[Home] [PAF News] [Checklist] [PAF Feedback] [PAF Search Page]

[General aspects] [Case studies] [Delimitation and subdivision]
[Information management] [Reports from taxonomic workshops]

[Up] [Next]

BIOCLIMATIC DELIMITATION AND SUBDIVISION OF THE ARCTIC

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It is not a simple task to define and subdivide the terrestrial part of the Arctic based on climatic criteria alone. A common criterion like mean July temperatures leads to an unbalanced treatment of oceanic vs. continental areas, and an insufficient network of meteorological stations with standardized, long-term data is also a problem. The occurrence of continuous permafrost diverges even more from other factors and extends far into the taiga in continental areas. The most polar (meaning regularly concentrated with the latitudes around the Pole) of all abiotic factors, the light regime, does not covary well with other abiotic factors nor with biological distribution patterns. Most large animals are migratory, or not clearly distributed along climatic gradients. The use of smaller, non-migratory animals as bioclimatic indicators is not very practical for general and coarse-scale purposes.

When a multitude of diverging criteria and standards are applied and added to political ambitions, a very strange delimitation of the Arctic emerges, such as the one adopted by the Conservation of Arctic Flora and Fauna (CAFF) (1994). In this case vast forested areas were included in the Arctic, even considerable middle boreal areas. For Alaska and North Norway the CAFF map of the Arctic even included small areas that have been classified as southern boreal in Alaska (Tuhkanen 1992) and Norway (Dahl et al. 1986), respectively.

Plants are strongly depending on climate. They are sedentary, usually long-lived in the Arctic, and their occurrence and abundance and sometimes growth form integrate responses to the long-term climate in their phytosphere. Edlund (1987) appropriately adopted the concept of 'plants as living weather stations'. However, there are some limitations. Many widespread species, such as *Saxifraga oppositifolia*, are not good climate indicators. Secondly, plant distributions are also influenced by historic developments, as seen in sectorial diversity both in flora and vegetation. And, thirdly, other factors than climate of course determine greatly the vegetation cover. Any vegetation map of an arctic area would normally have its polygons primarily differentiated along a soil moisture gradient (from mires to exposed ridge communities) unless a considerable altitudinal range is included. Thus, the selection of botanic criteria for bioclimatic mapping must be carefully related to the plants' responses to climatic gradients.

The aim of the present paper is to apply botanic criteria to define and subdivide the Arctic in units reflecting climatic gradients. The resulting maps should have a wider application than only botany. It is also the aim to select criteria so that the classification can also be transferred to regional and even local scales involving altitudinal differentiation. The overall idea is that the plant cover, being present everywhere, always has some of its elements available as bioclimatic indicators. A use of these elements can supply a much better spatial resolution for a derived bioclimatic map than the relatively scattered meteorological stations that have produced high-quality data sets.

Similar maps have been called 'geobotanical' (Aleksandrova 1980), 'climatic-phytogeographical' (Tuhkanen 1984, 1986), and 'phytogeographical (Yurtsev 1994). Here the name 'bioclimatic' will be used in the same way as by Edlund & Alt (1989), because of its simplicity and its aim of using plants to indirectly map climate. The units will be called 'zones' as they are arranged parallel to the latitudes in uniform landscapes, but modified strongly over large parts of the Arctic where there are mountain ranges and/or intricate patterns of land and sea surfaces. Readers who like to specify that they regard these as subdivisions of one arctic zone could instead call them subzones.

It is important to note the differences between bioclimatic maps and vegetation maps. Bioclimatic zones represent a climatic framework for what can be developed of floras and specific vegetation types on different habitats, but does not, contrary to vegetation mapping, indicate the geographic positions of the habitats and their vegetation. Thus an area dominated by dry, open, xerophytic vegetation and another area dominated by mires may be classified into the same bioclimatic zone, although they would be very differently classified in any vegetation map. It is also important to note that the climatic modification by the habitat is not taken into consideration. Thus the extremely different surface temperatures of a dry ridge community vs. a mire is a variation irrelevant for the present purpose.

Finally, it should be noted that there are important variations in the flora and vegetation within each zone longitudinally; which increase from the north to the south. This differentiation is essentially based on historical factors. In each sector a part of the flora is exclusive to that area and lacking in another. These changes accrue from differences in the relative importance of immigration of new floristic elements to the area and in situ evolution within them, which has evidently proceeded further in areas that have been ice-free longer – in particular the amphi-Beringian area in contrast to the more heavily glaciated North Atlantic. The floristic division of the Arctic into sectors as a reflection of different floristic histories was the main topic of the study by Yurtsev (1994), and his system of sectorial subdivisions is gaining acceptance, although with some modifications.

Previous attempts to define and subdivide the Arctic have led to a multitude of different classes, boundary lines, and names, and no system seems to have gained acceptance over others. The task is demanding, as it requires a strong generalization from a geobotanic reality with a high diversity. The difficulties can also be explained by a lack of circumarctic experience by different authors, and, not the least, by different traditions of classification among the arctic countries. During the Circumarctic Vegetation Mapping Project (CAVM) and the Panarctic Flora Project (PAF) scientists from the different arctic countries have met to discuss their concepts and to seek agreement (see Walker, M.D. et al. 1994, Walker, D.A. 1995) in the belief that there are benefits to an integrated circumarctic approach. Despite all the previous contributions to a subdivision of the Arctic and the treatment by Yurtsev (1994), it is still necessary to re-evaluate criteria for drawing zonal boundaries, to revise the boundaries themselves, and to select the most appropriate names.

The questions are the following:

1. What criteria are best selected for defining the Arctic as a whole and its bioclimatic zones – both in oceanic and continental areas?
2. How many zones are needed?
3. Should these zones be arranged in major groups within the Arctic?
4. What criteria should be applied to select names for zones that would be acceptable to a wide range of users?
5. Is it necessary to revise the borderlines between the zones as compared to existing maps?

Contents

Previous treatments

Bliss (1981) summarized in table form the most important treatments from the period 1951- 1981 including Polunin (1951), Porsild (1951), Gorodkov et al. (1954), Andreyev (1966), Aleksandrova (1970), Tedrow (1974), Bliss (1975) and Andreyev & Aleksandrova (1981). The scheme by Aleksandrova (1970) was slightly revised by Andreyev & Aleksandrova (1981), but treated much more comprehensively by Aleksandrova (1980) who also referred to additional studies, especially those covering the former USSR. Chernov & Matveyeva (1979) included a system similar to that of Gorodkov et al. (1954) and Andreyev (1966). These schemes included between three and seven units in different hierarchies and can be summarized in three categories:

I. Polunin (1951) separating the Arctic in three units; the ’High’, the ’Mid’ and the ’Low Arctic’.
II. Soviet authors included a northernmost ’desert’ unit (variously called ’arctic’ or ’polar desert’) which is in contrast to a much broader tundra part comprising several units. The northern part of the tundra was called ’arctic tundra’ which is a very narrow application of the name and differs from the wider concept used in the west. Southward, this zone was often followed by ’typical tundra’, which Aleksandrova (1980) abandoned. The southernmost zone was variously called ’southern’, ’shrub and tussock’ or ’subarctic’ tundra.
III. Bliss (1975) rejected ’Mid Arctic’ as a zone, and, consequently, used a more widely defined ’High Arctic’ to include most of it. As subunits of the ’High Arctic’ he adopted the ’polar desert’ concept in addition to a ’polar semi-desert’ for the neighboring unit to the south. It should, however, be underlined that the system proposed by Bliss (1975, 1981) is more influenced by a vegetation map approach than by a bioclimatic approach, and his subunits and also their geographical positions are not easily compared with both previous and later systems.

These three approaches became influential especially as the earlier studies became available in English with the appearance of Aleksandrova (1980) which exposed Soviet tradition to western European and North American scientists.

The floristic zonation scheme of Young (1971) was well received in Russia, especially with respect to his treatment of North America. His work was reprinted in Russian (Young 1978). The lack of acceptance in Europe may be because his ’Zone 4’ extended too far north in Greenland and too far south further east. Or it may be related to his emphasis on climate rather than glacial survival as the most important determinant of the floras of Jan Mayen and Svalbard, a view not easily accepted at that time, but more palatable now.

Since 1985 several proposals have been published, in addition to alternatives put forward during the CAVM discussions. Some interesting trends can be summarized:

a. Fennoscandian systems like those of Elvebakk (1985) and Tuhkanen (1986) relate closely to that of Aleksandrova (1980), but name the southernmost zone/the forest-tundra transition ’hemiarctic’, following a strong Finnish tradition

(Ahti et al. 1968), although the name may have been used also in Canada. Phytosociological syntaxa were used as criteria for the first time by Elvebakk (1985), who also used floristics quantitatively for similar purposes at a regional scale on Svalbard (Elvebakk 1989). Chernov & Matveyeva (1997) and Matveyeva (1998) maintained the pre-Aleksandrova system, but included only four zones.

d. Two studies (Longton 1997, Moen 1998) follow the tradition by Polunin (1951), but Moen (1998) subdivided Polunin's units and included five zones. Longton (1997) used a temperature aspect in his zonal names, which would be more appropriate along a longitudinal oceanity gradient than in latitudinal bioclimatic zonation.
e. Edlund & Alt (1989) emphasized the importance of growth forms and used these also in the naming of the zones.

Yurtsev (1994) followed the same first-level division as Bliss (1975), but rejected the concept of polar deserts that Bliss (1975) had adopted from Soviet tradition. Yurtsev (1994) also replaced the Low Arctic in Bliss (1975) and the 'subarctic' in Aleksandrova (1980) by the concept 'hypoarctic', a synonym of 'hyparctic' as used in previous Soviet literature. Yurtsev (1994) also used 'active species' as criteria and included a strict hierarchic organization in the nomenclature. The three major systems used in Russia now are compared in a table by Razzhivin (1999).

An overall summary shows that all the three major trends up to 1975 have been supported by new studies during the last two decades, with the addition of two new trends. Thus there is an even greater diversity of names, criteria, and concepts of first-level divisions of zones than there was 20 years ago. There is, however, increasing agreement on the content and definition of the zones, and the five units used by Elvebakk (1985), Yurtsev (1994) and Moen (1998) are basically the same. The newer systems, except those by Polunin (1951) and Chernov & Matveyeva (1997), are easily related to the five units of Elvebakk (1985) and Yurtsev (1994).

Contents

Material and methods

Is it possible, in this field of traditions and opinions, to deal with the topic less subjectively? The ongoing discussion both in the CAVM and PAF projects have revealed an agreement in applying toposequence studies for defining characteristics both of vegetation types and their abiotic components. Such sequences of communities along topographic gradients with parallel habitats on acidic and non-acidic substrates has been done for Svalbard (Elvebakk 1985), eastern parts of the Russian Arctic (Razzhivin

1999) and for the North Slope of Alaska (D.A. Walker in prep.). The most important vegetation types of each zone within a sector can be illustrated along a ridge - snow bed - wetland gradient, sometimes also including riparian habitats. This would relate the vegetation types to each other, and better allow for a comparison both between zones and sectors.

The information from each zone in a sector should include information on at least four major habitats or landscape units: (i) dry, exposed ridges, (ii) intermediate habitat, or mesic zonal site, (iii) snow beds, and (iv) wet sites, in addition also (v) riparian habitats.

'Dry, exposed ridges' are convex forms strongly exposed to wind and desiccation. Such areas have little or no snow cover during normal winter conditions in contrast to neighboring habitats, and plants are exposed to water and mechanical stresses. 'Zonal habitats' are habitats, which are intermediate with respect to all major ecological factors. They are neither strongly exposed to winds nor desiccation and are normally protected by snow during winter time, nor is there any stress related to a particular late-lying snow cover as compared to the often neighboring snow beds. Soil texture is intermediate, and data is avoided from sites with extremely favorable (south-facing) or unfavorable (north-facing) exposures. The other habitats are called 'azonal' because they are characterized by a particular stress factor, like desiccation, long snow cover, water saturation or instability.

The 'zonal habitat' is a wider and more neutral concept than the 'plakor' of Russian geobotanists, as the latter concept is related to a more or less flat and exposed landscape topography, and an acidic or weakly acidic fine-textured substrate. This combination is rarely met with in large parts of the Arctic, see discussion in Razzhivin (1999).

'Snow beds' strongly concave landforms where snow accumulates throughout the winter. Snow beds have a much shorter growth season than in neighboring habitats. Soil texture is mostly intermediate to coarse because of leaching. 'Wet sites' occur on flat or concave landforms and accumulate fine-textured materials with a high water-holding capacity. 'Riparian habitats' are along rivers, predominantly in eroding situations.

Ideally, such information should be collected from all present zones within each sector drawing on local expertise. Then information from the same zone throughout the circumpolar area should be compared and the common characteristics should be developed as a general characteristic if each arctic zone. Such information is not yet available, and the present paper attempts to give a general picture based on available information. Although incomplete it could illustrate a useful approach. A simplified apprach focusing on circumneutral 'original' substrates is used here, although a specification of alkaline and strongly acidic substrates would be most useful.

The approach focuses on communities, but vegetation physiognomy, growth forms, soil formation, and temperature regime will be integrated. Other possible criteria like phytogeographic affinity and 'active species' could be indirectly derived from knowledge about the communities.

The topographic gradient with its sequence of communities is mostly a local-scale phenomenon, but it is a pattern which repeats itself, and it is a generalized illustration of what vegetation types can be realized within a given climatic range (a zone). It varies circumpolarly according to what species and communities, which are present in the different sectors, and this variation is highest in the southernmost areas.

This approach could also be expanded to cover the controversial areas which have been mapped as arctic by some authors, e.g. on the CAFF map, but not by others. It is considered to be an illustrative way of presenting a set of botanic criteria at the same time.

As a method for evaluating name alternatives, nomenclatural criteria can be stated before one alternative is chosen before others. A set of criteria that can fulfill the demand of attracking users outside the group of arctic botanists could be the following criteria: a) simplicity, b) exclusivity, c) precision, d) internationality, e) information content, f) independence.

Contents

Results

Arctic vegetation zones (Figs. 1-5)

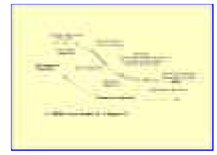
Fig. 1.

Simplified topographic gradients of arctic zones A and B.

Zone A (Fig.1) appears to be very homogeneous at a circumpolar scale with a very modest vascular plant cover (<5 %) on a near-barren substrate of skeleton soils with a desert physiognomy. The cryptogams are more prominent on acidic substrates than on limestones and shales. The arctic poppy is a characteristic plant on exposed ridges and zonal habitats. What has previously been called P. *radicatum*, *P. dahlianum* or *P. polare* in the different sectors, should, according to recent studies within the Panarctic Flora Project be treated as *P. dahlianum*, a single, circumpolar taxon dominating in the polar deserts. *Phippsia algida* is a characteristic species in snowbeds and wet sites. There are neither prostrate shrubs nor dwarfshrubs, although *Salix polaris*, *Salix arctica*, and *Dryas* species can be rarely found in the southernmost parts. *Carex* and *Eriophorum* species are also lacking or very rare as there are no true mires in zone A. The zone is not present in the amphi-Beringian area as shown by Bay

Fig. 2.

(1997).

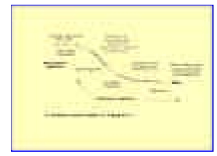


Simplified topographic gradient of arctic zone C.

Zone B (Fig.1) is characterized on a circumarctic scale by ridge communities with *Dryas* spp., zonal communities with Salix *arctica* or *S. polaris* as dominants and *Carex* spp. as common both on ridges, seashores and in wet sites together with *Eriophorum* spp. A discontinuous vegetation cover is typical.

In snow beds and mires there is a stronger differentiation between the different sectors. *Deschampsia alpina* tundra mires and *Poa alpina* snowbeds are only found in the West European sector of Zone B where the otherwise dominant *Carex aquatilis* subsp. *stans* is a rarity (Elvebakk 1997).

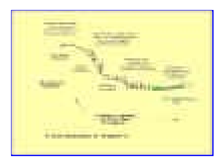
Fig. 3.



Simplified topographic gradient of arctic zone D.

Zone C (Fig. 2) is first and foremost characterized by a circumpolar occurrence of the dwarfshrub *Cassiope tetragona* (absent or very rare in the Arctic only between southern Svalbard and the Polar Urals). It is much more rare and less prominent in alkaline areas than on acidic substrates. In the West European sector of Zone C a snowbed community appears with *Ranunculus pygmaeus, Minuartia biflora* and *Trisetum spicatum* as characteristic species. Here there are also ocurrences of *Carex saxatilis* and *C. parallela* on calcareous substrates. *Carex subspathacea* is more widespread in mires in addition to its well-known dominance in seashore communities. In Svalbard such mires replace *Deschampsia alpina* tundra mires, which dominate areas in zone B with a thin and discontinuous peat layer (Elvebakk 1997).

Fig. 4.



Simplified topographic gradient of arctic zone E.

In Zone D (Fig. 3) *Dryas* communities are mixed with prostrate shrubs like *Loiseleuria decumbens, Arctostaphylos alpina, Diapensia lapponica* s. lat., and in Chukotka species like *Salix phlebophylla* and *S. sphenophylla*. In zonal habitats a number of dwarfshrubs from other genera (*Betula, Salix, Vaccinium, Empetrum, Ledum*) have here replaced *Cassiope*, as dominants.

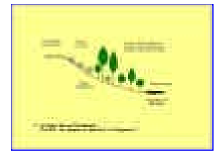
Snowbeds in Greenland are dominated by species like *Sibbaldia procumbens* and *Potentilla crantzii*. Wet sites have a much more important component of *Sphagnum* spp., which accounts for the oligotrophic soils.

In the West European sector Zone D is only present in the most favourable parts of Jan Mayen (Elvebakk & Spjelkavik 1995).

In the amphi-Beringian area much of the flat or gently rolling terrain on weakly acidic loess material is dominated by “tussock tundra” of *Eriophorum vaginatum*.

Fig. 5.

Zone E (Fig. 4) has a ridge vegetation of *Loiseleuria* and *Diapensia* on weakly acidic soils. Heavy acidification has restricted *Dryas* to more calcareous parent materials. Zonal habitats have a distinct podzol formation, and in addition to other dwarfshrubs, have shrubs taller than 0.5m among species of *Betula, Salix* and *Alnus*. In areas like northernmost Finnmark *Salix* shrubs are heavily grazed and destroyed by a dense, semi-domesticated reindeer population. Snowbeds have an important component of tall forbs like *Epilobium angustifolium* and *Angelica archangelica* in Greenland and many more species in the amphi-Beringian area. Bogs have *Sphagnum* dominance and a distinct hummocky structure. *Eriophorum vaginatum* tussock tundra dominates the landscape in the amphi-Beringian area, like in zone D. In riparian communities *Salix* species can be tall shrubs, for instance *Salix alaxensis* in the amphi-Beringian area. Here there are also small groves of trees of *Chosenia arbutifolia* and *Populus suaveolens* or *P. balsamifera* along rivers. These occurences locally delimit the absence of permafrost. A more detailed presentation of East Siberian toposequences is given by Razzhivin (1999).



Simplified topographic gradient of northern boreal heathlands.

Vegetation in neighbouring oceanic areas

Areas bordering Zone E towards the south, both in the North Atlantic and the amphi-Beringian sectors (Fig. 5) have frequently been included in the Arctic. Thus there is a need to explain more closely the zonal position of these areas. The best alternative is first to present toposequence schemes from these areas, and then show the criteria, and the conclusions drawn from the criteria. Then there will be a documentation on the rejection of these areas as arctic, which would hopefully act as a better support for the treatment given here, than simply neglecting such areas.

A characteristic aspect is that the open arctic-alpine ridge communities are now absent and replaced by a more or less continuous cover of dwarfshrubs from similar genera as in neighboring zonal habitats. In addition, snowbed communities are absent and replaced by forests, tall shrubs, or anthropochorous heathlands.

Forests can be present everywhere except in wet habitats, which are occupied by bogs or mires. This is the case in most of northernmost Fennoscandia, with *Betula pubescens* as the dominant in the northwest replaced by *Picea abies* in Finland and the Russian Kola Peninsula south of a *Betula* belt. In Alaska *Picea mariana* and *P. glauca* are dominants. In the weakly oceanic 'stlanik' of Chukotka there is a dominance of tall shrubs (2-6 m) of *Pinus pumila* and *Alnus fruticosa*. Stands of forests of *Populus suaveolens* and *Chosenia arbutifolia* are common along rivers.

In more strongly oceanic areas, like the narrow coastline of North Norway, large parts of Iceland and the boreal enclave of South Greenland the forests are less prominent. This is primarily because of anthropogeneous suppression including overgrazing.

This was especially detrimental in Iceland where the volcanic substrate is so strongly vulnerable to erosion. It is also a result of a characteristic landscape pattern, with strongly convex parts being strongly exposed to winds, and along the coast, to a surprisingly broad zone of saline sea-spray. Only the Aleutians have a landscape primarily and historically devoid of forests. These areas have been called northern boreal, both in the amphi-Beringian and the amphi-Atlantic sector (Tuhkanen 1992 and Dahl et al. 1986).

South of the northern boreal zone in Fennoscandia, but still reaching 70^{o} N, there is a middle boreal vegetation. Along the coast it is distinguished from the northern boreal zone by the occurrence of *Calluna* dominance, partly with *Pinus sylvestris* forests, and in central parts by communities dominated by *Alnus incana, Salix pentandra* and *Matteuccia struthiopteris*. In Iceland the area occupied by this zone is most strongly modified by human activity, and it is very favorable both as to climate and phenology, which is reflected in agriculture. Botanically the zone is best characterized by the presence of a few southern species (*Holcus lanatus, Succisa pratensis, Plantago lanceolata*) in grazed meadows, species which have a similar pattern in neighbouring Fennoscandia.

In Northern Norway even small areas of the southern boreal zone reaches the Arctic Circle, in favourable areas near the coast with strongly southern species of temperate affinity like *Ulmus glabra, Corylus avellana* and *Viburnum opulus*, as well as thermophilous *Pinus* forests (Dahl et al. 1986). The outer coastal heathlands in these areas are presently referred to as middle boreal, but this needs further studies. In Alaska a similar situation exist with middle boreal areas reaching the easternmost Aleutians and even the southern boreal area reaches adjacent areas (Tuhkanen 1992). However, Tuhkanen (1992) did not present much botanical criteria in support of his zonal maps in this area.

The Faeroe Islands that have been included in the Arctic in some contexts are also primarily tree-less, but belong to the boreo-nemoral zone. Their zonal position definitively has nothing to do with the Arctic, neither botanically nor climatically, see Tuhkanen (1987).

Another problem is represented by mountains adjacent to the southern limit of the Arctic. Here, arctic vegetation is displaced altitudinally to a mountain belt. However, where mountain chains are arranged in a latitudinal direction this vegetation more or less gradually changes into non-arctic, alpine vegetation. This transition is difficult t o define, and has been decided to be outside the scope of both the CAVM and the PAF projects

A new bioclimatic map of the Arctic

Included in this volume is a new map of the Arctic subdivided into five bioclimatic zones. The map is split into four parts for practical reasons; to allow for a better resolution. This map will also be included on the PAF web site. In the amphi-Atlantic sector this map shows a parallel delimitation of the Arctic in Fennoscandia and Iceland, including only the northernmost peninsulas, and adjacent oroarctic mountains towards the south are not included. This delimitation is in accordance with the Norwegian vegetation region map (Dahl et al. 1986) and with views held by the Icelandic representatives to the CAVM and PAF programs, E. Einarsson and H. Kristinsson, respectively.

A major revision of boundaries has taken place in Greenland. The general north-south gradient is combined with the east-west gradient, which is very prominent and mostly dominating over the latitudinal gradient. All along the Greenland coast there is a climatic and botanic gradient from the cool, exposed coast to the inner, protected parts of the numerous and long fjords. Thus, locally, the most important climatic gradient is running east-west and not north-south. This is reflected in the system of coastal and inland botanical districts found in all the classic Danish geobotanical literature on Greenland. On the present map zonal boundaries are not cutting across Greenland latitudinally as in previous maps, but are seen running in a north-south direction following the coastal gradient in addition to showing a general exchange of zones from the north to the south. The Boundaries mostly follow district boundaries and information in Feilberg (1984, 1987), Fredskild (1996), and Bay (1992, 1997). A draft of the map has also been commented on by B. Fredskild and F.J.A. Dani?ls (pers. comm.). Own experience has been used for central East Greenland, and in Scoresby Sund no fewer than four zones are mapped along the local east-west fiord gradient.

The boundaries for the three northernmost zones in Canada follow Edlund & Alt (1989), which is not interpreted in the same way as done by Yurtsev (1994). Thus zone C is extended northwards in the central, warm parts of Ellesmere Island and Axel heiberg Island. The southern zones follow Yurtsev (1994). Some minor changes have been made for Alaska as compared with Tuhkanen (1992) and Yurtsev (1994), following suggestions by R. Elven (pers. comm.), who indicated that theYukon delta, the Hudson Bay and the northeastern coast of Labrador are areas in need of regional studies on biogeographic zonation. The Aleutians are not included within the Arctic, although they are predominantly treeless.

The division of Russia follows Yurtsev (1994), except for the revisions made by Razzhivin (1999). The ’stlanik subzone’ and the ’zonal equivalents of IV and V outside the tundra zone’ treated by Yurtsev (1994) are not included within the Arctic.

Contents

Discussion

Delimitation of the Arctic

Throughout most of the Northern Hemisphere, the arctic treeline is the major criterion defining the southern limit of the Arctic. However, over some areas it not a distinct boundary but expressed as a forest-tundra transition, often called forest-tundra. It forms a narrow 10-50 km band in Canada and Alaska (Bliss 1997). Within this forest-tundra transition the tree component can vary due to the local history of fires. In Fennoscandia the transition has been treated as a separate zonal unit, the orohemiarctic by Ahti et al. (1968). This unit was expanded and mapped as the hemiarctic zone over a large area in northernmost Fennoscandia by Oksanen & Virtanen (1995). They omitted the prefix ‘oro-‘ indicating an altitudinal position, as the altitudinal difference is quite small. The latter expansion is considered here to be both an exaggeration of an ecotone, and a heterogeneous unit, and the map by Dahl et al. (1986) is instead referred to. The forest-tundra was mapped with a partially broad zonal distribution in Russia by Chernov & Matveyeva (1997) and included as a part of the northernmost boreal area both by these authors and most other authors dealing with Russia and North America. This is followed also here.

In coastal areas the pattern is more complicated as forests have a more restricted natural distribution, are more poorly developed and have been reduced historically due to anthropogenic influence. Along the Norwegian coast the treeless zone is now being narrowed by reinvasion of trees following the decline in traditional land-use, and the remaining treeless rim is mostly an effect of saline sea-spray during stormy events (Edvardsen et al. 1988). However, in northernmost Finnmark (see Dahl et al. 1986) and in adjacent areas of the Kola Peninsula there is a treeless coastal zone north of the northernmost *Betula pubescens* forests; the latter are confined to valleys separated by mountains. These areas are defined as arctic here. In addition to the forest criterion, snowbeds and arctic-alpine ridge communities are also found in the lowlands here, as opposed to the coastal lowlands further to the south. The delimitation coincides well with the 10^{o} C July isotherm.

In Iceland the forests has been much more devastated due to grazing and erosion, but the situation is basically similar to that in northernmost Fennoscandia. The northernmost peninsulas are situated north of the northernmost climatic *Betula pubescens* forests and are arctic. In Greenland a boreal enclave in the south is well documented, and was mapped (as ’subarctic’) regionally by Feilberg (1984).

Another problem of delimitation of the Arctic concerns mountain vegetation in northern boreal areas. Close to the Arctic the mountain vegetation is evidently similar to that of the Arctic, for instance in Fennoscandia, where all alpine vegetation was called 'oroarctic' by Ahti et al. (1968). Eurola (1974) claimed that the differences between the alpine belts of Fennoscandia and the arctic zones are much more striking than the similarities, and Elvebakk (1985) discussed problems in comparing the middle alpine belt in Fennoscandia with the arctic zones. Obviously, mountain areas close to the Arctic, like the mountains of of northern Fennoscandia and Iceland can be called oroarctic, but it is problematic to select criteria separating such oroarctic areas from alpine non-oroarctic vegetation, especially in the vast mountain chains with a large latitudinal extension like in North America, East Asia and the Urals. These problems should be left for special treatments, and oroarctic areas are therefore not included within the Arctic as defined here.

Criteria for zone definitions

The polar tree line is basically a criterion focusing on the advanced growth form of the zonal vegetation. In this context lignified species are considered more advanced than herbs, and large growth forms more advanced than smaller ones. The polar tree line basically marks the boundary of similar communities, but with a sectorial floristic differeentiation involving different tree species of the genera *Betula, Picea* and *Larix*. The polar tree-line is a botanic criterion that has been widely used to delimit Arctic, but is of more limited value in strongly oceanic areas. There is, for instance, a very large climatic gradient along the North Atlantic islands Jan Mayen, Iceland, Faeroe Islands, Shetland, the Hebrides etc., which is not much indicated by tree growth. A similar situation occurs along climatic gradients among the islands of the Bering Sea.

Trees of the northernmost forests are absent from dry ridges and wet sites, and the habitats of the snowbeds found further to the north are mostly inhabited by shrubs. However, trees do grow in riparian habitats even farther north. This is due to the fact that rivers penetrating to the Arctic from the south bring water that prevents the formation of permafrost. Tree growth can also be favored by the sheltered topography caused by river terraces thus creating favorable enclaves. Such deviating azonal occurrences along rivers are not rare in zone E, and may even exist in zone D in Chukotka, emphasizing that the criterion for zones involving growth forms are different for different habitats.

An extrapolated use of the criterion further north shows that four zones are easily defined. Zone A is defined by lack or only marginal presence of prostrate shrubs, zone B with presence of prostrate shrubs but absence or only marginal presence of the dwarfshrub *Cassiope tetragona*, zone C and D with presence of dwarfshrubs, and zone E with presence of shrubs. These criteria should be included within their communities, which can be described in a non-formalized ecologic/floristic/physiognomic manner, or in a formalized phytosociologic way, including syntaxon names. A treatment of syntaxa on a circumpolar scale was discussed for the Arctic by M. Walker et al. (1994). However, there is a lack of tradition for syntaxa on a circumpolar scale, consequently the syntaxonomic names appear alien to many users. Phytosociological syntaxa were used to define zones in the European Arctic by Elvebakk (1985), but for a broad audience these syntaxa are better replaced as primary criteria by simplified community names and/or descriptions and by growth forms.

The shortcomings of growth-form criteria appear in the separation of zone C and D, and in the delimitation of the Arctic in some oceanic parts of the world. Here a supplementary use of vegetation communities in zonal habitats is recommended. The communities dominated by *Betula nana* s. lat., *Vaccinium uliginosum* s. lat. and *Empetrum nigrum* are different from those of *Cassiope tetragona*, see M. Walker et al. (1994). This coincides with the phytogeographic affinities, as all the dwarfshrubs replacing *Cassiope* are also found in the Arctic and in boreal areas ('hypoarctic' in Russian tradition). The limit between heathlands dominated by *Cassiope* in the north and the hypoarctic genera in the south correspond to the classic boundary between the Low Arctic and the High Arctic (sensu Bliss 1981, and not recognizing any Mid Arctic) or between the arctic and the hypoarctic groups of subzones in the sense of Yurtsev (1994).

The disappearance of open ridge communities characterized by *Loiseleuria procumbens* and *Diapensia lapponica* as well as snowbed communities when passing from zone E southwards are important supplementary criteria to tree growth for delimiting the Arctic, especially in coastal areas. Longer growing seasons, higher humidity and less drought stress explain why widespread shrubs and dwarfshrubs from neighboring habitats also cover the ridges. Similarly, a longer growth season, less permanent snow cover during winter and more rain explain why snow bed habitats are not developed, except in topographically extreme situations like gorges etc. Generally, the occurrence of forests creates turbulence patterns and a much more even distribution of snow than in non-forested areas. In non-forested areas enhanced and directional wind forces over exposed areas remove snow and redeposit it in leeward sides where turbulences are created. Thus, the disapperarance of the ridge and the snow bed communities are also generally correlated with the polar tree line and with the arctic boundary, also where the tree-line alone is not sufficient to define the Arctic.

Physiognomy of the land and vegetation cover are overlapping criteria that should be evaluated. Between zone A and B a distinct physiognomic difference occurs with the barren desert-like Zone A bordering a much more vegetated but still discontinuous cover in Zone B. The gradient to continuous cover takes place in zonal habitats between zone B and C, and does not co-occur with the High-Low Arctic boundary. Discontinuous cover also continues i.e. on ridges even further to the south into unit D. This vegetation cover gradient between zone B and D is considered much less conspicuous than the difference between zone A and B. The appearance of shrubs in zone E can be considered an important physiognomic character, easily noticed because it is so different from the common tundra of low plant growth forms further north.

Between zone C and D there is a consistent physiognomy difference in the amphi-Beringian area due to the dominance of *Eriophorum vaginatum* tussock tundra in quite exposed habitats. The reason for its occurrence in this sector is still not understood. The dominance of fine-textured loess material is probably a result from processes during periods with periglacial conditions. A long history with mostly no glacial activity can explain the time span needed for leaching, and a higher temperature, more precipitation and a history of less cryoturbation than further north may explain an abrupt pH boundary coinciding with the northern tussock tundra boundary (Walker et al. 1998). The existence of the characteristic tussock tundra has also been related to the post-glacial extinction of megaherbivores (Zimov et al. 1995), although this hypothesis is not generally accepted.

Most situations elsewhere in the Arctic where fine-textured materials dominate in exposed areas are related to carbonate-rich parent rocks or allochthonous sediments. Such substrates are hostile to the establishment of *Eriophorum vaginatum*, which is otherwise a common circumboreal species. The same statement could be made for *Sphagnum* spp. The occurrences of acidic and very fine-textured soils on exposed areas (called plakor) causes a lack of drainage and paludification that is uncommon on similar topographic situations elsewhere in the Arctic. These special habitat characteristics may explain why these sites may not deserve thr name ‘zonal habitat’, which instead could be reserved for better drained slopes where instead dwarfshrubs and shrubs dominate, also in the amphi-Beringian area.

To conclude, the advanced growth forms in communities of zonal habitats is considered the most precise and user-friendly primary criteria for the definition of bioclimatic zones. However, a more complete use of communities, including those of azonal habitats, gives a much better basis, and allows a better treatment of areas with contrasting substrate chemistry and areas with oceanic climate. Such criteria are also necessary to portray the classic boundary between the Low and the High Arctic in the sense of Bliss (1981). For local studies phytogeographic analysis of the complete species composition is even possible (Elvebakk 1990).

How many zones?

Only four growth-form-defined zones within the Arctic would suppress the classical distinction between the High and the Low Arctic. Unless growing depauperately in alkaline soil, *Cassiope tetragona* is an erect dwarfshrub with the same growth form as the *Betula*, *Vaccinium*, *Salix* and *Empetrum* species which replace it in zone D. Also phytogeographically, the changed balance between a majority of arctic or arctic/alpine species to species with their major distribution further south supportes the need to maintain the distinction between zones C and D. To lump zones B and C would ignore the growth-form criteria, and an important climatic, floristic and community gradient (Elvebakk 1985, Edlund & Alt 1989). A recent defense of zone A as a separate entity was given by Bay (1997). A split of zone A is possible (Aleksandrova 1980, Tuhkanen 1986), but as this zone is so marginal, poor in species, covering a narrow climatic range and a small geographic area, this is thought unnecessary. Thus five zones are recognized here, and each unit more or less corresponds to a 2º C range of mean July temperatures.

First-level grouping of zones

In present systems there are two major grouping of zones. One emphasizes the difference between zone C and D (High vs. Low Arctic or 'arctic' vs. hypoarctic') which is based mostly on phytogeographical affinities. The alternative is to have a first-level grouping with zone A and zone E as the extremes separated from a central group of three zones, and this is advocated here. The lack of all lignified species (zone A vs. B), the occurrence of shrubs (zone E vs. D), as well as the occurrence of trees (zone E vs. F) are fundamental and easily observed. These are manifested as vegetation physiognomy like the desert-like appearance in the north and the occurences of shrubs in the south.

The tundra concept is quite problematic. Etymologically, the word relates to Finnish 'tunturi' used for treeless isolated mountains in North Finland, but also to similar words in the languages of related linguistic groups like the Sami people (and the nenets?). Most of the Finnish mountains, however, are so low that their vegetation is 'low alpine'.The Sami language uses other words for more dramatic mountain forms, so the tundra concept relates to a 'tundra vegetation' (low vegetation of shrubs/dwarf shrubs, herbs and cryptogams) and allmenn flat or gentlty rolling landscape element. The landscape form and its vegetation pattern in the European part of Russia is in harmony with such a concept. In botanical literature this is reflected in the very narrow concept in the former Soviet Union/Russia with 'typical tundra' for zone C/D, the intermediate zones. This was also emphasized by Bliss (1997) who defined tundras as areas ‘where plant cover is nearly complete and where woody species, sedges, and grasses predominate’. He used ‘tundra’ only for vegetation equivalent to zones D and E. Yurtsev (1991), in the English summary, applied a long definition focusing on the role of the low-growing shrub growth forms and the predominance of continuous or discontinuous tundra peat, a view agreeing well with the narrow definition used by Bliss (1997). However, he stated that the open frost boils in this typical tundra landscape are also a part of the tundra. And even zone A where such barren landscapes dominate and where the core element he started with in the definition is lacking, should be referred to as tundra.

A definition of ‘arctic tundra’ involving areas with a dominance of lignified species, herbs and cryptogams and lack of trees for climatic reasons, probably is in best harmony with the original concept as developed in Russia from their contact with the northern linguistic people.

A wide global definition of ‘any cold, treeless area’ as adopted by Wielgolaski (1997) has been much used in the west, particularly in North America. However, we can concentrate on our issue ‘arctic tundra’, without having to deal with the various definitions and problems related to concepts like ‘alpine tundra’ and ‘antarctic tundra’.

The polar deserts have some areas with a higher plant cover than typical of the zone, as also stated by Aleksandrova (1980). This is for instance the case in easternmost Edgeoya, Svalbard, where a dense moss cover dominated by *Tomentypnum nitens* covers local areas, under a polar desert temperature regime, but heavily influenced by precipitation, fog and intensive reindeer grazing through millennia (Elvebakk 1997). But all zones have deviating areas, even tropical deserts have forests (oases). Barren limestone areas dominate far south of the climatic polar deserts in arctic Canada, but barren vegetation occurs on specific substrates in most climatic regions. The climatic polar deserts were convincingly described by Bay (1997). Physiognomy and ecology unites the polar deserts with the subnival belts of mountains further south, although the species compositions are very different (Bohn 1997).

The terminology ‘polar desert’ is a concept where basically a very low temperature sum prevents the establishment of a more luxuriant vegetation, and not humidity in itself like in temperate to tropical deserts. However, in both cases a humid environment is available for plant growth only during a very short period; when it is not frozen in the near-polar area, and a short period after precipitation in temperate/tropical areas.

A definition of ‘polar desert’ could involve a barren, unglaciated area near the poles, where low temperatures prevent the establishment of closed vegetation dominated by lignified species, herbs and cryptogams on zonal sites and Cyperaceae dominated mires on wet sites. This definition relates to the arctic areas, whereas a definition of ‘antarctic polar deserts’ should focus on the absence of cushion plant vegetation, otherwise so typical of the wind-blown subantarctic islands. When taking into account also the antarctic areas, polar deserts may even deserve a status as a separate biome.

Polar deserts may have had a fluctuating status during the Holocene, and this zone is the part of the Arctic most vulnerable to a predicted global warming.

Evaluation of nomenclature following the selected criteria

a) Simplicity

Names like ’southern variant of the arctic tundra subzone’ and others including a intricate nomenclatural hierarchy are not acceptable. This does not imply that hierarchy in the system is not clear nor consistent, but names should be simplified, and in most cases this can easily be achieved. Another name that should be discarded for the same reason is the ’Enriched prostrate shrub zone’. Also the name ’prostrate’ in itself is not evidently understood by a broad international audience unless it is de-latinized, and the alternative ‘creeping’ should be reserved for animals!

b) Exclusivity

The use of growth-form names like ‘Herb and cryptogam zone’ is not exclusive, as the name-giving categories are found in all zones. Some modifying adjectives like ’arctic’ are necessary.

c) Precision

Some names have been used in such different senses that a precise meaning consequently has been lost. This is particularly the case with the word ’subarctic’ (Hämet-Ahti 1981), which has mostly been used for northern boreal situations, although Aleksandrova (1980) used it about the southern parts of the Arctic. It is also necessary to specify tundra as ’arctic’ to to distinguish it from ‘alpine’ and ‘antarctic tundras’. However, the use of parallel names at the same hierarchical level like ’High arctic tundra subzone’ and ’Arctic tundra subzone’ as well as 'Arctic tundra' and 'Typical tundra' should not be encouraged.

The words High and Low Arctic could have different interpretations: whether recognizing High and the Low Arctic (the High Arctic s. lat., zones A-C) or recognizing both the High, Mid and Low Arctic (High Arctic. s. str.). In the former system the polar desert is only the northernmost of three high arctic zones, e.g. Bliss (1975). In the system of Yurtsev (1994) the High Arctic is much narrower, comprising only the northernmost zone called polar desert by others. There is also a third interpretation where High Arctic is applied to zone A and most or all of zone B (Moen 1998).

High and Low refers to latitudes, thus semantically meaning only 'north' and 'south'. In Fennoscandia the words 'high' and 'low' are restricted in use to altitudinal units, called 'belts', as opposed to 'zones'. This use of 'belts' has a similar tradition in Russia (Yurtsev et al. 1997). 'High' and 'Low Arctic' are probably the most widespread designations used when differentiating the Arctic in two parts only.

d) Internationality

The terms 'hemiarctic' and 'hypoarctic' are practically unknown outside of Fennoscandia and Russia, respectively, except among specialists, and should be avoided for general use.

e) Information contents

The names should contain information that relates the names to easily observed or conceived properties, and avoid redundant information.

f) Independent use

The names should also be so self-explanatory that the name of one zone could be used independently without a demand for knowledge of names of other zones, or one of several names for the whole Arctic. As both 'tundra' and 'polar desert' are commonly used about areas outside the Arctic, it is necessary to include the name 'arctic' about all the zonal units.

A proposed nomenclature

To eliminate too many alternatives the following three alternatives are presented here as a basis for a discussion (Table). None of these have previously been published as they appear here.

Table. A proposed nomenclature of arctic zones (explanation in the text).

These alternatives emphasize vegetetion physiognomy (I), growth forms (II), and the traditional phytogeographic division in the High and Low Arctic (III), with various combinations of north-south differentiation (IV).

My basic opinion is that communities of both zonal and azonal habitats are the best criteria for defining the various zones. This was also the criteria used by Aleksandrova (1980). Phytosociologic nomenclature allows for a definition of communities at different hierarchic levels, and an application of high-level units is necessary to obtain a circumpolar system. The lack of knowledge is the most serious problem in this respect. The restricted familiarity to the formalized syntaxon names in the Braun-Brlanquet tradition, also among botanists, is a smaller problem, because these names should be explained in a more accessible version, anyway.

But for a name system, the three alternatives can be considered as different aspects of vegetation communities. The dominant ‘advanced’ growth forms actually form the vegetation physiognomy. But should we use the growth forms or the vegetation physiognomy names as zonal names?

Let us look at the neighboring biome to the south. It is dominated by the advanced growth form ‘trees’, but it is not called the ‘teee zone’, but a ‘forest’. As a forest it is distinguished from other forests by the name ‘boreal ‘ or ‘taiga’, and not by its advanced growth forms. Also the genera in question, *Betula*, *Picea* and *Larix* actually all have three different growth forms. Furthermore, there is no diversity of advanced growth forms available for naming the subunits of the boreal biome/zonobiome/zone.

The same is the case elsewhere. We do not call the equatorial area the ‘broad-leaved, sclerophyllous, evergreen tree zone’, although this growth form dominates and makes up the ‘tropical rainforest’. We can continue with savannas, deserts, ‘temperate forests’ etc., and see that some name referring to the vegetation physiognomy, sometimes in combination with a name referring to climate, has been chosen as a general name of the biome, also including its animal components.

Because the Arctic includes the transition from a forest to practically nothing, there is a better sequence of growth forms available here than in most other biomes, but how is vegetation physiognomy realized in the Arctic?

Any person who visits the Arctic can easily observe the transition from occurrences of forests to a tree-less vegetation with shrubs, then to a quite dense vegetation without shrubs, and, finally, to the barren landscape in the northernmost areas. In this context shrubs are defined as all lignified individuals taller than 40 or 50 cm, which are not trees. A detailed subdivision in ‘tall’, ‘low’, ‘erect dwarf-‘ (‘why then are not dwarfshrubs semantically a subtype of low shrubs?’), ‘semi-erect dwarf-‘ and ‘prostrate dwarf-shrubs‘ is much too detailed for a general purpose and for naming. The role of the dwarf-shrubs in the central parts is not so physiognomically striking. It would not be wise to neglect the possibility of utilizing such broadly observed aspects in the name of the zones, to attract many users, and to be in harmony with a general naming tradition.

The northernmost and southernmost zonal units of the Arctic are most different from the others in vegetation physiognomy. The southernmost deserves a vegetation physiognomy name for a community with the growth forms shrubs (parallel to forest for a tree community). In Nordic languages it would be ‘kratt/krat’ and not ‘busk’. It would probably be ‘shrubland’ in English, as ‘scrub’ is used for a more xeric vegatation. ’Arctic shrubland tundra zone ’ is a little bit too long, but when ‘shrub’ is associated with ‘tundra’ it is a physiognomic concept, and ‘arctic shrub-tundra zone’ is shorter.

The central zones could have been called ‘heathland tundra’, which is the vegetation physiognomy name for dwarfshrub dominated communities, or a combination of dwarfshrub and tundra. However, this component is not so physiognomically different from the remaining vegatation. Also their variation is not sufficient to eliminate the use of the northern-southern name element, and such additions would make the name much too long.

The names ‘northern’, ‘middle’ and ‘southern’ are geographic, but are immediately associated with a climate gradient (like ‘high’ and ‘low’), and can be incorporated in the bioclimatic nomenclature. In the northernmost area ‘polar desert’ is a well-established name.

Alternative III is regarded as the least appropriate proposal. The information value is low, as the names are only combinations of a single semantic concept, ’north-south’, used in three combinations. Bearing in mind the different interpretations of ’High Arctic’, the name ’middle high arctic zone’ for zone B is liable to increase the confusion with ’Mid Arctic’ which has a different circumscription.

Alternative II has a problem because growth form names are only available to four zones. Also the names involved are not exclusive, and the differential criteria are found in the name of the neighboring zone. This means that the herbs in the ‘herb zone’ are equally or more present in the zones further towards the south, and instead the lack of the prostrate shrubs are actually the differential criterion. The use of differential criteria is not problematic to explain, but as a name I find it less appropriate than a name referring to the <u>scarcity</u> of herbs (and other growth forms), typical of this zone. In general, vegetation physiognomy is thought to have a more direct association and appeal to a wide range of users than the growth forms themselves.

Proposal I has been accepted in a slightly different version for standard floras of Norway and the Nordic countries (Lid & Lid 1994, Jonsell 1991), is in general use by the Norwegian Polar Institute and Environmental authorities, and will be used as it is for the forthcoming European vegetation map. This proposal also has its strongest ties with Soviet/Russian tradition. In this country there are, indeed, several versions with different numbers of zones, prevailing both in their tradition and in active use today, see Razzhivin (1999). Aleksandrova (1980) improved Soviet tradition in one respect by broadening the 'arctic tundra' concept, which has been incorporated into the present proposal. However, she also introduced the 'subarctic tundras', which is in conflict with western tradition where it is used about areas south of the Arctic (which also the name itself refers to), cf. Hamet-Ahti (1981). In this case I have instead used one of the traditional names from the pre-Aleksandrova tradition. The southernmost zone had various names in the pre-Aleksandrova systems, but Gorodkov et al. (1954) in the authoritative 'Vegetation map of the USSR', as translated by Lavrenko & Ponjatovskaya (1956) included shrub-tundra in the major characteristic.

In our present attempt on harmonization, where North America, West Europe and Russia both have their national tradition and national diversity, is there a reason why I as a West European author should emphasize the links to Soviet/Russian tradition? First, I should say that in spite of much thinking I have found no better alternative, and in addition, I would list three points:

1. It was there that the tundra concept (which many have changed) was born.
2. It was there that the polar desert concept (which has subsequently been revised in North America) was born.
3. It was the country where both vegetation mapping and zonal mapping within the Arctic had a much stronger activity and tradition than in the other two sections of the Arctic.

Contents

Conclusions

1. An increasing diversity in names, entities and criteria used for delimitation and subdivision of the Arctic has, surprisingly, been accompanied by increasing agreement on the contents and definition of bioclimatic zones. Time has come to harmonize the approaches and find a user-friendly, concise nomenclature.
2. Five zones seem to be an optimal number for describing

climatic variation by use of botanic indicators.
4. Communities seem to be the best basic criteria for subdivisions, involving those of both zonal (ecologically ‘intermediate’) and azonal habitats, and using high level units for a circumpolar system. The use of aspects of the communities, like growth forms of the woody species and vegetation physiognomy are easily communicated criteria, although they are not sufficient alone in defining all units.

Zone A is defined by a barren aspect, and lack of any communities with lignified species, and lack of peat-producing mires with cyperaceous plants. Zone B has communities with prostrate with by real mires with *Carex* and *Eriophorum* dominance. Zone C has

1. *Cassiope* communities in zonal habitats, although these are less prominent on alkaline substrates, where some thermophilous mire communities occur. *Epilobium latifolium* riparian communities are common. In zone D the zonal communities have a shift to more southern dwarfshrubs genera like *Betula, Empetrum, Vaccinium* and *Salix*, some of them restricted to acidic substrates. Zone E has shrubs of *Betula*, *Alnus* and *Salix* in zonal sites with a podzol soil profile, and with ombrogeneous bogs and tall-herbs in some snow bed situations, and forest groves along large rivers which bring warm water from the south. In some coastal areas where forests are little prominent the disappearance of both *Diapensia – Loiseleuria* exposed ridge communities and snow bed communities can be used as additional criteria to define the Arctic.
2. In naming, the use of vegetation physiognomy is considered to be the best direct characteristics, which also could attract a wide scope of users.
3. Names were evaluated with respect to their simplicity, exclusivity, precision, internationality, information content and independence. The following is recommended for arctic bioclimatic zones starting from the north:

    - Arctic polar desert zone
    - Northern arctic tundra zone
    - Middle arctic tundra zone
    - Southern arctic tundra zone
    - Arctic shrub-tundra zone

These names would include the original definitions of arctic tundra and polar desert as these have been developed in the former USSR.

Contents

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