particular community of intermediate snow-cover, accompanied by *Brachythecium reflexum*, *Peltigera kristinssonii*, *Oxyria digyna* and *Ranunculus pygmaeus*. *C. cerastoides* is also associating with *Alchemilla glomerulans* in its one and only habitat on Bjørnøya.

29. *Cerastium regelii* Ostenf. (73).

Unevenly distributed and largely avoiding the Kulm areas. It appears to be one of the hardiest species, ascending to 454 m on Skuld and 350 m a.s.l. on Hambergfjell. On the mountain tops it grows branched in shale debris, or more contracted, on polygon mud.

Flowering specimens were found i.a. at the sheltered *Carex lachenalii* station by Lakselva, 15 m a.s.l.

30. *Stellaria humifusa* Rottb. (13).

Six new stations were added, and the species appears as dispersed in brink vegetation (Table 7, A 1.2). It was met with also at the lake Skutilen, 65 m a.s.l., and 3 km from the sea. This is well above the supposed Holocene marine limit. Bird dispersal to this site appears probable. Here it is accompanied by *Arctophila fulva* in *Drepanocladus intermedius—Hygrohypnum* carpets.

31. *Silene acaulis* L. (57).

Particularly numerous on calcarenite plains (Bedrock group II. 2) to the NW; in the Spirifer limestone areas to the N, and in the limestone, dolomite and baryte areas to the SE. It was one of the few plants growing on lead-poisoned dolomite and baryte barrens on the hill Blyhatten.

The vertical range of *S. acaulis* is moderate, attaining 220 m a.s.l. on the southernmost station, where it is sterile.

32. *Ranunculus hyperboreus* Rottb. (38).

Dispersed on the island, mainly along the brink and on the northern plain where ponds are numerous.

Occurring also on the summit plateau of Hambergfjell, 435 m a.s.l., sterile but vegetatively luxuriant.

Although promoted by manure, *R. hyperboreus* occurs at oligotrophic pools with *Sphagnum riparium* and *Calliergon sarmentosum*.

More commonly it is growing with *Calliergon stramineum*, *Cardamine nymanii*, *Hippuris vulgaris*, and *Dupontia psilosantha*.

33. *Ranunculus pygmaeus* Wg. (35).

Of restricted local distribution, reaching 200 m a.s.l. on the N plateau of Miseryfjellet.

The species appears as demanding and prefers well vegetated sites in the carbonatite areas.

34. *Ranunculus sulphureus* Sol. (65).

Widespread and locally common, ascending to 350 m on Skuld and 240 m a.s.l. in Ymerdalen. A substantial part of its stations is above 100 m a.s.l.

The species frequents various habitats, i.a. blockfields and gravel polygons in the sandstone areas, shale screes in the upper slopes of Miseryfjellet, and luxuriant herb communities along watercourses in the carbonatite areas (Fig. 9).

35. *Papaver dahlianum* Nordhagen (48).

Confined to carbonatite lithosol in the N and S part of the island (Table 7, C 1.1), apparently lacking in the NW part and in the Kulm areas. Nor were there poppies in the Triassic shale screes on Miseryfjellet. *P. dahlianum* is numerous and well-developed only on the S side of Miseryfjellet, at Kvalrosselva, and in parts of Ymerdalen.

Fig. 9. Ranunculus sulphureus flowering in Ymerdalen, southern part of Bjørnøya. Luxuriant meadow on Tetradium limestone, sheltered site.
16 August 1983.

P. dahlianum ranges from 12 m at the radio station to 200 m a.s.l. on the W side of Ymerdalen. Plants from wind-exposed dolomite ridges are contracted and often sterile, irrespective of altitude.

36. *Arabis alpina* L. (18).

Confined to the southern, hilly part of the island, where it ascends to 190—210 m a.s.l. on both sides of Ymerdalen.

A usual substratum is well-drained, coarse dolomite or limestone talus supporting very few cryptogams and the following vascular species: *Draba alpina*, *Papaver dahlianum*, *Saxifraga caespitosa*, *S. oppositifolia*, and *Silene acaulis* (Table 7, C 1.1).

Sterile rosettes are frequent, indicating unfavourable conditions for flowering.

37. *Cardamine nymanii* Gand. (67).

Dispersed over the island, ascending to 230 m in Ymerdalen; 220 m a.s.l. on the N plateau of Miseryfjellet.

Growing on flushed moss carpets by streams and ponds, the species may also enter the Kulm sandstone areas.

Flowering is rare as previously stated (Engelskjøn & Schweitzer 1970), but takes place in favourable habitats from mid-August onwards.

38. *Cochlearia groenlandica* L. (approximately 200).

Concentrated in bird-cliffs along the entire coast as well as in the Ymerdalen kittiwake rookeries, but also dispersed to the interior. As to number of stations and biomass, it must be the most important vascular species of Bjørnøya. It ascends to the high plateaux and summits on Miseryfjellet, 454 m, Hambergfjell, 440 m, and Fuglefjell, 410 m a.s.l. In non-manured situations as on the shale screes of Miseryfjellet, specimens are contracted and lilac-flowered. In cliffs and gullies of the rookeries, well-developed, pure *Cochlearia* stands are seen everywhere. The bird-influenced summit plateaux support a *Cochlearia—Drepanocladus uncinatus* sociation with few other vascular plant species (Table 7, A 2.1).

39. *Draba alpina* L. (89).

Widespread in parts of the island; ascending to 300 m between Hambergfjell and Alfredfjell, and to 240 m a.s.l. on Miseryfjellet.

D. alpina is common in the carbonatite areas, and it is merely an exception to find it on sandstone.

Often contracted and with a few flowers on the wind-exposed dolomite barrens, but with a well-developed stature in moss carpet communities.

40. *Draba norvegica* Gunn. (70).

Widespread and occasionally also growing in the Kulm areas. It often occurs together with *D. alpina*, and they reach the same altitude limit: 300 m a.s.l. between Hambergfjell and Alfredfjell, 240 m a.s.l. at Krykkjedammen, upper Ymerdalen.

In slightly manured communities on the brink, *D. norvegica* appears to be locally more frequent than the preceding species.

41. *Sedum rosea* (L.) Scop. ssp. *arcticum* (Borissova) Engelskjøn & Schweitzer (55).

Previously considered restricted to the brink sections with Kulm or other bedrock poor in lime, two new stations were found in the interior, on cherty dolomite and hard calcarenite respectively. We did not find it above 70 m a.s.l., but the locality of Brattbakk (1984) between Beinneset and Revdalen on the SE coast may be above 100 m.

The species forms an interesting community of its own, see Engelskjøn & Schweitzer (1970) and the present Table 7B. 3.

42. *Saxifraga aizoides* L. (4).

The original locality of Schweitzer (Engelskjøn & Schweitzer 1970) was investigated in 1983. About 110 tufts are dispersed on a peaty, soliflucted, dolomite lithosol area to the SE of the hill 100.4 m on Blåsen, between 50 and 65 m a.s.l. Another population was found on alluvial silt 120 m a.s.l. on the S slope of Miseryfjellet, here less numerous and associated with *Equisetum scirpoides* and *Salix polaris*. A third locality was discovered by Brattbakk (1984) between Ymerdalen and Ellasjøen.

The species is restricted on Bjørnøya and appears exacting as to subsoil and hydrology. Flowering starts in mid-August.

43. *Saxifraga caespitosa* L. (108).

I now assess this to be the most ecologically versatile and common saxifrage on Bjørnøya (cf. Engelskjøn & Schweitzer 1970, p. 17). This may not be fully evident from the distribution map because some stations may have been left unnoticed, due to its commonness.

However, it has a preference for the low-lying carbonatite areas, flourishing also on the dolomite barrens.

S. caespitosa ascends to the high plateaux of Skuld (450 m) and Hambergfjell (430 m a.s.l.).

44. *Saxifraga cernua* L. (101).

Formerly considered as the most widespread saxifrage, this species has somewhat fewer localities than *S. caespitosa*, but is more conspicuous due to its stature and larger flowers.

S. cernua seems more exacting than *S. caespitosa*, by avoiding wind-exposed crest and brink areas. Well-developed plants are found in protected herbaceous communities in the carbonatite areas, but it is also alpine, reaching 440 m a.s.l. on the Triassic shale screes on Miseryfjellet. Schweitzer (pers. comm.) noted it in the southern, bird-influenced valleys and mountain slopes.

45. *Saxifraga foliolosa* R. Br. (1).

This important accession to the Bjørnøya vascular flora was made by Brattbakk (1984). The species grows locally on Oswaldfjell, S of Gluggdalsvatna, at an altitude of approximately 120 m a.s.l.

46. *Saxifraga hirculus* L. (49).

The map shows a continuous distribution along rivers and lakes at the southern end of the island, whereas it is rare on the northern half. Confined to carbonatite rocks and best developed in eutrophic bryophyte carpets.

It was also noted on flushed, cryoturbated limestone gravel, mainly in a vegetative state, e.g. W of Lakselva on the N coast and S of Røyevatn.

The species was sterile at its altitudinal limit, a mossy dolomite ridge 220 m a.s.l. on the SE coast.

47. *Saxifraga nivalis* L. (72).

Dispersed, but apparently rare on some stretches of the NW quadrant and in the interior sandstone barrens. It prefers a broken micro-topography, like around Lakselva, below Miseryfjellet, and near the kittiwake rookeries in Ymerdalen.

Found up to 400 m a.s.l. on Hambergfjell.

48. *Saxifraga oppositifolia* L. (81).

Most common, and locally dominant, in the northern and southern parts of the island where carbonatites prevail. The few finds in sandstone areas seem related to limestone admixture in polygons. The species is absent from interior Kulm areas as well as in sections of the brink with bedrock poor in lime.

At its upper limit on Fuglefjell, 310 m a.s.l., only well outside the manured zone and confined to an escarpment with exposed Cora limestone on the edge of Ymerdalen.

49. *Saxifraga rivularis* L. s.str. (78).

Numerous in bryophyte carpets along the brink, in the Ellasjøen depression, and around Miseryfjellet.

The species shows a preference for moist moss carpets, and is often the only vascular plant species. Reaching 440 m a.s.l. on Hambergfjell and on Skuld, it is among the hardiest species (Table 7, B. 1).

50. *Saxifraga tenuis* (Wg.) H. Smith (42).

As different from *S. nivalis*, this species grows in flushed, eutrophic habitats, preferentially in the carbonatite areas away from the brink and bird rookeries.

The highest record is in *Scorpidium turgescens—Hygrohypnum* communities on the Spirifer limestone plateau on Skuld, 220 m a.s.l.

51. *Chrysosplenium tetrandrum* (Lund) Th. Fries (10).

Sporadical on Bjørnøya but locally frequent in springy bryophyte communities below limestone precipices at Miseryfjellet and Ymerdalen (to 200 m a.s.l.), as well as in a bird-influenced brook trail from Måketjørn, 15 m a.s.l., at Kapp Levin on the E coast (Table 7, B.2).

It is accompanied by bryophytes such as *Brachythecium salebrosum*, *Plagiomnium ellipticum*, *Marchantia polymorpha*, *Paludella squarrosa*, *Philonotis* spp., *Rhytidiadelphus squarrosus*, filamentous chlorophyceans, and well-developed *Saxifraga cernua* or *S. hirculus*.

52. *Alchemilla glomerulans* Bus. (1).

Confined to a wind-protected gully eroded in a Spirifer limestone plateau on the N coast, 200—300 m S of Bjørnøya Radio. Three large individuals were found together with *Festuca rubra*, *Oxyria digyna*, *Cerastium arcticum*, *C. cerastoides*, *Ranunculus pygmaeus*, and *Saxifraga cernua*. Among the bryophyte carpets surrounding them I noted *Brachythecium reflexum*, *Drepanocladus uncinatus, Philonotis* sp., and *Timmia austriaca.*

This species assemblage gives the impression of being native. However, it is close to the station area, and several introduced species were found nearby. This casts some doubts on the spontaneity of *A. glomerulans* on Bjørnøya, cf. the section on introduced species. A singular station is also known at Jan Mayen (Lid 1964), here connected with fox burrows.

It is of interest to observe the development of *Alchemilla glomerulans* on Bjørnøya during the coming years.

53. *Hippuris vulgaris* L. (22).

At pond and stream margins from 10 to 30 m a.s.l., mainly on the N and W coasts. In 1983 found at Ellasjøen, where it was previously unknown although the place is well investigated (Rønning 1959). Very large numbers were seen in the lakes of N. Flakmyrvatna, where *Hippuris* appears to be promoted by some disturbance and manuring by polar gulls and skuas of the floating moss carpets.

54. *Taraxacum cymbifolium* H. Lindb. (5).

Previously treated by Engelskjøn (1967), some new details of its distribution and performance on Bjørnøya are provided here.

1) The main occurrence is in the brook valley S of Røedvika on the SE coast, 40—55 m a.s.l. *T. cymbifolium* occupies a herb community (Table 7, C 2.3), but is also entering a more exposed *Festuca rubra—Oxyria* community on the brink, as more contracted plants. It is competed by closed *F. rubra* carpets in the polar gull area at the mouth of the small valley facing the sea. The number of individuals counts more than 200.

2) A brook ravine N of Kvalrossbukta, dry in August, 20 m a.s.l. *T. cymbifolium* occupies a similar intermediate zone between a wind-exposed, barren plateau and the streambed. There were about 30 individuals.

3) A tributary brook ravine N of Kvalrosselva, 250 m from the sea and 20—30 m a.s.l. *T. cymbifolium* grows in herb communities, on loose alluvial gravel, and on shale debris, partly together with well-developed *Papaver dahlianum*, totally about 200 individuals.

4) According to Mr. Idar Tetlivold, former head of Bjørnøya Radio station, there is a *Taraxacum* growth at the outlet of Ellasjøen on the SW coast. I was not aware of this find during our stay in 1983, and no specimens have been secured. The record is presumably correct as to generic determination.

5) A few *Taraxacum* specimens were found at Tunheim City in 1957 and 1967, but not rediscovered in 1983. The primary occurence may be located in cliffs facing the sea, or it has disappeared because of the mining activities.

The introduced vascular element on Bjørnøya

Here is summarized the status of non-indigenous species, found up to the present, around the actual and former settlements (Hanssen & Holmboe 1925; Rønning 1959; Engelskjøn & Schweitzer 1970).

1. *Agrostis capillaris* L.

One sterile tuft S of the Radio station, in a protected gully 15 m a.s.l. (1983). Previously not recorded from Bjørnøya.

2. *Deschampsia caespitosa* (L.) PB.

Persisting at Tunheim and in a protected gully S of the Radio station (1983), as well as at Krillvatn (Brattbakk 1984). Culms develop in late August, but ripe seed were not observed.

3. *Poa alpina* L. var. *alpina*.

A non-viviparous strain was found in the gully S of Bjørnøya Radio, represented by four vigorous tufts flowering on 22 August 1983. I suspect it to be introduced, because all native strains appear to be viviparous (cf. Engelskjøn & Schweitzer 1970, pp. 6—7). A similar strain from Tunheim (Rønning 1959) appears extinct.

4. *Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit.

Tall-growing, deviant biotypes persist in one place at Tunheim, at Hammerfeststua in Herwighamna close to the Radio station (1983), and at Krillvatn (Brattbakk 1984). They are richly flowering and ripen seed. We cannot discount the possibility of their being luxuriant modifications of the native biotype (Engelskjøn & Schweitzer 1970, p. 7).

5. *Rumex acetosa* L.

Persisting at Engelskelva N of Tunheim City, close to the walking route to Bjørnøya Radio (1983), but only sterile, and at Krillvatn (Brattbakk 1984).

6. *Stellaria media* (L.) Vill.

Not rediscovered (cf. Engelskjøn, Kramer & Schweitzer 1972), probably extinct.

7. *Ranunculus acris* L.

Not rediscovered at any of the former settlements, presumably extinct.

8. *Alchemilla filicaulis* Bus.

Formerly at Krillvatn (Rønning 1959) but not rediscovered up to 1983—1984 and presumably extinct.

8. Historical and ecological aspects of the Bjørnøya flora and vegetation

The time and extent of Pleistocene glaciations affecting the Barents Sea and Bjørnøya are still a matter of discussion. Conflicting views have been presented also by geologists on the conditions during the Vistula glacial maximum, about 18,000 years ago (for review, see Elverhøi & Solheim 1983).

Horn & Orvin (1928) found numerous traces of glaciation and indicated (p. 55) a submergence of the northern low plain of Bjørnøya 'in a part of the last Ice-period'.

Considering Svalbard at large, Salvigsen & Nydal (1981) provide ample documentation of the Middle Vistulan having been an interstadial with less glaciation than at present. The Late Vistulan glacier advance was limited on the western part of Spitsbergen, but this ice sheet covered the eastern archipelago completely (Salvigsen 1981). The Early Vistulan, about 100,000 years ago, was a period of extensive glaciation with the possible exception of alpine nunataks on Prins Karls Forland. The palaeogeographical reconstruction by Liestøl (1972), leaving shelf areas on NW Spitsbergen ice-free, should also be considered as well as the chronology indicated by Miller (1982).

The available Quaternary geological evidence can be summarized as follows: The northern part of the Barents Sea region was a glaciation centre during the Late Vistulan. The ice sheet probably passed Bjørnøya and advanced S and W to the margins of the Barents Sea shelf. But conditions on land and the chronology of glaciation and deglaciation of Bjørnøya are still inconclusive.

Hyvärinen (1968, 1972) describes pollen spectra from two lakes on Bjørnøya, going back to 8300 years B. P. His observation of *Alnus, Betula, Pinus,* and even thermophilous tree pollen transported to Bjørnøya is of considerable interest. The phytogeography of Bjørnøya was discussed by Hadač (1941, 1960), Rønning (1959), and Engelskjøn & Schweitzer (1970). This discussion has been impeded by the insufficient Quaternary geological knowledge of the Barents Sea region. Because the evidence is still ambiguous, nothing can be said of definite phytogeographical consequence. However, an ecological approach could be attempted to elucidate certain phytogeographical problems pertaining to the Bjørnøya flora.

Irrespective of the time and extent of the Barents Sea glaciations, high-glacial conditions have affected Bjørnøya at times and caused an ecological change. The shift from an ice-free to a pack ice sea around the island implies lower temperatures and a different circulation pattern (Lamb 1972; Olausson 1972).

Solar radiation was influenced by a higher atmospheric transmittivity due to less water vapour and seafog (Kukla 1972), and we may imagine a climate on Bjørnøya quite different from the present maritime Arctic one.

A considerable local glaciation would restrict the plant habitats, but the possibility of ice-free shelf areas must be considered.

The 400 m high precipices at the southern end of Bjørnøya (Fig. 10) would be the least liable to accumulate glacier ice, cf. the conditons on the cliff coast of Bouvetøya, South Atlantic Ocean (Orheim 1981). The sea-bird populations may have decreased during pack ice conditions so as to reduce their edaphic influence.

The botanical problem may be as follows: Which of the present-day vascular species could

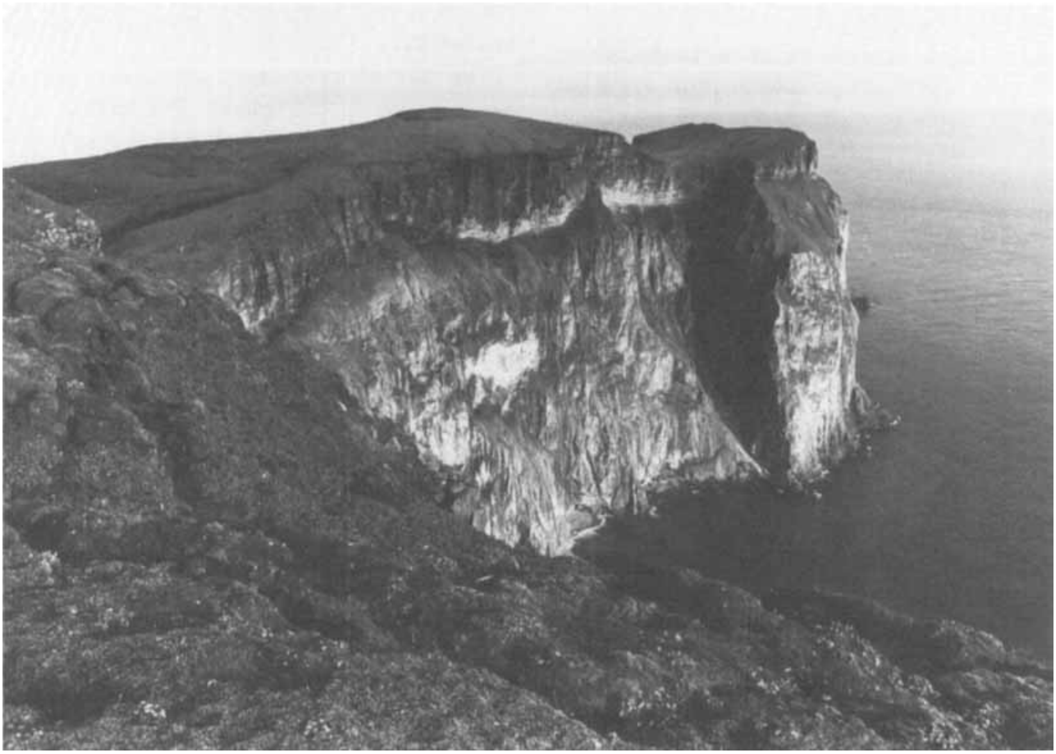


Fig. 10. The southern end of Bjørnøya seen from the Hambergfjell plateau. 350 m high precipices below Fuglefjell. Crevassed *Drepanocladus uncinatus — Tortula ruralis* peat on plateau margin, with *Cochlearia groenlandica.* 16 August 1983.

endure in steep cliffs throughout a glacial period, when ground heating was chiefly caused by radiation? Judged from their present-day performance on Bjørnøya, two thirds of the species could hardly persist under such conditions. The remaining third might well survive glacial conditions, e.g. *Poa alpina, Festuca vivipara, Deschampsia alpina, Phippsia* spp., most *Saxifraga* spp. except *S. aizoides* and *S. hirculus, Cerastium arcticum, C. regelii, Ranunculus sulphureus, Papaver dahlianum, Draba alpina,* and *D. norvegica.* This is an assemblage of ubiquitous Arctic species, some of which are known to perform well also in the extreme polar climate of Severnaja Semlja (Korotkevitsj 1958; Semenov 1970), and Semlja Frantsa Josifa (Hanssen & Lid 1932; Tolmatsjev & Sjukhtina 1974; Aleksandrova 1977).

Ecological 'completeness' of the Bjørnøya vegetation

An objective for the renewed investigation of Bjørnøya was to study the amount of ecological diversity and the potential for that biome to support more than the 52 vascular native species known up to 1970. Two accessions to the flora of the island were made, viz. *Alchemilla glomerulans* and *Saxifraga foliolosa,* the latter discovered by Brattbakk (1984).

In my opinion, we can expect discovery of few vascular species on Bjørnøya in the future. Then the question arises of the ecological potential of Bjørnøya to support species which are absent there, but occur in Spitsbergen *and* North Fennoscandia. Examples are *Ranunculus glacialis* and *Cardamine bellidifolia,* both missing on Bjørnøya, but thriving well in North Norway, at Jan Mayen , and on Spitsbergen, *R. glacialis* only on the southwest coast of Spitsbergen.

To analyse this problem, I have listed 144 well-documented species of the Svalbard flora in nine ecological groups (Table 10). Three levels of thermal demands are defined, as seen from

Table 10. Principal vascular species of Svalbard, tabulated as to hydrological and thermal preference.
* Occurring on Bjørnøya. $(\frac{m}{n})$ fraction of species group present on Bjørnøya.

Water-logged habitats	Intermediately drained habitats		Well-drained habitats	
Low thermal demands				
**Juncus biglumis* **Deschampsia alpina* *Pleuropogon sabinei* **Phippsia algida* **P. concinna* *Carex ursina* **Ranunculus hyperboreus* **Saxifraga foliolosa* *S. svalbardensis*	*Luzula arctica* **L. arcuata* s. lat. **Alopecurus alpinus* **Poa alpina* var. *vivipara* *P. arctica* **P. pratensis* ssp. *alpigena* **Festuca vivipara* — different biotypes *Colpodium vahlianum* *Puccinellia angustata* **Carex lachenalii* **Oxyria digyna* **Sagina intermedia* *Stellaria crassipes* **Cerastium arcticum* **C. regelii*	*Ranunculus nivalis* **R. sulphureus* *Braya purpurascens* **Cochlearia groenlandica* *Cardamine bellidifolia* **Draba alpina* *D. bellii* *D. lactea* *D. micropetala* *D. oxycarpa* **Saxifraga cernua* *S. flagellaris* *S. hyperborea* **S. rivularis* **S. tenuis*	*Poa abbreviata* *Festuca hyperborea* *Carex nardina* *Minuartia rubella* **Papaver dahlianum* *Draba nivalis* **D. norvegica* **Saxifraga caespitosa* **S. nivalis* **S. oppositifolia* *Potentilla hyparctica* *P. pulchella*	
$(\frac{6}{9})$		$(\frac{16}{31})$	$(\frac{5}{12})$	
Intermediate thermal demands				
**Equisetum arvense* **E. variegatum* **Arctophila fulva* **Calamagrostis neglecta* *Deschampsia brevifolia* *Dupontia fisheri* **D. psilosantha* *Eriophorum scheuchzeri* *E. triste* *Carex parallela* **C. subspathacea* **Koenigia islandica* **Cardamine nymanii* *Petasites frigidus* *Ranunculus spitsbergensis*	*Huperzia selago* *Trisetum spicatum* **Puccinellia phryganodes* *Carex glareosa* *C. misandra* **Salix herbacea* **S. polaris* **S. reticulata* **Polygonum viviparum* *Minuartia biflora* *M. rossii* **Cerastium cerastoides* **Stellaria humifusa* *Silene wahlbergella* **Ranunculus pygmaeus* *Eutrema edwardsii*	**Arabis alpina* **Chrysosplenium tetrandrum* **Saxifraga aizoides* *S. hieraciifolia* **S. hirculus* *Cassiope hypnoides* *Pedicularis hirsuta* *Erigeron humilis* *Taraxacum arcticum* *T. brachyceras* **T. cymbifolium*	**Equisetum scirpoides* *Hierochloë alpina* *Poa glauca* *P. hartzii* *Festuca baffinensis* **F. rubra* *Carex rupestris* *Arenaria pseudofrigida* *Honckenya peploides* **Silene acaulis* *S. furcata* *Draba arctica* *D. daurica* *D. fladnizensis* **Sedum rosea* *Potentilla nivea*	*Dryas octopetala* *Cassiope tetragona* *Mertensia maritima* *Pedicularis lanata* ssp. *dasyantha* *Polemonium boreale* *Campanula uniflora* *Erigeron uniflorus* *Arnica alpina*
$(\frac{8}{15})$		$(\frac{13}{27})$		$(\frac{4}{24})$

(continued)

Table 10. (continued)

High thermal demands			
	Junucus castaneus *J. triglumis* *Luzula wahlenbergii* *Arctagrostis latifolia* *Kobresia simpliciuscula* *Carex amblyorhyncha* *C. saxatilis* *Ranunculus lapponicus* *R. pallasii* **Hippuris vulgaris*	*Tofieldia pusilla* *Juncus arcticus* *Carex maritima* *Salix glauca* *Betula nana* *Minuartia stricta* *Potentilla crantzii* **Alchemilla glomerulans* *Rubus chamaemorus* *Vaccinium microphyllum*	*Cystopteris fragilis* ssp. *dickieana* *Woodsia glabella* *Ranunculus auricomus* s. lat. *Empetrum hermaphroditum* *Gentianella tenella* *Campanula rotundifolia* s. lat.
	$(\frac{1}{10})$	$(\frac{1}{10})$	$(\frac{0}{26})$
Total	$(\frac{15}{34})$	$(\frac{30}{68})$	$(\frac{9}{42})$

Not included in this survey are: *Botrychium lunaria, Puccinellia svalbardensis, Colpodium vacillans, Carex capillaris, C. aquatilis* ssp. *stans, Sagina caespitosa, Arenaria humifusa, Sibbaldia procumbens*, and *Euphrasia frigida* — because of very restricted or local occurrences, or ecological performance not well known on Spitsbergen.

altitude limits in Scandinavia and Svalbard and the performance of the species on the North and East coasts of Spitsbergen. Three classes of hydrological preference may usually be estimated at the plants' habitats. It may be noted that a seasonal hydrophile, e.g. *Ranunculus nivalis*, is not ranked together with tundra swamp plants, e.g. *R. pallasii*. However, there are transitory cases, and my classification is tentative.

A simple contingency test based on Table 10 proves an over-representantion in the vascular flora of Bjørnøya of species adapted to cold and water-logged conditions, compared to Svalbard as a whole. Conversely, there is a certain under-representation of species demanding higher summer temperatures, especially of lignified species. Absent from Bjørnøya but growing in Scandinavia and on Spitsbergen are *Salix glauca* (very rare on Spitsbergen, cf. Schweitzer 1966), *Betula nana, Dryas octopetala, Cassiope tetragona*, and *Empetrum hermaphroditum*.

Even ubiquitous Arctic species are missing, e.g. *Carex rupestris* and *Trisetum spicatum*. Furthermore, we note the absence from Bjørnøya of several chionophobous species with low temperature demands, i.a. *Carex nardina, Minuartia rubella, Braya purpurascens*, and *Draba nivalis*. We also miss some chionophilous species: *Ranunculus glacialis, R. nivalis, Cardamine bellidifolia*, and *Cassiope hypnoides*.

Rather surprising is the lack of *Papaver dahlianum* on the high ground of Bjørnøya, such as the summits of Miseryfjellet. On Spitsbergen it ascends to 1100 m above sea level (Sunding 1966) and is among the most cold-tolerant Arctic species. The limitations of *Papaver* on Bjørnøya may be related to the humid climate and snow-influenced vegetation, detrimental to Scapiflora papavers, according to my observations in Norway and Svalbard.

A closer study of the bryo- and lichenflora of Bjørnøya will probably reveal similar patterns of eco-geographical significance. Several arctic-alpine species are absent, e.g. *Alectoria ochroleuca, Thamnolia vermicularis*, and *Cetraria cucullata*. The absence of *Usnea sphacelata* is difficult to explain in climatic terms because this lichen is so frequent at Jan Mayen and in Iceland

(Lynge 1926, 1941). The lack of a suitable stony substratum on the upper slopes and on the summits of Miseryfjellet may be a contributing cause.

Chionophilous or oceanic species dominate the cryptogamic vegetation, e.g. *Cetraria delisei, Cladina mitis, Brachythecium glaciale, B. salebrosum*, and *Rhacomitrium lanuginosum*. This shows the close relationship to the coastal vegetation section of Spitsbergen, named the *Cladonia mitis*-zone by Eurola (1968).

Very little can be concluded about the dispersal adaptations of the Bjørnøya vascular plants. Only about 10% of the species could be considered as anemochores by definition. The three arctic-littoral species may well disperse by sea currents. 15% reproduce mainly by vegetative propagules; among these, *Saxifraga foliolosa* is most restricted on the island. A generalized dispersal (Berg 1983) must be regarded as the main dispersal principle of the Bjørnøya flora. Several animal and geophysical vectors are involved. Also some man-introduced species perform well, e.g. non-viviparous *Poa alpina* and a biotype of *P. pratensis* ssp. *alpigena*.

The absence of several widespread, arctic-alpine species from Bjørnøya may lead to speculation whether the biome is ecologically 'complete' or not, cf. Bertram & Lack (1938) who discussed the faunal aspects. Obviously, several species might succeed if introduced to Bjørnøya, e.g. the chionophilous *Ranunculus glacialis* and *Cardamine bellidifolia*, both of which are frequent on Jan Mayen (Lid 1964). The air and vegetation temperatures and the hygric conditions would promote snow-bed plants and tundra swamp hygrophytes to settle down as members of the Bjørnøya flora.

Snow-avoiding species grow on wind-exposed crests and often tend to be stunted — *Papaver dahlianum* is a good example from Bjørnøya. The steady fog and the wind chill may also contribute to nanism among the vascular plants.

Places with favourable exposure and wind protection are often affected by bird colonies which cause development of *Cochlearia* or *Festuca rubra* communities with a few other species.

Some species which are now confined to shallow ponds could have been introduced by birds during the Holocene, e.g. *Hippuris vulgaris*. The local biotype of *Festuca vivipara* may be of southern provenance because of its low chromosome number 2n = 28, as against 2n = 49 on Spitsbergen (Engelskjøn 1979). But the histories of these two species on Bjørnøya may be different. Recalling the glacial history of the Barents Sea (Salvigsen & Nydal 1981), the local *F. vivipara* biotype could be a vestige of a pre-Vistulan flora. This possibility was also pointed out by Hadač (1941, 1960) and Rønning (1959) for other species, including the lichen- and bryoflora.

To avoid simplistic conclusions, more studies are needed of all aspects of the flora of Bjørnøya, and attention should be paid to advances in Quaternary research in the North Atlantic—Barents Sea region.

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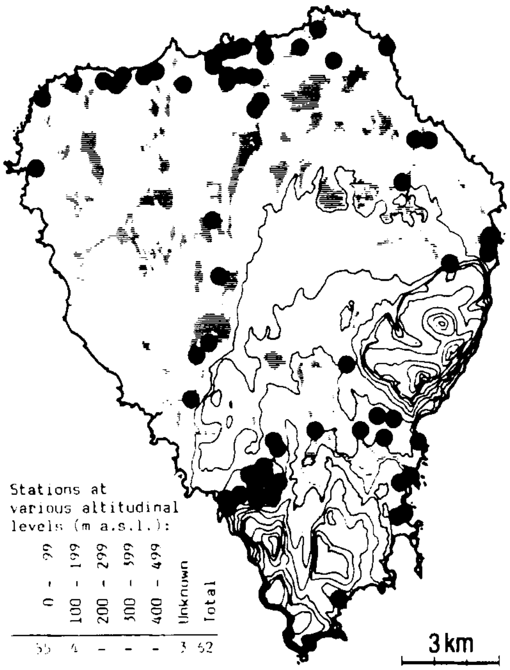
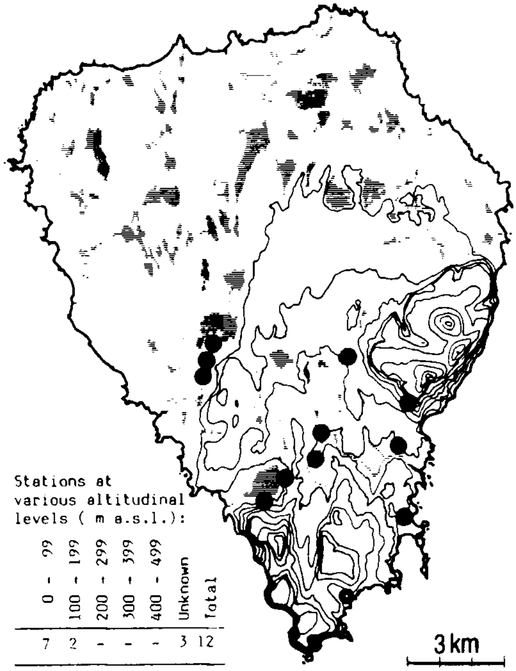
Maps 1–54

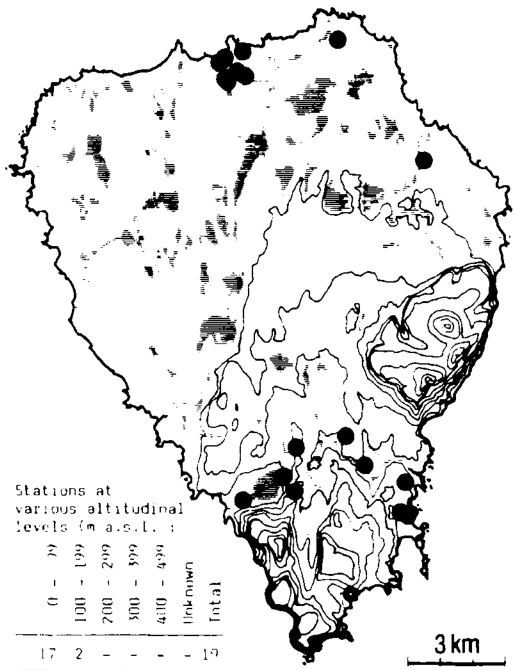
1. *Equisetum arvense* L.



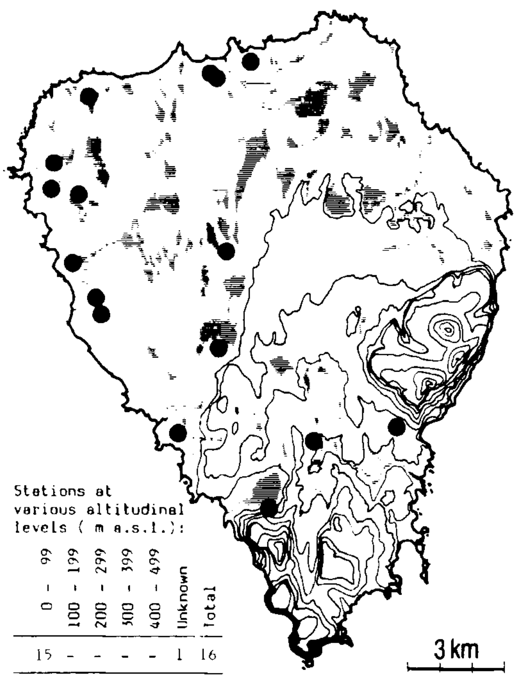
2. *Equisetum scirpoides* Rich.



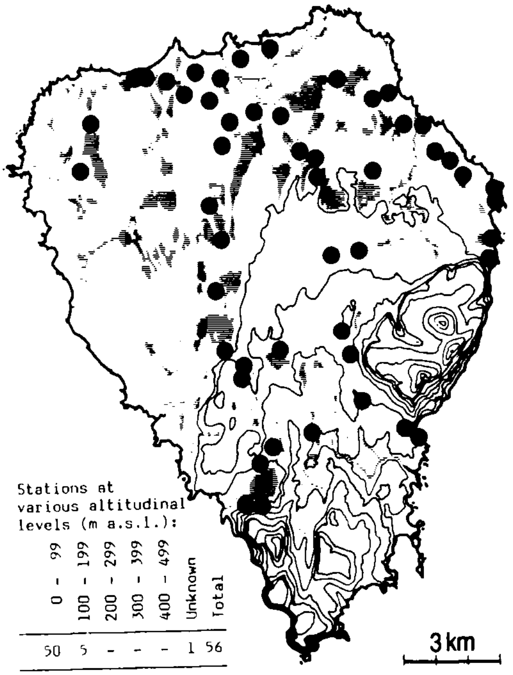
3. *Equisetum variegatum* Schleich.



4. *Juncus biglumis* L.



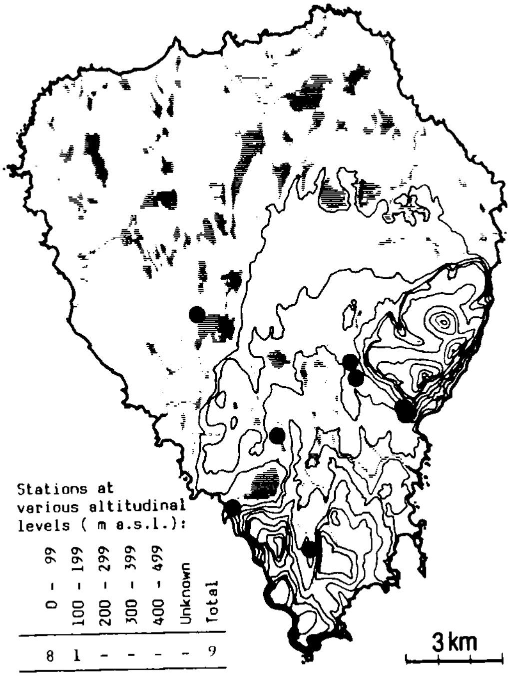
5. *Luzula arcuata* (Wg.) Sw. ssp. *arcuata*



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
50	5	-	-	-	1	56

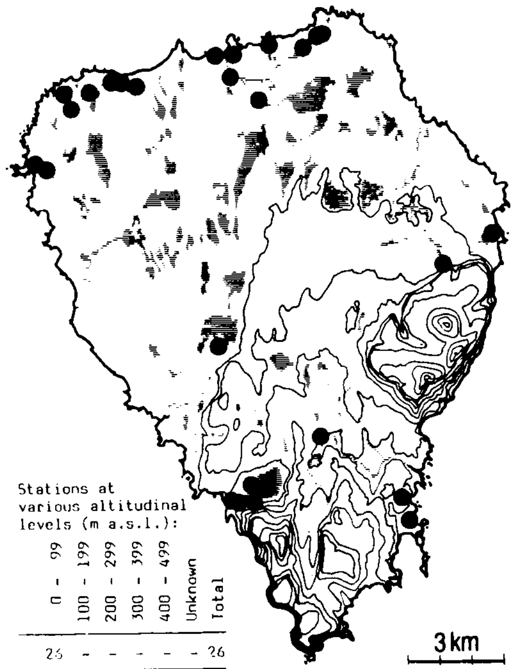
6. *Alopecurus alpinus* Sm.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
8	1	-	-	-	-	9

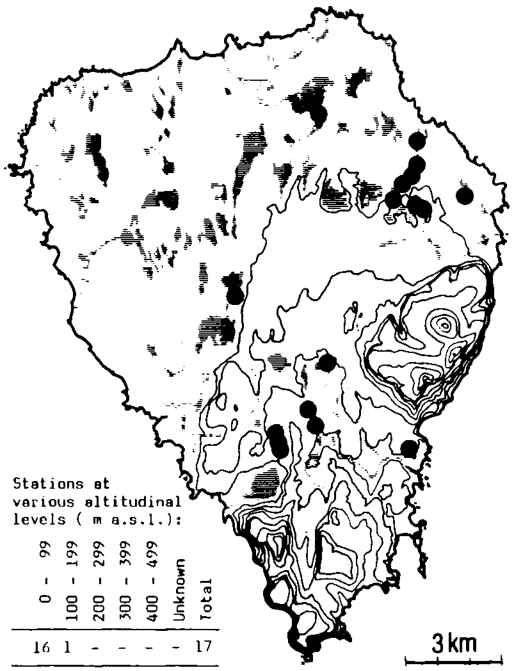
7. *Calamagrostis neglecta* (Ehrh.) G.M.S.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
26	-	-	-	-	-	26

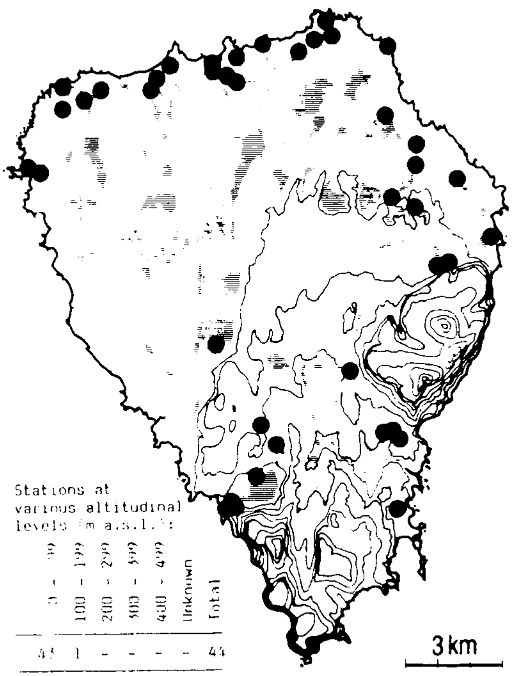
8. *Arctophila fulva* (Trin.) Rupr.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
16	1	-	-	-	-	17

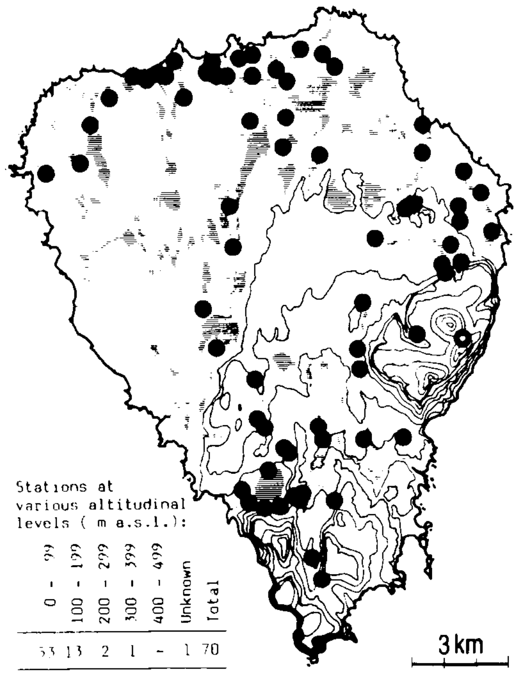
9. *Dupontia psilosantha* Rupr.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
43	1	-	-	-	-	44

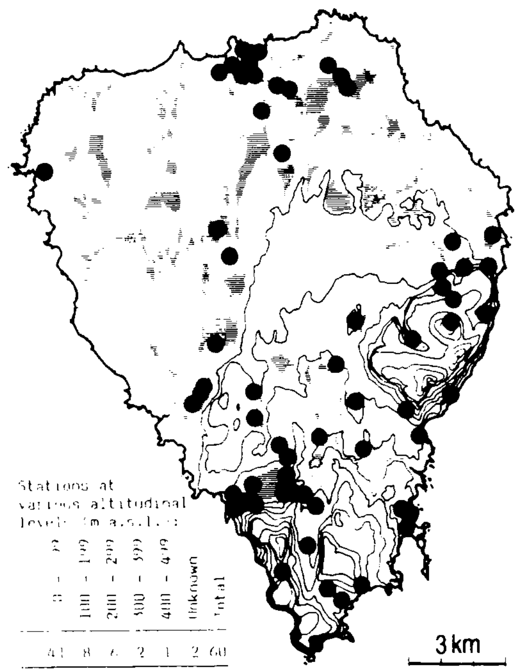
10. *Deschampsia alpina* (L.) R. & S.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
53	13	2	1	-	1	70

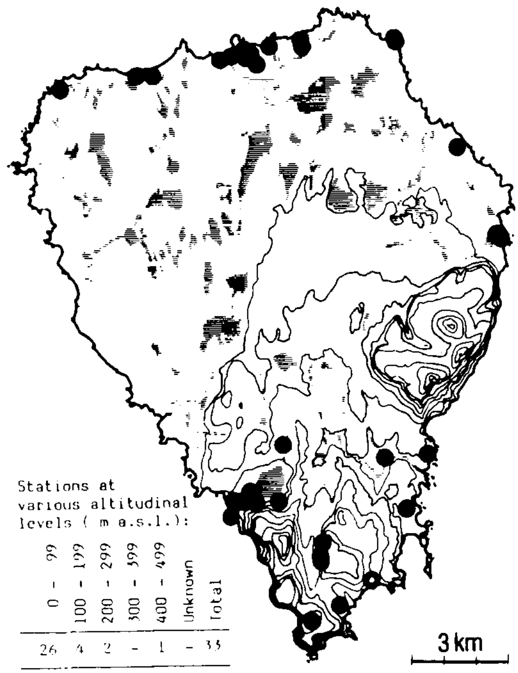
11. *Poa alpina* L. var. *vivipara* L.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
41	8	6	2	1	2	60

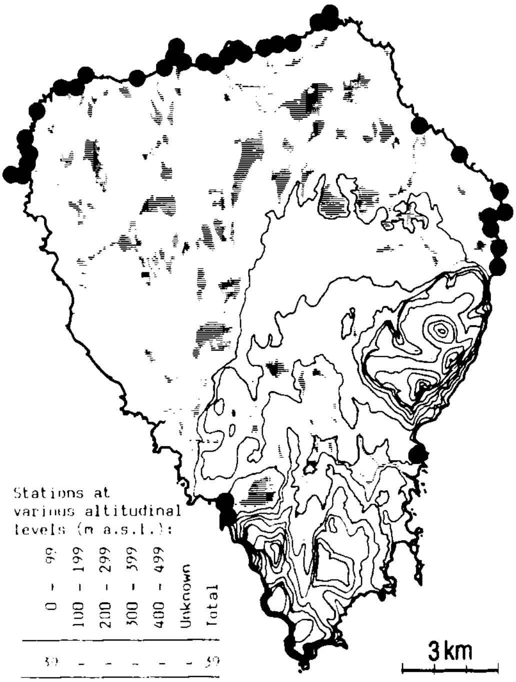
12. *Poa pratensis* L. ssp. *alpigena* (Fr.) Hiit.



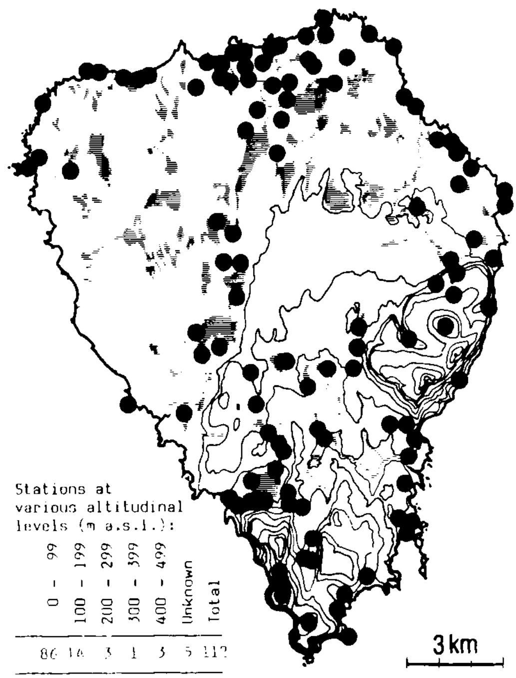
Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
26	4	2	-	1	-	33

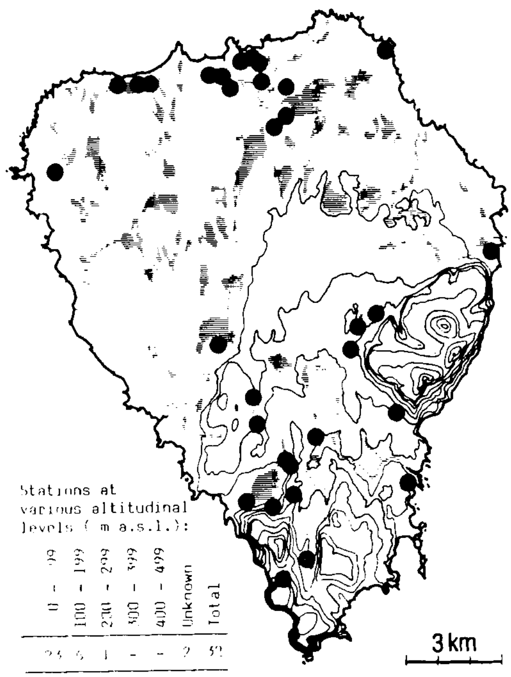
13. *Puccinellia phryganodes* (Trin.) Scribn. & Merr.



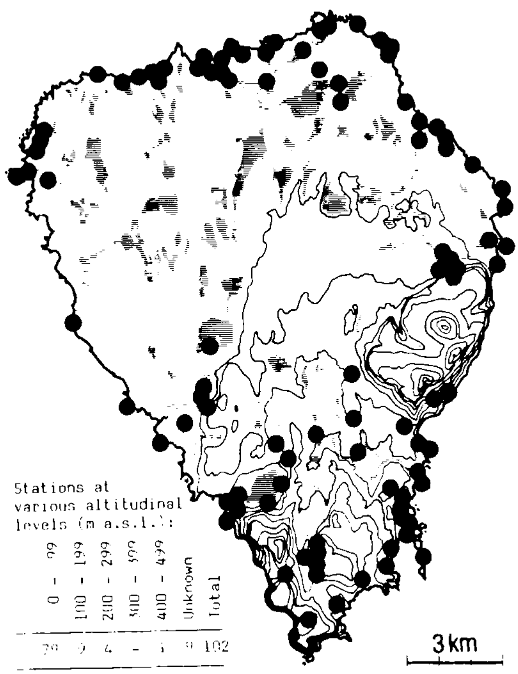
14. *Phippsia algida* (Sol.) R. Br.



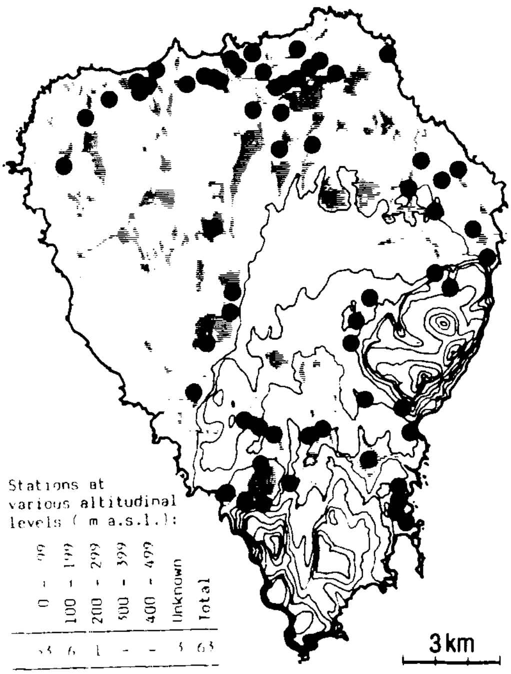
15. *Phippsia concinna* (Th. Fr.) Lindeb.



16. *Festuca rubra* L.



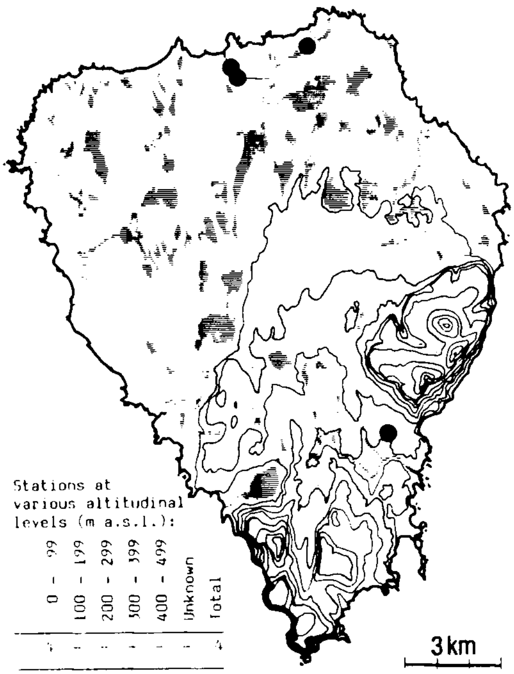
17. *Festuca vivipara* (L.) Sm.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
53	6	1	-	-	3	63

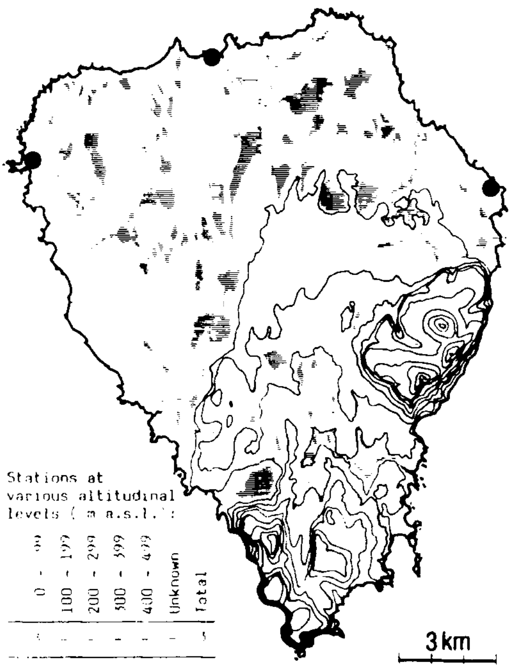
18. *Carex lachenalii* Schkuhr



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
4	-	-	-	-	-	4

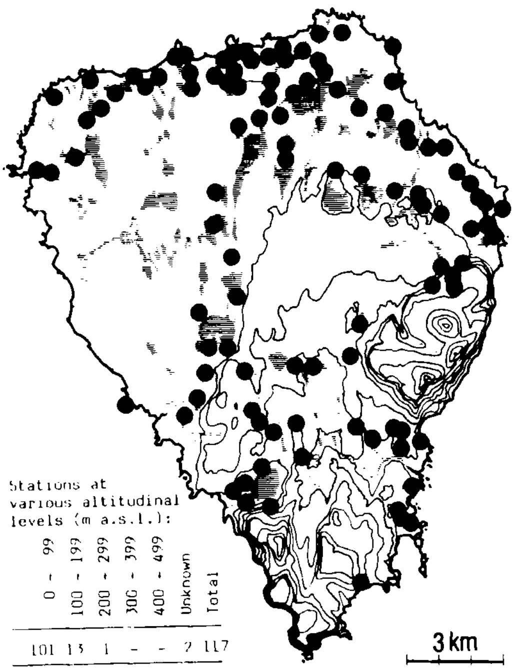
19. *Carex subspathacea* Wormsk.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
5	-	-	-	-	-	5

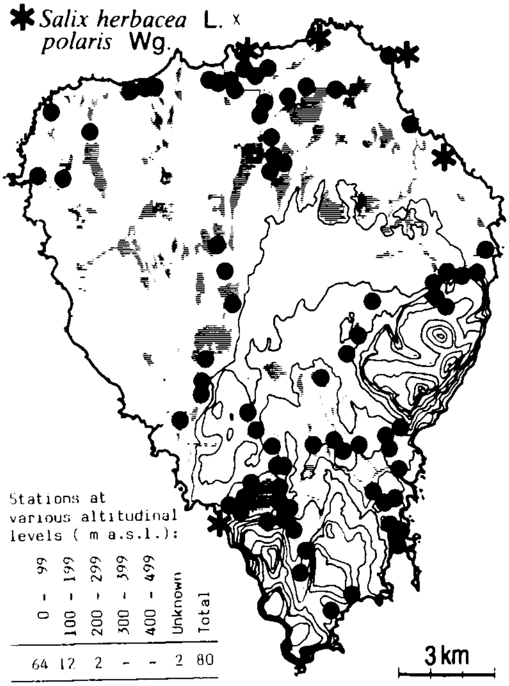
20. *Salix herbacea* L.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
101	13	1	-	-	2	117

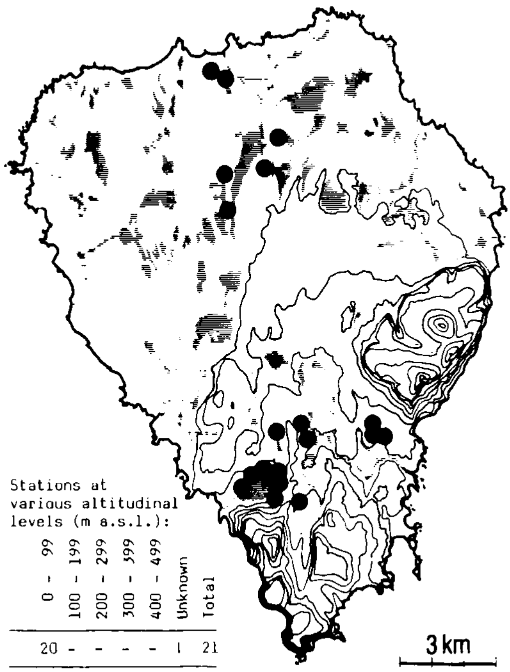
21. *Salix polaris* Wg.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
64	12	2	-	-	2	80

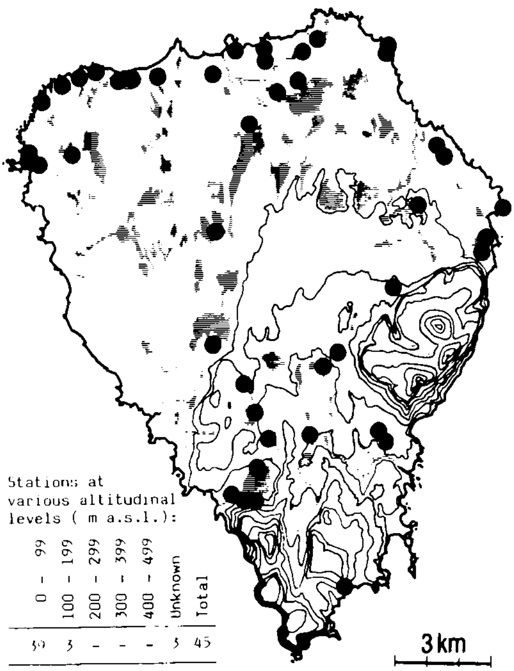
22. *Salix reticulata* L.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
20	-	-	-	-	1	21

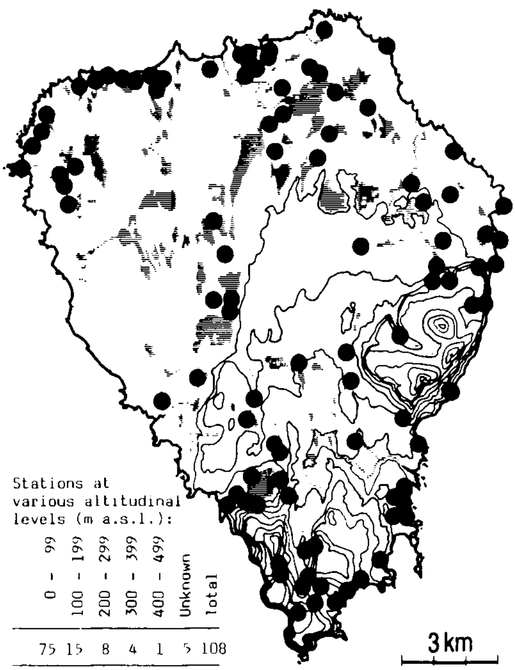
23. *Koenigia islandica* L.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
39	3	-	-	-	3	45

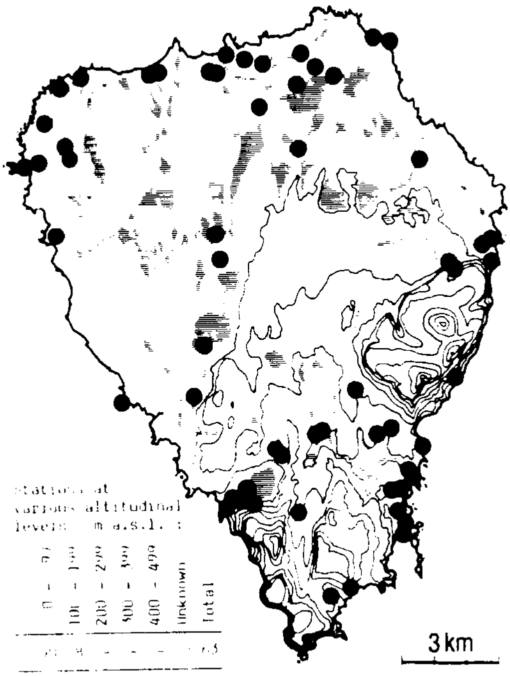
24. *Oxyria digyna* (L.) Hill



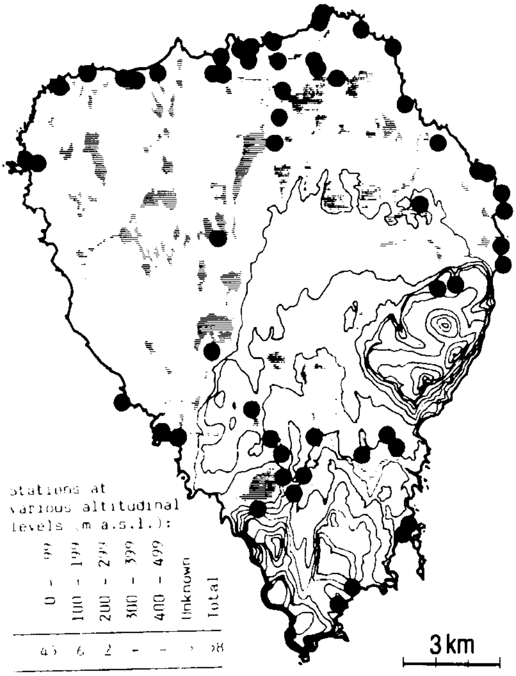
Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
75	15	8	4	1	5	108

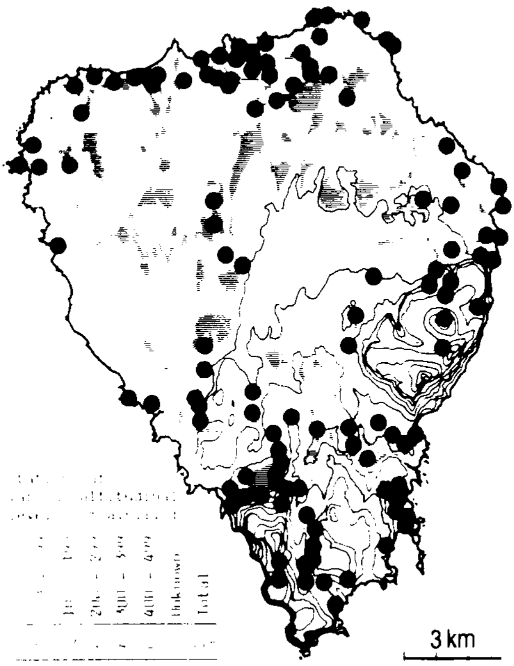
25. *Polygonum viviparum* L.



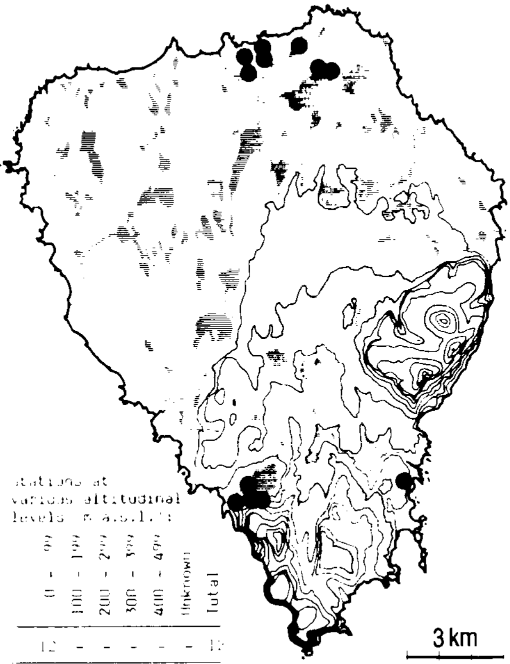
26. *Sagina intermedia* Fenzl



27. *Cerastium arcticum* Lge.

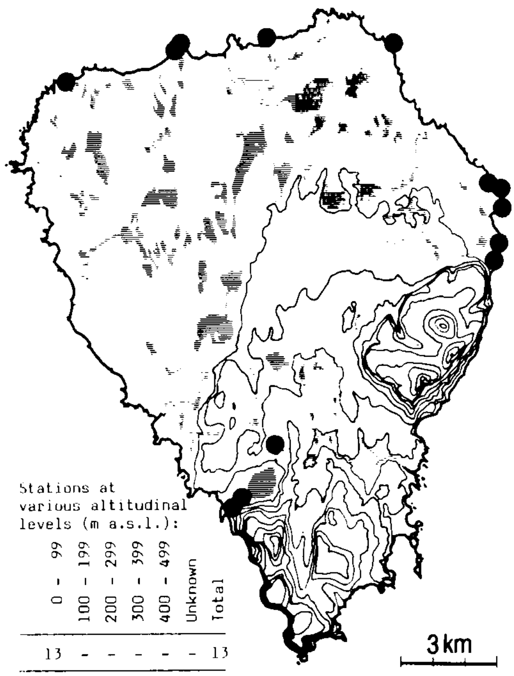


28. *Cerastium cerastoides* (L.) Britton

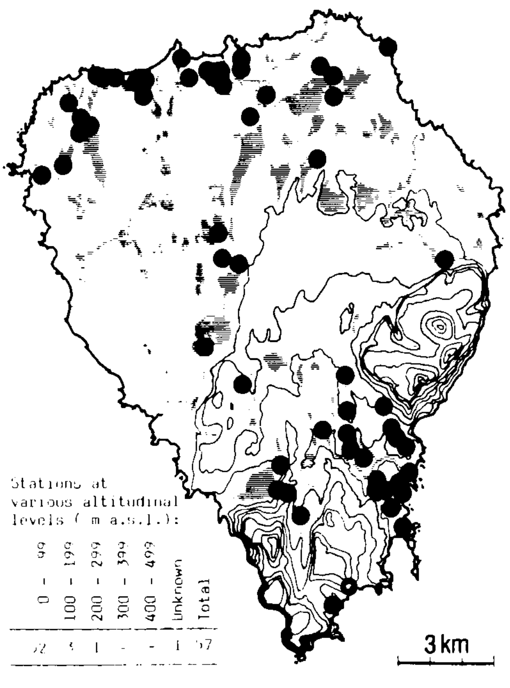


29. *Cerastium regelii* Ostenf.

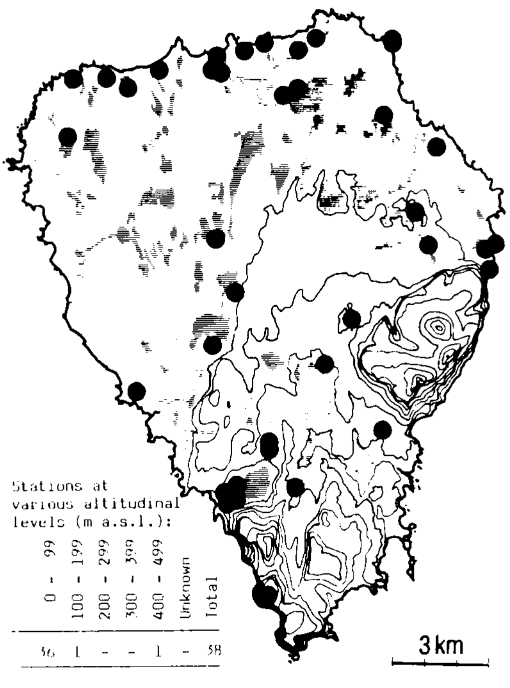
30. *Stellaria humifusa* Rottb.



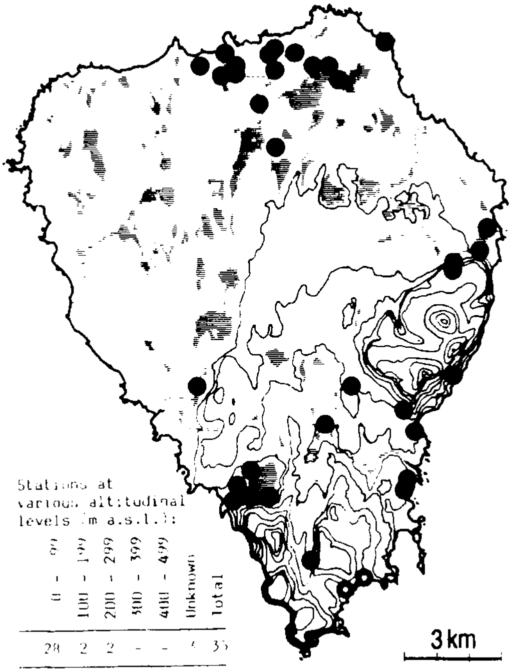
31. *Silene acaulis* L.



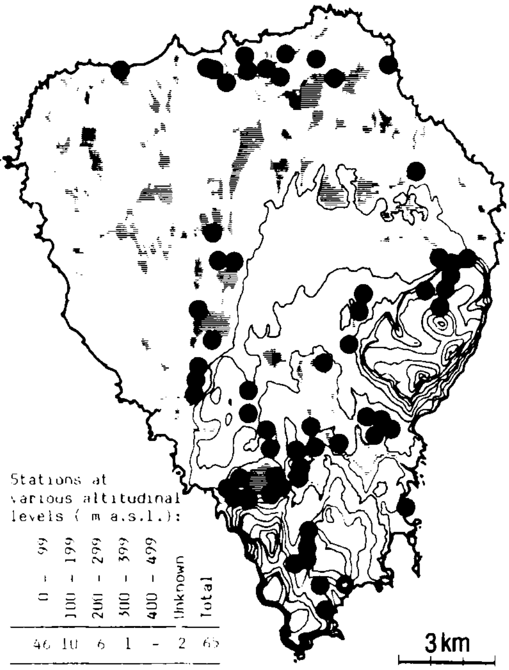
32. *Ranunculus hyperboreus* Rottb.



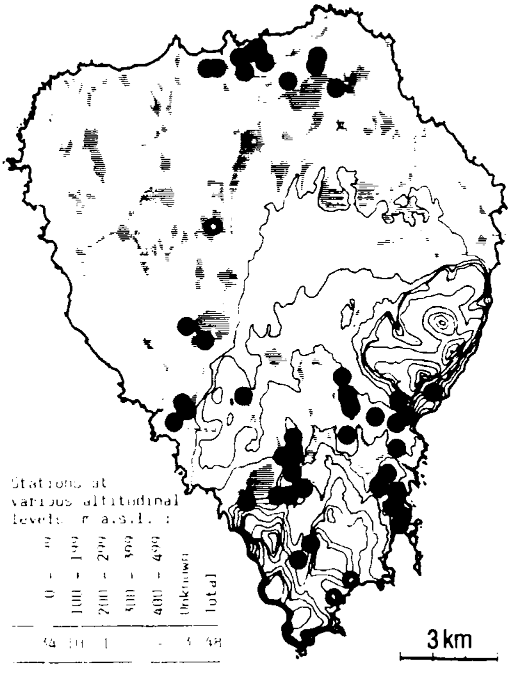
33. *Ranunculus pygmaeus* Wg.



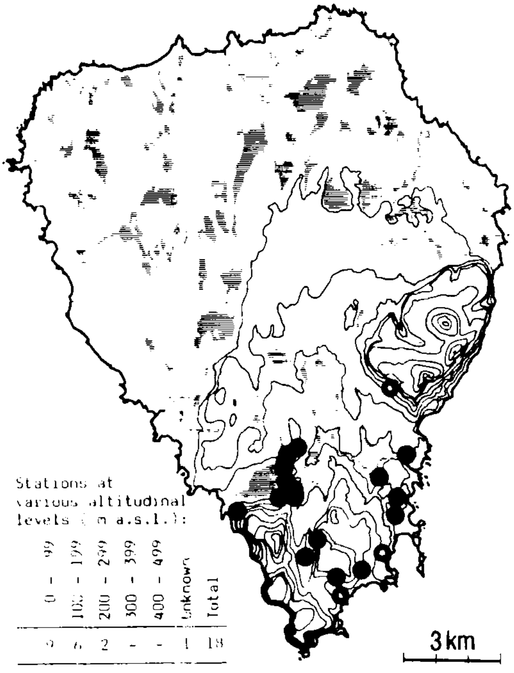
34. *Ranunculus sulphureus* Sol.



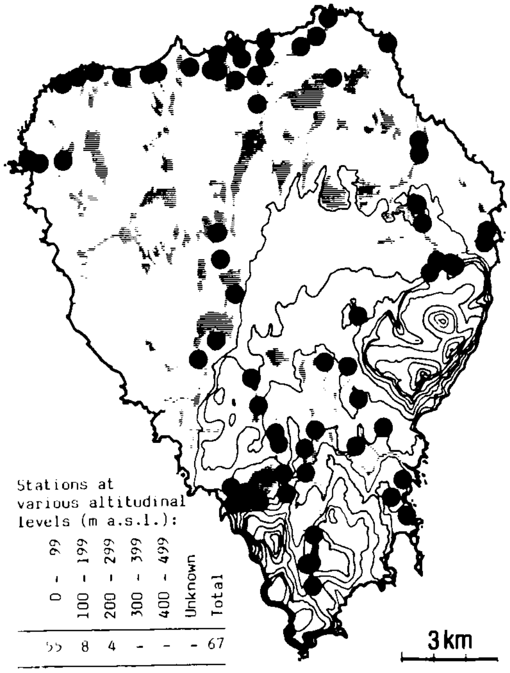
35. *Papaver dahlianum* Nordhagen



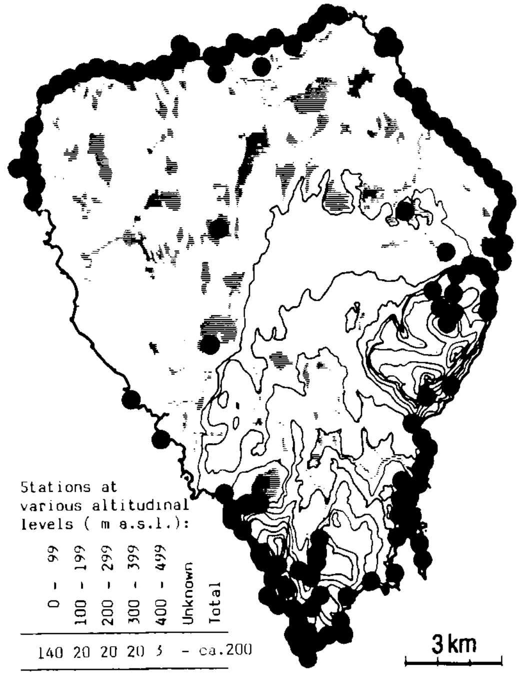
36. *Arabis alpina* L.



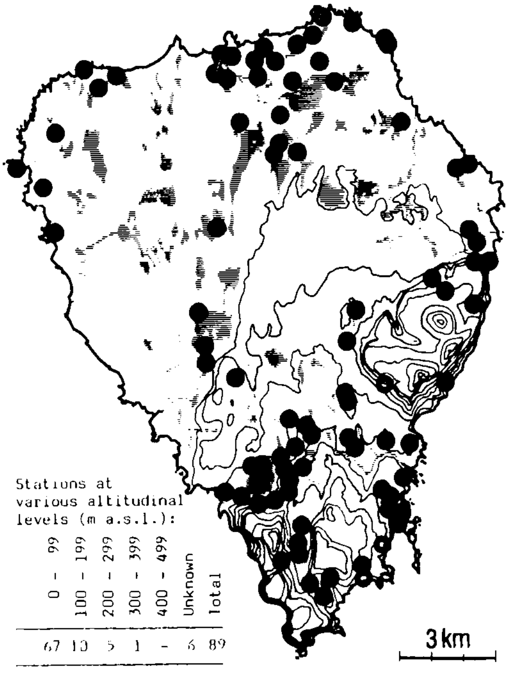
37. *Cardamine nymanii* Gand.



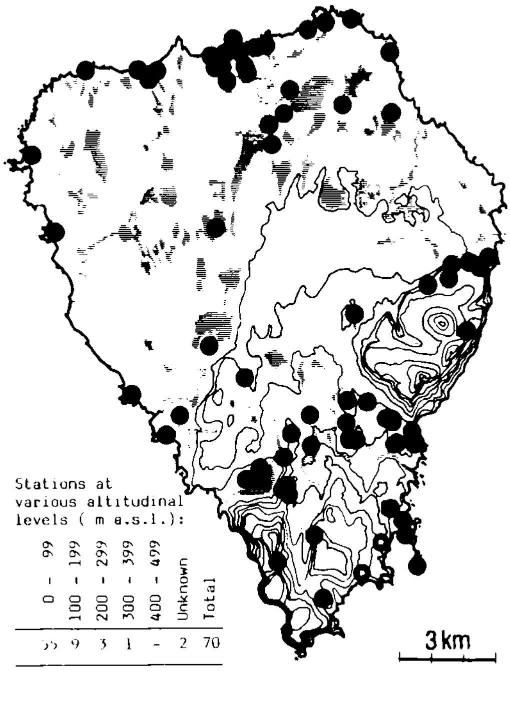
38. *Cochlearia groenlandica* L.



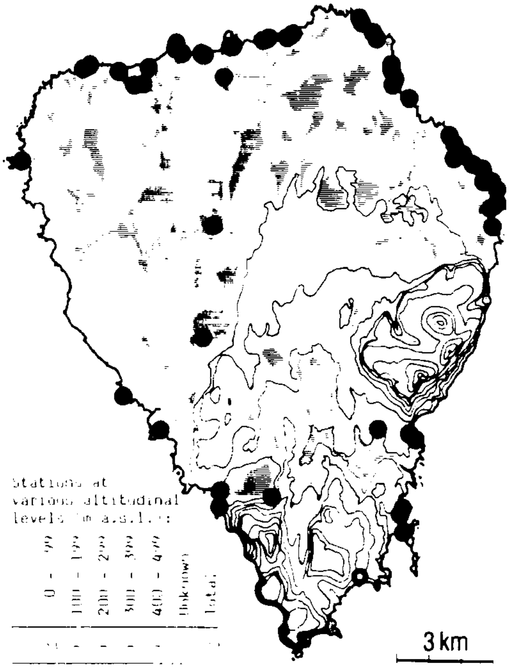
39. *Draba alpina* L.



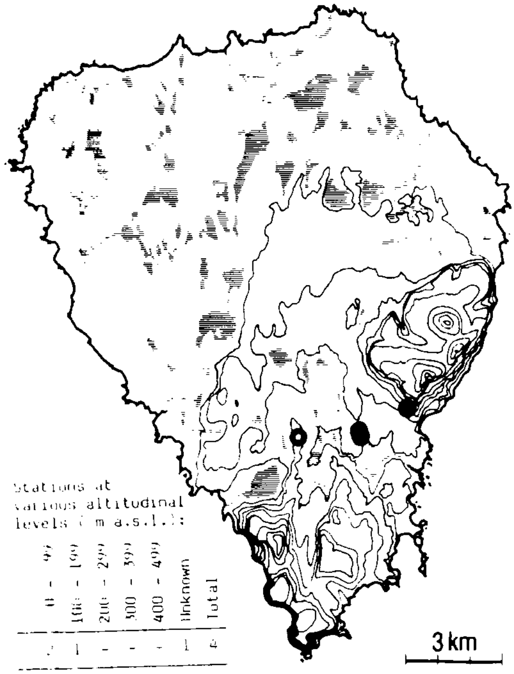
40. *Draba norvegica* Gunn.



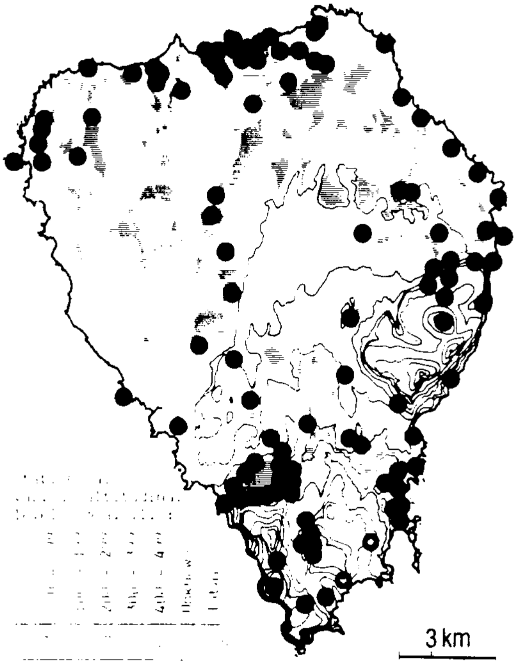
41. *Sedum rosea* (L.) Scop. ssp. *arcticum* (Boriss.) Engelskjøn & Schweitzer



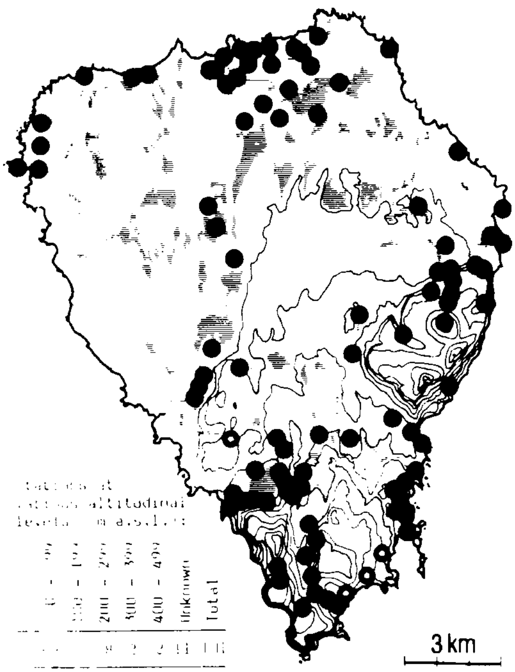
42. *Saxifraga aizoides* L.



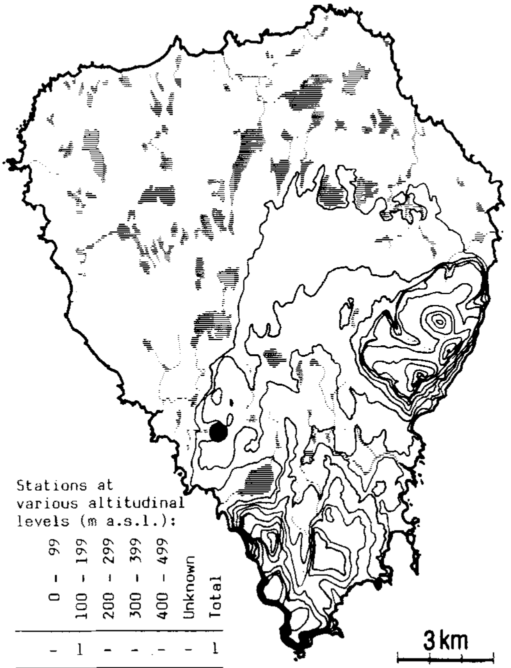
43. *Saxifraga caespitosa* L.



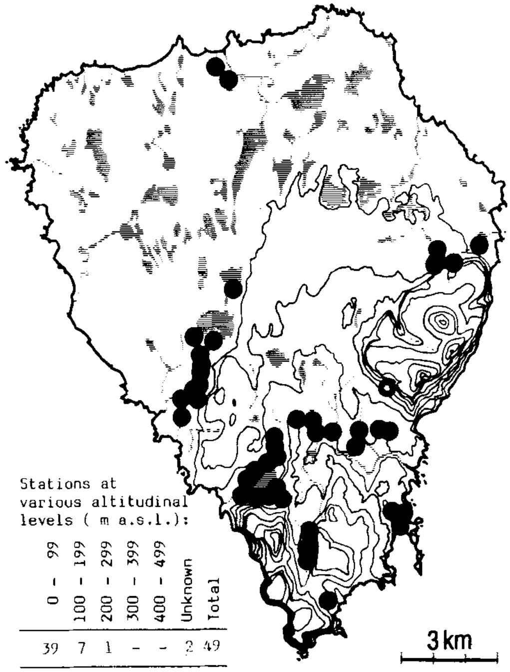
44. *Saxifraga cernua* L.



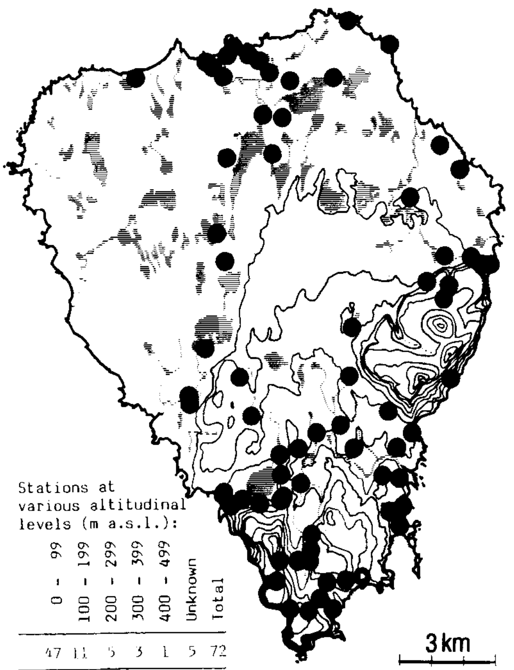
45. *Saxifraga foliolosa* R. Br.



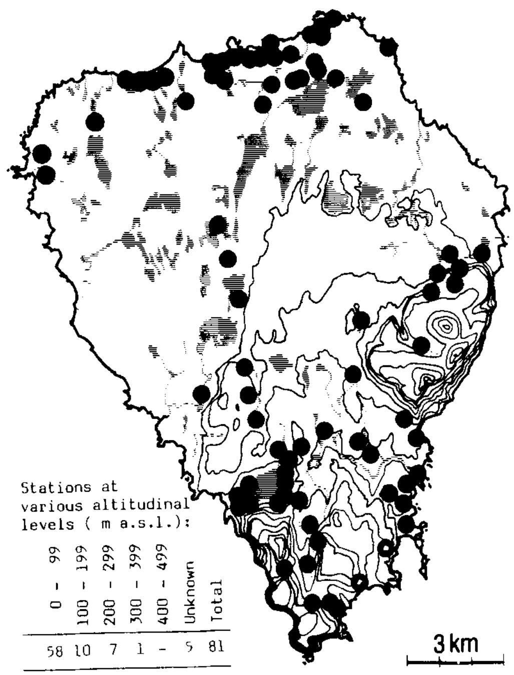
46. *Saxifraga hirculus* L.



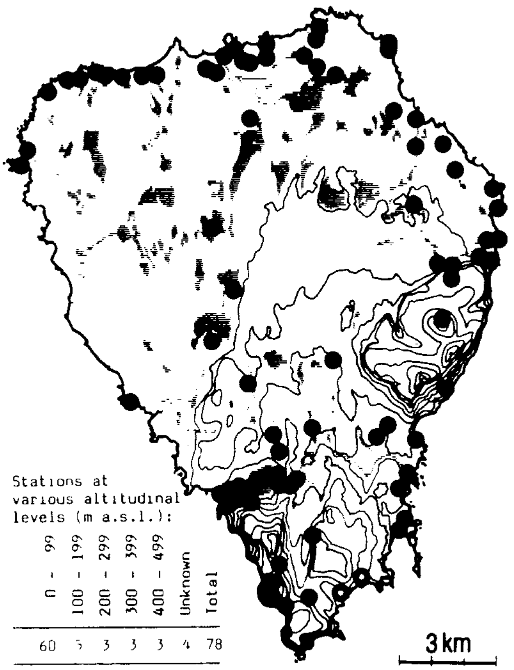
47. *Saxifraga nivalis* L.



48. *Saxifraga oppositifolia* L.



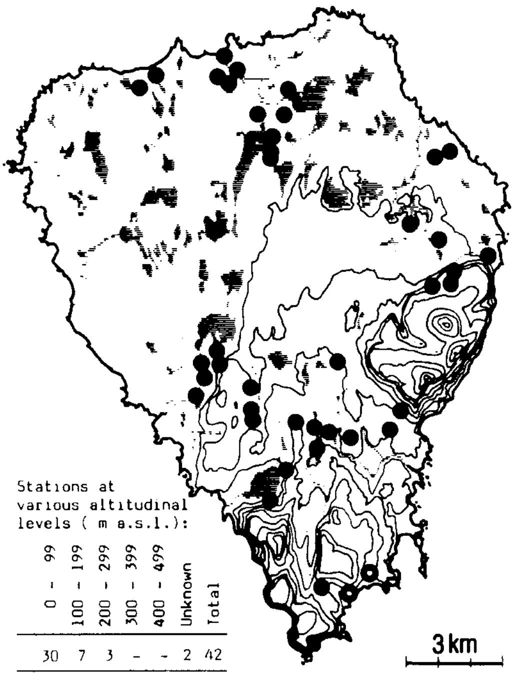
49. *Saxifraga rivularis* L.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
60	5	3	3	3	4	78

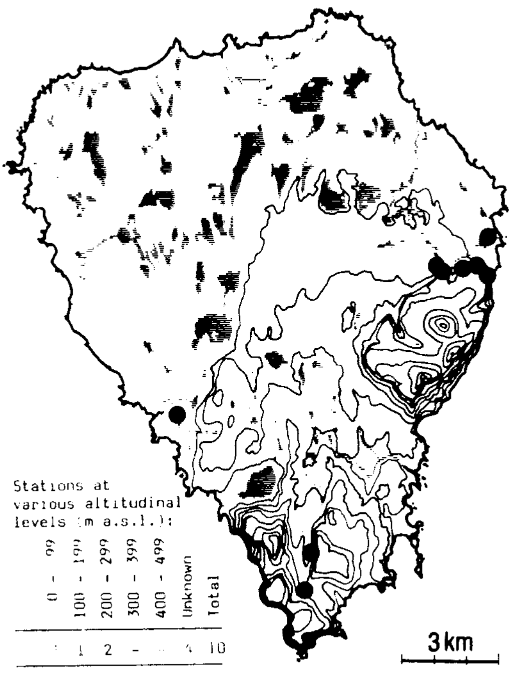
50. *Saxifraga tenuis* (Wg.) H.Sm.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
30	7	3	-	-	2	42

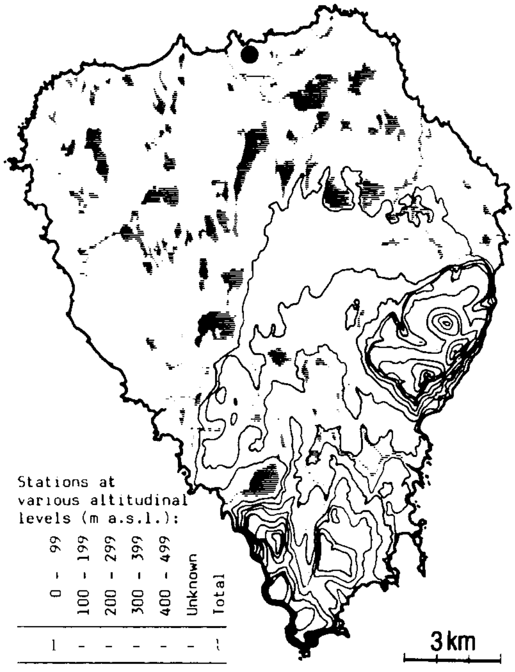
51. *Chrysosplenium tetrandrum* (Lund) Th. Fries



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
[illegible]	1	2	-	-	4	10

52. *Alchemilla glomerulans* Bus.



Stations at various altitudinal levels (m a.s.l.):

0 - 99	100 - 199	200 - 299	300 - 399	400 - 499	Unknown	Total
1	-	-	-	-	-	1

53. *Hippuris vulgaris* L.

54. *Taraxacum cymbifolium* H.Lindb.