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## The Second International Workshop on Circumpolar Vegetation Classification and Mapping: a tribute to Boris A. Yurtsev

by Donald A. WALKER, Fairbanks, Alaska, Arve ELVEBAKK, Tromsø, Norway, Stephen S. TALBOT, Anchorage, Alaska, Fred J. A. DANIËLS, Münster, Germany

### 1 Introduction

The Second International Workshop on Circumpolar Vegetation Classification and Mapping was held in Tromsø, Norway, 2–6 June 2004. The workshop was a step toward a unified international method for classifying and mapping arctic vegetation. It celebrated the completion of an eleven-year effort to make a vegetation map of the Arctic and brought together vegetation scientists from around the world to present the latest information regarding arctic syntaxonomy, geobotany, mapping, and new computer programs for studying arctic plant communities. The basic rationale for the conference was the same as that of the First International Workshop on Classification of Arctic Vegetation held in 1992 in Boulder, CO, USA – global scale arctic research programs, modeling efforts, educational materials, development and conservation efforts require a common language for describing arctic ecosystems (WALKER et al. 1994).

### 2 Boris A. Yurtsev

The conference honored the lifetime achievement of Boris Yurtsev, one of the great arctic botanists and a driving force behind the Conservation of Arctic Fauna and Flora (CAFF) Program (TALBOT & MURRAY 2001), the Panarctic Flora Project (NORDAL & RAZZHIVIN 1999), and the Circumpolar Arctic Vegetation Map (CAVM TEAM 2003). Boris was a geobotanist known widely for his work in taxonomy. He was the author of no fewer than 49 of the 96 taxa listed as rare, endemic vascular plants of the Arctic (TALBOT et al. 1999). He was much involved in the history of flora and vegetation of the Arctic, particularly in the Beringian sector. He introduced florogenetic concepts like Meta-Arctic and Mega-Beringia, see YURTSEV (1997). Throughout his career he studied northern forest-steppe and tundra-steppe communities (see YURTSEV 2001), particularly in the amphiberingian region where Wrangel Island with its unique biodiversity was his favorite area (YURTSEV 1996).

For the CAVM Project his seminal paper at the Boulder workshop (YURTSEV 1994) was the organizing principle for the map. His vision was



achieved – a map with a hierarchic structure based largely on the Russian concept of phytogeographic zones and his floristic subprovinces. During his last years he struggled with health problems. However, his passion for arctic geobotany and his love for academic debates on this topic were stronger than his illness, and he managed to attend several international workshops during this period. During our last workshop he presented the Russian tradition of comparative floristics, recently published in Russian (YURTSEV 2004).

It was with sadness that we received the news of his passing on the 14 Dec 2004. We will miss Boris as a warm friend and colleague, and as a discussion partner with encyclopedic knowledge about arctic geobotany. He was an extraordinary person we will always remember. It is an honor for us to dedicate this volume to the memory of Boris A. Yurtsev.

### 3 The Circumpolar Arctic Vegetation Map

The Tromsø workshop was in part a celebration of the completion of the CAVM. One of the major accomplishments of the 1992 Boulder conference was a resolution to develop a map that portrays all of the Arctic with a unified legend. The project struggled for a few years because of insufficient funding to accomplish such a large undertaking, but several workshops in St. Petersburg, Moscow, Arendal, Fairbanks, and Anchorage maintained the interest and commitment of the international team of participants and helped to develop the method for making the map. In 1999, a grant from the US National Science Foundation with supplemental funding from the US Fish and Wildlife Service provided the means to complete and publish the map. Happily, we were able to celebrate our shared goal of making the map before our hero and mentor, Boris Yurtsev, passed away.

Two of the major questions facing Arctic terrestrial ecologists at the moment are what will happen to the tundra regions as the global climate warms (ACIA 2004) and what will happen as the region undergoes rapid industrial development and land-use changes (NELLEMAN et al. 2001)? Changes to the vegetation will have major consequences for the permafrost, snow, hydrology, soils, wildlife, and people who live in the Arctic. They also have global implications because of albedo and trace-gas feedbacks to Earth's climate system (BERINGER et al. 2001; CHAPIN III et al. 2000). Over the past 40 years, all the Arctic countries have conducted numerous independent large well-funded inter-disciplinary arctic research studies that have greatly expanded our knowledge of the functioning of tundra ecosystems; however, most attempts to describe the diversity of plant communities in the Arctic have been *ad hoc* efforts; each region used different methods of vegetation classification and mapping. A unified approach to describing and mapping the Earth's vegetation is essential for answering questions at global scales. If we are to develop a unified approach to describing the vegetation of the entire globe, the Arctic is the place to start. Of all the global biomes, the arctic tundra lends itself most

to a unified approach to classification and mapping because there is a high level of floristic, physiognomic, and syntaxonomic similarity across the entire biome.

The CAVM provides a new perspective to view the Arctic and a framework for a wide diversity of Arctic studies. The map was published by the US Fish and Wildlife Service as CAFF Map No. 1. The history, methods, and analysis of the map are presented in WALKER et al. (2005). The CAVM shows the Arctic as a complex, highly diverse biome with the arctic tree line forming the southern boundary of the map. The vegetated portion of the Arctic covers about 5 million km<sup>2</sup>, about half the size of the United States or two-thirds the size of Australia, but unlike Australia, which is a compact continent, the Arctic is strung out like a thin necklace around the Arctic Ocean with extraordinarily long ecological transition zones. Long linear boundaries between bioclimate subzones combined with large differences in tundra structure and composition that are manifest across relatively short climate gradients make the tundra biome especially susceptible to climatic change. To the south the boreal forest is expanding into the tundra along much of its 25,000-km treeline. To the north the tundra is connected to the Arctic Ocean, which is currently undergoing a rapid reduction in its perennial sea-ice cover (COMISO 2005). It is a surprisingly maritime biome. The Arctic has large portion of the total coastline of the world. Although calculating coastline lengths is a classic fractal problem, at the scale of the CAVM, it is 177,000 km long, greater than that of any country except Canada. About 80 % of the lowland portions of the Arctic tundra lie within 100 km of the ice-covered Arctic Ocean. The sea ice and cold sea create the low summer temperatures necessary for tundra's presence. An extremely steep coastal temperature gradient causes several bioclimatic subzones to be compressed near the coastlines of much of the Arctic. The sea ice also connects the northernmost parts of the Arctic land surfaces, and probably also facilitates long-distance dispersal of diaspores. The striking circumpolar similarity in flora and vegetation of the northernmost part of the Arctic may be explained by the migration possibilities offered by the frozen sea.

The map should prove especially useful to vegetation change modelers because it uses plant physiognomy and dominant plant functional types rather than bioclimate zones as the primary foundation for the map, revealing a much more complex mosaic of vegetation than has been apparent from the subzonal units on previous bioclimate maps. The map also contains a great deal of ancillary information; inset maps display bioclimate subzones, floristic provinces, topography, lake cover, landscape types, substrate pH, vegetation greenness, and aboveground plant biomass. The legend and supplementary tables describe the dominant vegetation composition and structure within the bioclimate subzones and map units. The map is strongly anchored in the Braun-Blanquet approach. For the majority of the tundra region, tables were constructed that show the dominant plant communities along toposequences in each bioclimate subzone and floristic province. Several of the presentations at the workshop used the detailed plant-community information to make plant-community-level maps at



finer scales. The paper by RAYNOLDS et al. (2005) describes the method for doing this at 1:4 million-scale for Arctic Alaska.

#### 4 Arctic phytosociology

The first International Workshop on Classification of Arctic Vegetation in Boulder, CO, USA 1992 (WALKER et al. 1995) strongly stimulated arctic phytosociological and syntaxonomical research. DIERSSEN (1996) published a milestone synthesis of the vegetation of Northern Europe, while others described a fair number of associations and higher syntaxa from areas all over the Arctic. Examples include dwarf-shrub heath vegetation of SW Alaska by DANIËLS et al. (2004), riparian willow shrub vegetation of the Arctic Slope of Alaska by SCHICKHOFF et al. (2002), Canadian riparian vegetation by GOULD & WALKER (1999), *Dryas integrifolia* tundra of NW Greenland and tundra vegetation of NE Greenland by LÜNTERBUSCH & DANIËLS (2004) and FREDSKILD (1998) respectively and the vegetation of NW Svalbard by MÖLLER (2000). Syntaxonomy of Russian Arctic vegetation was dealt with by e.g. ZANOKHA (2001, 2003), SEKRETAREVA (2003) and MATVEYEVA (1998, 2002).

The present special issue also reflects this ongoing process. KADE et al. (2005) analysed, described and classified the vegetation of frost boil complexes in the Low Arctic of Alaska, DIERSSEN & DIERSSEN (2005) surveyed syntaxonomy and synecology of arctic mire and related vegetation types of West Greenland, while KUCHEROV & DANIËLS (2005) presented a first syntaxonomic approach to the Carici-Kobresietea class in Chukotka. TALBOT et al. (2005) analysed and classified Amphi-Pacific boreal alder communities. In conclusion, we observe an enlarged syntaxonomical and synecological knowledge of arctic and related vegetation, however a coherent circumpolar picture is still far away. The circumpolar classes Carici-Kobresietea, Loiseleurio-Vaccinietea, Salicetea herbaceae, Scheuchzerio-Caricetea and the seashore vegetation (Asteretea tripolii, Honckenyo-Elymetea arenariae) are better known than other classes, but rock, acidic dry grassland, moist dwarf shrub heath, spring, tall forb and shrub and amphibious and aquatic vegetation are still poorly known. In particular, two climatologically contrasting, typical arctic vegetation formations need urgent special attention: the polar desert vegetation with the lowest summer temperatures (Subzone A) and the arctic steppe vegetation with the highest summer temperatures ("hot spot vegetation", "Calamagrostietea purpurascens") (cf. ELVEBAKK 2005) including related continental haline vegetation. The biodiversity, syntaxonomy, synecology, distribution, history and origin of these two formations are poorly known and they will likely suffer the most strongly from global warming. Moreover, contrary to boreal regions (cf. ODLAND 2005), mountain vegetation in the Arctic is poorly known (cf. CAVM Team 2003). First results of a study aiming at the distinction of vegetation types and belts in arctic mountains and comparison with latitudinal subzones of the Arctic are pre-

sented by SIEG & DANIËLS (2005). The importance of cryptogam synusiae as structure element of arctic vegetation is outlined by BÜLTMANN (2005).

#### 5 Summary of the workshop agenda and achievements

The conference was held at two sites. The opening session on 2 June was at the Planetarium on the campus of the University of Tromsø, with a welcome by Tore O. Vorren, Dean of the Faculty of Science. A keynote address by Christian Nellesen, head of the GLOBIO initiative within the United Nations Environment Programme, GRID-Arendal, Norway, described the key role that vegetation mapping is playing in forecasting possible outcomes of global environmental policies. In the evening, the conference banquet and celebration of the completion of the CAVM were at the Fjellheisen Restaurant, overlooking the lovely city of Tromsø, the surrounding islands and fiords. The remainder of the workshop was at the Sommarøy Conference Center 60 km west of Tromsø. A total of 41 talks and posters were presented. The abstracts of the talks and posters are available from the Alaska Geobotany Center, University of Alaska, Fairbanks (ANONYMOUS 2004). Four papers focused on floristic aspects of arctic vegetation, 25 focused on classification and syntaxonomy, and 12 focused on vegetation mapping. Eighteen papers were submitted for inclusion in this special issue of *Phytocoenologia*, twelve of which made it through review and are included here.

#### 6 The Conservation of Arctic Flora and Fauna (CAFF) and look to the future for Arctic vegetation science

The program for the Conservation of Arctic Flora and Fauna (CAFF) of the Arctic Council was a sponsor of the workshop and the CAVM. CAFF was established to address the special needs of Arctic ecosystems, species and their habitats in the rapidly developing Arctic region. As one of the Working Groups of the Arctic Council, its primary role is to advise the Arctic Council member states (Canada, Denmark/Greenland, Faroe Islands, Finland, Iceland, Norway, Russia, Sweden and the United States) on conservation matters and sustainable use issues of international significance and common concern. Since its inaugural meeting in Ottawa, Canada in 1992, the CAFF program has provided scientists, conservation managers and groups, and indigenous people of the north with a distinct forum in which to tackle a wide range of Arctic conservation issues at the circumpolar level. CAFF's main goals, which are achieved in keeping with the concepts of sustainable development and utilization, are to 1) conserve Arctic flora and fauna, their diversity and their habitats; 2) protect the Arctic ecosystems from threats; 3) improve conservation management laws, regulations and practices for the Arctic; and 4) integrate Arctic interests into global conservation efforts. When appropriate, CAFF organizes its work through the establishment of expert sub-groups. One subgroup, the CAFF



Flora Group (CFG), was established in 1999 to identify circumpolar flora conservation priorities and provide the CAFF Board with advice and recommendations for joint actions. At the Tenth CAFF Biennial Meeting in Anchorage, Alaska, 14–16 September 2004, the CFG acted on one of the items in the resolution from the Tromsø workshop (see below) and made a recommendation, which was formally endorsed by CAFF, for development of a Circumpolar Boreal Vegetation Map, related to global change and modeling vegetation change, expanding the region covered by the Circumpolar Arctic Vegetation Map (CAVM) into CAFF boreal regions to the south. The CFG plans to work cooperatively with others to formulate a strategy for developing a boreal map. A first step is to convene an international workshop of boreal vegetation mapping specialists.

The last day of the workshop was devoted to looking to the future – how to involve vegetation scientists more strongly in some of the ongoing and future research initiatives in the Arctic. The involvement of vegetation scientists in the International Polar Year was seen as a particularly important goal. The attendees identified several areas for future syntaxonomical research including the poorly known regions and the vegetation types mentioned earlier. We need a more complete circumpolar picture of the variation of plant cover using uniform methods, which enables assessment and evaluation of their general significance and allows conservation measures. Interdisciplinary approaches to vegetation studies involving paleoecologists and molecular phytotaxonomists are highly desirable to reveal causes of regional patterns of community diversity and to trace their origin and history. The establishment of electronic databases of high quality vegetation relevés surely will speed up the process of vegetation analysis and classification, as will an annotated list of validly described syntaxa from arctic territories. Finally there is a strong need for revisiting well studied areas, and for establishing long-term monitoring sites in the Arctic (e.g. GLORIA – Global Observation Research Initiative in Alpine Environments – sites; GRABHERR et al. 2001) allowing a more detailed modelling and predictions of future vegetation changes. Ideas for new initiatives included: (1) investigations of arctic “hotspots” (ELVEBAKK 2005), enclaves with extrazonally warm climates and a resulting high biodiversity, and with strong climatic gradients to surrounding areas (2) arctic transects with a focus on transition zones, polar deserts, and long-term change observations; (3) a web-based prodromus or checklist of Arctic syntaxa with an annotated hierarchic structure, including a photo database of arctic plant communities; (4) a web-based listing of all arctic vegetation mapping efforts and merging of the vegetation data with other circumpolar mapping efforts, including the checklists of the circumpolar flora prepared by the Pan-Arctic Flora Working Group and the CAFF Flora group, and maps of pan-Arctic soils, glacial geology, and permafrost; (6) development of vegetation-habitat relationships to allow modeling and linkage with wildlife groups; (7) creation of web-based list server for arctic vegetation science discussions; and (8) development of a circumpolar boreal forest map using the same methods as the CAVM. The last idea was considered particularly important because very

few questions relevant to the Arctic stop at tree line. Most rivers flowing into the Arctic Ocean have their origins far to the south of the map boundary. Climate and vegetation-change models, analysis of animal migrations, roads, and industrial developments, and arctic-human interactions all require maps that include the boreal forest and biomes even further south. The most logical boundary for an extension of the map was considered one that includes all of the boreal forest and the watershed of the Arctic Ocean. These ideas were summarized in the workshop resolution that was adopted at the close of the workshop.

## 7 Resolution of the workshop

- Whereas, vegetation is critical to all aspects of terrestrial systems including the flux of carbon and nutrients to streams and the Arctic Ocean, trace gases to the atmosphere, and heat to the permafrost, and is an essential component of human subsistence activities and wildlife habitat, and is variously sensitive to a multitude of anthropogenic disturbances; and
- Whereas, the group of international arctic vegetation scientists assembled here has special geobotanical expertise that lends itself to the classification, mapping, and analysis of climatic and other environmental controls on vegetation patterns and processes, and
- Whereas, there is a need for terrestrial vegetation components in many science initiatives now being proposed for the International Polar Year (IPY),

Be it resolved that the undersigned group will take the following steps to assure that vegetation is properly considered in these initiatives:

1. Seek representation to be involved on various arctic science planning committees, including ICARP II (International Conference for Arctic Research Planning II), SEARCH (Study of Environmental Arctic Change), IPY, etc. to promote multi-disciplinary international studies of arctic vegetation and contiguous boreal systems.
2. Provide critical input into site selection for international collaborative inventory and monitoring projects, including transects and networks of sites.
3. Provide the essential vegetation characterization at these sites.
4. Provide the essential spatial databases for vegetation and other geobotanical variables, at multiple scales at these sites.
5. Develop a monitoring program that achieves a fuller understanding of the changes in vegetation composition and structure due to climate change, and anthropogenic changes through time.
6. Assure that we achieve an understanding of the vegetation and changes along the full Arctic climate gradient in each bioclimate subzone over the long term, especially in the extreme polar deserts, transitional ecotonal areas, and sites that may be especially sensitive to change, such as riparian areas, wetlands, snowbeds, mountain tops, and areas of high biological



and microclimatic diversity ("hotspots"), and also sites that are currently affected by anthropogenic influences.

Furthermore, we will do the following:

1. Build on the Circumpolar Arctic Vegetation Map (CAVM) by identifying, ranking and mapping regions of high diversity/rareness/value; and their vulnerability to global and local climatic change and anthropogenic impacts, i.e. "Arctic hotspots";
2. Analyze the CAVM in conjunction with other circumpolar databases, such as the soil and permafrost maps, and time series remote sensing information;
3. Develop an annotated list of vegetation-types (syntaxa) for the Arctic;
4. Extend the CAVM to a spatial domain that is useful for analysis of change across the treeline, including the boreal forest region, in collaboration with other international mapping programs such as the International Geosphere Biosphere Programme (IGBP);
5. Extend the mapping and characterization to multiple scales at selected sites across the Arctic;
6. Develop a web-based geographic information system (GIS) for analysis and distribution of mapped data; and
7. Emphasize the use of the data for educational, training and outreach purposes and involving other Arctic groups including the Arctic Council, the International Arctic Science Committee (IASC), the Arctic Research Commission of the United States, and other government agencies, non-governmental organizations, and scientific research and conservation groups, including the Conservation of Arctic Fauna and Flora project (CAFF), World Conservation Union (IUCN), World Wildlife Fund (WWF), Circumpolar Environmental Observatory Network (CEON), and the Circum-Arctic Terrestrial Biodiversity initiative (CAT-B).

Attendees at the Workshop  
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#### Addresses of the authors:

Dr. Donald A. WALKER, Prof., Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska Fairbanks, Fairbanks, AK 99775, USA. E-mail: ffdaw@uaf.edu

Dr. Arve ELVEBAKK, Prof., University of Tromsø, Department of Biology, N-9037 Tromsø, Norway. E-mail: arve.elvebakk@ib.uit.no

Dr. Stephen S. TALBOT, U. S. Fish and Wildlife Service, 1011 East Tudor Road, Anchorage, AK 99503, USA. E-mail: stephen\_talbot@fws.gov

Dr. Fred J. A. DANIËLS, Prof., Institute of Plant Ecology, University of Münster, Hindenburgplatz 55, 48143 Münster, Germany. E-mail: daniels@uni-muenster.de