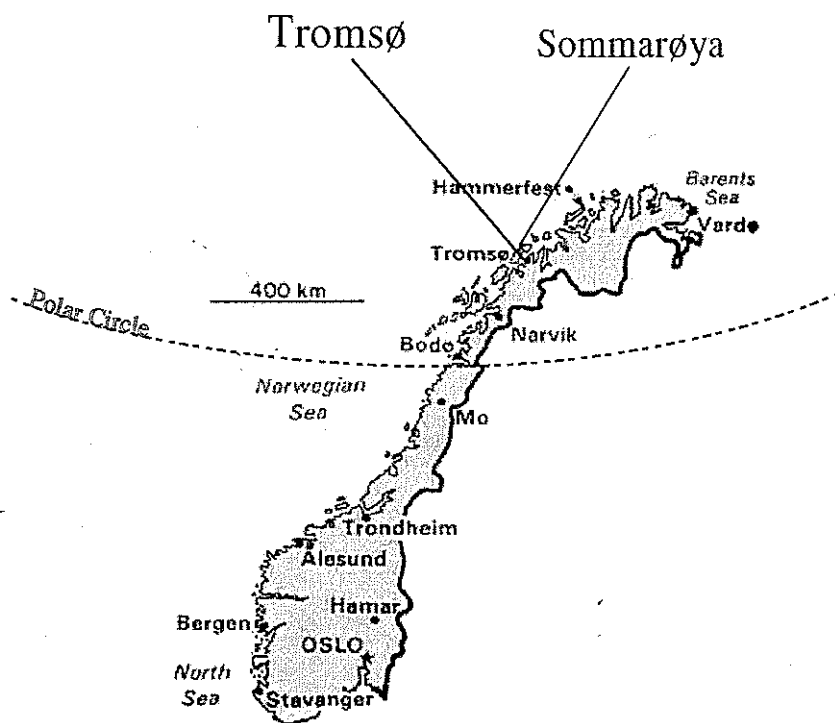


Second International Workshop on Circumpolar Vegetation Classification and Mapping



Tromsø, Norway, 2-6 June, 2004

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Second International Workshop On Circumpolar Vegetation Classification and Mapping Agenda

Tromsø, Norway, 2-6 June 2004

Wednesday, 2 June 2004

- 12:00-14:00 Registration at Planetarium**
14:00-16:30 Opening session at Planetarium
14:00-14:10 Welcome from Arve Elvebakk
14:10-14:20 Welcome from Tore O. Vorren, Tromsø University Dean of the Faculty of Science
14:20-14:30 Conference overview by Skip Walker
14:30-14:40 Conference introduction by Fred Daniëls
14:40-14:50 Conference introduction by Stephen Talbot

14:50-16:00 *Break with small buffet*

16:00-16:30 **Keynote address:**
The role of Arctic vegetation mapping in forecasting possible outcomes of global environmental policies: GLOBIO
Christian Nellemann, United Nations Environment Programme, GRID-Arendal, Norway.

16:30-17:30 **Tour of Botanical Garden**

17:30-17:50 Bus from Planetarium to cable car
17:50-18:05 Cable car

18:05-20:00 **Mountain hike**

20:00-23:00 *Dinner at Fjellheisen Restaurant*

23:00-23:15 Cable car
23:15-23:35 Bus from cable car to Polar Rainbow Hotel

Thursday, 3 June 2004

- 7:00-9:00 *Breakfast at Polar Rainbow Hotel*
9:00-10:00 Bus to Sommarøya

11:00-12:30 **Session I – Circumpolar and general (chair – Bill Gould)**
11:00-11:20 **Keynote:**
A vegetation map of the arctic tundra biome (scale 1:7,500,000):
Overview, methods, legend, and analysis
D.A.(Skip) Walker, M.K. Raynolds, H.A. Maier and the CAVM Team

- 11:20-11:40 Modelling dynamics of circumpolar ecosystems under changing climate
Wolfgang Cramer
- 11:40-12:00 JUICE – an alternative for computer vegetation analysis and classification
Lubomir Tichy
- 12:00-12:20 A new vegetation-based method for bioclimatic mapping applied to the arctic boundary area in Finnmark, Norway
Stein Rune Karlsen, Arve Elvebakk and Bernt Johansen

12:20-13:50 *Lunch*

13:50-15:30 Session II - Canada, Greenland (chair – Helga Bültmann)

13:50-14:10 Keynote:

Altitudinal Zonation of Vegetation in Continental West Greenland, with Special Reference to Snowbed Vegetation

Birgit Sieg and Fred J. A. Daniëls

- 14:10-14:30 Cassiope tetragona-dominated snowbed communities along the Thomsen River, Banks Island, Canada

Patrick Kuss

- 14:30-14:50 Variation in plant community composition along topographic and climatic gradients in the Canadian Arctic: results of the CAVM Canadian transect
William Gould, D.A. Walker, M.K. Reynolds, F.J.A. Daniëls, A. Elvebakk, and N. Matveyeva

- 14:50-15:10 Characterization of the arctic vegetation of Canada in comparison with that of Northwestern Eurasia

Satoru Kojima

- 15:10-15:30 Syntaxonomy of arctic terricolous lichen vegetation, a survey and an example from oceanic low-arctic SE-Greenland

Helga Bültmann

15:30-16:00 *Break*

Poster Session: To be visited during coffee breaks throughout conference:

1. Remarks on coastal salt-marsh and dune vegetation of the northern part of West Greenland
Ortrun Lepping and Fred J.A. Daniëls
2. Case studies of synsociological vegetation units in Spitsbergen and the Canadian Arctic Archipelago
|Dietbert Thannheiser
3. Coastal ecosystems of the Pechora River Region
V.V. Elsakov and E.E. Kulugina
4. Plant communities on sandy deflation scars in the sub-Pechora tundra, northeastern Russia
Ekaterina Kuljugina
5. Tundra-like vegetation of the northern Kola Peninsula: some questions of classification and botanical-geographic affinities
Svetlana Chinenko

6. Vegetation of the upper Kuparuk River region in the relationship to glacial geology and surficial geomorphology
C.A. Munger, D.A. Walker
7. Biocomplexity of frost boil ecosystems on the Arctic Slope, Alaska
D.A. Walker, V.E. Romanovsky, W.B. Krantz, S. Li, C.L. Ping, J.A. Knudson, R.A. Peterson, M.K. Raynolds, H.E. Epstein, J.G. Jia, D.C. Wirth, L. Kiesz.
8. The Circumpolar Arctic Vegetation Map
CAVM Team
9. Manipulation of vegetation canopy and the effects on cryoturbation regime in Alaskan Arctic tundra
A. Kade and D.A. Walker
10. Vegetation of southern Kronprins Christian Land, eastern North Greenland and Sverdrup Pass, central Ellesmere Island, Nunavut, Canada
Fred J.A. Daniëls
11. An ecosystem map for northern Alaska
Torre Jorgenson and Michael Heiner

16:00-18:00 Session III - Iceland and Norway (chair – Eythor Einarsson)

16:00-16:20 Keynote:

Snowfield, mire and spring complexes in Arctic and boreal areas
Klaus Dierßen

16:20-16:40 Large-scale vegetation mapping in Iceland

Gudmundur Gudjonsson and Eythor Einarsson

16:40-17:00 Distribution patterns in the Icelandic flora in relation to the arctic line

Hördur Kristinsson

17:00-17:20 High-Arctic steppes in the Wijdefjorden area, central Svalbard

Arve Elvebakk & Lennart Nilsen

17:20-17:40 Predictive habitat distribution models for plants in an arctic tundra environment: a case study using *Dryas octopetala* L.

Pieter Beck, Lennart Nilsen and Daniel Joly

17:40-18:00 A vegetation map of Svalbard on the scale of 1: 4 million

Arve Elvebakk

18:00-18:20 The bioclimatic zonal position of Sommarøya, a small coastal island of north Norway

Arve Elvebakk & Per Helge Nylund

19:00-21:00 Dinner

21:00 Evening excursion to Hillesøya Mountain

Friday, 4 June 2004

7:00-8:40 Breakfast

- 8:40-10:00 Session IV - Fennoscandia and Russia (chair – Stein Rune Karlsen)**
8:40-9:00 Keynote:
 Mapping vegetation zones and sections in northern Fennoscandia using remote sensing and GIS
Bernt Johansen, Stein Rune Karlsen and Arve Elvebakk
- 9:00-9:20 Oligotrophic vegetation in Central Scandinavian mountains – gradients in species and community distribution
Arvid Odland
- 9:20-9:40 Using indices of regional frequency and activeness for phytogeographic analysis of plant cover
Boris A. Yurtsev
- 9:40-10:00 Treeless vegetation of northern and northeastern Fennoscandia - an area with Finnish, Russian and Braun-Blanquet approaches to classification
Natalia E. Koroleva
- 10:00-10:30 *Break*
- 10:30-12:30 Session V - Russia (chair – Irina Safronova)**
10:30-10:50 Keynote:
 Classification of polar desert vegetation: available data, problems and perspectives
Nadezhda V. Matveyeva
- 10:50-11:10 Classification of vegetation of technogenic landscapes of the Russian Far North
Olga I. Sumina and Svetlana I. Mironova
- 11:10-11:30 The Russian geobotanical layers in the CAVM
Galina V. Ananjeva (Malkova), Dmitry S. Drozdov, Yury V. Korostelev
- 11:30-11:50 Recent advances in landscape mapping in Russia
Evgeny S. Melnikov, Dmitry S. Drozdov, Yury V. Korostelev, Galina V. Malkova and Nataliya G. Moskalenko
- 11:50-12:10 A plant community map of West Siberia
Nataliya G. Moskalenko
- 12:10-12:30 Dominant growth-form classification of plant communities as a basis for the legend of vegetation maps
Adrian E. Katenin
- 12:30-13:30 *Lunch*
- 13:30-15:30 Session VI - Russia (chair – Olga Sumina)**
13:30-13:50 Keynote:
 Zonal patterns in vegetation of the Russian arctic caused by bedrock and surficial geology, permafrost, and coastal effects
Volodya Yu. Razzhivin
- 13:50-14:10 Coastal ecosystems of the Pechora River Region
V.V. Elsakov and E.E. Kulugina
- 14:10-14:30 Plant communities on sandy deflation scars in the sub-Pechora tundra, northeastern Russia

- Ekaterina Kuljugina*
 14:30-14:50 Russian School traditions for constructing legends for Arctic vegetation maps
- Irina N. Safronova*
 14:50-15:10 Review of Carici-Kobresietea vegetation in central Chukotka
Ilya Kucherov and Fred J. A. Daniëls
- 15:10-15:30 Vegetation and environments of northeastern Koryak (southern Chukotka, Russia)
Volodya Yu. Razzhivin
- 15:30-16:00 *Break*
- 16:00-18:00 Session VII - Alaska (chair – Stephen Talbot)**
- 16:00-16:20 **Keynote:**
 Ecological land classification and mapping on the Beaufort Coastal Plain of northern Alaska
M. Torre Jorgenson, Joanna E. Roth, Michael Emers, Erik Pullman, Sharon Schlentner, and Wendy Davis
- 16:20-16:40 Landcover mapping in the Arctic by the U. S. Geological Survey
Carl J. Markon
- 16:40-17:00 Comparative phytosociological investigation of subalpine alder thickets in Southwestern Alaska and the North Pacific
Stephen S. Talbot and Sandra Looman Talbot, and Fred J. A. Daniëls
- 17:00-17:20 Classification and ordination of frost-boil ecosystems along a climate gradient in the Low Arctic, Alaska
Anja Kade, Donald A. Walker, Martha K. Reynolds
- 17:20-17:40 Community mapping of Alaska based on the Circumpolar Arctic Vegetation Map
M.K. Reynolds, D.A. Walker, H.A. Maier
- 19:00-21:00 *Dinner*
- 21:00 *Evening excursion*

Saturday, 5 June 2004

- 7:00-8:30 *Breakfast*
- 8:30-9:30 Software demonstrations: JUICE, TurboVeg, web site for European vegetation map, TerraExplorer, PLANTS database
- 9:30-10:30 **Plenary Session** - discussion of future of Arctic vegetation classification and mapping (Co-chairs - Fred Daniëls, Skip Walker,)
- 10:30-11:00 *Break*
- 11:00-12:30 Divide participants into four working groups

12:30 - 13:30 *Lunch*

13:30-14:30 Working groups continue meeting

14:30-15:00 *Break*

15:00-17:00 **Plenary Session & Wrap-up** (Co-chair - Fred Daniëls, Skip Walker)

18:00 *Seashore Sami-style banquet*

Sunday, 6 June 2004

Departure day-early departures to Tromsø as needed

7:00-9:00 *Breakfast*

9:00-11:00 Continued discussion opportunity for small groups

11:00-12:00 Departure of remaining participants from Sommarøya to Tromsø

Abstracts

PREDICTIVE HABITAT DISTRIBUTION MODELS FOR PLANTS IN AN ARCTIC TUNDRA ENVIRONMENT: A CASE STUDY USING *DRYAS OCTOPETALA* L.

Pieter Beck¹, Lennart Nilsen¹, Daniel Joly²

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In recent years, many studies have been performed to assess the impact of climate change on arctic plant species. Most of these studies measured vegetative and sexual responses to environmental variation at the organism or sub-population level. So far, few studies have allowed for quantitative estimates of species distribution in an altered arctic environment. Predictive habitat distribution models provide tools to 1) predict the geographical distribution of species based on the ecological gradients, and 2) estimate how distributions of species respond to environmental change.

In the present study, Generalized Linear Models were used to predictively model the distribution of *Dryas octopetala*, an intensively studied dwarf shrub, around Kongsfjorden on Spitsbergen. A logistic GLM was used to predict the occurrence of the species and a Gaussian GLM was used to predict its abundance at the sites where it occurred. The final models included predictor variables related to temperature, topographical position, topographical aspect, geology, water cover and the distance to the open sea.

Validation of the models and the resulting potential habitat distribution maps showed that the method, using a GIS database with data on environmental variables at a spatial resolution of 20 m, is useful to model the present distribution of *D. octopetala*. The results further indicated that data on snow distribution would be most useful to predict the local and regional distribution of plant species in arctic environments. Such data would also allow quantitative estimates of the impact of changes in temperature and winter precipitation on the distribution of plant species.

SYNTAXONOMY OF ARCTIC TERRICOLOUS LICHEN VEGETATION, A SURVEY AND AN EXAMPLE FROM OCEANIC LOW-ARCTIC SE-GREENLAND

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In the Arctic, cryptogams usually are an equal or dominant part of a plant community or landscape. The cryptogam fraction can be described as a part of a phytocoenon. However, typical combinations of cryptogam species can occur in more than one phytocoenon or in more than one continent. These cryptogam combinations can be described as microcoena. As a phytocoenon, a microcoenon can be validly described according to the code of phytosociological nomenclature (Weber et al. 2001), but is usually of smaller area (usually 1 sq.m. or less). Even if a "microcoenosis" covers a vast area in the Arctic, the species composition will probably be the same as in a smaller stand.

Microcoena are effective indicators of small-scale differences in habitat (e.g. pH, snow cover, wind, disturbance, air moisture/fog, harshness of habitat) and are very useful tools for a rapid screening of the complexity of a landscape. Microcoena, and especially typical complexes of microcoena, can even be useful for mapping on a medium scale or for mapping diversity.

This paper will give a survey of the higher syntaxa of terricolous lichen vegetation of the Arctic. As an example details of the terricolous lichen vegetation from Ammassalik (oceanic, low-arctic SE-Greenland) are shown. The vegetation of the study area is mainly dwarf shrub heath and grass vegetation on more or less acidic substrate, erect dwarf shrub tundra and noncarbonate mountain complexes (CAVM Team 2003). Different lichen vegetation occurs in a variety of habitat types, from snow beds to wind-exposed ridges. Syntaxonomy of microcoena, diversity, habitats and their relationship to phytocoena will be shown. A simplified example of the relationship is given in Table 1.

Table 1. Sample relationship between phytocoena and microcoena. Snow cover decreases from top down (phytocoena) and from left to right (microcoena).

"micro"-alliance	Solorinion croceae (snow)	Cladonion arbusculae	Cetrarion nivalis (wind)
<i>class</i>	<i>number of microcoena (number of relevés)</i>		
Salicetea herbaceae	6 (35)	3 (27)	
Caricetea curvulae		1 (15)	
Loiseleurio-Vaccinietea		2 (20)	3 (14)

The distribution of microcoena displays snow cover and wind-exposure well: Solorinion croceae is connected to Salicetea herbaceae, Cetrarion nivalis to Loiseleurio-Vaccinietea. In stands of the Salicetea herbaceae and Loiseleurio-Vaccinietea under less extreme conditions, the lichen complement consists of the intermediate Cladonion arbusculae. A CCA showed snow cover and wind-exposure as the main factors determining floristic composition in the oceanic Ammassalik area.

In a future study, relevés originating from NW- and SW-Greenland will be added, including continental areas and base-rich soils.

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TUNDRA-LIKE VEGETATION OF THE NORTHERN KOLA PENINSULA: SOME QUESTIONS OF CLASSIFICATION AND BOTANICAL-GEOGRAPHIC AFFINITIES

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The treeless territory in the northern part of the Kola Peninsula differs from the "typical" part of the Arctic. The mild maritime climate and almost lack of permafrost results in flora and vegetation peculiarities, e.g. increased role of boreal species and respectively low participation of arctic and arctic-alpine ones. There is a controversy about the zonal position of this territory: some botanists include it in the southern (=subarctic, or hypoarctic) part of the tundra, and others (e.g. Yurtsev et al. 1978; Ahti et al., 1968 etc.) do not include it in the Arctic. Another peculiarity is the limited distribution of shrub tundras, which are normally characteristic of the southern tundra subzone, and decreased importance of *Betula nana* in comparison with *Empetrum hermaphroditum*. This is usually explained by the effect of the maritime climate. There is an opinion (for example, Breslina, 1969, et al.), that some Kola crowberry-dominated communities on the coast, particularly on islands, are not related to tundras, but belong to a special vegetation type – "coastal heaths", occurring mainly in the North-Atlantic and North-Pacific coasts, and thus, are more closely related to coastal shrub communities of the temperate zone.

The aim of this work is to study the diversity of "tundra-like" vegetation, including tundras and similar communities of the eastern part of the northern Kola Peninsula, and their botanical-geographic affinities. It includes classification of these communities, and comparison according to floristic composition and phytocenotical structure with "true" tundras of other Arctic regions and with North-Atlantic heaths.

The term "heath" is applied very broadly to different communities of various latitudinal zones. The ones of most interest to our study are the natural (not anthropogenic) North-Atlantic lowland dwarf-shrub communities: some Scandinavian coastal heaths – resembling Kola communities with the same or similar dominating species (such as *Empetrum nigrum*, *Vaccinium vitis-idaea*, *V. myrtillus*, *V. uliginosum* in the field layer and some mosses (*Pleurozium schreberi*, *Hylocomium splendens*) and lichens (*Cetraria islandica*, *Flavocetraria nivalis*, *F. cucullata*, *Cladonia arbuscula* s.l., *C. rangiferina*, *C. stellaris*) in the ground layer), and also Icelandic heaths.

According to our own impressions and literature data, the Kola coast communities that are most like some North-Atlantic heaths are the dwarf shrub-moss tundras (usually with abundant *Empetrum hermaphroditum*, *Phyllodoce caerulea*, *Chamaepericlymenum suecicum*, *Vaccinium myrtillus*, *Pleurozium schreberi*, *Hylocomium splendens*, *Drepanocladus* spp.), which have the most boreal character; and some lichen-dwarf shrub ones (usually dominated by *Empetrum hermaphroditum*, with an admixture of *Betula nana*, *Vaccinium vitis-idaea* s.l., *Loiseleuria procumbens*, *Arctous alpina*; in the ground layer more often *Dicranum* spp., *Drepanocladus* spp., *Cetraria islandica*, *Flavocetraria nivalis*, *Cladonia arbuscula* s.l., *C. rangiferina*, *C. uncialis*, etc. are abundant). On the most elevated wind-swept and winter snow-free habitats, discontinuous tundras with a predominance of lichens (*Ochrolechia* spp., *Alectoria nigricans*, *A. ochroleuca*,

Sphaerophorus globosus, *Cladonia uncialis*, *C. arbuscula* s.l. *Thamnolia vermicularis*, etc.) and rare prostrate dwarf shrubs (*Empetrum hermaphroditum*, *Arctous alpina*, *Loiseleuria procumbens*, *Betula nana*, *Diapensia lapponica*, *Dryas octopetala*, *Vaccinium vitis-idaea*, *V. uliginosum*) occur. These have the "most arctic" aspect and least species in common with the Atlantic heaths. There is no impression that there is a clear limit between most of the coastal crowberry communities and the other ones, or that there is a necessity to separate them on the upper levels of the plant communities classification.

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VEGETATION OF SOUTHERN KRONPRINS CHRISTIAN LAND, EASTERN
NORTH GREENLAND AND SVERDRUP PASS, CENTRAL ELLESMERE ISLAND,
NUNAVUT, CANADA

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A phytosociological survey is presented of two inland areas of the northern North-American Arctic: southern Kronprins Christian Land, Greenland (A) and Sverdrup Pass area, central Ellesmere Island, Nunavut, Canada (B). Area A is extremely poorly known (a.o. Daniëls 1999, Alstrup et al. 2000), area B is ecologically well-studied (cf. Svoboda & Freedman 1994, see also Zhurbenko & Daniëls 2003).

The present phytosociological and syntaxonomical survey is based on 125 relevés, vegetation descriptions, and phyto-sociological comparisons with other Arctic regions. The following associations/community types are well represented: *Pleuropogonetum sabinei* (? nov.) (AB); *Drepanoclado-Caricetum stantis*, *Eriophoreto-Caricetum stantis* (? nov.), and *Eriophoretum scheuchzeri* (all AB) and *Calliergono-Caricetum saxatilis* (A), (all belonging to cl. *Scheuchzerio-Caricetea*); *Phippsietum algidae-concinnae* (A) (cl. *Salicetea herbaceae*); *Dryadio integrifoliae-Cassiopetum tetragonae* nov. and *Carici-Dryadetum integrifoliae* (both AB, cl. *Carici-Kobresietea*); *Collemo-Poetum abbreviatae* nov. (A) and *Saxifraga tricuspidata* community (B) (both cl. "*Calamagrostietea purpurascens*"); *Papaveretum radicatae* (AB, cl. *Thlaspietea*). Riparian vegetation was rarely observed.

The vegetation types are characterized by their species composition, structure, synecology and distribution. The valley bottom of Sverdrup Pass (B) and the lowland of the Greenlandic research area (A) represent the Arctic subzone C, and the areas of higher elevation vegetation belts b and a (cf. CAVM Team 2003). Phytosociological similarity of both areas is strong as an expression of similar ecological settings and vegetation history. Both areas belong to the Ellesmere-North Greenland floristic province (CAVM Team 2003).

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SNOWFIELD, MIRE AND SPRING COMPLEXES IN ARCTIC AND BOREAL AREAS

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The vegetation types of arctic and alpine snowfields, fen systems and springs consist of species adapted to extreme ecological environments. They are sometimes poor in species and widely distributed in the holarctic region. This distribution is azonal, but may become zonal in alpine and oro-arctic belts and arctic regions as well.

This paper focuses on the small-scale gradients, and complexity of the site conditions, and broad scale of the vegetation-type distribution. Examples are given from Western Greenland, Svalbard, Northern Scandinavia and Siberia. Proposals for the phytosociological classification for mapping purposes are presented.

COASTAL ECOSYSTEMS OF THE PECHORA RIVER REGION

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This study was conducted during 2000-2003 on the coastal part of East-European Russia (near the Pechora Delta, the Kolokolkova, Kuznetskaja and Pechorskaja Bays, and the coast of the Barents Sea). The main part of the study area is included in the Nenetskii Reserve and is composed of natural landscapes, except for a few sites which had oil borehole activity and some derelict fishery-industry villages.

Modern landscape types were mapped and classified using LANDSAT 7 ETM. The landscapes were formed in two ways: silt carried by the Pechora River and sand drifted from the Barents Sea (Figure 1).

Water from the Pechora River carries moraine clay sediments to bays and forms marshes (marine halophytic meadows); these occupy vast areas along the coast of the Barents Sea and Pechora Bay. Low marshes (with diagnostic species *Hippuris tetraphyla*, *Puccinellia phryganodes*, *Carex subspathacea* and *Stellaria humifusa*) flood with every tide. Middle marshes flood only during "syzygial" tide (*Carex mackenzii*, *Dupontia psilosantha*, *Potentilla egedii*, *Plantago schrenkii*, *Arcanthemum hultenii* and others). High marshes never flood (*Salix reptans*, *Rhodiola rosea* and *Parnassia palustris*); the salt regime is a more important factor here. The surface and subsoil water varied widely from 50 to 12,230 mS/cm (sea water in coastal areas was 21,000 mS/cm) and pH 4.9-9.2. Above-ground productivity ranges from 10 to 300 g/m². The area is important for nesting geese. A literature review demonstrated that this area is historically younger than western variants.

The second method of deposition is sand drifting from the Barents Sea, forming a dune landscape (to 9 m height) with rare coverage of the halophyte *Honckenya oblongifolia* and the psammophytes *Leymus arenarius* and *Deschampsia obensis*. Over time, the salt washes out and sandy areas are vegetated by *Polemonium boreale*, *Juncus arcticus*, *Tanacetum bipinnatum*, *Festuca rubra*, *Rumex acetosella* and *Armeria scabra*.

On elevated terrestrial sites, dwarf shrub-lichen tundra communities dominated by *Empetrum hermaphroditum* and *Arctous alpina* occur on stripes with low snow cover.

On the basis of geobotanical descriptions, 31 vegetation classes were delineated and most of the units are at the classification level of associations.

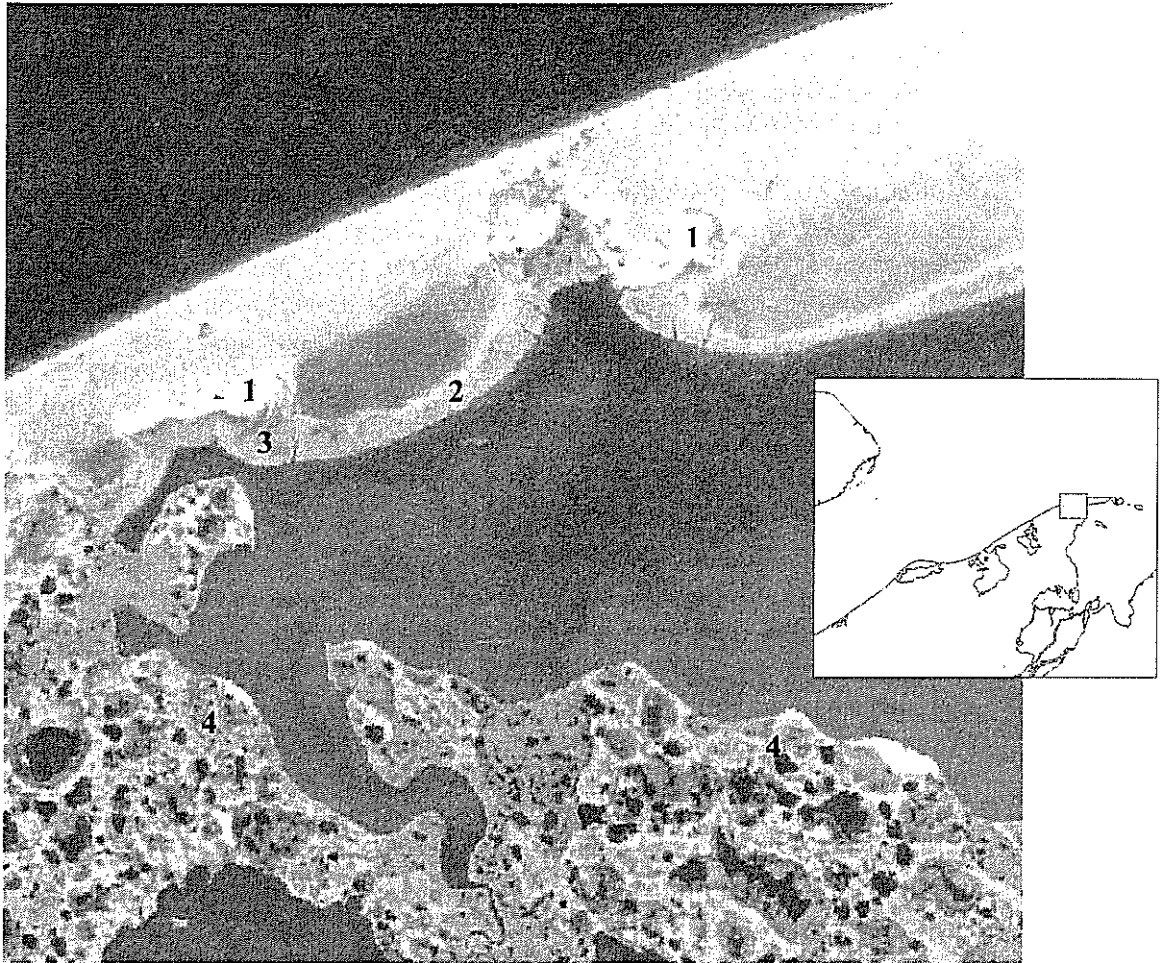


Figure 1. Distribution of major natural landscape types within the investigation area.

Satellite images TM 7, channels 4, 3, 2 (05.07.96). Key: 1. large sand ridges, dunes; 2. flat sand area (deflation basis coincide with sand (ground) level); 3. marine halophytic meadows (marshes); 4. tundra formations.

A VEGETATION MAP OF SVALBARD ON THE SCALE OF 1 : 4 MILLION

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The author was involved in the mapping of Svalbard both on the circumpolar map (CAVM Team 2003) and on the European vegetation map (Bohn et al. 2000). The former was on the scale 1:7.5 million, the latter 1:2.5 million and only portrayed bioclimatic zones. Several constraints are involved in such coarse-scale maps. The 1:7.5 million scale necessary to portray the whole Arctic on one sheet, makes Svalbard something like 6 cm large, but still seven map units were included on the CAVM map. However, their spatial distributions are necessarily very approximate, as can be seen when comparing with a map portraying contour lines of Svalbard. Like Greenland it has a very dramatic topography, and no homogeneous areas are large enough to match the given scale. Another constraint is the descriptions of the map units. The CAVM map units were adapted to a circumpolar description, which actually is the major achievement of this map. However, this also hides some of the local vegetation characteristics. The present contribution is an attempt to map the vegetation of Svalbard on a better scale, and compare the map polygon pattern, the number of mapping units and the descriptions of the units with the CAVM map. The draft version of the present map is 1:2.5 million, anticipated printed version 1:4 million, which is the same as the draft version of the CAVM map, before it was concluded that it could not be printed on a better scale than 1:7 million.

The present map production is based on similar data sets like the CAVM map, but less emphasis is given to a CIR Composite because of the cloud cover and the strong topographical heterogeneity even at the 2.5 million scale. Basic data are NDVI maps of most of Svalbard shown by Berge (1998), bedrock maps of Svalbard (Hjelle & Lauritzen 1982; Winsnes 1988), my own unpublished data on bioclimatic zones which are somewhat more detailed than the map included by Elvebakk (1997), published maps and publications, and personal experience from many sites in Svalbard, except in the eastern and southernmost parts.

The present map includes 15 vegetation units. Even at this scale there is no overlap between units over the three major bioclimatic zones present in Svalbard (CAVM names in brackets). The warmest, the middle arctic tundra zone, MATZ (= subzone C) has seven exclusive units; the intermediate northern arctic tundra zone, NATZ (= subzone B), with five exclusive units; and the very cold arctic polar desert, APDZ (= subzone A), has three exclusive units. Within each major bioclimatic zone the map units are differentiated according to bedrock substrate, hydrology, and, in rare cases, erosion and manuring.

The largest ecological diversity is within the MATZ. Here, there is an extremely arid area in the rain shadow along the windy Wijdefjorden area including tributary fiords, which is witnessed by the very low level of glaciation on the adjacent peninsula towards the west. This area is called 'high arctic steppes' by Elvebakk & Nilsen (2004, this volume) and is characterized by the dominance of *Potentilla pulchella*-*Puccinellia angustata* vegetation and saline soils; for a more detailed discussion, see Elvebakk & Nilsen (2004). Areas

which are still dry on well-drained limestone substrates, but not extremely arid, are dominated by *Dryas octopetala* vegetation and mapped in central Spitsbergen and in an area at Blomstrandhalvøya near Ny-Ålesund. In less drained areas in the same areas there is also a unit characterized by the combination of *Dryas octopetala* and a high cover of bryophytes, particularly *Tomentypnum nitens*. This vegetation type may in addition depend on the manuring effect of local reindeer populations, which are sedentary and probably modify their preferred grazing areas maintained during millennia. On neutral to acidic substrates there is a parallel mapping unit characterized by *Cassiope tetragona*.

Several central Spitsbergen valleys are strongly dominated by erosion and accumulation, both during times of flooding and because of aeolian sand and silt transport. These areas include both perennial mud flats and unstable areas with a pioneer vegetation characterized by *Bistorta vivipara* (own observations) or *Saxifraga oppositifolia*, like at Woodfjorden (Möller & Thannheiser 2003).

Finally, well-developed and peat-producing mires/fens only develop within this bioclimatic zone. Around Isfjorden there are several mapped polygons of calcareous fens, whereas acidic mires are only mapped in a large area at Reindalen due to its siliceous substrate. This area was recently protected.

The dry to mesic areas of the northern arctic tundra zone (= subzone B) are characterized by communities characterized by *Luzula nivalis* and *L. confusa* on calcareous and acidic substrates, respectively. *Dryas octopetala* communities occur also here, but cover much smaller areas than in the MATZ, and are therefore integrated within the map units characterized by *Luzula nivalis* and its alliance Luzulion nivalis. Topographic sites occupied by mires in warmer areas, instead have a discontinuous plant cover characterized by the ampho-Atlantic *Deschampsia alpina*, and no peat production. This community was discussed by Elvebakk (1994), and is a specific to flat, cool and coastal areas in Svalbard. Areas with long-lasting snow cover, and fine-textured substrates are dominated by *Poa alpina*, another Svalbard vegetation speciality, dominated by a species which has a much more southern distribution further to the west in the Arctic. Such communities cover vast areas in the flat Reindyrflya area, mapped on the scale 1:20,000 by Brattbakk (1985).

Along the coast there are numerous bird cliffs. The largest ones produce large green to golden carpets on the slopes below, with a very characteristic ecology and are called moss tundras (Vanderpuye et al. 2002). Four such areas are large enough to be included as map polygons here, and they have been compared to sizes of bird colonies (Mehlum & Fjeld 1987). Other large bird cliffs only have very steep slopes or sea below them, and do not produce this vegetation to any extent.

The polar desert areas (= subzone A) of Svalbard are mapped here with three map units. Two units are differentiated based on substrate characteristics, a *Papaver dahlianum* ssp. *polare* community on disintegrating weakly acidic to calcareous substrates and a *Luzula confusa* dominated unit on strongly acidic substrates. The former has the 'classic' appearance of a *Papaver* polar desert, with widely scattered *Papaver* individuals, and

much unstable and barren mineral substrate. In areas with more snow cover these communities are replaced by communities of *Cerastium regelii* and *Phippsia algida*, integrated in this mapping unit. All visited mountain plateaus in central parts of Spitsbergen have this vegetation, but on limestone the cover is even more sparse or even absent.

On hard siliceous substrates the bedrock disintegrates into boulders, and these areas have a block-field appearance, similar to high-alpine or subnival belts in mountains further to the south. Due to greater substrate stability, bryophytes and lichens can be abundant, but vascular plants are extremely sparse and do not include the otherwise ubiquitous *Salix polaris*. These two units apparently cover the largest areas in the present vegetation map, but it is a bit exaggerated. The map scale does not permit including an intermediate altitudinal NATZ belt between the MATZ and APDZ vegetation types in central Spitsbergen, although most of these mountains are so steep that this belt covers small and mostly unstable slopes.

In the eastern Svalbard islands Barentsøya and Edgeøya, a polar desert climate supports a much higher biomass over large areas, compared with normal climatic response. This is thought to be formation of moss tundra, probably mostly discontinuous, as a response to intensive reindeer grazing over millennia, like its equivalent in the warmer central Spitsbergen area, the latter including also *Dryas octopetala*.

The present map divides the Svalbard CAVM polygons/units of B2 and G1 in two parallels each, #13/14 and #8/9, respectively, differentiated according to substrate chemistry, although the CAVM-nunatak unit B3n partly corresponds to #13. The CAVM unit W1 also lumps the present wetland units #6, 7, 11 and 15. The distinct Svalbard community #10 apparently not found anywhere else, has been integrated with the subzone C unit, here corresponding with #3. The Svalbard polygons of CAVM units G2, P1 and P2 roughly correspond to the present units #3, 2 and 4.

In addition, the present map includes a high-arctic steppe unit. Due to their small spatial extents no arctic steppes or tundra-steppes were included in the CAVM map. Unstable valley bottom vegetation and bird cliff vegetation were not included in the CAVM map, at least the latter obviously because of its small polygon size.

To conclude, the change in scale permitted, as expected, a greater variety in map units and increased accuracy in the cartographic presentation of polygons. In the CAVM map all polygons mapped in Svalbard were integrated in units broadly defined on a circumpolar scale, and some of their characteristics were lost. Units # 10, 11, 12 and, more uncertainly, # 15 are not expected to occur much outside Svalbard, except in the poorly known northern part of Novaya Zemlya.

The present map allows for an evaluation of vegetation units in relation to conservation purposes, and with the latest conservation efforts in Svalbard, all of the 15 map units are well protected with one exception; the steppes at Wijdefjorden.

The entire CAVM map included 13 map units in addition to mountain complexes, all of these more or less circumpolar in appearance on the map. An obvious further step is to improve the scale and allow for more units, units with a regional character, and more accurate cartographic presentations to be made. This can be done country-wise or researcher-based, but the best alternative would be to maintain a circumpolar perspective, cooperative effort and data bases and concentrate on certain parts of the circumpolar variation pattern in turns. Such topics could be the wettest (mires), coldest ('polar deserts'), driest/alkaline areas, and resulting maps would have a strong impact on conservation issues within the Arctic.

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HIGH-ARCTIC STEPPES IN THE WIJDEFJORDEN AREA, CENTRAL SVALBARD

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Northern steppes are known from boreal and low-arctic areas of Siberia, Alaska and Greenland (e.g. Murray et al. 1983, Hansen 1986, Yurtsev 2001). They occupy small areas in the locally warmest and driest areas in the landscape, and have an exclusive floristic element, with species like *Calamagrostis purpurascens*, *Carex supina* and many more. In the High Arctic, a specific drought-associated vegetation characterized by species like *Potentilla pulchella* and *Puccinellia phryganodes* has been described from small areas in Svalbard (Möller 2000) and large areas in central Ellesmere Island. This type has been called 'cryo-xeric-halophyte vegetation of arctic takkyrs' (= salt-pans) by Yurtsev (2001).

During our survey for conservation purposes of the strongly continental, rarely visited and botanically poorly known Wijdefjorden area, we met with a strange botanical landscape which we now propose to call 'high-arctic steppe' (Figures 1 and 2). Our arguments for this concept are integrated in eight criteria below, some of them adapted from Yurtsev (2001).

- 1) **Exclusive vegetation.** Ridge communities are dominated by *Potentilla pulchella*, *Puccinellia angustata*, *P. svalbardensis*, *Poa hartzii*, and a totally different and impoverished *Dryas octopetala* community that is restricted to protected sites. The topographical positions of snowbed and drainage channels sites are occupied by dry *Festuca rubra* ssp. *arctica*/*Braya purpurascens* and *Carex misandra* communities, respectively.
- 2) **Exclusive phytogeography.** The driest communities have a higher concentration of high arctic species than any other known community, and a conspicuously low proportion of arctic-alpine species. The species composition is totally different from those of the low arctic/boreal steppes.
- 3) **Exclusivity at landscape level.** Previously, these communities have only been reported from small ridge areas in Svalbard (Möller 2001), but at Wijdefjorden they dominate the landscape. In a steeper part of the area with hard siliceous rocks and less allochthonous deposits, *Carex rupestris* dominates the landscape completely, giving it a straw-coloured aspect.
- 4) **Dominance of graminoids.** This graminoid-dominance contrasts with tundra communities that are dominated by dwarf-shrubs, bryophytes and fruticose lichens, with a perennial above-ground biomass.
- 5) **Arid climate.** No meteorological data are available, but reports from trappers, our own observations of obvious drought stress phenomena, and an almost total lack of surface water indicate an annual precipitation level estimated to be comparable to Eureka in

Ellesmere Island (60 mm). A very high wind frequency along the main fjords is probably necessary so far to the north to maintain a sufficient aridity, as the steppe character is lacking in small side valleys in the Wijdefjorden area.

6) **Saline soils.** White salt crusts were observed everywhere, about 30 soil samples had soil pH values above 9.0, seven had values above 10.0, and values above 9 were found to a soil depth of 20 cm and to altitudes up to 320 m. This pattern existed both on the western side with calcareous bedrock and on the eastern side with siliceous bedrock, because of previous sea and glacier deposits in addition to a continuous wind transport of allochthonous sediments.

7) **Surface mineral soil domination.** No organic surface accumulation exists, plant remains are instead blown away, and root biomass is the most important organic input to the soil. Open mineral soil fractions account for about 95 % of surface areas.

8) **Difference from polar deserts.** Polar deserts also have a very low plant cover, but there the structural difference from tundra is due to a very low temperature sum and not aridity, and the vegetation, flora and environmental factors are very different.

Due to a variety of global nomenclature traditions for naming treeless cold vs. treeless arid and cold areas, the name 'high-arctic steppes' is considered to be the most precise name for these areas, which are surprisingly different from arctic tundras, low-arctic steppes/tundra steppes and arctic polar deserts.

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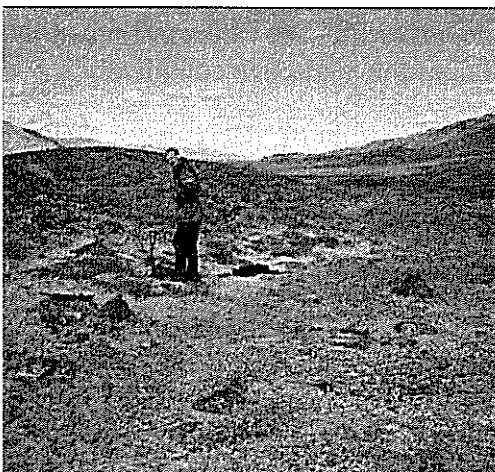


Figure 1. A high arctic steppe community at Wijdefjorden with *Poa hartzii* and abundant salt accumulation at the surface

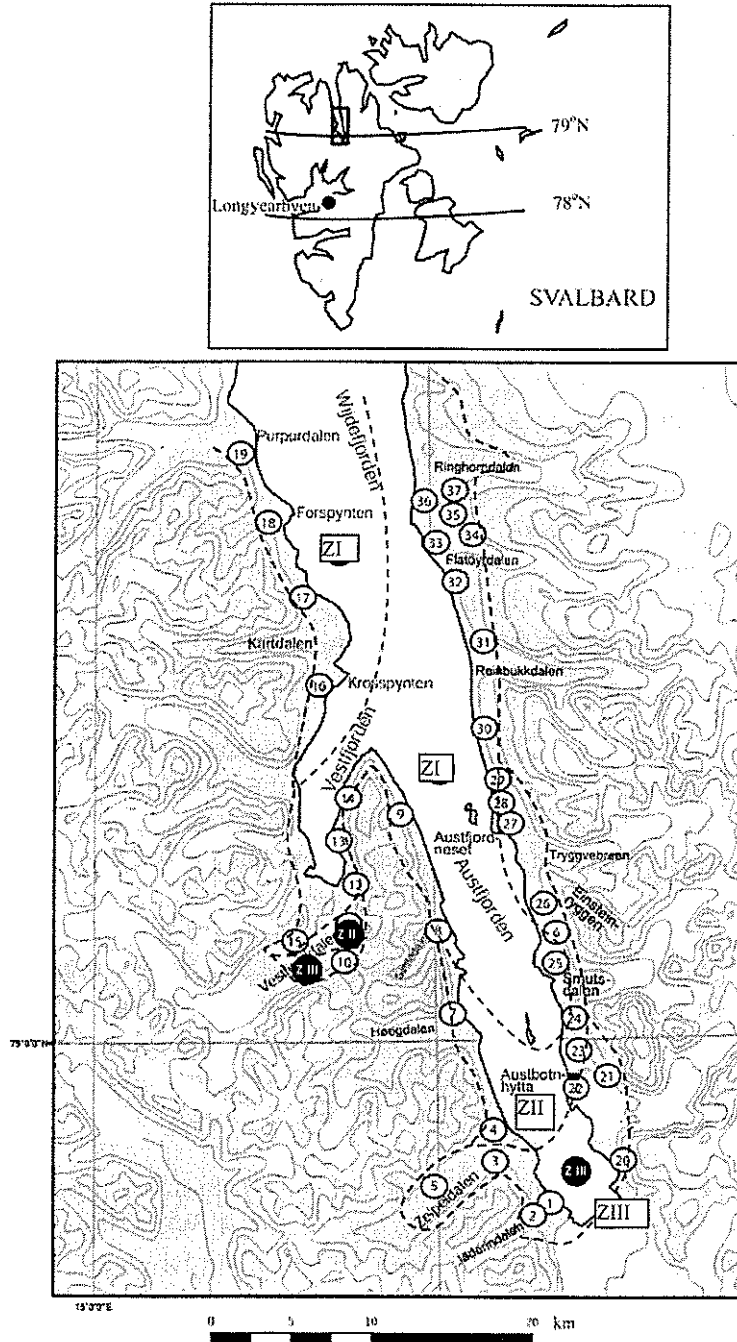


Figure 2. Map showing three different zonal units within the study area. Zones are delimited as dotted lines. Z I: Steppes dominant in landscape. Z II: Steppe vegetation subordinate in landscape. Z III: Ordinary middle-arctic tundra vegetation. The numbered white ring symbols indicate visited sites.

THE BIOCLIMATIC ZONAL POSITION OF SOMMARØYA, A SMALL COASTAL ISLAND OF NORTH NORWAY

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The coast of northern Norway is characterized by a hilly or mountainous topography, strongly dissected by fiords, inlets and islands, and mostly dominated by bedrock. This creates a strong climatic diversity, but also involves some uniform climate gradients, such as stronger marine influences in the west. The marine influence, including frequent exposure to winds and salt spray, results in a less dominant role for trees. This area is part of the problematic northern oceanic North Atlantic and Bering Sea areas. In bioclimatic studies, a major question is: should these areas be classified as arctic or as poorly-forested areas coastal boreal? After much discussion, the Circumpolar Vegetation Map programme (CAVM Team 2003) decided on the latter alternative. This choice was supported by all bioclimatic Fennoscandian studies, but conflicted with the political use of the word 'arctic' as in the original CAFF map (CAFF 1994). In Yurtsev (1994), these areas were excluded from the Arctic based on floristic criteria, but included based on 'phytogeographic' criteria, the latter emphasizing the modest role of forests.

As the CAVM program now concludes with an international workshop and local excursions at Sommarøya, 60 km west of Tromsø, it might be appropriate to discuss the bioclimatic position of this area in more detail as an example, particularly since it was addressed in a master's degree on bioclimatology thesis by Nylund (1997).

The above study used a bioclimatic method similar to that of Karlsen & Elvebakk (2003), but with a different set of indicator species adapted to a different climatic gradient, and also two groups of indicator species. Both are related to similar temperature sum thresholds, but one to a continental-type of climate with a relative short growing season and relative high mean July temperatures, and the other to a mild coastal climate with a long growing season and relatively low July temperatures.

To interpret these studies, some definitions of the northern and middle boreal zones or subzones (NBZ and MBZ, respectively), must be used. We will use the Fennoscandian system adapted to the vegetation and flora of North Norway with birch (*Betula pubescens*) forests with scattered *Sorbus aucuparia* trees, and, in wet sites, *Salix myrsinifolia* ssp. *borealis* forests, as positive criteria for NBZ, against the southernmost tundra and low-alpine belt. Forests of *Pinus sylvestris*, *Populus tremula* and *Salix caprea* ssp. *sericea* penetrate 'half-way' into the NBZ, and are defined within the weakest group of indicators for a study dealing with the northern parts of boreal areas. *Alnus incana*/*Prunus padus* forests, with their character species *Matteuccia struthiopteris*, *Salix pentandra* forests and rare calciferous *Pinus sylvestris* forests are positive criteria for the MBZ, but along the coast these are replaced by *Calluna vulgaris*-*Pinus sylvestris* forests. In addition, many floristic criteria can be used, but there is no tradition as in Russia, of using the absence of northern species such as *Rubus chamaemorus* and *Nephroma arcticum* and possibly *Geranium sylvaticum*, to define southern zones.

In the Sommarøya area there are only *Betula pubescens* and *Salix myrsinifolia* forests. The first *Alnus* forests are found another 13 km to the SE, and the first coastal *Pinus* forests some 25 km to the east. One would expect the forests of Sommarøya to be thermophilous and better developed on SW facing slopes, but instead they are well-developed on E and NE-facing slopes, at both Sommarøya and Hillesøya. This pattern may be explained by salt-spray producing storms, which come most frequently from the southwest, particularly during autumn. Salt spray can probably have local negative effects at quite some distance from the seashore. Other effects limiting forests are convex bedrock substrates producing very little soil, and the summit effect of a windy climate. Even at Tromsø, where the general altitudinal forest line is at 400 m, the summit effect at small hills represents an altitudinal forest-line depression to altitudes of about 270 m.

Small individuals of *Salix pentandra*, *Salix caprea* and *Populus tremula* are present at Sommarøya, and the cultural depression of forests can be clearly seen, with a massive invasion of small birch and various *Salix* individuals in areas previously intensely grazed by sheep and other livestock animals. Very small farms in combination with fisheries, which were previously the backbone of the economy of our coastal communities, are now history, and a massive regrowth of juvenile trees is taking place along the whole coast, transforming the landscape.

Instead of forest criteria, other indicator species such as *Paris quadrifolia*, *Dryopteris filix-mas*, *Rubus idaeus*, *Veronica officinalis*, *Avenula pubescens* and *Sedum annuum*, contribute to the Index of thermophily values. Moreover, a very important set of cryptogams characterizes the area bioclimatologically, such as *Plagiothecium undulatum*, *Rhytidiadelphus loreus*, *Mnium hornum*, *Hylocomiastrum umbratum*, *Antitrichia curtispindula*, *Cirriphyllum piliferum*, *Calliergonella cuspidata*, *Homalothecium sericeum*, *Frullania dilatata*, *Entodon concinnus*, *Campyllum chrysophyllum*, *Xanthoparmelia conspersa* (Nylund 1997), and at Hillesøya, *Isothecium myosuroides*, *Isopterygium elegans*, *Dicranodontium denudatum* and *Rhabdoweisia crispata* (Elvebakk 1985).

The best calibration of I_t values against bioclimatic zones in the area is probably the map by Ingebrigtsen (2000), where middle-boreal-type forests disappear below index values of ca. 10. This agrees also with Nylund (1997) and shows Tromsø to be just above this boundary. A similar situation occurs on the northern slopes at Sommarøya, whereas the remaining area is clearly middle boreal, like the strongly exposed coastal area at Torsvåg. A fourth coastal locality, Nord-Lenangen, has very low I_t values, and is strongly exposed to cold winds, whereas the more southern coastal study area at Grøtøya, north of Bodø, has very high Index values around 90.

Regarding climatic data, temperature sums or biotemperature (the sum of all positive monthly mean values) are considered the most relevant factor. An ongoing study by Elvebakk (in prep.) covering northernmost Europe, shows that the transition between tundra and NBZ takes place near a biotemperature of ca. 36 °C, the NBZ/MBZ transition at about 47 °C, and the MBZ/SBZ transition at about 62 °C, uniformly along the

oceanity/continentality gradient. These correlations are far better ($r^2 = 0.82$) than those involving mean July temperatures for the same area ($r^2 = 0.25$). Again, Sommarøya is clearly within the MBZ, whereas Tromsø is on the NBZ/MBZ transition, and Grøtøya at the MBZ/SBZ transition.

Finally, one should note that the Russian tradition defines the MBZ and SBZ further to the south than the Fennoscandian systems, as seen in the lack of congruence in the new European Vegetation Map (Bohn et al. 2000). Our ongoing study supports the Fennoscandian-based NBZ/MBZ boundary, but an evaluation against practical criteria and a consideration of the whole boreal zone and its neighbouring hemi-boreal zone should be done before a final conclusion is reached.

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VARIATION IN PLANT COMMUNITY COMPOSITION ALONG TOPOGRAPHIC AND CLIMATIC GRADIENTS IN THE CANADIAN ARCTIC: RESULTS OF THE CAVM CANADIAN TRANSECT

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Plant community composition in the Canadian Arctic is primarily controlled by variation in climate, substrate, topographic position, and disturbance. Within a given climatic regime and substrate, predictable patterns of community composition are found on ridge, slope, valley, late and early melting snowbeds, and active and stable floodplains. Low Arctic communities exhibit a wider range of composition (higher beta diversity) along topographic sequences than their high Arctic counterparts. Variation in community composition along toposequences is a fine-scale landscape feature that can be mapped over large regions by its incorporation as a predictable element of the landscape, with distinct landscape units being comprised of relative amounts of dry, mesic, wet, snowbed, and streamside vegetation. This vegetation can in turn be described by the dominant communities associated with each topographic position within biogeoclimatic subzones. We present a map of biogeoclimatic regions and vegetation of the Canadian Arctic with emphasis on variation in plant community composition along toposequences within biogeoclimatic units.

LARGE-SCALE VEGETATION MAPPING IN ICELAND

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Vegetation mapping in Iceland started in 1955 at the Agricultural Research Institute (ARI). The main purpose was to determine the carrying capacity of the vegetation of the grazing areas in the central highlands and thus provide a basis for their management. The fieldwork was carried out with the aid of aerial photographs and a map made at a scale of 1:40,000 (Jóhannesson and Thorsteinsson 1957). The vegetation was classified into six main vegetation complexes: 1) dry land vegetation, 2) half bogs, 3) bogs, 4) fens, 5) aquatic vegetation, and 6) land without vegetation. The main vegetation complexes were divided into 16 orders which were sub-divided into 98 sociations, the smallest units used. These units are based on growth forms and dominant species of vascular plants in the upper layers of the vegetation and were developed by the botanist Steindór Steindórsson (1981). In 1968, vegetation mapping of the lowlands was also started, with the same main purpose. In the last 30 years vegetation mapping has been used increasingly for environmental assessment of both highland and lowland areas (Einarsson 1994,1995).



Figure 1. Areas in Iceland where vegetation field mapping was completed by 2003.

Fieldwork for vegetation mapping has now been completed for more than two thirds of the country. The Central Highlands are mostly completed but more than half of the lowland still remains. About 120 maps at scales of 1:20,000 to 1:40,000 have been published. During the last decade, 16% of the mapped area was digitized and updated with the aid of new ortho-photo maps and Spot and Landsat satellite images. In 1995, the Icelandic Institute of Natural History (IINH) took over the task of vegetation mapping in Iceland from ARI. In 1998, an overview Vegetation Map of Iceland (1:500,000) was compiled by Gudmundur Gudjonsson and Einar Gíslason, and published by IINH (Gudjonsson and Gíslason, 1998). The map was compiled with help of Landsat satellite images (1:250,000) and based on all vegetation data available at the time. In recent years,

the IINH has used vegetation mapping as a base for large-scale habitat classification and mapping in Iceland.

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MAPPING VEGETATION ZONES AND SECTIONS IN NORTHERN FENNOSCANDIA USING REMOTE SENSING AND GIS

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When describing the vegetation patterns of northern Fennoscandia, at least three independent gradients should be taken into account: north-south, oceanic-continental and altitudinal gradients. Several scientists have addressed the problem of working out a biogeographical subdivision of the region. Eurola and Vorren (1980) divided the area into six zones and subzones based on mire vegetation. Haapasaari (1988) emphasized the macroclimatic gradient and covered northern Fennoscandia with an impressive network of sample plots. Oksanen and Virtanen (1995) sampled the altitudinal and topographic gradients in six areas from Tromsø in the west, to Utsjoki in the east. This approach attempted to discriminate community sequences or vegetation patterns along the topographic-altitudinal gradient complexes. In addition to these studies, several other scientists have addressed the problems of dividing northern Fennoscandia into biogeographical zones and sections (Tuhkanen 1980, 1984; Moen 1987, 1999; Ahti et al. 1968, Hämet-Ahti 1963, 1981; Dahl et al 1986; CAVM Team 2003).

When summarizing these efforts there is no doubt that the outermost coast of Varanger Peninsula belongs to the Arctic region. On the Kola Peninsula, several Russian scientists have drawn the border between the arctic and boreal zones from Rybachi Peninsula in the west and further east along the northern parts of the Kola Peninsula. Both the CAVM Team (2003) and Oksanen & Virtanen (1995) oppose this view. In the map drawn by the CAVM Team, the Kola Peninsula is within the boreal region, while Oksanen & Virtanen regard the continental parts of Finnmark and Troms as parts of their hemi-arctic subzone.

In this study, satellite images are used to map the vegetation formations in northern Fennoscandia. Data from the MODIS satellite are used to give an overall impression of large-scale distribution of vegetation types, while data from Landsat TM/ETM+ are used to depict the vegetation types in more detail. The MODIS data cover the whole study area, while Landsat data only cover the areas in Norway, northern Sweden, northern Finland and the western parts of the Kola Peninsula. First, unsupervised classifications of the Landsat TM/ETM data were used to produce vegetation maps. The maps were then merged together, covering most of the western parts of the study area. The interpretation of the Landsat images is based on field notes, available vegetation maps based on traditional methods, and studies of relevant literature. The results from this process are used in the interpretation of the MODIS data.

The image classification analyses of Landsat TM/ETM+ images for vegetation mapping purposes are divided into two main operations - the pre- and post-classification processes. The pre-classification process involves selection of a proper classification method, separation of the data set into spectral clusters, analysis of the spectral content of the separated classes, and aggregation of classes into spectral entities based on spectral

similarity and spectral separability. Experience from producing vegetation maps based on Landsat TM/ETM+ images has shown that certain vegetation units are difficult to separate based on spectral information only. Depending on the topographic location, underlying geology, elevation, and vegetation complexity, a spectral class may include quite different land cover types. The aim of the post-classification process is to improve the pre-classified product by use of ancillary data, and to relate the resulting classes to the vegetation system valid for the study area.

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ECOLOGICAL LAND CLASSIFICATION AND MAPPING ON THE BEAUFORT COASTAL PLAIN OF NORTHERN ALASKA

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We conducted an ecological land survey (ELS) that inventoried, classified, and mapped the ecological characteristics of a portion (69,582 ha) of the northeastern National Petroleum Reserve–Alaska that is being considered for oil development. The classification used a hierarchical approach that aggregated numerous ecological components into ecotypes, with co-varying properties that partitioned the variability of a wide range of ecological characteristics. The mapping of integrated terrain units (ITUs) based on these relationships provided a spatial database structure that preserved the diversity of environmental characteristics across the landscape. This linkage of ecological characteristics within a spatial database facilitates spatial analyses for engineering and environmental applications and enhanced our ability to predict the response of ecosystems to human impacts.

Individual ecological components (e.g., geomorphic unit, soil texture, slope position, drainage, soil chemistry, and plant association) were classified according to standard systems developed for Alaska to the extent possible. Plant associations were developed using TWINSpan, detrended correspondence analysis, and sorted table analysis. Ecotypes were developed through the use of contingency tables to identify common relationships and central tendencies among ecological components. A total of 25 terrestrial geomorphic units, 19 aquatic geomorphic units (waterbodies), 24 surface forms, and 22 vegetation classes were identified and were combined into a reduced set of 42 ecotypes, based on analysis of hierarchical associations among the ecological components.

Mapping was done at both local (1:10,000) and landscape (1:250,000) scales. At the local scale, mapping used an integrated terrain unit (ITU) approach that incorporated geomorphic units (surficial geology and waterbodies), surface forms (related to permafrost processes), and vegetation. The use of these three parameters created 325 ITU combinations. The ITUs allowed map presentation of individual components, as well as the 42 ecotypes derived from the ITUs. At the landscape level (1:250,000 scale), the study area and surrounding coastal plain were divided into 8 ecodistricts (e.g., Western Beaufort Coastal Plain) and 26 ecosubdistricts (e.g., Ikpikpuk Upper Coastal Plain) representing physiographic regions with repeating assemblages of geomorphic units and vegetation.

Common ecosystems on the coastal plain included upland moist tussock meadows (27.4% of area), lowland moist sedge–shrub meadows (19.5%), lowland lakes (11.4%), lowland wet sedge meadows (9.4%), lowland basin complex (8.8%), and lacustrine wet sedge meadows (1.4%). Floodplains were dominated by riverine lakes (3.7%), riverine wet sedge meadows (3.6%), riverine moist sedge–shrub meadows (2.8%), riverine moist low willow shrub (0.9%), and lower perennial rivers (0.8%). Coastal areas were

dominated by coastal moist barrens (1.4%), coastal wet sedge meadows (0.5%), nearshore water (0.5%), and coastal lakes (0.4%).

Knowledge of the patterns and processes of ecological development on the landscape form the basis for evaluating the capabilities of the land to support wildlife and for evaluating the potential impacts of land management activities. Accordingly, the ITU map and simplified conceptual model rules were used to derive wildlife habitats, predict flood distribution and frequency, and differentiate the sensitivity of ecosystems to oil spills and winter off-road traffic.

AN ECOSYSTEMS MAP FOR NORTHERN ALASKA

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In response to a need for a unified ecological map for ecoregional planning in northern Alaska by the Nature Conservancy, we developed a map of local-scale ecosystems (ecotypes) that encompasses the Brooks Range, Brooks Foothills, and Beaufort Coastal Plain ecoregions. Our approach to ecological land classification and mapping combined vegetation structure associated with existing landcover maps derived from satellite image processing, with physiography (i.e., coastal, floodplain, alpine), topography (DEM modeling), and bedrock characteristics to model ecotypes that best partition geomorphic, hydrologic, pedologic, and vegetative characteristics.

We developed a classification that included 7 alpine, 9 upland, 5 lowland, 10 riverine, 4 coastal, and 1 human-modified ecotypes that encompass a broad diversity of ecological characteristics ranging from boreal forests in the southern Brooks Range to brackish meadows along the Beaufort Sea coast.

As input to map development, we used four existing landcover maps for the: North Slope by Muller et al. (1999), Gates of the Arctic National Park and Preserve by the Earth Satellite Corporation and Alaska Natural Heritage Program (1999), northwest Alaska parks by the National Park Service (1999), and the Arctic National Wildlife Refuge by Markon (1986). For physiography, we manually delineated floodplains and coastal areas at 1:100,000-scale on NASA Geocover satellite imagery, and differentiated alpine, upland and lowland areas by using a digital elevation model to characterize elevation, slope, moisture index, and land position (concavity/convexity index). Bedrock geology was adapted from Moore et al. (1994). Glacial extent was obtained from USGS maps, as compiled by Manley (pers. comm.).

Rule-based models were developed to recode the map classes from the individual landcover maps into ecotypes. In the resulting map, upland ecotypes covered 57% of the 308,208-km² area and were dominated by Upland Shrub Birch-Willow Tundra (20%), Upland Shrubby Tussock Tundra (19%), Upland Tussock Tundra (6%), Upland Moist Sedge-Shrub Tundra (7%), and Upland Spruce Forest (2%). Alpine ecotypes (18%) were dominated by Alpine Noncarbonate Dryas Dwarf Shrub Tundra (11%) and Alpine Noncarbonate Barrens (5%). Lowland ecotypes (17%) were dominated by Lowland Moist Sedge-Shrub Tundra (6%), Lowland Wet Sedge Tundra (5%), and Lakes (3%). Riverine ecotypes (5%) were dominated by Riverine Moist Sedge-Shrub Tundra (2%) and Riverine Wet Sedge Tundra (1%). Coastal ecotypes (3%) were dominated by Coastal Water (2%) and Coastal Wet Sedge Tundra (0.4%). The Human-modified ecotype covered <0.1%. Each ecotype typically is associated with 2_4 geomorphic units, 2_4 closely related soil types, 1_3 plant associations, and differing permafrost conditions. For ecoregional planning, the map was used to identify rare ecosystems and high-value wildlife habitats deserving priority protection.

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CLASSIFICATION AND ORDINATION OF FROST-BOIL ECOSYSTEMS ALONG A CLIMATE GRADIENT IN THE LOW ARCTIC, ALASKA

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The vegetation and soil patterns in arctic tundra are influenced by the distribution of frost boils, which are circular patterned-ground features. Frost boils are strongly correlated with soil, vegetation and cryoturbation activity, and their morphology is largely controlled by climate (Walker et al. 2004). We examined frost-boil ecosystems at seven study sites along a S-N transect from the Arctic Foothills of the Brooks Range to the Beaufort Sea coast along the northern segment of the Dalton Highway, Alaska. The sites varied from acidic tundra in Subzone E of the circumpolar arctic vegetation map (CAVM Team 2003) to nonacidic tundra in Subzone D and C.

We established 117 relevés in frost boils and interboil areas using the centralized replicate sampling procedure. We recorded vegetation, soil and site information, and maximum snow and thaw depths during 2000 through 2003. We classified the vegetation according to the Braun-Blanquet sorted-table method (Dierschke 1994) and used Detrended Correspondence Analysis (Hill and Gauch 1980) ordinations to analyze relationships between variation in vegetation and environmental variables.

We identified the following associations and tentative community types (Table 1). In Subzone E, the acidic tundra was classified as the *Sphagno-Eriophoretum vaginati* association (Walker et al. 1994), the wet frost boils as the *Anthelia juratzkana-Juncus biglumis* community type (Walker et al. 1994), and the mound-like frost boils as the *Racomitrium lanuginosum-Carex bigelowii* community type. In Subzone D, we assigned the moist nonacidic tundra to the *Dryado integrifoliae-Caricetum bigelowii* association (Walker et al. 1994), the wet nonacidic tundra to the *Scorpidium scorpioides-Carex aquatilis* community type and the frost boils to the *Saxifraga oppositifolia-Polyblastia sendtneri* community type. The information from this study adds a more complete picture of the zonal plant communities in Subzones E and D in northern Alaska. In Subzone C, we identified the moist and dry coastal tundra as the *Saxifraga cernua-Carex aquatilis* community type and the *Dryas integrifolia-Saxifraga oppositifolia* community type, respectively, and the frost boils as the *Polyblastia sendtneri-Braya purpurascens* community type.

The ordination analysis displays the position of the plant associations and community types, and environmental variables that are highly correlated with the sample plots (Figure 1). Along axis 1, the percentage of bare soil and pH increase, and air temperature, elevation and total plant cover decrease. This axis can be viewed primarily as the bioclimate gradient. Axis 2 is correlated with increasing soil moisture, vegetation height and depth of the organic horizon and decreasing thaw depth. Disturbance through cryoturbation is the underlying factor for axis 2, with frost boils being grouped towards the lower half of the ordination space. When complete, the classification and ordination of frost-boil communities will provide considerable insight into the interactions among climate, substrate, disturbance and arctic plant communities.

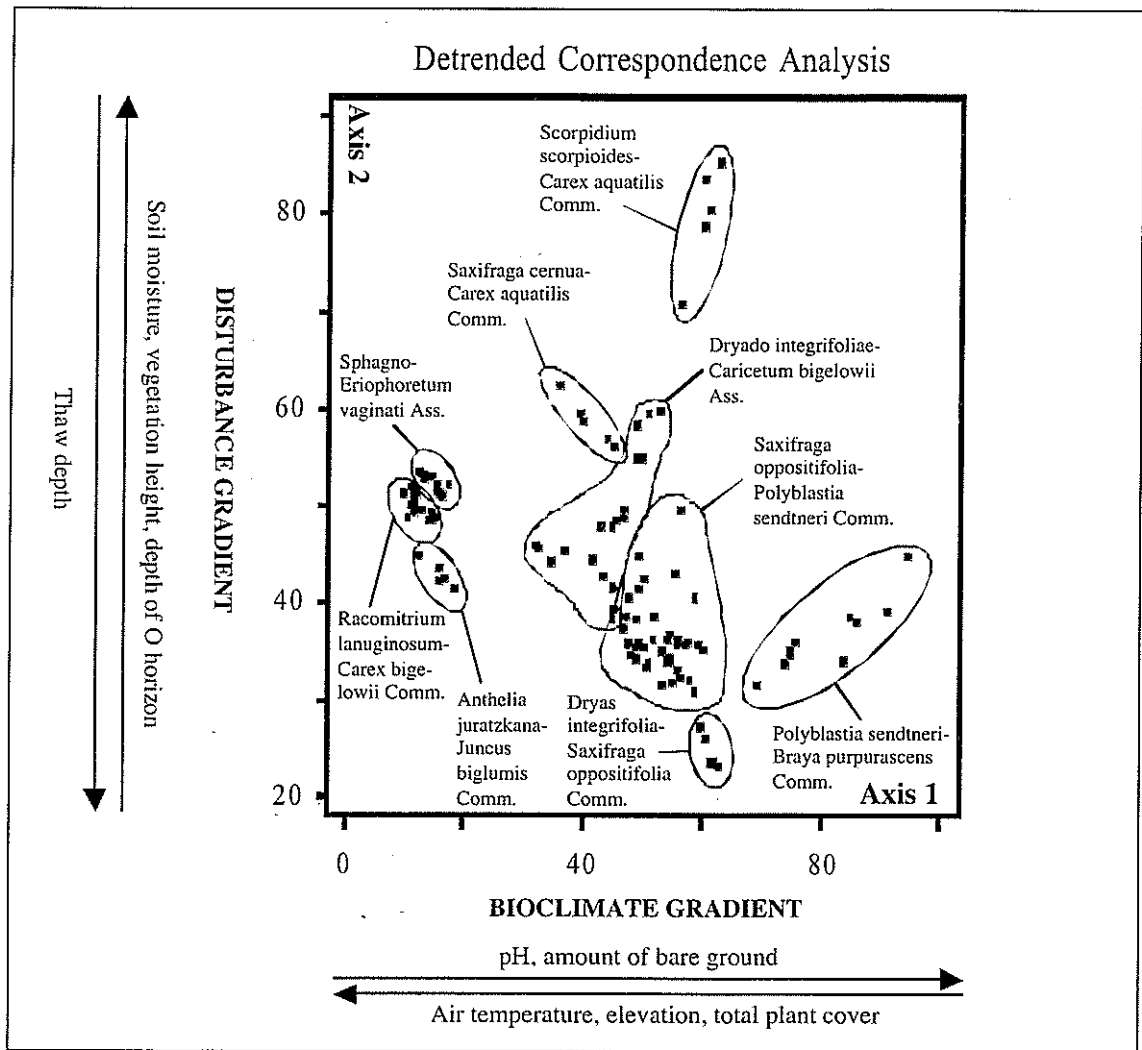


Fig. 1. Detrended Correspondence Analysis-ordination graph. The plant associations and community types are depicted within the ordination space. Axis 1 represents a complex bioclimate gradient, and axis 2 shows a disturbance gradient.

Table 1. Classification of plant communities of frost-boil ecosystems in the Alaskan Low Arctic.

Subzone C		
Frost boils	<i>Polyblastia sendtneri-Braya purpurascens</i> comm.	?
Interboils (dry)	<i>Dryas integrifolia-Saxifraga oppositifolia</i> comm.	Cl. Elyno-Seslerietea Br.-Bl. 1984 ?
Interboils (moist)	<i>Saxifraga cernua-Carex aquatilis</i> comm.	
Subzone D		
Frost boils	<i>Saxifraga oppositifolia-Polyblastia sendtneri</i> comm.	?
Interboils (moist)	<i>Dryado integrifoliae-Caricetum bigelowii</i> ass. M.D. Walker et al. 1994	Cl. Scheuchzerio-Caricetea fuscae Tx. 1937
Interboils (wet)	<i>Scorpidium scorpioides-Carex aquatilis</i> comm.	?
Subzone E		
Frost boils (wet)	<i>Anthelia juratzkana-Juncus biglumis</i> comm. M.D. Walker et al. 1994	Cl. Salicetea herbacea Br.-Bl. 1984?
Mounds	<i>Racomitrium lanuginosum-Carex bigelowii</i> comm.	?
Interboils	<i>Sphagno-Eriophoretum vaginati</i> ass. M.D. Walker et al. 1994	Cl. Oxycocco-Sphagnetea Br.-Bl. et Tx. 1943

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A NEW VEGETATION-BASED METHOD FOR BIOCLIMATIC MAPPING APPLIED TO THE ARCTIC BOUNDARY AREA IN FINNMARK, NORWAY

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This study describes a new method for bioclimatic mapping where the vegetation cover is the main source of climate information. The study area is composed of four subareas, all situated in the northeastern-most part of mainland Norway (Figure 1). The four subareas were chosen to represent most of the climatic, topographic, geomorphologic, and botanic diversity along the arctic-boreal gradient in the area. The four meteorological stations in the area show a climatic gradient with mean July temperature ranging from 10.1 to 12.3 °C.

The new vegetation-based method is based on the fact that most plant species and plant communities both in the Arctic and adjacent areas have a distribution pattern limited by temperature-sum thresholds to a varying extent. The vegetation is mapped using Landsat TM data and a contextual correction process in GIS. The total distribution patterns of the mapped vegetation units and the high-to-frequent and dominant species are compared with summer temperatures. Twenty-one of the mapped vegetation types were defined as thermophilous and categorized in five groups of temperature indicators. Then the mapped vegetation types were grouped according to minimum biotemperature demands and assigned indicator values. The indicator value and degree of cover of each the thermophilous vegetation types, mapped within 500 x 500-m study units, are combined in a Vegetation-based Index of Thermophily VI_{tm} . This new vegetation-based method is based on the same basic idea as a recently published floristic-based method for calculating a Floristic-based Index of Thermophily FI_{tm} (Karlsen & Elvebakk 2003).

The Vegetation-based Index of Thermophily VI_{tm} values showed a strong positive relationship with the temperatures measured during the years 2001 and 2002, with r^2 values of 0.79 and 0.85, respectively. As interpreted from the relationship with temperature measurements and FI_{tm} values, the vegetation-based method seems to work at a broad range of ecological conditions. However, in very dry, acidic sites and in areas dominated by boulder fields with only fragmented vegetation cover between the boulders, the correlations are lower. The VI_{tm} values are related to growing degree days in a normal year, and 13 bioclimatic classes are mapped in four subareas (Figure 2). The results show climatic gradients with temperatures increasing from the cold coast towards the interior, from wind-exposed convex hills towards wind-protected valleys, and from mountains plateaus towards south-facing lowlands. The birch forest line is estimated to occur at a level of about 980 °C-days. The bioclimatic map units are lumped together to correspond to the more coarse bioclimatic units used on a circumpolar scale, and the northeasternmost subarea at the coast is positioned within the arctic shrub-tundra zone (or subzone E on the CAVM map), whereas the other subareas are within the low alpine belt and the northern boreal zone.

The vegetation-based method has potential for bioclimatic mapping of large areas in a cost-effective way. The floristic-based method is more accurate and more flexible, but is labour-intensive and can only cover smaller areas. The two methods seem to complement each other.

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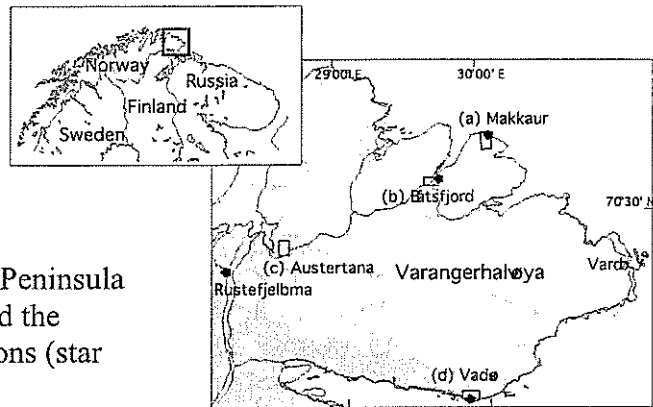


Figure 1. Map of Varangerhalvøya Peninsula showing the four study subareas and the location of the meteorological stations (star symbol).

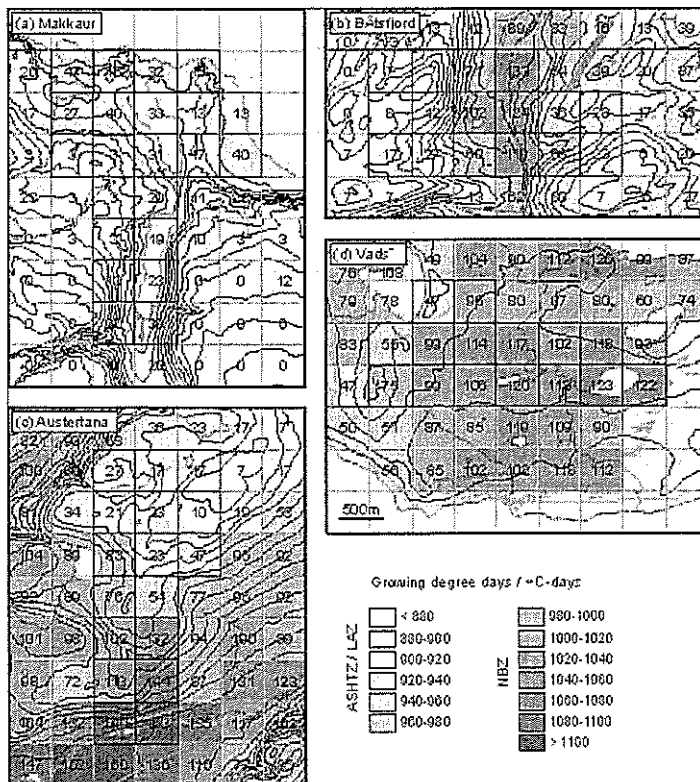


Figure 2. A bioclimatic map of the study areas. The numbers are the Modified Vegetation-based Index of Thermophily VI_{tm} values of the study units. The VI_{tm} values are related to growing degree days of a normal year, and the 13 colour codes each represent a range of 20 growing-degree days, or a range of 12.5 VI_{tm} units.

DOMINANT GROWTH-FORM CLASSIFICATION OF PLANT COMMUNITIES AS A BASIS FOR THE LEGEND OF VEGETATION MAPS

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Small-scale vegetation map must mirror the general characteristics of the composition and structure of vegetation cover of large areas, including its location in one or another vegetation zone/subzone and floristic region. On vegetation maps, only common higher units of the dominant growth-forms of plant communities can be shown. These are shown as: type of vegetation, plant formation and their combination. The higher classification units are distinguished on the basis of taxonomic (species) or growth-form categories of plants dominating the upper (essential) canopy layer in plant communities. Undoubtedly, dominant species are the best indicators of environments rather than less abundant ones.

The map one should show, first of all, the units of classification confined to placor habitats (plain, loam substrate, moderate draining), i.e. the zonal types, and then vegetation units found on some other forms of relief or substrate of other chemical composition. The latter may be vegetation of mires, mountains, river valleys as well as sand, stony and saline substrates.

Within one longitudinal sector of the Russian Arctic similarities have been found between floras of northern and southern hypo-arctic tundras and neighboring taiga zone. The same is true of dominant species, some types of vegetation and plant formations. This phenomenon is explained by the fact that the areas all belong to the same floristic region.

In other longitudinal sectors of the Russian Arctic and Subarctic different species dominate plant communities within the same zone. Woodlands at the northern forest boundary in the northern Komi are formed by *Pinus obovata* and *Betula tortuosa*, in West Siberia by *Larix sibirica*, in East Siberia by *L. dahurica*, in the Far East by *L. cajanderi*. In the western Russian Arctic, *Betula nana* prevails in southern tundra, whereas in its eastern regions *Betula exilis* is dominant.

The change of growth form of dominant species indicates major changes in environment. For instance, in the transitional area from north taiga to southern tundra, the species dominating the upper layer may change its growth form or disappear altogether. In the latter case the lower (or ground) canopy layer become the upper one. The new community forms related to the other type of vegetation, and the territory may belong in a different zone, subzone or altitudinal belt (in mountains).

Using the dominant growth-form approach to classification of plant communities, the vertical and horizontal structure of phytocoenoses are used to distinguish the classification units. This is very important for classification of vegetation in the arctic and mountain tundra, where one-layer communities of prostrate plants and spots of bare ground of various form and size are widely distributed.

A knowledge of characteristics indicated by dominant species permits field work to be restricted to detailed studies of vegetation in key plots which include all of the diversity of relief in the area being mapped. On the basis of this data, it is possible to decipher aerial photographs of the whole area.

CHARACTERIZATION OF THE ARCTIC VEGETATION OF CANADA IN COMPARISON WITH THAT OF NORTHWESTERN EURASIA

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In Canada, arctic vegetation covers approximately 2.4 million km², i.e. 27% of the total land area. Because of its broad geographical extent, vegetation and environmental conditions vary greatly from region to region. The arctic vegetation of Canada has been broadly classified and some zonation systems were proposed, notably, by Polunin (1951), Zoltai (1977), Bliss (1977, 1988), Edlund (1983), Wiken et al. (1986), CCELC (1989). The present paper briefly reviews these systems and discusses vegetation classification hierarchies of Arctic Canada in a global context with special reference to the vegetation of Cornwallis and Ellesmere Islands. The syntaxonomical hierarchy of the Canadian Arctic is compared to that of northwestern Eurasia, and Svalbard (which has a totally different arctic environment).

The prime factor characterizing the Canadian Arctic is a very frigid and dry continental type of climate. Conrad's (1946) continentality index ranges from 45 to more than 60 for Canadian Arctic. Indeed, it is 61 for Eureka and 58 for Cambridge Bay, which is equivalent to the interior regions of the North American continent. In contrast, the continentality index of the western Eurasian Arctic is generally less than 45 (Tuhkanen 1984), and in Svalbard it is 20. This implies that the Canadian Arctic vegetation develops in more arid and winter-cold climatic conditions than that of northwestern Eurasia. Soils of the Canadian Arctic are, by and large, more base-rich with generally higher pH values than those of Svalbard. This may be due to a more continental climate type in Canada, which decreases the rate of soil leaching and results in higher pH.

As far as geographical location is concerned, Svalbard is comparable to the High Arctic of Canada. The zonal vegetation of High Arctic Canada is represented by *Salix arctica* - *Dryas integrifolia* community (Salico arcticae - Dryadetum integrifoliae) (Edlund 1983, Svoboda & Freeman 1994). In Svalbard, *Cassiope tetragona* - *Dryas octopetala* community (Cassiopo tetragonae - Dryadetum octopetalae) represents the zonal vegetation (Elvebakk 1985, 1994). In other words, the lower prevalence or restricted occurrence of *Cassiope tetragona* may be considered one of the vegetation characteristics of the Canadian High Arctic in comparison with that of Svalbard. The ecological significance of *Cassiope tetragona* is also discussed.

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TREELESS VEGETATION OF NORTHERN AND NORTHEASTERN
FENNOSCANDIA - AN AREA WITH FINNISH, RUSSIAN AND BRAUN-
BLANQUET APPROACHES TO CLASSIFICATION

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Northern and northeastern Fennoscandia includes northeastern areas of Finland, northernmost Norway, and northern coastal and mountain areas of Murmansk Province. Treeless heathlands and barrens prevail in lowlands and mountains here. This area is a meeting point of various science traditions and approaches to plant cover description and analysis.

In Finnish classification, field and ground layer dominants are traditionally emphasized in the description and naming of community types (site-types). These units are grouped based on gradient relationships, rather than on hierarchies. Russian classification of tundra plant cover uses associations as basic units with uniform structure and the same dominant species. Hierarchy is based on life-forms of the dominants. The Uppsala school of classification developed a combined approach to classification of mainly mountain vegetation: the basic units associations and sociations, defined as vegetation-types with uniform floristic composition and structure, were fitted into alliances and orders in a Braun-Blanquet hierarchy.

There are some phytocological surveys based on Braun-Blanquet principles, of Scandinavian vegetation types, mainly in mountains of the boreal zone (Vevelev 1985, Dahl 1987, Dierssen 1992). A synthesis of heath types of northern Fennoscandia was presented by Haapasaaari (1988) and Oksanen and Virtanen (1995).

This paper aims at 1) a survey of treeless vegetation of northeastern Fennoscandia in terms of Braun-Blanquet approach, and 2) finding correspondence between the types described earlier in northern Fennoscandia and the syntaxa presented in this survey. Most significant is relating the results of Braun-Blanquet classification and traditional Finnish and Russian approaches. The area investigated includes the Barents Sea shore, raised shore rocky terrain, extensive uplift fields (Kejvy) and areas above timberline in mountains (Khibinsky, Lovozersky, Chuna tundra and Sal'nye tundra).

Dwarf shrub vegetation, sometimes with scattered mountain birch, prevails on rocky terrains and in mountains; this type was related to *Phyllocladon-Vaccinium myrtilli* Nordh. 1936 and *Loiseleurio-Diapension* Br.-Bl., Siss. & Vlieger 1939, Daniëls 1982. Snow-bed communities of *Salicion herbaceae* Br.-Bl., Br.-Bl. & Jenny 1926 and rock-crevice vegetation of *Asplenietea trichomanis* Br.-Bl. ap., Meier & Br.-Bl. 1934 are more common in mountains. Early snow-bed graminoid vegetation belongs to *Nardo-Caricion bigelowii* Nordh. 1943. Graminoid-dominated vegetation of *Carici rupestris-Kobresietea bellardi* Ohba 1974 occurs on basin rocky terrains. Beach vegetation belongs to *Honckenyo-Elymion arenariae* Fernandez-Galiano 1954, Tx. 1966 and *Caricion glareosae* Nordh. 1954. Mountain mires are related mainly to *Caricion nigrae* Koch 1926 em. Nordh. 1936 and *Sphagno-Tomenthypnion* Dahl 1956; bogs on

seashore terrain belong mainly to *Oxycocco-Empetrium hermaphroditi* Nordh. 1936. Spring meadows fit in *Adenostylion alliariae* Br.-Bl. 1925 and willow-dominated grassy wetlands along springs belong to *Salicion phylicifoliae* Dierssen 1992.

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DISTRIBUTION PATTERNS IN THE ICELANDIC FLORA IN RELATION TO THE ARCTIC LINE

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Distribution maps of lichens, bryophytes and vascular plants in the Icelandic flora reveal several groups of plants with similar distribution pattern. Five main different patterns are encountered that can be related to climate. Plants favoring an oceanic climate are concentrated in the West and South (*Cladonia rangiformis*, *Ramalina subfarinacea*), those favoring continental climate are mainly found in inland areas of the Northeast (*Carex glacialis*, *Erigeron humilis*, *Alectoria ochroleuca*, *Melanelia agnata*, *M. infumata*). Plants that depend on prolonged snow cover in the winter are mainly found in three northern areas with coastal mountains (*Athyrium distentifolium*, *Blechnum spicant*, *Cornus suecica*, *Crepis paludosa*). Thermophilic species are concentrated on south-facing slopes in the southern part of Iceland (*Succisa pratensis*, *Plantago lanceolata*, *Prunella vulgaris*), and plants with an alpine/arctic distribution are generally distributed in mountains throughout the country, or along the northern coast (*Allantoparmelia alpicola*, *Caloplaca alcarum*, *Lecanora straminea*, *Luzula arcuata*, *Ranunculus glacialis*, *Saxifraga foliolosa*). Very few distribution patterns can be related to geology (*Bryoxiphium norvegicum*, *Ranunculus glacialis*).

Other distribution types have to be explained by history. We must keep in mind, that only 10-12 thousand years have passed since Iceland was more or less covered by ice. Many plants arrived soon after the end of the ice age, distributed relatively quickly around the country, and are now common everywhere. Those with limited possibilities for long distance dispersal either did not reach the country, or often arrived centuries later. For many of them, the short time since their arrival has not been sufficient to get distributed all around the country (*Anthyllis vulneraria*, *Campanula rotundifolia*, *Cladonia bellidiflora*, *Cornicularia normoerica*). This seems the best explanation for many plants with eastern distribution; they arrived originally from the east and have not yet had enough time to distribute all over the country (*Ajuga pyramidalis*, *Alchemilla faeroensis*, *Oxalis acetosella*, *Cornicularia normoerica*).

In an effort to draw a naturally defined arctic line around the globe to delimit the arctic region from boreal areas, the northernmost parts of Iceland and Scandinavia are included in the Arctic. In defining this line in Iceland, climatic factors are used as criteria, as well as the absence of boreal plant species – species generally not reaching the Arctic, rather than the presence of arctic species. Arctic species are generally also found in alpine regions south of the arctic border. In Iceland arctic species are distributed more or less throughout the country in the mountains, or they may be found only in mountains south of the arctic boarder rather than along the northern coast. The arctic line can, however, be shown using distribution maps, by excluding alpine records higher than 200 m above sea level. An example of this is distribution map showing only the lowland occurrences of *Luzula arcuata*. This species occurs in lowlands only along the northern coast of Iceland.

REVIEW OF CARICI-KOBRESIETEA VEGETATION IN CENTRAL CHUKOTKA

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The cryo-xerophytic vegetation (cl. Carici-Kobresietea, o. Kobresio-Dryadetalia) is classified for the middle reaches of the Amguema River (178° W, 67° N), a key area for Central Chukotka. The *Dryas punctata* tundras are represented by the new regional association, Sileno stenophyllae-Dryadetum (alliance Oxytropidion nigrescentis Ohba 1974). Subass. Asahineatosum chysanthae occurs on rubble slopes in the low mountains; its variants are var. Asahinea scholanderi (patchy lichen-dryad tundras on scree) and var. Hedysarum truncatum (closed dryad mountain tundras). Two other subassociations occur on river terraces of different ages, mostly on sandy-pebbly deposits. Subass. typicum is represented by two variants. The typical variant is that of the patchy *Dryas* tundras, which thoroughly dominate the dry ecotopes of river terraces. Similar communities have also been reported from Western Chukotka to Western Alaska, as well as from the Putorana Plateau. The variant Diapensia obovata occurs on topsoil with higher humus content, and under soil humidity conditions transitional from dry to mesic. Subass. Rhododendretosum camtschatici is restricted to watershed sites with slightly increased snow accumulation.

For the cryo-xerophytic meadows, steppes and tundra-steppes of Beringia, a new alliance, Androsacio arctisibiricae-Asterion alpini, and two suballiances are proposed. Salicenion glaucae refers to *Dryas* tundras co-dominated by *Kobresia myosuroides*, with only the association, Kobresio-Dryadetum, in the study area. Three variants are distinguished. Dracocephalo palmati-Potentillion niveae comprises different types of the non-tundra cryo-xerophytic vegetation. Eremogono capillaris-Caricetum rupestris (type of the alliance and the suballiance) consists of the two variants: the typical variant (rather common communities of wind-exposed slopes and ridges dominated by *Carex rupestris*) and the Helictotrichon krylovii variant (the driest type of the relict steppe, extremely rare in the area). Another association, Thymo oxyodonti-Caricetum obtusatae, represents the more typical cryophytic steppes at the easternmost limit of their distribution in Eurasia, always restricted to southern slopes. The Cerastium arvense variant is observed on the present-day river terrace slopes, and the Saxifraga firma variant occurs on ancient residual terraces with more pebbles in the soil.

PLANT COMMUNITIES ON SANDY DEFLATION SCARS IN THE SUB-PECHORA TUNDRA, NORTHEASTERN RUSSIA

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Vegetation of sandy deflation scars in tundras of the Pechora basin (east of the Malozemelskaya Tundra (the Sedujaha River basin) and west of the Bolshezemelskaya Tundra (the Ortina River basin) in north-eastern European Russia) was studied from 1996-1998. This region is located in the northern and southern hypoarctic tundra subzone (Yurtsev et al. 1978). The relief is hilly, and deflation scars caused by wind erosion form on the Quaternary sediments (Atlas of Arctic 1985). Snow cover is low. Zonal vegetation types are dwarf-shrub and shrub tundras.

Plant cover of sandy deflation scars is heterogeneous. Vegetation was described from 118 relatively homogenous 5-x-5 m sample plots. The vegetation was classified according to the Braun-Blanquet approach (Aleksandrova 1969). The communities are related to two known associations, and in one of them five new variants are proposed. In addition, one association with two sub-associations and 4 variants are newly described.

Arctostaphylo-Empetretum hermaphroditi (Zinserling 1935) Koroleva 1994 (Phyllodoco-Vaccinion myrtilli, Loiseleurio-Vaccinieta) is confined to hill summits of the Sedujaha River basin. Elymo-Festucetum arenariae (Regel) Nordh. 55 (Honckenyo-Elymion arenariae, Honckenyo-Elymetea arenariae) is located on dry sites such as coastal dunes in the Ortina River basin (cf. Koroleva, 1999) and in the watersheds on unstable sand in central parts of sandy deflation scars. The substrate is well-sorted yellow sand without horizons. The newly described association Rumici graminifolii-Festucetum sabulosae (Galio-_oelerion, Koelerio-_orynephoretea) is confined to watersheds in the continental tundra on vast sandy spaces of the Ortina River basin; some of these are covered by fine pebbles.

Each sandy deflation scar is a complex of communities comprising several variants of plant associations. These communities are similar to coastal ones. On sandy deflation scars the communities are distributed as patches, while along coastlines of seas or large lakes they form contiguous belts. The low diversity of the associations may be explained by extreme environmental conditions (e.g. wind-induced dryness, nutrient-poor and unstable substrate). The large number of variants of the association is an expression of the dynamic character of these ecotopes and the seral character of the communities.

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CASSIOPE TETRAGONA-DOMINATED SNOWBED COMMUNITIES ALONG THE THOMSEN RIVER, BANKS ISLAND, CANADA

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Vegetation description using the Braun-Blanquet approach documented *Cassiope tetragona*-dominated snowbed communities of different expositions on mainly nonacidic substrates. Five transects and 23 relevés described the snowbed toposequence. These are complemented in part with thaw depth measurements and pedological data from three soil pits. The distinctness and similarity to snowbed syntaxa from Alaska (Walker *et al.* 1994) is discussed. Additionally, range extensions of several vascular plant species are documented.

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REMARKS ON COASTAL SALT-MARSH AND DUNE VEGETATION OF THE NORTHERN PART OF WEST GREENLAND

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Phytosociological research of coastal vegetation north of Disko Island, West Greenland is very scant. Thus during the summer of 1998 we sampled 55 relevés of coastal salt marsh, dune and cliff vegetation in the Ummannaq District between ca 70°15' N and 72°N. Habitat analyses included soil texture and salinity. In sheltered bays and deltas salt marsh, vegetation of the *Asteretea tripolii* occurs. From the lower to upper salt marshes, a clear zonation pattern following a salinity gradient can be observed: *Puccinellietum phryganodis*, *Caricetum subspathaceae*, *Caricetum glareosae* (three subassociations) and *Caricetum ursinae*. On dry gravelly and stoney beaches, *Honckenya diffusa* - *Mertensia maritima* vegetation occurs. The dominant species on low dunes and shore walls are *Leymus mollis* and *Honckenya peploides*. These communities are classified as *Honckenyo-Elymetea arenarii*. Vegetation on exposed gravelly and stony cliffs are influenced by salt spray. Important species of such habitats are *Cochlearia groenlandica*, *Melandrium triflorum* and *Stellaria humifusa*, as well as *Cerastium alpinum* and *Artemisia borealis*.

Syntaxonomy, nomenclature, synecology and distribution of the communities are discussed. All are known from southern regions along the west and east coasts of Greenland (cf. Böcher 1954, de Molenaar 1974, Vestergaard 1978). Some occur also in Northeast Greenland (Fredskild 1998).

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THE RUSSIAN GEOBOTANICAL LAYERS IN THE CAVM

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The Russian part of the Circumpolar Arctic Vegetation Map (CAVM) was divided by B. Yurtsev into 11 floristic provinces, based on the floristic differences between regions. The largest floristic province is the Taimyr, and the smallest is the Kharaulakh. The Russian Arctic is also divided latitudinally into five bioclimatic subzones. The climatic conditions of each subzone define their geobotanical features, such as vertical and horizontal structure of plant cover, total phytomass, and major plant growth forms. Figure 1 shows the percent of the area of the Russian Arctic in each subzone, divided by mountains (shaded) and lowlands (not shaded). Subzone E comprises almost half of the Russian Arctic area (41.7 %).

Bioclimatic subzones were divided into map units according to the landscape map of Arctic Russia. The phytocenose, or zonal plant community, grows in a homogeneous area with homogeneous structure, lithology and soil moisture. These homogeneous areas were the basis for mapping the Russian portion of the CAVM, along with geological, geomorphological, geobotanical and other maps, and remote sensing imagery.

Initially the vegetation map of the Russian Arctic consisted of more than 100 types. These were combined into 15 dominant units by plant growth form. Less common types and inclusions are included in the detailed description of the vegetation units. The complex mix of vegetation along riparian corridors is an important element of the Russian Arctic. Because of the small scale of the map, these corridors could only be indicated by a line on the CAVM.

The set of map units vary by subzone according to general climate differences. Additional variation is caused by differences in surface geology and soil moisture conditions. More complex landscapes are geobotanically more heterogeneous. This is illustrated by two fragments of the CAVM located in similar climatic conditions. The landscape of the Yana-Kolyma lowland is geomorphologically and geologically homogeneous, composed of widespread foothill plain landscapes mixed with alluvial and lacustrine-alluvial sediments with various lithologies (Figure 2). As a result, geobotanical conditions of this province are also homogeneous. The Taimyr Peninsula has a very complex landscape structure. Low plains, high plains and mountains are all found here (Figure 3). Consequently, numerous vegetation types occur in this area.

Creation of the planimetric landscape map with detailed characteristics for each type (bioclimatic zone, landscape genesis and age, lithology), has allowed us to manipulate the information and to create original vegetation maps for specific purposes.

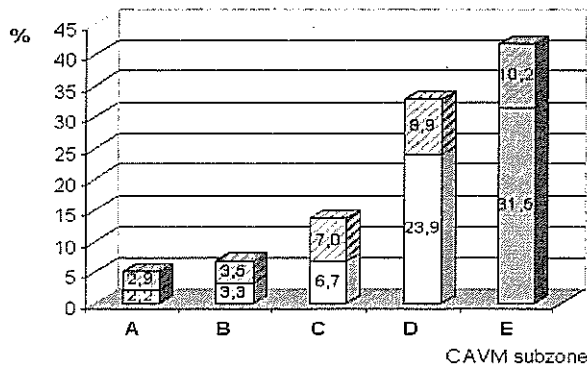


Figure 1. Relative frequency of Russian Arctic subzones

Figure 2. Landscape structure of the Yana-Kolyma lowland.

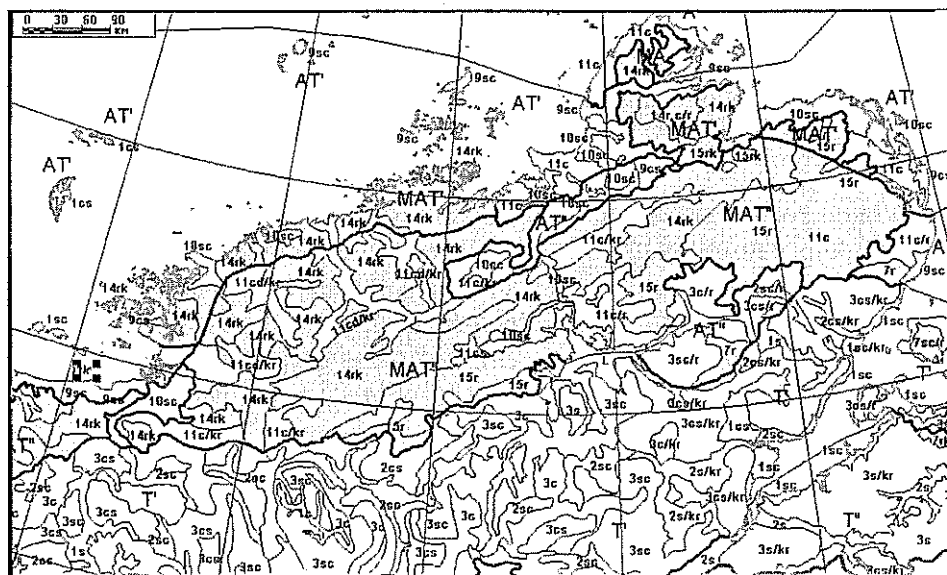
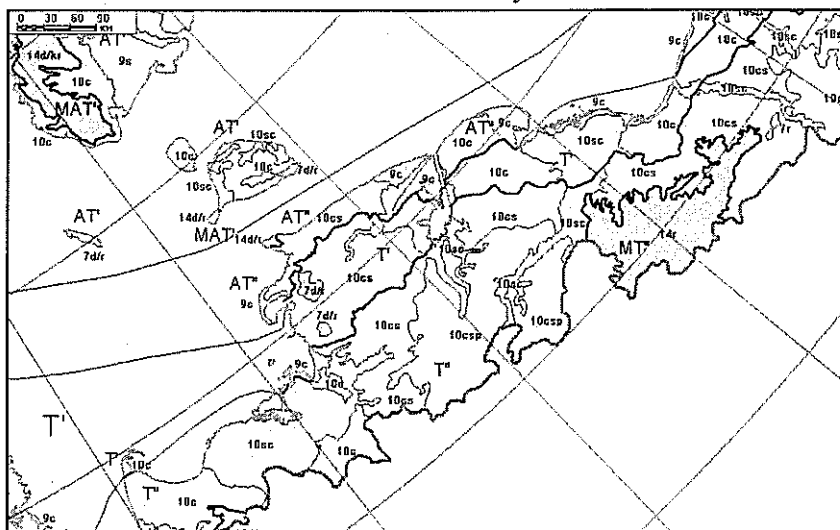


Fig.3. Taimyr landscape structure

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LANDCOVER MAPPING IN THE ARCTIC BY THE U. S. GEOLOGICAL SURVEY

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The U.S. Geological Survey has performed a number of different remotely-sensed based land cover mapping projects in the Arctic, particularly in Arctic Alaska. Aerial photographs have been used to collect detailed information over small- to medium-sized areas. They are utilized as standard management tools and can be obtained using equipment ranging from hand-held 35-mm cameras to precision metric mapping cameras. More recently, satellite data have become equally, if not more important. They offer synoptic views of landscapes at a wide variety of scales, digitally or manually interpreted; and are easily merged with other digital data bases. They include sensors that range from moderately high resolution (ASTER [15-m], SPOT [20-m]), medium resolution (Landsat MSS [50-m] and Landsat TM [30-m]), to low resolution (AVHRR [1 km]). Information from both types of sensors have provided and will continue to provide baseline land cover and land use data for research, conservation, management, and planning of U.S. Geological Survey activities in the Arctic. Currently, these data are being used to perform a multi-temporal/multi-resolution land cover mapping project in the Teshekpuk Lake area of the Alaskan Arctic coastal plain (Figure 1).

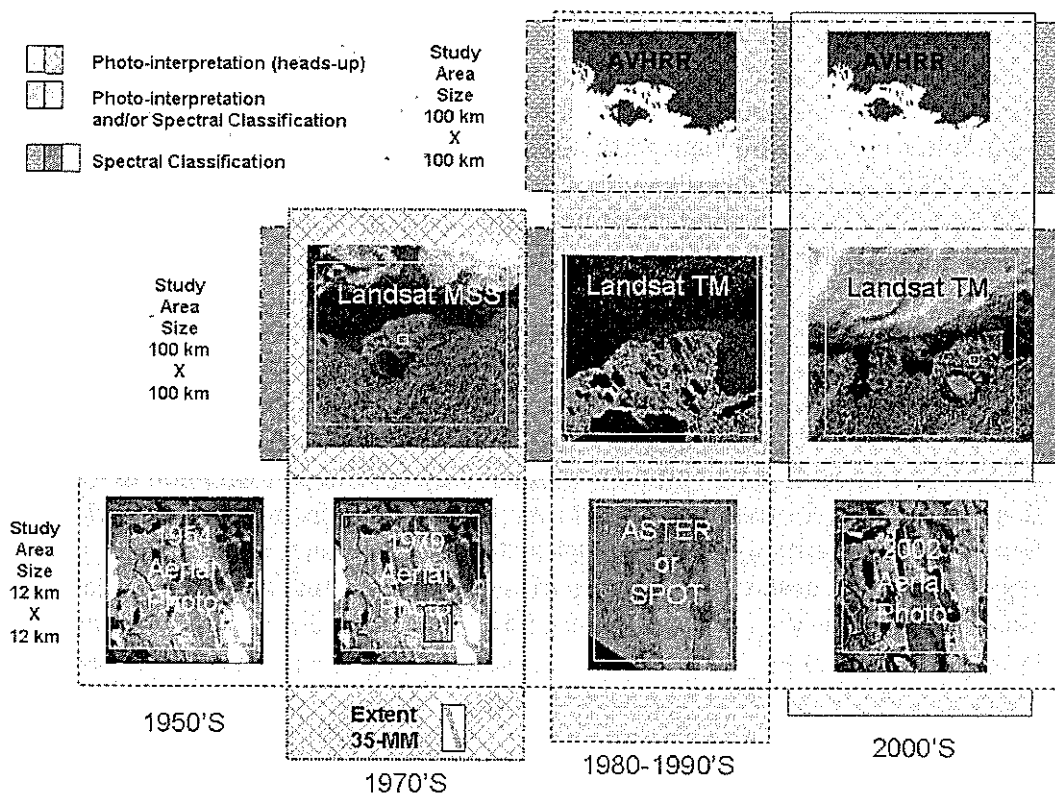


Figure 1. Use of multiple temporal periods, data types, and scales to study the effects of time and scale on mapping arctic tundra types.

CLASSIFICATION OF POLAR DESERT VEGETATION: AVAILABLE DATA, PROBLEMS AND PERSPECTIVES

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The first step before classifying the vegetation of the polar desert zone is delimiting its territory following criteria suggested by arctic vegetation scientists who consider it a separate zone. I follow Aleksandrova (1971, 1980, 1983, 1988) both in the use of the name – polar desert zone - and in the territory that includes in the Eurasian part of the Arctic ocean: North-Eastern Land (Svalbard), Franz-Josef Land, the northernmost parts of Novaya Zemlya, as well as Victoria, Vize, Ushakov and Uedineniya islands within the Barentz province, Severnaya Zemlya and DeLong archipelagos, and the northernmost Taymyr Peninsula (Cape Chelyuskin) within the Siberian province; the narrow strip of Peary Land in Greenland (Bay 1997), a few small northern islands of the Elisabeth Islands and the northernmost part of the Ellesmere Island in Canada (Edlund 1990, CAVM Team 2003). The name used for this zonal subdivision unit on the Circumpolar Arctic Vegetation Map (CAVM Team 2003) was "bioclimatic subzone A".

Polar deserts were distinguished as a separate zone in the past when there was little information on its vegetation. The situation has changed significantly since that time. The most detailed data are 70 relevés for Franz Josef Land (Aleksandrova 1983). A few relevés were published for Cape Cheluskin (Matveyeva 1979) and Oktyabrskoi Revolutsii Island (Korotkevich 1972; Khodachek 1986). A few relevés with obviously incomplete cryptogamic data were published for the northernmost fringe of Greenland (Bay 1997) and some islands in the Canadian Arctic (Bliss & Svoboda 1984, Bliss et al. 1984). All this is not a good situation for the classification of vegetation of the northernmost part of the Arctic.

Another problem concerns the composition of plant communities, which in general have low species diversity (poor local and regional floras), and the wide ecological range of the majority of species. Together these facts lead to the absence of good character and differential species, which makes it difficult to differentiate syntaxa. Also important are the changes in ecological optimum of many key species as compared to the tundra zone; this prevents the formal inclusion of new syntaxa into the existing classification system according to the Braun-Blanquet approach. The combinations of species growing together in polar desert communities differ from those that now are included in the tundra class *Loiseleurio-Vaccinietea* Egger 1952. Thus there is a necessity of the creation of new upper level units, for the zonal vegetation of the polar deserts (Elvebakk 1985, 1994; Daniëls et al. 2000).

Problems arise with naming new syntaxonomical units because many new syntaxa at the association (or subassociation) level in polar deserts are the "starting" or "core" units of the previously described syntaxa in southern (alpine) regions. These are rich in non-arctic and often even non-alpine species. It would be reasonable to use arctic species already employed in the names of the southern syntaxa, however, history cannot be changed and new, more appropriate names should be found.

New data on polar desert vegetation were recently gathered on Bolshevik Island (Severnaya Zemlya Archipelago). The information on 250 relevés that belong to 22 syntaxonomical units (14 associations, 2 subassociations and 6 communities types) are presented at the meeting and will be published in the journal "Vegetation of Russia" in 2004. The next step will be to classify the Franz Josef Land data using the Braun-Blanquet approach and to compare it with the Bolshevik Island data and all available relevés (or text information) from Oktyabrskoi Revolutsii Island and other small islands within the Eurasian part of the Arctic. This would include all available information on polar deserts within the Russian Arctic.

The polar deserts of the Canadian Arctic are even more poorly known; however, it is reasonable to assemble all published data and to attempt to classify them into an existing system. It would be very desirable to visit some islands in Canada and describe them in the same detailed way as was done for Bolshevik Island and Franz Josef Land, at least for the widespread communities. Only if this work is accomplished will it be possible to return to the discussion of the status of polar deserts in a global, zonal context.

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RECENT ADVANCES IN LANDSCAPE MAPPING IN RUSSIA

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A landscape map of the Russian Arctic Region was produced at the Earth Cryosphere Institute. This map synthesizes a great deal of information on the composition, structure and properties of natural geosystems, including permafrost temperatures, exogenic geological processes, hydro-meteorological parameters, and data from satellite images and published maps of the Arctic Region of Russia (Bedrock Geology map, 1966; Engineering-geological map, 1972; Map of the Quarternary Geology, 1976; Landscape map, 1980; Vegetation map, 1990; Soil map, 1995).

The landscape map was compiled using the geosystem approach (Melnikov et al 1991). The natural geosystems shown on the landscape map will be used for compiling derivative maps. Interactions between landscapes and their components (relief, vegetation, soil etc.) were used to update the earlier compiled landscape map and adapt it for theme mapping. For example, the landscape map was adapted to problems of geobotanical mapping. Three groups of landscapes were differentiated according to geochemical properties of rocks that are important to vegetation (acidic, not acidic and saline).

GIS technology was used to compile the landscape map. PARADOX and regional and local GIS databases were developed using the GEODRAW/GEOGRAPH and ARCINFO/ARCVIEW software programs. This allows digital synthetic and topical maps to be rapidly produced using geocryological, landscape and geobotanical information registered to the primary cartographical data.

The landscape database includes attributes as shown on the legend to Figure 1: 1) Zonal (from high arctic to southern hypoarctic tundra) and altitudinal landscape units (plains and mountains), 2) Morphogenetic groups and landscape varieties, and 3) Lithology. The morphogenetic groups are based on level areas with similar elevation. Low plain landscapes were created mainly by recent marine submergence, and high plains by recent emergence. Marine, alluvial, fluvial, lacustrine and glacial landscapes are distinguished by the genesis of the deposits composing them. Six different lithology types are shown (peat, clay or silt, sand, coarse clastic deposits bedrock, karst-susceptible bedrock). Modifying symbols indicate saline soils, acidic magmatic bedrock, and mafic bedrock. A fragment of this map is shown in Figure 1.

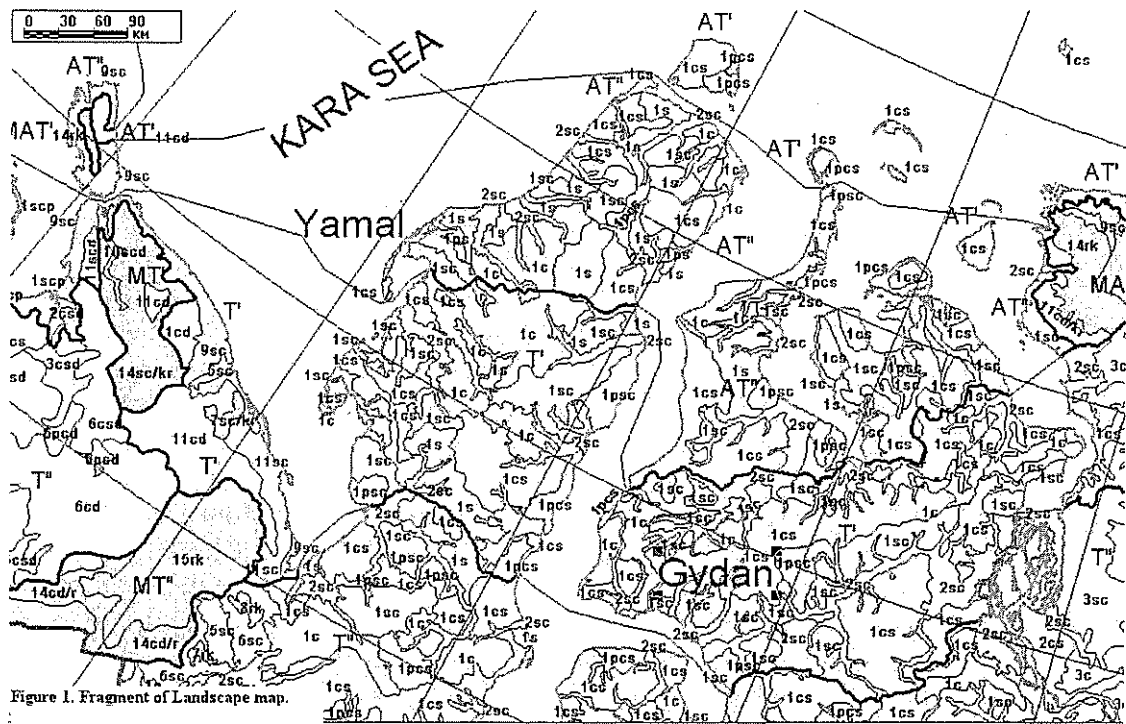


Figure 1. Fragment of Landscape map.

1. Zonal, subzonal & altitudinal-longitudinal landscape units

- A. Plains
- AT⁰ - high arctic tundra (subzone 1)
 - AT¹ - northern arctic tundra (subzone 2)
 - AT² - southern arctic tundra (subzone 3)
 - T¹ - northern hypoarctic tundra (subzone 4)
 - T² - southern hypoarctic tundra (subzone 5)
- B. Mountains
- MA - mountains high arctic tundra (subzone 1)
 - MAT¹ - mountains arctic tundra (subzone 2)
 - MAT² - mountains arctic tundra (subzone 3)
 - MT¹ - mountains northern hypoarctic tundra (subzone 4)
 - MT² - mountains southern hypoarctic tundra (subzone 5)
 - MFT¹ - mountains northern forest tundra (silvnik; subzone 6)

2. Morphogenetic groups & landscape varieties

- A. Landscapes of low plains created by most recent submergence:
- 1 - marine and icy-marine (m, gm)
 - 2 - fluvial, lacustrine-fluvial and lacustrine (a, l, la)
 - 3 - glacial (til) and glacioluvial (g, f)
- B. Landscapes of high plains and plateau, created by most recent emergence:
- 5 - fluvial, lacustrine-fluvial and lacustrine (a, l, la)
 - 6 - glacial (til) and glacioluvial (g, f)
 - 7 - erosional-denudational
 - 8 - landscapes of tablelands and plateaus with a prevalence of most recent upwarping and block emergence
- C. Landscapes of intermontane and foothill plain
- 9 - marine (m)
 - 10 - fluvial, lacustrine-fluvial and lacustrine (a, l, la)
 - 11 - glacial (til) and glacioluvial (g, f)
 - 12 - deluvial, alluvial-proluvial and solifluctional (d, ap, s)
 - 13 - accumulative undifferentiated

D. Landscapes of mountains (low, middle and high)

- 14 - erosional-denudational mekosopctnik
- 15 - table mountain, mountains of denudation, mountain ranges and chain

TYPES OF LITHOGENIC BASES OF LANDSCAPE

- A. Unlifted rocks (soils)
- p - peat
 - s - sand
 - c - clay and silt
 - d - coarse clastic deposits (debris)
 - - saline ground (white pattern 45 grad. on original background)

- B. Lifted rocks:
- r - bedrocks
 - k - karst-able bedrocks

Combinations of letters indicate composition of soils or rocks (cs), or overlaying of soils over rocks (c/r). Symbols are listed in order of rock (soil) predominance.

- Only for magmatic rock:
- - acid and mafic magmatic bedrocks (white vertical lines on original background)
 - - acid magmatic bedrocks (white pattern 90 grad. on original background)

4. Boundaries
- zonal, subzonal and altitudinal-longitudinal landscape types and subtypes
 - morphogenetic landscape varieties and types of lithogenic base of landscapes
 - north forest boundary
 - - Glacier
 - - Lake

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A PLANT COMMUNITY MAP OF WEST SIBERIA

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A plant community map of West Siberia was based of the following cartographical sources: Vegetation Map of USSR, scale 1:4,000,000 (Belov 1990), Vegetation Map of the Yamal-Nenetzky National District, scale 1:1,000,000 (Avramchik 1961), Vegetation Map of the West-Siberian Plain, scale 1:1,500,000 (Sochava 1976), and materials from long-term field work by the author (Moskalenko 1999). A portion of the map is shown in Figure 1.

The Integrated Map of Landscape Units of the Russian Arctic was used as the cartographic basis for the plant community map of West Siberia, according to the method proposed by Walker (1999) for the Circumpolar Arctic Vegetation Map. The legend for the plant community map is based on specially compiled look-up tables containing information on dominant plant communities occurring in different landscape conditions. The legend is organized on the zonal principle: characterization of plant communities is based on subdivisions of the Arctic Tundra bioclimatic zone (Table 1). Sometimes a plains landscape can be characterized by a single predominant type of tundra vegetation. More often, landscapes are characterized by a particular combination of different types of tundra vegetation. Vegetation descriptions are accompanied by brief characterizations of environmental conditions (moisture conditions, character of the substrate).

The relatively simple and homogenous geological history of the West Siberia Plain affects the character of the vegetation. A clear dependence of vegetation on climatic conditions, with well-expressed latitudinal zonation is observed. For example, sedge-moss tundras of the Arctic subzones dominated by *Carex arctisibirica* and *Aulacomnium turgidum* in moist acidic clayey and sandy sites, are replaced in the Northern Hypoarctic subzone by hemiprostrate dwarf shrub-sedge-moss tundras dominated by *Betula nana*, *Carex arctisibirica*, *Dicranum congestum* and *Aulacomnium turgidum*. Hemiprostrate dwarf shrub-moss-lichen tundras dominated by *Betula nana*, *Salix pulchra*, *Aulacomnium turgidum*, and *Cladina stellaris* occupy similar sites in the Southern Hypoarctic subzone. In Hypoarctic subzones, these tundras usually form complexes with tussock cotton grass-moss tundras (*Eriophorum vaginatum*, *Sphagnum lenense*, *S. balticum*).

Analysis of the map shows that the vegetation of regions covered by the map identifies essential floristic and physiognomy differences caused by geological and climatic features of this region. Only mire and halophytic plant communities in different subzones demonstrate significant similarity.

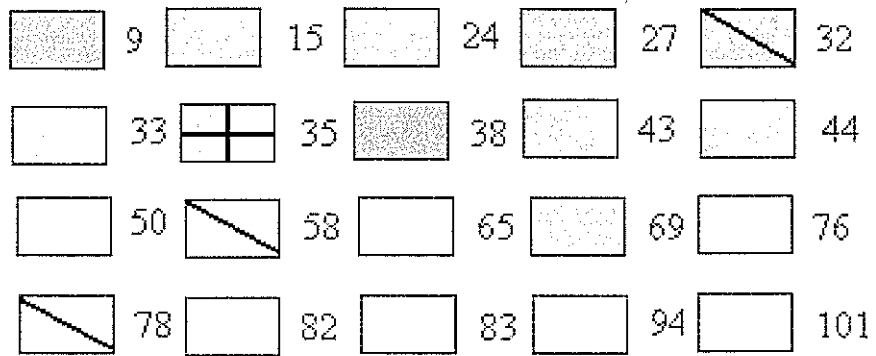
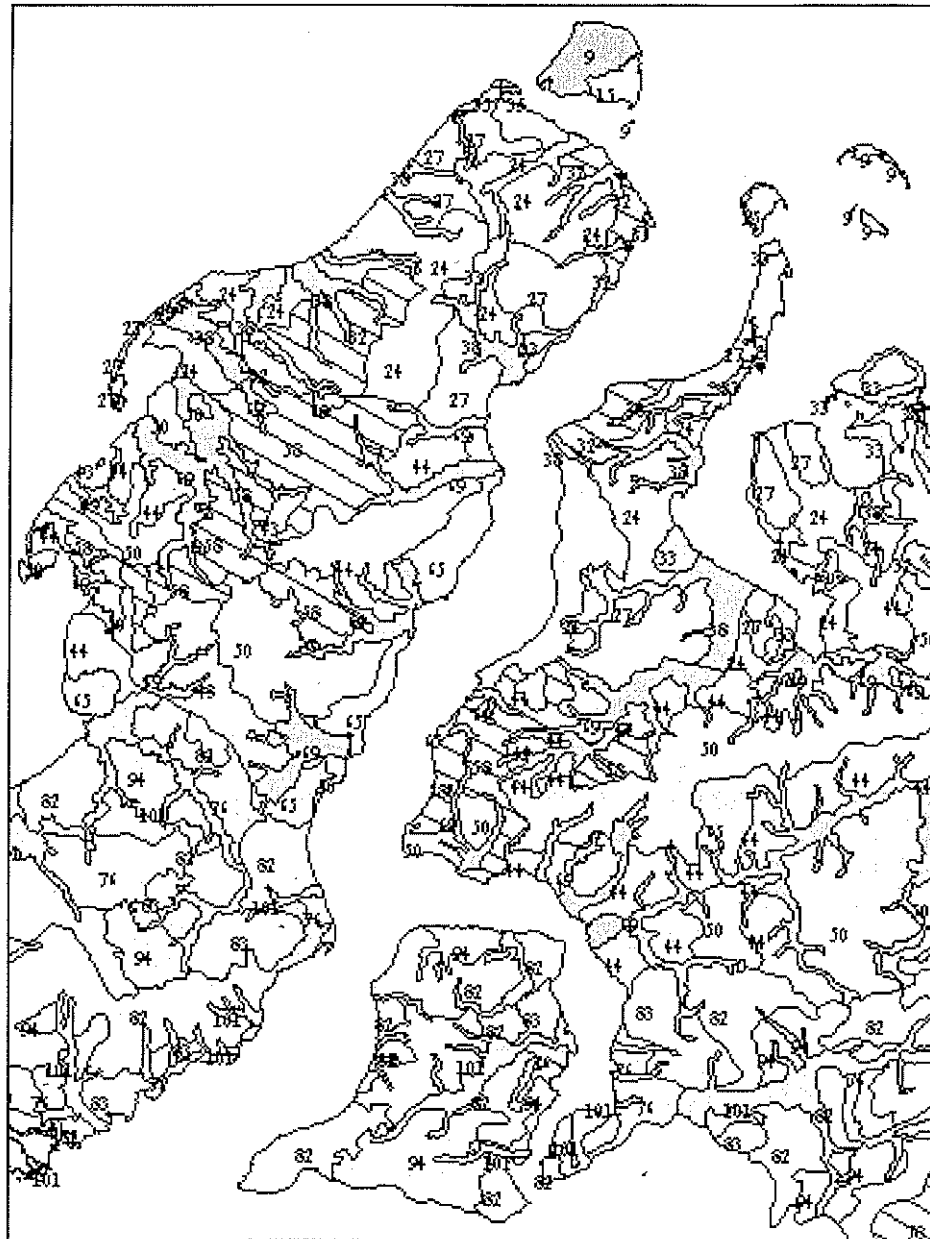


Figure 1. Plant community map of West Siberia.

Table 1. Legend of the plant community map of West Siberia

Map unit	Description	Community 1	Community 2
Zone B Northern arctic tundra			
9	Moist acidic moss-sedge tundra	Aulacomnium turgidum-Carex arctisibirica	
15	Wet acidic moss-sedge mire	Calliergon sarmentosum-Carex stans+Eriophorum polystachion	
Zone C Southern arctic tundra			
24	Dry acidic prostrate dwarf shrub-sedge-lichen tundra with psammophytes	Salix nummularia-Carex arctisibirica-Alectoria ochroleuca	Cetraria cucullata +Dicranum elongatum-Hierochloe alpina
27	Moist acidic sedge-moss tundra	Carex arctisibirica-Aulacomnium turgidum	
32	Moist nonacidic and acidic prostrate dwarf shrub-sedge-moss tundra	Dryas subincisa+Salix polaris-Carex arctisibirica-Dicranum elongatum	
33	Wet acidic sedge-grass-moss mire	Carex stans-Calliergon sarmentosum+Drepanocladus exannulatus	Carex stans+Eriophorum polystachion-Calliergon sarmentosum+Sphagnum squarrosum
35	Wet saline grass-sedge meadows	Puccinellia phryganodes-Carex subspathacea	
38	Riparian acidic sedge-moss bogs and willow-forb shrublands	Carex stans+Eriophorum polystachion-Calliergon sarmentosum	Salix glauca-Pedicularis sudetica
Zone D Northern hypoarctic tundra			
43	Dry acidic dwarf shrub-lichen tundra with psammophytes	Salix nummularia+Dryas subincisa -Cetraria cucullata	
44	Dry acidic dwarf shrub-grass-moss-lichen tundra	Ledum decumbens-Vaccinium minus-Cetraria cucullata + Racomitrium lanuginosum	
50	Moist acidic low shrub-sedge-moss tundra	Betula nana-Carex arctisibirica - Dicranum congestum + Aulacomnium turgidum	Eriophorum vaginatum-Sphagnum lenense
58	Moist nonacidic prostrate dwarf shrub-low shrub-forb-moss tundra	Dryas punctata-Saxifraga nelsoniana-Dicranum congestum	Salix glauca+Salix lanata-Petasites frigidus-Aulacomnium palustre
65	Wet acidic sedge-dwarf shrub-moss mire	Carex aquatilis-Drepanocladus exannulatus + D. fluitans	Ledum decumbens-Carex stans-Sphagnum lenense
69	Riparian acidic sedge-moss mire and low shrub-sedge-moss tundra	Carex stans-Drepanocladus revolvens-Calliergon giganteum +Meesia triquetra	Salix lanata+Salix glauca-Calamagrostis neglecta + Carex stans-Aulacomnium turgidum + Tomentypnum nitens
Zone E Southern hypoarctic tundra			
76	Dry acidic dwarf shrub-sedge-lichen-moss tundra with psammophytes	Ledum decumbens-Vaccinium vitis-idaea +Empetrum subholarcticum-Cladina mitis	Dryas subincisa-Carex arctisibirica-Cladina rangiferina+Racomitrium lanuginosum
78	Dry nonacidic low shrub-prostrate dwarf shrub-forb-lichen-moss tundra	Dryas subincisa+Diapensia lapponica-Pedicularis sudetica-Alectoria ochroleuca+Racomitrium lanuginosum	Salix glauca+S. lanata-Petasites frigidus-Aulacomnium palustre

82	Moist acidic dwarf shrub-sedge-moss-lichen tundra	Betula nana + Salix pulchra-Aulacomnium turgidum +Cladina stellaris	Eriophorum vaginatum-Dicranum elongatum +Sphagnum balticum
83	Moist acidic dwarf shrub-low shrub-forb-moss-lichen tundra	Betula nana-Dryas punctata-Aulacomnium turgidum+Cladina stellaris	Salix lanata-Vaccinium microphyllum-Polemonium acutiflorum-Aulacomnium palustre
94	Wet acidic low shrub-dwarf shrub-sedge-forb-moss-lichen mire	Salix lapponicum-Betula nana-Carex aquatilis-Calliergon stramineum+ Sphagnum lindbergii	Ledum palustre+Eriophorum vaginatum-Rubus chamaemorus-Sphagnum fuscum+Cladina stellaris
101	Riparian acidic sedge-moss mire and grass-forb-sedge-moss shrublands	Carex aquatilis+Eriophorum polystachion-Calliergon stramineum	Salix lanata-Calamagrostis langsdorfii-Pedicularis sudetica-Carex aquatilis-Aulacomnium turgidum+ Drepanocladus uncinatus

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OLIGOTROPHIC VEGETATION IN CENTRAL SCANDINAVIAN MOUNTAINS – GRADIENTS IN SPECIES AND COMMUNITY DISTRIBUTION

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Fennoscandian alpine vegetation has been studied for more than a century (Økland & Bendiksen 1995, Haapaasari 1998). In this traditional approach, regional vegetation descriptions were recorded based on quadrat analyses in homogenous stands, and phytosociological classifications were made. From these studies, the main patterns in vegetation composition and species distribution along important ecological gradients became well known, but a comparison of these vegetation communities at different phytosociological levels had not been performed.

The present study is based on a compilation of earlier published data, stratified to include only oligotrophic/ mesotrophic forest-, heath- and snow-bed communities from the southern part of the Scandinavian mountains. In total 305 described communities with data from more than 2200 stands and 4800 quadrates are included. The sampling unit analysed here are the described communities which have both species frequencies and mean cover degrees. On the basis of these data, an importance value ($IV = \square \text{ Frequency of the species in the community} * \text{ species mean cover (Hult-Sernander scale)}$) was calculated for each species in each community.

The main objective of the present study are to: 1) quantify similarities and dissimilarities between previously described mountain vegetation communities using indirect gradient analysis (DCA) (ter Braak & Smilauer 1998) and classification (TWINSPAN) (Hill 1979), 2) compare the results in relation to previously proposed phytosociological classification of the Scandinavian mountain vegetation, 3) interpret the main gradients in the data, and 4) analyse the response of species along the main ordination axis.

The main DCA gradient is interpreted to represent differences in snow-cover, and the second axis a complex gradient in soil thickness, soil moisture and altitude. The main gradient separating the three community clusters was the amount of exposed lichen and ericaceous-dominated communities, graminoid- and *Salix herbacea* dominated communities, and extreme moss-dominated snow-beds. This indicates that the sampling procedures separated three main clusters which are mostly associated with snow layer duration. The second most important gradient separated mainly mesic from xeric communities (sensu Økland & Bendiksen 1985). Using a general linear model (GLM) for each of the 258 taxa, showed that the widths of the response curves were highly variable, indicating variable degree of tolerance.

This study shows that the occurrences of species in different mountain communities can be used as indicators for different positions along the main mountain vegetation gradient, but many species have large (more than 1 SD units) tolerances.

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PLANT COMMUNITY-LEVEL MAPPING OF ALASKA BASED ON THE CIRCUMPOLAR ARCTIC VEGETATION MAP

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Fifteen cover types appear on the Circumpolar Arctic Vegetation Map (CAVM), 12 of which occur in Alaska. These cover types are circumpolar in distribution, and are described on the basis of the growth forms of the plants that characterize each type. More detailed plant-community-level information is available for much of the Arctic. This paper demonstrates an approach for displaying this information, using Alaska as an example.

In the process of creating the CAVM, the variation in communities between different floristic provinces was captured in tables that listed dominant plant communities for each of five topographic positions (dry exposed sites, moist sites, wet sites, snowbeds, and riparian areas) in each subzone within each floristic province (Walker et al. 2002). The three tables for the Alaska floristic provinces: Northern Alaska, Beringian Alaska, and North Beringian Islands, were combined into one table, listing the communities occurring on each of the topographic positions on acidic and nonacidic substrates in each subzone. The Braun-Blanquet association (if known), common and characteristic species, and the literature citation for the community description are included in the table. A portion of this table describing 83 Alaskan arctic plant communities is shown in Table 1.

Each polygon on the CAVM was re-coded with a label that contains the original CAVM cover type, followed by a numerical suffix denoting the dominant community (Figure 1). The legend for the map (Table 2) describes the physiognomy of the unit, and references the appropriate community in Table 1. A total of 33 map units are now displayed for Alaska, compared to the original 12 cover types on the CAVM.

Two map units were stippled to portray differences in edaphic characteristics: G4.1, tussock tundra on a sandy substrate on the Arctic Coastal Plain, and W3.2, slightly brackish wet sedge on the coast of the Yukon-Kuskokwim Delta.

The largest polygon on the CAVM map of Alaska covers the wetlands of the Yukon-Kuskokwim Delta. This polygon was divided into four types (Figure 2). A slightly-brackish type (W3.2) occurs along much of the coast. Farther inland, increases in elevation and age of the landscape, and changes in hydrologic characteristics are accompanied by changes in sedge species. Unit W3.3 has inclusions of uplifted ice-rich permafrost areas with drier lichen-shrub vegetation. The wetlands along the Yukon and Kuskokwim Rivers are a complex of productive wet sedge meadows and tall shrub thickets, with a bright red AVHRR signature. The type that occurs farthest inland (W3.5) is most similar to wet sedge types in other parts of Subzone E.

The map and toposequence table portray the variation in communities found within the CAVM cover types in Alaska. Although too large to include in this abstract, the full table and 1:4 million -scale map are available from the author. Similar tables were

created for all parts of the Arctic as part of process of creating the CAVM; and can be used by the CAVM mappers to construct community level maps for other parts of the Arctic. Application of this method to the circumpolar extent of the CAVM would result in valuable detailed information on regional variation within the 15 cover types.

Table 1. Excerpt from Table of Alaska communities by bioclimate subzone, topographic position, and substrate type. The full table includes 95 community descriptions.

Alaska Subzone C (North Slope Coastal Plain, Northern Alaska)

Habitat along the meso-topographic gradient	Acidic substrates (community # 1-7)	Non-acidic substrates (community # 8-12)
Dry exposed sites	1. Prostrate dwarf shrub (<i>Salix rotundifolia</i>), lichen (<i>Alectoria nigricans</i> , <i>Bryocaulon divergens</i> , <i>Dactylina arctica</i>), rush (<i>Luzula confusa</i> , <i>L. arctica</i>), grass (<i>Arctagrostis latifolia</i>), forb (<i>Potentilla hyparctica</i> , <i>Pedicularis lanata</i>), bryophyte (<i>Polytrichum strictum</i> , <i>Dicranum elongatum</i> , <i>Gymnomitrium coralloides</i>) Nodum II, Webber 1978; <i>Sphaerophorus globosus-Luzula confusa</i> subtype <i>Salix rotundifolia</i> , Elias et al. 1996 (Barrow, dry beach and river terraces)	8. Prostrate dwarf shrub (<i>Dryas integrifolia</i>), sedge (<i>Carex rupestris</i>), lichen (<i>Lecanora epibryon</i> , <i>Thamnolia subuliformis</i>) Type B12, Walker, 1985; probably = Unit 18 this table (coastal dry nonacidic gravelly sites)

Table 2. Legend for the map of dominant plant physiognomy of Alaska tundra plant communities

Map Unit	Dominant physiognomy and plant communities
B2.1	Lichen communities on recent lava flows. Complex of community 72 and unvegetated lava; in mosaic with areas not covered by lava (comm. 73), Seward Peninsula.
B3d.1	Graminoid, prostrate dwarf-shrub communities (comm. 14), in complex with snowbeds, talus slopes and meadow communities, on frost-riven granite, St. Lawrence Island.
B3e.1	Prostrate dwarf-shrub, graminoid communities on acidic slopes (comm. 35, 36), in complex with snowbeds (comm. 60, 61), talus slopes and meadow communities, Brooks Range, Alaska.
B3e.2	Prostrate dwarf-shrub, lichen communities on dry granitic slopes (comm. 39), in complex with snowbeds (comm.62), talus slopes and meadow communities, Seward Peninsula and Northwestern Alaska.
B3e.3	Erect dwarf-shrub, lichen communities on dry acidic slopes (comm. 40), in complex with snowbeds, talus slopes and meadow communities, Kuskokwim Mountains, Alaska.
B4d.1	Prostrate dwarf shrub, forb, lichen communities (comm. 26) in complex with snowbeds (comm. 30, 31), talus slopes and meadow communities, on dry limestone slopes, York Mountains, Seward Peninsula, Alaska.
B4d.2	Graminoid, dwarf shrub communities, moist areas on Pleistocene lava of the Kookooligit Range, St. Lawrence Island (comm. 28).
B4e.1	Prostrate dwarf-shrub, sedge communities (comm. 70) in complex with snowbeds (comm. 77, 78), talus slopes and meadow communities, on dry limestone slopes, Brooks Range, Alaska.
B4e.2	Prostrate dwarf-shrub, forb, lichen communities (comm. 71) in complex with snowbeds, talus slopes and meadow communities, on dry limestone slopes, Seward Peninsula and Northwestern Alaska.
G3.1	Non-tussock sedge, dwarf shrub, moss communities on the non-acidic portions of Subzone D, northern coastal plain, Alaska (comm. 27)

G3.2	Graminoid, prostrate dwarf -shrub, forb communities on mesic areas of St. Lawrence Island, Alaska (comm. 18).
G3.3	Non-tussock sedge, dwarf shrub, forb, moss communities on non-acidic portions of Subzone E, foothills of the Brooks Range and portions of the Seward Peninsula, Alaska (comm. 73).
G4.1	Tussock sedge, dwarf shrub, moss communities on sand in Subzone D, northern coastal plain, Alaska (comm. 16). stippled
G4.2	Tussock sedge, dwarf shrub, moss communities on loess, foothills of the Brooks Range, Seward Peninsula, ice-rich permafrost areas of Yukon-Kuskokwim Delta, and foothills of the Kuskokwim Mountains, Alaska (comm. 41).
G4.3	Graminoid, dwarf-shrub communities. Successional gradient of fire-dominated tussock sedge communities, ranging from grass-dominated (soon after fire, comm. 44) to communities similar to tussock tundra to the north and south (comm. 41), to lichen-ri
P2.1	Prostrate dwarf-shrub lichen communities on St. Matthew Island, Alaska. Community 15 on dry flats, slopes and ridges, with large areas of sedge, prostrate dwarf- shrub tundra (comm. 19).
S1.1	Erect dwarf-shrub communities on the foothills of the Brooks Range, Alaska (comm. 42).
S1.2	Erect dwarf-shrub, lichen communities on the foothills of the mountains of the Seward Peninsula, Alaska (comm. 46).
S1.3	Erect and prostrate dwarf-shrub communities on volcanic outcrops in the Yukon Delta area, Alaska (comm. 47), commonly in complexes with rock outcrops and low shrub drainages (comm. 43).
S1.4	Erect dwarf-shrub, lichen communities on the foothills of the Kuskokwim Mountains (comm. 48), commonly in complexes with rock outcrops and low shrub drainages (comm. 43).
S2.1	Low-shrub communities with open to closed canopies of willows, birch or alder, in valleys and foothills of the Brooks Range, Seward Peninsula mountains, and Kuskokwim Mountains, Alaska (comm. 43).
W1.1	Wet graminoid, moss communities on acidic coastal areas in northern Alaska (comm. 4), with moist communities (comm. 2) on higher microsites.
W1.2	Wet graminoid, moss communities on nonacidic coastal in northern Alaska (comm. 10), with moist communities (comm. 9) on higher microsites.
W2.1	Wet sedge, moss communities on acidic northern coastal plain and northern Seward Peninsula, Alaska (comm. 20), with moist communities (G4.1, comm. 16) on higher microsites.
W2.2	Wet sedge, moss communities on nonacidic northern coastal plain, lagoons and estuaries on northern coast of Seward Peninsula, Alaska (comm. 29), with moist communities (G3.1, comm. 27) on higher microsites.
W3.1	Wet sedge, moss communities on acidic areas of the Seward Peninsula and Selawik Basin, Alaska (comm. 52), with moist communities (G4.2, comm. 41) on higher microsites.
W3.2	Wet sedge communities (comm. 53), in slightly saline coastal areas, in complex with water, Yukon-Kuskokwim Delta, Alaska. stippled
W3.3	Wet sedge communities (comm. 54), in complex with ponds, and drier lichen-ericaceous dwarf shrub vegetation (S1.2, comm. 46) in central portions of the Yukon-Kuskokwim Delta, Alaska.
W3.4	Wet sedge communities (comm.55) in complex with shrub thickets (comm. 68) along rivers on the Yukon-Kuskokwim Delta, Alaska.
W3.5	Wet sedge communities (comm. 55) in complex with lakes and drier tussock graminoid -shrub communities (G4.2, comm. 41) in interior portions of the Yukon-Kuskokwim Delta, Alaska.
W3.7	Wet sedge, prostrate dwarf-shrub communities on Nunivak Island, Alaska (comm. 59).
W3.6	Wet sedge, moss communities on nonacidic areas of the North Slope, Seward Peninsula, Alaska (comm. 75) with moist communities (G3.3, comm. 73) on higher microsites.

Acknowledgements: Funding for this project came from NSF Grant # OPP-9908-829. Thanks to Carl Markon, Stephen Talbot, M.Torre Jorgenson, Gerald Tande, Kate Doran, Brian Person and Chris Babcock for input on vegetation of the Yukon-Kuskokwim Delta. Thanks also to Daniel Ruthrauff and David Klein for input on the vegetation of St. Matthew Island.

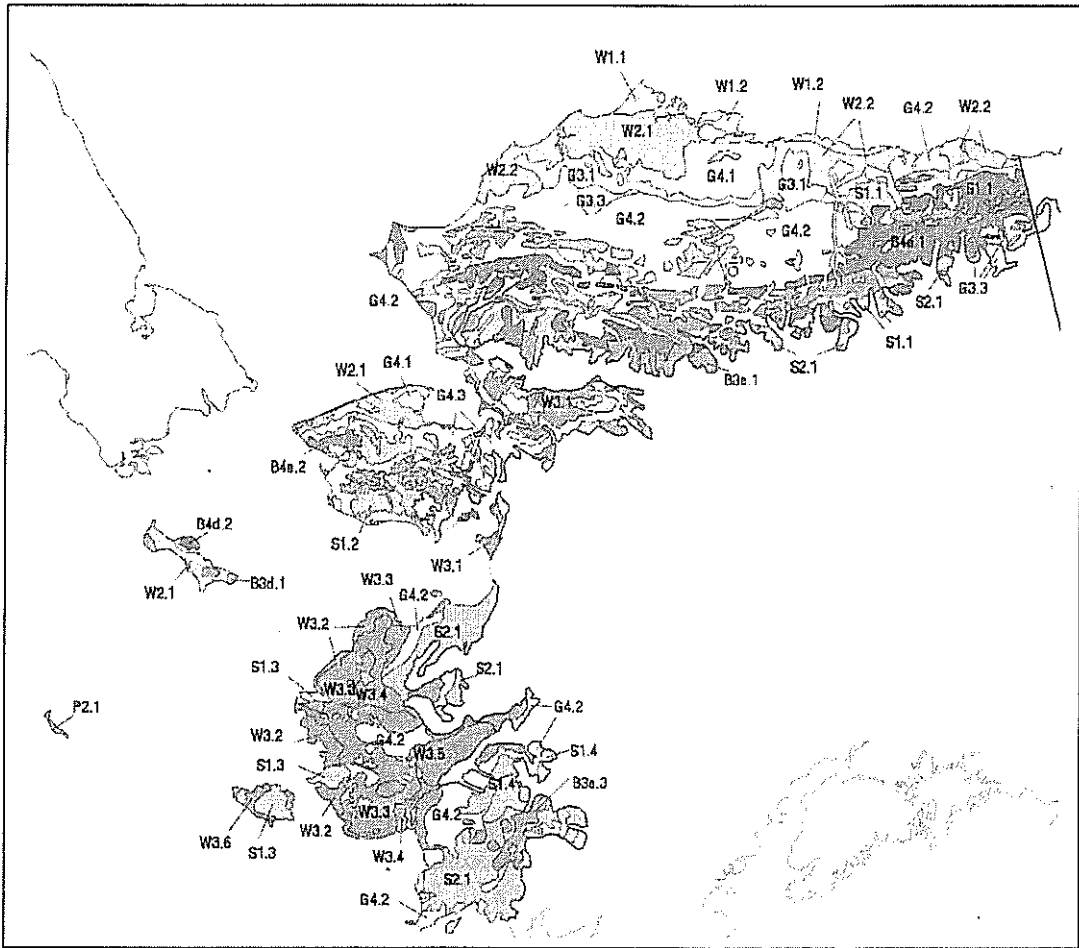


Figure 1. Reduced map of community types in Alaska.

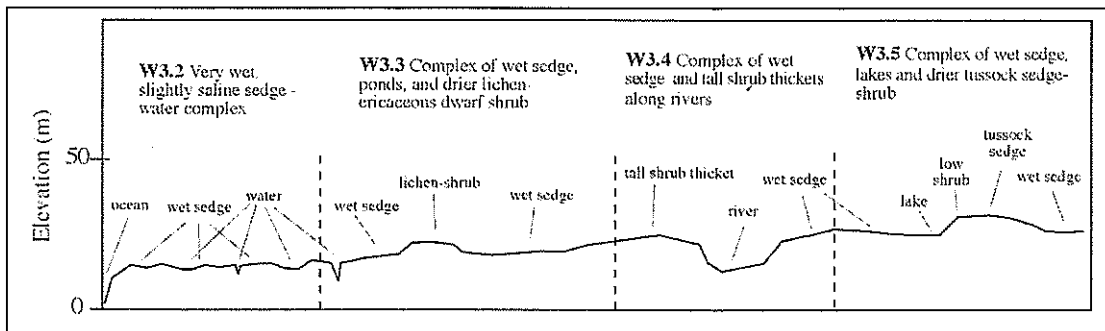


Figure 2. Conceptual diagram of vegetation types of the Yukon-Kuskokwim Delta from the coast inland (left to right, approx. 150 km; although all areas have finer-scale heterogeneity, and the full gradient can be found within 30 km of the coast in some places).

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VEGETATION AND ENVIRONMENTS OF NORTHEASTERN KORYAK (SOUTHERN CHUKOTKA, RUSSIA)

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Vegetation of a dwarf-shrub tundra enclave (Razzhivin 1994, Belikovich 2001) within the low shrub tundra subzone in the vicinity of coastal Pekulneiskoye Lake (NE Koryak Range, coastal SE-facing slope) was studied in 1984-1986. 76 relevés from 9 transects and 3 localities were analyzed using TWINSPAN and DCA (CANOCO program) to classify plant communities into environmentally interpretable entities.

The vegetation is strongly controlled by the coastal maritime climate, which results in a lack of both stlanik (*Pinus pumila*, *Alnus fruticosa*) and low shrub (e.g. willows) vegetation. The absence of dwarf shrub-tussock (*Eriophorum vaginatum*) tundra may be due to lack of high ice content permafrost and deep active layer throughout the enclave, and Quaternary glaciation. Wet meadows dominated by *Carex stans*, *C. rariflora*, *Eriophorum angustifolium*, *E. russeolum*, etc. occupy the lowlands surrounding Vaamochka and Kaipylgin lakes. Coastal plain and moraine hills formed by Quaternary gravelly well-drained sediments are dominated by prostrate and hemiprostrate shrubs (*Empetrum nigrum*, *Ledum decumbens*, *Vaccinium vitis-idaea* var. *minus*, *Arctous alpina*, *Salix sphenophylla*, etc.). Lichen tundra is common throughout the Koryak Range. It is often enriched by *Rhododendron camtschaticum*, *Phyllodoce coerulea*, *Loiseleuria procumbens*, *Cassiope tetragona*, etc., indicating deep snow cover. Dwarf shrub (*Betula exilis*, *Ledum decumbens*, *Vaccinium uliginosum* ssp. *microphyllum*, *V. vitis-idaea* var. *minus*, etc.)-moss-lichen tundra is occasional. Mountain slopes facing the sea are vegetated by sparse prostrate shrub (*Dryas punctata*, *Diapensia obovata*, *Salix arctica*, *S. phlebophylla*, *Empetrum nigrum*, *Arctous alpina*, etc.)-moss-lichen tundra rich in herbs, whereas slopes facing inland to intermountain valleys are covered by continuous erect dwarf-shrub (*Betula exilis*, *Ledum decumbens*, *Vaccinium uliginosum* ssp. *microphyllum*, *Pentaphylloides fruticosa*)-moss-lichen tundra and snowbed vegetation (*Phyllodoce coerulea*, *Rhododendron camtschaticum*, *Salix polaris*, *S. chamissonis*, *Saxifraga merckii*, *S. porsildiana*, *Erigeron humilis*, *Poa paucispicula*, etc.).

The climatic gradient from the coastal prostrate and hemiprostrate dwarf-shrub tundra subzone to the low shrub (arctic shrub) tundra subzone (indicated by *Alnus fruticosa* and willows) is sharp. A coastal dwarf-shrub tundra belt, 5-20 km wide, coincides with the area of marine summer fog that penetrates inland. Pekulneiskoye Lake (ca 30 m deep) was previously a sea gulf (fiord); it was recently cut off and is now separated from the sea by a gravelly bank. It is mostly surrounded by dwarf-shrub tundra due to the maritime climate.

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ZONAL PATTERNS IN VEGETATION OF THE RUSSIAN ARCTIC CAUSED BY BEDROCK AND SURFICIAL GEOLOGY, PERMAFROST, AND COASTAL EFFECTS.

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The Russian tradition for describing zonation of the Arctic is strongly influenced by the "plakor" concept both in geobotanical (Aleksandrova 1980, Chernov and Matveyeva 1997) and phytogeographic (Yurtsev 1994) approaches. The plakor concept (Vysotsky 1909) is focused on environments showing the best correlation with the climate, reflecting a balance of incoming warmth and precipitation in a particular region as a uniform indicator of climatically determined zonation. Plakor is an elevated flat site with ground water located relatively deep below the surface, which does not influence the soil profile. High ice-content permafrost of mesic to wet sites with fine-textured parent material, and the permafrost table at 0.2-0.7 m depth, is a barrier to the drainage of water. The plakor concept does not fit for loamy and clayey soils associated with high ice content permafrost which dominate in eastern Siberia and northeastern Asia (Razzhivin 1999). Dwarf shrub-tussock tundra on high ice content permafrost habitats displays inflexibility to climate and is uniform throughout Low Arctic and northern larch taiga (Razzhivin 1995). The toposequence approach (Elvebakk 1999) applied for each kind of bedrock (Sokolov and Konyushkov 1998) provides an interpretable robust biogeographic comparison of different regions throughout the circumpolar North.

In view of the special importance of zonal mapping for predictive modeling of vegetation dynamics, it is necessary to recognize regional vegetation patterns, caused by macroclimate versus local "microclimate" and bedrock. The cooling effect of arctic and subarctic seas has sharp local coastal effect on vegetation in comparison with a long distance climatic gradient of oceanicity-continentalty. There is no clear consistency in recognition of coastal effects and tundra subzones throughout the Euroasian Arctic. Regional toposequences and zonal patterns of southern Chukotka, Wrangel Island, Taimyr Peninsula, Kolguev Island and their climatic and edaphic environmental controls are discussed.

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RUSSIAN SCHOOL TRADITIONS FOR CONSTRUCTING LEGENDS FOR ARCTIC VEGETATION MAPS

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Russian botanists-cartographers have a great deal of experience in creating small-scale maps for various regions, including the Russian Arctic. The Russian cartographic school tradition is to construct regional-typological legends. This approach combines typological and geographical characteristics. Typological characteristics are based on vegetation classification. For small-scale maps, geographical characteristics are more important in the legend. The map legends have a hierarchic arrangement of subtitles, and may be presented in text, table or matrix forms. Let us illustrate these principles using several maps as examples.

A map of vegetation of the circumpolar Arctic was published in the Atlas of the Arctic in 1985. The highest subdivision of its legend is between "Tundra vegetation" and "Boreal vegetation". Tundra vegetation in plain areas is divided into 35 units (17 of them for the Russian Arctic), and 1 in mountainous areas. Subdivisions of the next rank correspond to subzonal types: "High Arctic tundras (polar deserts)", "Arctic tundras", "Northern tundras" and "Southern tundras". The next rank of subtitles describes general typological characteristics for each subzonal (latitudinal) type. For the types mentioned above, they are: "sparse groupings of high arctic and arctic-alpine species and polygonal high arctic tundras", "herbs-dwarf shrub-moss and dwarf shrub-lichen dominated by arctic species with significant component of hypoarctic species", "shrub, dwarf shrub and cottongrass tundras dominated by hypoarctic species with significant component of arctic species in northern boundary, and boreal species in southern part". The lowest cartographic unit corresponds to geographic variants, revealing species composition of typological units from the previous rank, and nearly always describes the spatial heterogeneity of vegetation in combination with other community types: mires, woodlands, alder-willow thickets, etc. The petrophyte (rocky) and psammophyte (sandy) variants of subzonal types are shown by cartographic marks; and hachures show mountain variants. Special numbers set apart tundra altitudinal belts in the mountains of the tundra zone.

The "Vegetation map of the USSR, scale 1:4,000,000", published in 1990, uses 22 cartographic units to portray vegetation of the Russian Arctic. "Polar deserts" and "Tundras" are mapped in a common higher level. "Tundras" are divided into "Plains" and "Mountains". The next level of subtitles distinguishes subzonal (latitudinal) types of plain tundras: "Arctic", "Northern" and "Southern". The lowest subdivisions of the legend contain typological characteristics of the subzonal types, with variation in vegetation from west to east shown by letters. Different hachures used for edaphic variants increases the information displayed on map. The legend is presented in text and table forms. In the table, "Polar deserts" and "Tundras" are united into a single "Polar desert-tundra region". Two tables were compiled: "Vegetation of plains" and "Vegetation of mountains". They include columns corresponding to subzonal divisions, types of plant communities and regional subdivisions of vegetation.

New data on diverse features of vegetation leads to increasing information capacity of maps. For instance, edaphic variants can be displayed not only cartographically, but can also be an important element of the text legend. Such maps for the Arctic have not yet been compiled.

ALTITUDINAL ZONATION OF VEGETATION IN CONTINENTAL WEST GREENLAND, WITH SPECIAL REFERENCE TO SNOWBED VEGETATION

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This paper gives a brief introduction to the AZV (Altitudinal Zonation of Vegetation) project carried out in the inland area of West Greenland. The aim of this project is to test the altitudinal zonation hypothesis of the CAVM Team (2003) and to provide a model of altitudinal vegetation belts in bioclimate subzone E (Arctic Shrub Zone) of the Circumpolar Arctic Vegetation Map (CAVM). The model will be based on data collected during fieldwork in the years 2000 to 2003. Data consist of 500 vegetation relevés, three vegetation maps, floristic investigations, soil analyses and temperature measurements carried out in different altitudes from sea level up to 1070 m above sea level (a.s.l.).

In accordance with the concept of the CAVM Team, three altitudinal belts can be distinguished in the investigation area. The lowest belt (up to approx. 400 m a.s.l.) and middle altitudinal belt (approx. 400 - 800 m a.s.l.) are both dominated by dwarf-shrub vegetation. In order to distinguish these belts, plant communities, vegetation pattern and floristics have to be taken into consideration. In contrast, the highest belt (above 800 m a.s.l.) can be clearly delimited due to the dominance of graminoids.

Snowbed vegetation plays a major part in the distinction of the altitudinal belts. Therefore a detailed description of this vegetation complex is presented. In the lowest belt snowbed vegetation and its typical species are absent. In mid altitudes, most of the stands are only fragmentarily developed and of small extent. In the highest belt snowbed vegetation covers large areas on northern slopes and differentiates into several well-developed plant communities. In general, the *Phippsietum algidae-concinnae* Nordh. 1943 occurs at late snow-free sites and the *Cassiopo-Salicetum* (Fries 1913) Nordh. 1936 represents the early-melting snowbed vegetation. Differences in vegetation pattern between snowbeds of the middle and the highest altitudinal belt are discussed.

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CLASSIFICATION OF VEGETATION OF TECHNOGENIC LANDSCAPES OF THE RUSSIA FAR NORTH

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Industrial development in Russia is expanding northward, and disturbed areas are increasing in the Far North. Landscapes with exposed ground caused by various artificial factors, including mechanical and chemical agents during industrial development of an area, are termed "technogenic" in the Russian literature. They occur mostly along the southern boundary of the tundra zone and in the forest-tundra. Northern industrial centers like Vorkuta and Noril'sk have large disturbed areas surrounding them. Disturbance is widespread in all regions with intensive industrial development; the largest denuded patches are found in regions with open pit mining (Yakutia and Chukotka), or associated with oil-field development (Northwest Siberia, Komi Republic, and Nenets Autonomous Okrug).

Natural vegetation recovery on technogenic habitats is slow, and large areas have bare substrates devoid of vegetation. Recovery during primary succession on totally denuded patches reveals the regenerative potential of the local flora and vegetation. Classification of vegetation of such disturbed landscapes not only gives information on the diversity of pioneer plant communities and stages of succession, but also helps reveal common tendencies in the recovery processes in different regions of the North (Sumina 1995a).

The real research "boom" on industrial impacts on tundra occurred in the 1980's. Field investigations were carried out all over the Russian Far North, and their topics were connected with the main trends of industrial development in each respective region (Sumina, 2000). At the same time only a few authors (Gogoleva & Cherosov, 1987; Sumina, 1994; Cherosov, 1995; Forbes & Sumina, 1999; Mironova et al. 1990; Mironova, 1996, 2000; Poiseeva, 2000) worked out the problem of classification of 'technogenic' vegetation (vegetation of technogenic landscapes). All the researchers mentioned above used the Braun-Blanquet approach to classification or a modification by Kopecky & Hejny (1974) and Kopecky (1984), because this method is more effective for classification of a great variety of anthropogenic plant communities than a method based on dominant species (Sumina, 1995b).

Syntaxa belonging to different levels, from class to association, and others like 'community type' were distinguished. Each syntaxonomical level has significance within a specific spatial scale. For example, class characterizes the vegetation of a large region (regional scale), and 'community type' refers to a relatively small area (local scale). Using the same approach to classify the vegetation of technogenic landscapes to compare different regions of the Russian North with each other is difficult. All these related problems are discussed in the present paper, where a complete review of current data on the classification of 'technogenic' vegetation is made.

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COMPARATIVE PHYTOSOCIOLOGICAL INVESTIGATION OF SUBALPINE
ALDER THICKETS IN SOUTHWESTERN ALASKA AND THE NORTH PACIFIC

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We present the first vegetation analysis of subalpine alder (*Alnus viridis*) thickets in southwestern Alaska. The data are primarily from mesic, hilly and mountainous sites ranging from the westernmost tip of the Alaska Peninsula to the northern Kenai Peninsula, spanning 1,000 km on an E-W gradient and 700 km on a N-S gradient. 126 relevés from 19 sites represent the range of structural and compositional variation in the matrix of vegetation and landform diversity. Data were analyzed by multivariate methods using the ClustanGraphics (Wishart 2003), Juice 6.1 (Tichy 2002) and Mulva-5 (Wildi & Orlóci 1996) computer programs and ordered with Wildi's numerical procedure to produce results similar to traditional phytosociological tabular classification (Wildi 1989).

Four major communities are distinguished: *Alnus viridis-Calamagrostis canadensis*, *Alnus viridis-Rubus spectabilis*, *Alnus viridis-Athyrium filix-femina*, and *Alnus viridis-Oplopanax horridus* thickets. These communities are well-differentiated, although they form a syntaxonomical continuum. The composition and structure of these communities are described and interpreted in relation to complex environmental factors. These factors are analyzed using Jancey's ranking on F-values. Community composition is primarily related to elevation, longitude, soil moisture, and latitude. Phytogeographic comparison of southwestern Alaska alder communities with those elsewhere in the North Pacific suggests a close relationship to south central Alaska, with floristic similarities to coastal British Columbia, Canada, and eastern and southern parts of the Kamchatka Peninsula, Russia. Within the Northern Hemisphere, vascular plant species of southwestern Alaska alder thickets primarily occur in East Asia and North America (36%), while 26% are circumpolar, and 22% are restricted to North America. From a latitudinal perspective, the distribution of vascular plant species within these alder thickets peaks in the high-subarctic, low-subarctic, and temperate latitudinal zones of Scoggan (1978), with low representation of arctic species.

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CASE STUDIES OF SYN SOCIOLOGICAL VEGETATION UNITS IN SPITSBERGEN AND THE CANADIAN ARCTIC ARCHIPELAGO

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The case studies under consideration are based on synsociological research work conducted in the European and Canadian Arctic (Spitsbergen, Victoria Island). On each island the vegetation units (associations and communities) are classified in different vegetation zones according to the method of Braun-Blanquet (1964). The grouping of vegetation units leads to the formation of vegetation complexes (sigmeta). Two distinct constancy tables reveal the wide spatial differences in the vegetation of the tundra in the research areas. As a result, *Caricetum stantis-Geosigmatum* (Canada) and *Salicetum polaris-Geosigmatum* (Spitsbergen) were described; these consist of several sigmeta.

JUICE – AN ALTERNATIVE FOR COMPUTER VEGETATION ANALYSIS AND CLASSIFICATION

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The JUICE program is designed as a Microsoft® WINDOWS application for editing, classification, and analysis of large phytosociological tables. This software utilizes many functions for easy manipulation of table and header data. The program is optimized for use in association with TURBOVEG software, which is the most widespread database program for storing phytosociological data in Europe. Data import is also possible using a spreadsheet data format. Basic functions useful for editing and final publishing of phytosociological tables are assisted through a number of analytic possibilities (Beals smoothing, Ellenberg indicator values, similarity indices, beta-diversity, interspecific associations, diagnostic, dominant and constant species of synoptic tables etc.) and classification using COCKTAIL, TWINSPAN and PC-ORD methods. Easy simulation of artificial data for testing is possible. Tables, synoptic tables, headers and different types of analyses (fidelities, species groups, indicator values, synoptic tables, diagnostic species etc.) can be exported in four data formats: 1) MS-DOS text, 2) Rich text format for word processors (e.g. Microsoft WORD), 3) spreadsheet format (e.g. Microsoft EXCEL) and 4) database format (Microsoft ACCESS). The program directly supports cooperation with the DMAP mapping package and creates Cornell condensed files for other classification utilities such as CANOCO or PC-ORD. The JUICE program has been continuously developed since 1998 as a freeware application in the vegetation science group at the Department of Botany, Masaryk University, Brno, Czech Republic. JUICE is frequently updated and available to all at the Internet address <http://www.sci.muni.cz/botany/juice.htm>.

A VEGETATION MAP OF THE ARCTIC TUNDRA BIOME (SCALE 1: 7 500 000):
Overview, methods, legend, and Analysis

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We present a 1:7.5 million-scale Circumpolar Arctic Vegetation Map (CAVM). This paper describes the methods used in making the map, the critical terminology and definitions that were adopted, the descriptions of the major map units, and area analysis of the map. The map is a major landmark because it is the first map of a complete global biome at a comparable level of detail. It unites previously disparate approaches that have been used to describe Arctic vegetation in North America and Eurasia by using a physiognomic approach to describe the map units. The map covers the Arctic Bioclimate Zone, which lies north of the limit of trees and is characterized by an Arctic climate, Arctic flora, and tundra vegetation. Six nations, Canada, Greenland, Iceland, Norway, Russia, and the United States, have Arctic lands within their boundaries. Fifteen vegetation types are mapped based on dominant plant functional types. An integrated mapping approach was used, whereby all map polygons include the following attributes: bioclimate subzones, floristic province, landscape types, lake cover, and substrate chemistry. The information is in a geographic information system (GIS) database. Elevation and the maximum normalized difference vegetation index (NDVI) are in separate coverages at 1-km pixel resolution. Information from previous vegetation maps was used when available. Most of the Arctic, however, required interpreting the vegetation from small-scale satellite images and expert knowledge. Tables of detailed plant-community-level information were used to construct the map. Future maps at larger scale can use this information to portray the dominant plant communities in each of the major floristic regions of the Arctic. The map will be useful for global and regional computer models of climate change, land-use planning, conservation studies, resource development, and education. Some results from the area analysis include:

- The area of the Arctic is 7.1 million km² (5.05 million km² are ice free) (Table 1).
- Of the vegetated portion of the Arctic, approximately 26% is dominated by erect-shrub tundras (units S1 and S2); 18% is peaty graminoid tundras (units G3 and G4), 13% mountain complexes (Units B3 and B4), 12% barrens (units B1 and B2), 11%

graminoid tundras on mineral soils (units G1 and G2, 11% prostrate-shrub tundras (units P1 and P2), and 7% wetlands (units W1, W2, W3, and lakes) (Table 1).

- Canada has the most cover of the barren (B1, B2) and prostrate-shrub (P1 and P2) vegetation types. Russia has the most cover of the erect shrub vegetation types (S1 and S2) (Table 2).
- Canada has the most terrain in the Arctic (36% of the total), and by far the most in the High Arctic (Subzones A, B, and C: 62% of the total); whereas Russia has the most terrain in the Low Arctic (Subzones D and E: 42% of the total). Alaska has 7% of the Arctic, much of which is mountainous (Table 3).
- Excluding glaciers, Subzone A covers 0.1 million km² (2%), Subzone B covers 0.5 million km² (9%), Subzone C covers 1.2 million km² (23%), Subzone D covers 1.6 million km² (30%), and Subzone E covers 1.8 million km² (36%) (Table 3).
- Total above-ground plant biomass for the Arctic is estimated at 2.5 x 10¹⁵ g. Phytomass is exponentially related to summer temperature along both latitude and elevation gradients. Subzone A averages 39 g m⁻², and Subzone E averages 818 g m⁻². Areas above 2000 m in elevation average 21 g m⁻², while areas below 333 m average 522 g m⁻². Phytomass is also affected by substrate, glacial history, and proximity to warm ocean currents.
- The majority of the Arctic is acidic tundra, which on average has higher biomass per unit area, 579 g m⁻², compared to 381 g m⁻² in nonacidic tundra areas and 156 g m⁻² on limestone areas.

Table 1. Area (10³ km²) of vegetation map units within each subzone and the whole Arctic.

Map Unit	Subzone A		Subzone B		Subzone C		Subzone D		Subzone E		Greenland Ice Cap		TOTAL		
	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct. Arctic	Pct. Unglac. Arctic
B1	48	24	122	24	55	4							225	3.2	4.5
B2			1	0.2	181	14	164	10	26	1			372	5.2	7.4
B3	13	7	69	13	146	11	165	11	146	8			539	7.6	10.7
B4			51	10	19	1	5	1.0	58	3			132	1.9	2.6
G1	37	19	89	17	15	1		0					141	2.0	2.8
G2			45	9	300	23	19	1	65	4			429	6.0	8.5
G3					35	3	399	25	134	7			569	8.0	11.3
G4							100	6	236	13			336	4.7	6.7
P1	0.3	0.2	56	11	213	16	129	8	1	0.3			399	5.6	7.9
P2					108	8	31	2					140	2.0	2.8
S1					3	0.7	257	16	429	23			689	9.7	13.7
S2					2	0.5	62	4	548	30			613	8.6	12.1
W1	2	1	15	3	81	6	3	0.5					101	1.4	2.0
W2							135	9	1	0.3			136	1.9	2.7
W3									159	9			159	2.2	3.2
glacier areas with nunataks	14	7	2	0.3	12	1	62	4					89	1.3	0.0
Other glaciers	80	41	61	12	122	9	12	1	2	0.3	1787	100	1975	27.8	0.0
Lakes			1	0.2	8	1	26	2	32	2			67	0.9	1.3
TOTAL	195	100	511	100	1301	101	1570	101	1837	101	1787	100	7110	100.0	100.0
Percent of the Arctic	2.7		7.2		18.3		22.1		25.8						
Percent of unglaciated Arctic	2.0		8.9		23.1		29.6		36.4						
Total nonglacier area =	5046														

Table 2. Area of the vegetation types within the Arctic countries.

COUNTRY	CANADA		GREENLAND		ICELAND		RUSSIA		NORWAY		USA	
	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct
B1	207	8	3	0.1			9	0.5	6	10		
B2	371	15										
B3	46	2	224	10			233	12			36	7
B4	36	1	33	2			20	1			43	9
G1	80	3					58	3	2	4		
G2	269	11					158	8	0.4	0.6	1	0.1
G3	309	12					223	12			37	8
G4	29	1					177	9			131	27
P1	288	11	21	1			87	5	3	5		
P2	107	4	22	1			3	0.2	6	9	1	0.3
S1	351	14	27	1			263	14			49	10
S2	150	6	3	0.1	6	89	393	21	3	4	58	12
W1	50	2					39	2	5	8	7	1.4
W2	27	1					65	3			45	9
W3	19	1					68	4			72	15
glaciers w/ nunataks	16	1	59	3					14	23		
other glaciers	153	6	1742	81	1	9	55	3	23	37	1	0.2
lakes	47	2	2	0.1			14	0.8			4	0.8
TOTAL	2553	100	2137	100	7	97	186	100	63	100	485	99
Pct of Arctic		36		30		0.1		26		1		7

Table 3. Area of the subzones within the Arctic countries

Subzone	CANADA				GREENLAND				ICELAND			
	Total		Unglaciaded		Total		Unglaciaded		Total		Unglaciaded	
	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct
A	53	2	51	2	4.5	0.2	4	1.3				
B	246	10	209	9	126	6	100	29.7				
C	955	37	828	35	97	5	90	26.7				
D	689	27	686	29	184	9	113	33.8				
E	610	24	610	26	28	1	28	8.5	6.8	100.0	6	100.0
Greenland Ice Cap					1697	79						
TOTAL	2553	100	2384	100	2137	100	335	100.0	6.8	100	6	100.0

Table 3 (cont.)

Subzone	NORWAY				RUSSIA				UNITED STATES				TOTAL			
	Total		Unglaciaded		Total		Unglaciaded		Total		Unglaciaded		Total		Unglaciaded	
	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct	Area	Pct
A	44	69	6	23	93	5	39	2					195	3	100	2
B	8	13	8	33	130	7	130	7					511	7	447	9
C	9	14	9	34	234	13	234	13	7	1	7	1	1301	18	1167	23
D					622	33	622	34	76	16	76	16	1570	22	1496	30
E	3	4	3	11	787	42	787	43	405	83	403	83	1839	26	1837	36
Greenland Ice Cap													1697	24		
TOTAL	63	100	26	100	1866	100	1811	100	487	100	486	100	7113	100	5048	100

USING INDICES OF REGIONAL CONSTANCY AND ACTIVENESS FOR PHYTOGEOGRAPHIC ANALYSIS OF PLANT COVER

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Theoretical background for methods:

The concepts "flora" (the total set of plant species co-existing over some area) and "vegetation" (the set of plant communities) are both attributes "plant cover" (the total set of plant individuals over the area). The functional concept of flora is a hierarchical system of populations of all plant species within a given area (Yurtsev 1982). This approach recognizes three categories of spatial hierarchy: intra-landscape, landscape and regional. Intra-landscape units include: micro-habitats (relatively homogeneous plant community), meso-habitats including various microhabitats of a single class (snow-beds, wind-swept snow-poor summits and ridges, etc.), and macro-habitats (incomplete set of regular habitat classes). The whole landscape can be called a "mega-habitat", and includes a full set of habitat classes (some rare or relict ones could be lacking).

An obvious gap between the level of a micro-habitat and that of the lowest phytochorion (a phytogeographic area or a subzone within it) was closed by A.I. Tolmachev's (1931) concept of a "concrete flora" (approximately corresponding to the flora of a landscape), or a local flora. This structured the concept of regional flora, allowing some quantification and statistical analysis of a flora's plant cover.

"Local flora" is a unit derived from the "area-minimum" of a concrete flora: due to limited species diversity in a concrete flora, its composition may be sampled within the flora polygon. If the center of the sampling area is put on the boundary between two or three concrete floras, one can sample several partial floras under the same climate, in the process of sampling a larger territory (Yurtsev 1975, Shelyag-Sosonko 1980). The size recommended by A.I. Tolmachev for the Arctic is ca 100 km², but in practice it can be increased up to 300 km² (such radius can be examined by daily routes). This approach allows us to extrapolate from a community level to other levels of floral spatial hierarchy, and to record specific patterns of taxonomic distribution.

A measure of whether a species is thriving and of its fitness to the environment was called "activeness" (Yurtsev 1968). Depending on hierarchic level, it can be divided into partial activeness (for plant community), landscape activeness (for landscape) and regional activeness. It can be expressed a species' cover in a community, landscape, or regional flora, i.e the degree that the taxon fills its "horizon of life". The landscape value may be calculated by summing the partial floras' activeness values for the most important species. But the lack of necessary data for such calculations made us suggest a system with three components: width of habitat range, the occurrence and significant abundance in characteristic habitats, and 3 to 5 grade scales.

Results of studies in Asian Arctic:

The Far North Vegetation Laboratory of the Komarov Botanical Institute is summarizing the results of floristic studies in the Asian Arctic (1964-2003). We are using the landscape method to analyze 96 local floras from six subprovinces within three provinces of the Asian Arctic (taxonomical and typological analysis) (Yurtsev et al. 2002). The occurrence of each species in the total of the 96 floras was called "constancy", and was graphed by subprovince (Figures 1 and 2). There are many species which occur in only one local flora in the subprovince, fewer that occur in 2-4 floras, and a low number that occur in more floras. In less extensive phytochorias in a more uniform zonal situation (Wrangel Island; South Chukotka, Figure 2) there are many species that are found in all of the floras. These data provide unexpected ways for determining regional activeness (if combined with data on landscape activeness of the species in the model local floras within the subprovince): at higher constancy the regional activeness increases relative to the landscape, and *vice versa*.

To divide the total flora into classes by the pattern of distribution of species among the local floras of the subprovince we separated the section of 1-2 occurrences and that of 75-100% constancy, and started classification with the largest intermediate section. Floras were classified in several groups, depending on the position of the species on the curve (with 20%, 25% or 33% species in each).

As recommended by Braun-Blanquet school for processing relevés of syntaxa: at first one should extract the species with more or less continuous distribution in a part the phytochorion, but lacking or rare outside of it. The boundary could be latitudinal (zonal) or longitudinal (sectoral), reflecting a shift in availability of summer warmth or precipitation. The other not extremely rare species demonstrate macro-mosaic pattern: the mosaic of carbonate *versus* acidic landscapes, the alternation of topography forms in combination with different lithology, presence or lack of vertical zonation in mountains, branched linear structures of flood-plains areas, or coastal ecotones.

After classifying the largest (central) group of species we can return to the most rare species, and distribute them into established groups. These could contain local relicts, plants of unique habitats (like hot springs, steppe colonies in the Arctic, etc.), occasionally introduced weeds, or species common in at the boundaries of neighboring subzones or sectors.

The third group, with high constancy, may contain the really ubiquitous plants with high activeness, including bioclimate indicators, but also the modal elements of previously recognized groups if they demonstrate clearly increased constancy in them. The highly active species group deserves special analysis by taxonomic and typological composition.

I would like to finish by saying that the above methods work well with a grid-system of flora mapping if combined with elementary, local and partial flora methodology. It is a fundamental method with variety of uses.

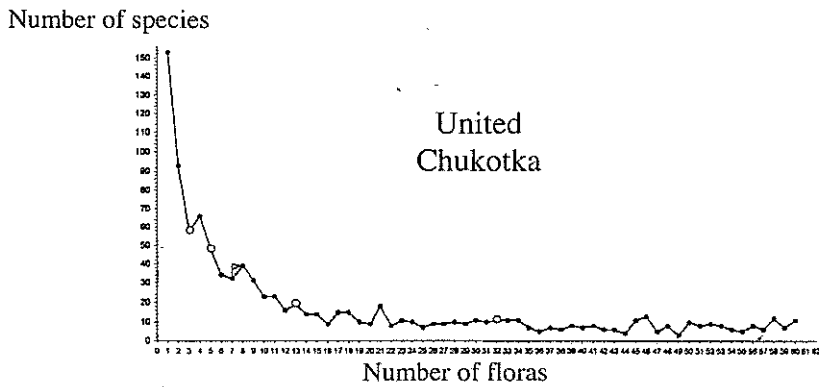
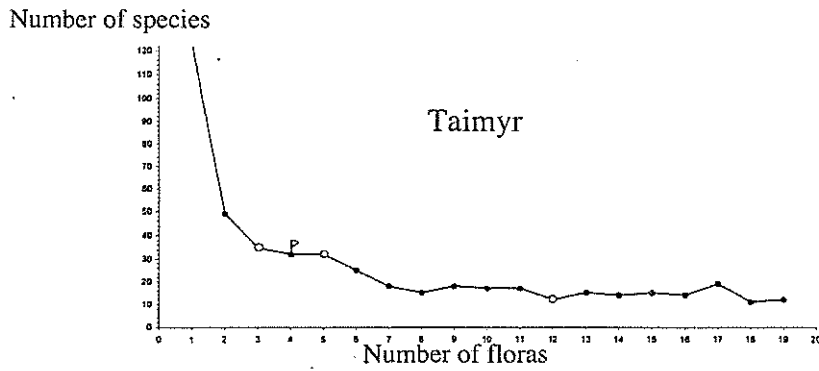
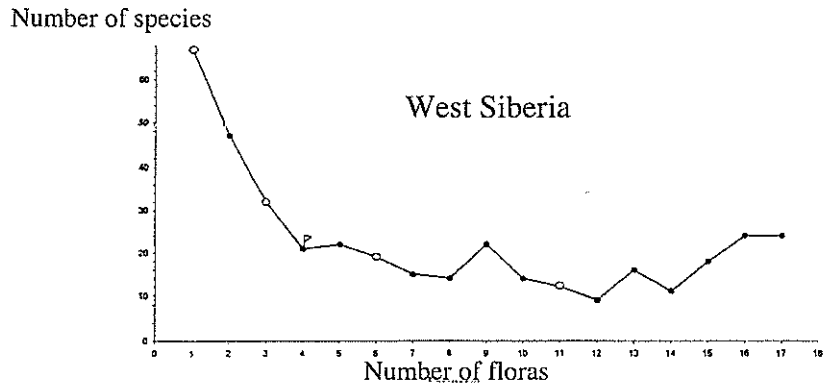
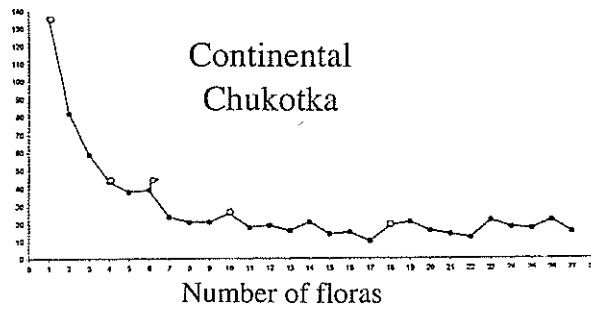
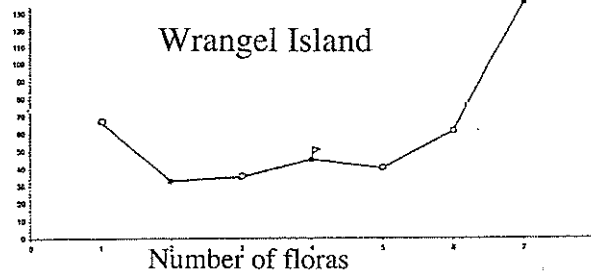


Figure 1. Constancy of plant species in local floras of two subprovinces (West Siberian and Taimyr) and the united Chukotka province of the Asian Arctic, showing how many species occurred in only one flora, in two floras, etc. The final data point shows how many species occurred in all of the sampled floras.

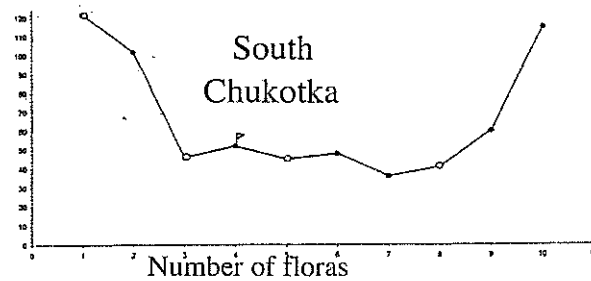
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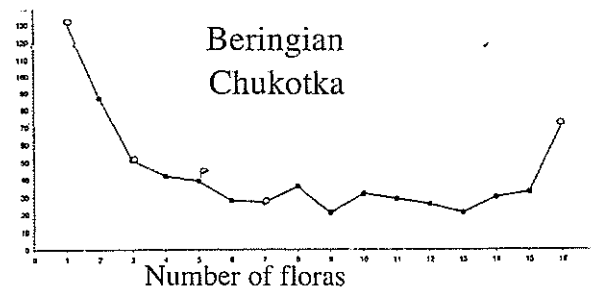


Figure 2. Constancy of plant species in local floras for four subprovinces of the Chukotka province of the Asian Arctic: Continental Chukotka, Wrangel Island, South Chukotka and Beringian Chukotka. The graphs show how many species occurred in only one flora, in two floras, etc. The final data point shows how many species occurred in all of the sampled floras.

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