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Conservation of Arctic Flora and Fauna

CAFF Flora Group

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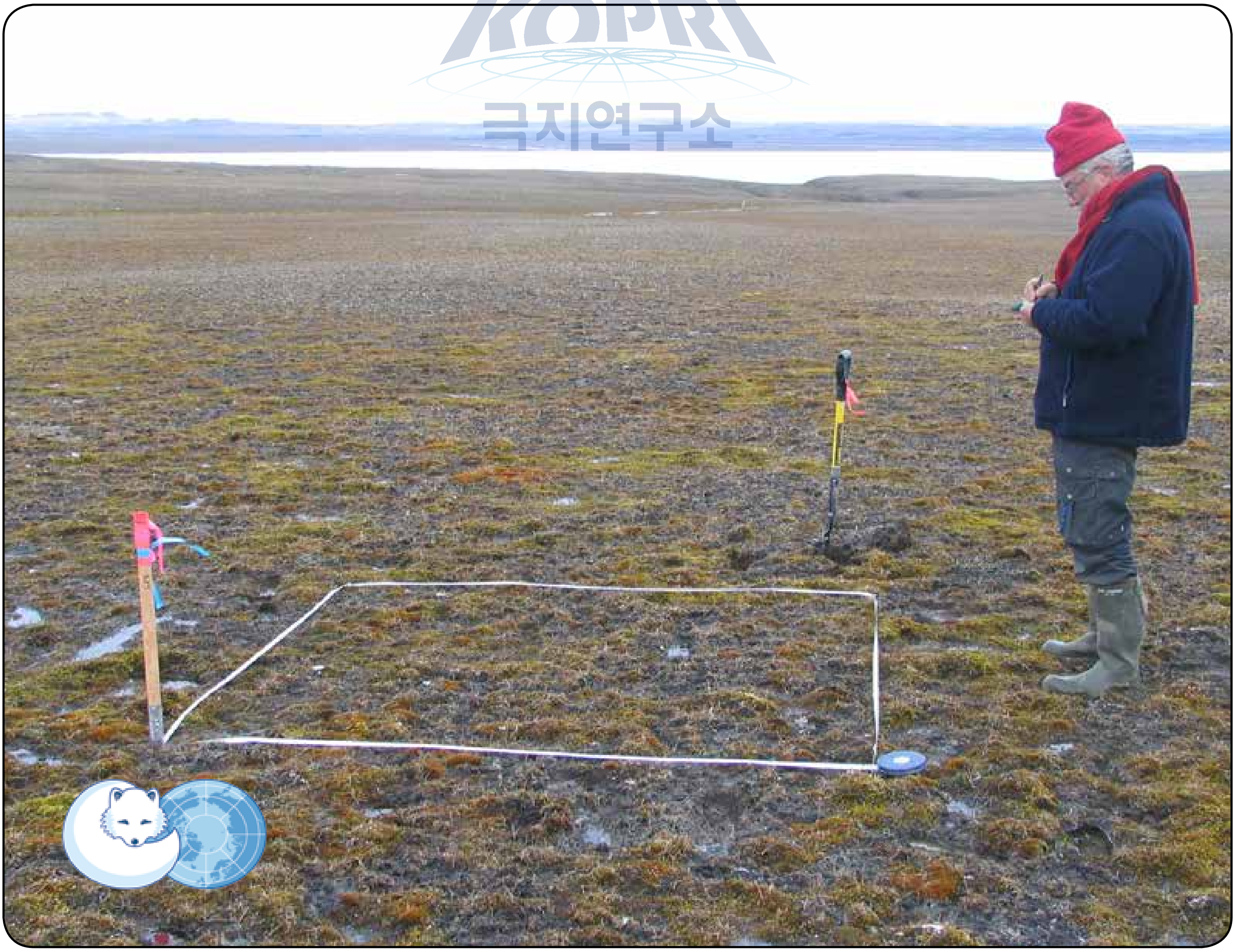

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Cover photo: Fred Daniëls sampling a wet relevé plot in the high Arctic at Isachsen, Ellef Ringnes Island, Canada. Dominant species in the relevé include *Luzula nivalis*, *Alopecurus alpinus*, *Schistidium holmenianum*, *Oncophorus wahlenbergii*, *Aulacomnium turgidum*, *Polytrichastrum alpinum*, *Collema ceraniscum*, and *Lecidea ramulosa* Photo: D.A. Walker, July 2005.

Back cover photo: Snowbed vegetation in the high Arctic at Isachsen, Ellef Ringnes Island, Canada. Photo: Fred Daniëls, July 2005.

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Table of Contents

Acknowledgements

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Preface

21 years to common ground: protecting our shared biodiversity legacy

Marilyn D. Walker

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AVA's roots began in Boulder, Colorado, in the Spring of 1992, when I convened the first Circumpolar Arctic Vegetation Workshop, consisting of a small group of dedicated vegetation specialists from the US, Canada, Germany, the Soviet Union, Norway, and Finland. Although many of the attendees had met at least a few of the others who were present, it was the first time that a group of specialists interested primarily in arctic phytosociology had ever come together to focus solely on the concepts of classification. There were many different approaches in use at the time, and the language and communication barriers that existed were significant.

The political and technological changes the world was going through at the time were the catalyst for the development of a circumpolar view of the Arctic. Glasnost opened up the Soviet Union and made real collaboration with our colleagues possible for the first time. The National Science Foundation had recently launched NSFNET, a backbone of connectivity that would soon connect with other networks, forming the "network of networks" we now know as the World Wide Web. Satellite data were becoming increasingly available, switching the ecologist's view from the ground to space, where the unity of the region was much more evident.

Studies of arctic flora also argue for a common phytosociological approach. The flora is regionally depauperate compared to other parts of the globe, and much of it is in common throughout. Where species are missing, they often have ecological equivalents that are associated with the same communities as in other regions.

My trip to the Taimyr Peninsula, in the summer of 1991 as a guest of the Soviet Academy of Sciences, opened my eyes to the critical importance of sharing data on vegetation and species distribution. A growing legacy of data was scattered on bits of paper, in file drawers and notebooks, and increasingly on "floppy disks". As I edited and created the Boulder workshop volume (Walker et al. 1994), I grew to appreciate the potential of databases to create a common language and method for properly describing and understanding arctic vegetation.

The workshop concluded with a resolution to create a global database of arctic vegetation plots. Realizing that goal has taken decades, again driven by improvements in database technology as well as a growing national and global awareness of the value of these data to our own heritage and need to manage our lands. The Vegbank Project (http://vegbank.org, also Harris et al. 2001) tackled many of the complex issues regarding data rights, database structure, storage issues, and more. Vegbank is now recognized as a lead example in the growing field of ecoinformatics, which depends on readily available data from a wide variety of sources (Krishna 2008).

The Krakow workshop is finally the beginning of the concrete realization of an arctic vegetation database. The issue before the community now is not whether to do this, but how quickly can it be done, as critical datasets are already being lost.

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Introductory talk

Overview of the Arctic Vegetation Archive Workshop, 14-16 April, Krakow, Poland

D.A. Walker

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Introduction

Arctic vegetation data provide baseline descriptive information regarding the vegetative land cover present in the Arctic under the prevailing climate. The data are potentially valuable for a wide range of studies, including foundation vegetation and soil classification research, species-diversity models, wildlife habitat research, permafrost models, and land-cover and ecosystem-change modeling. The data are even more valuable because of the large time, costs, and risks associated with collecting vegetation data in remote areas of the Arctic. Arctic vegetation data have been intensively collected from many parts of the Arctic since the 1930s by many individuals using a variety of methods and are scattered across many institutions in a variety of formats. Not all of these data are recoverable. Some of the data are maintained in electronic databases managed by various research groups and agencies working in the Arctic. Many of the classic vegetation survey data are in danger of becoming lost because they were never electronically catalogued. Thus, there is an urgent need to archive these data in a consistent format before they are lost. The Arctic Vegetation Archive (AVA) is a coordinated effort to identify and preserve key Arctic vegetation data sets for use in a panarctic vegetation classification and as a resource for climate-change and biodiversity research.

The basic concept for the AVA was laid out in CAFF Strategy Series No. 5 (Walker and Raynolds 2011). Additionally, two workshops held in Roskilde, Denmark in 2012 (Walker et al. 2013) laid the foundation for this first international AVA Workshop, which was held in Krakow, Poland, 14-16 April 2013, in association with the Arctic Science Summit Week 2013. The goal of the Krakow workshop was to bring together vegetation scientists from the circumpolar Arctic countries to provide a first estimate of the data available and to begin building the database.

Background

Several milestones led to this meeting:

1992	The first International Arctic Vegetation Classification Workshop in Boulder, Colorado, resolved to develop a database of arctic relevés and a prodromus of vegetation types for the Arctic. Several papers presented at the workshop reviewed the status of phytosociological research in the Arctic and were published in the *Journal of Vegetation Science* (Walker et al. 1994).
2003	The Circumpolar Arctic Vegetation Map (CAVM Team 2003, Walker et al. 2005b) was published and helped to redefine the need for a vegetation classification for the Arctic. The attendees at the concluding workshop in Tromsø, June 2004 recommitted themselves to making the necessary database. Several contributions to the Tromsø workshop were published in *Phytocoenologia* (Daniels et al. 2005).
2011	The Conservation of Arctic Flora and Fauna (CAFF) and the International Arctic Science Committee endorsed the International Arctic Vegetation Database concept (later changed to the Arctic Vegetation Archive). CAFF recognizes the project as an important part of its Arctic biodiveristybiodiversity efforts and published the IAVD Concept Paper (Walker and Raynolds 2011).
2012	Two workshops sponsored by the Nordic Network on climate and Biodiversity (CBIO-NET) in Roskilde, Denmark, helped to lay the foundation for the Krakow workshop and highlighted the application of the AVA for modeling and predicting biodiversity trends based on patterns of plant distribution data that could be derived from an Arctic vegetation archive (Walker et al. 2013).
2013	Support from the International Arctic Science Committee, CAFF, and the U.S. National Aeronautics and Space Administration's Land-Cover and Land-Use Change program made this workshop possible.

Summary of the Krakow workshop

Forty-two people participated in the Krakow AVA workshop. Twenty-five papers were presented that included reviews of the history and need for the AVA, the status of vegetation data collection and classification in each of the circumpolar countries, and reviews of the various database approaches currently in use. Most of these were converted into short papers for this proceedings volume to provide a record of the workshop activities.

The major accomplishments of the workshop were: 1) a thorough review of the numbers and quality of plot samples in the each of the countries; 2) a consensus among the Arctic countries regarding the geographic scope of the database, the types of data that will be included, and the general approach for building the database; and 3) the initial steps for recruiting people and resources to complete the database. The following summary contains the daily activities of the workshop, major accomplishments, and final workshop resolution.

Day 1: Joint CAFF FG/AVA meeting, review of the AVA concept, species database issues, and potential applications of the AVA

The first day of the meeting contained a joint meeting between the AVA group and the CAFF Flora Group that met during the preceding two days (April 12-13). After welcomes by Skip Walker and Kári Fannar Lárusson (CAFF Program Officer), the meeting began with a keynote address by Fred Daniëls, who reviewed the history of the AVA and need for the database. Marilyn Walker, who initiated the idea of an international approach in 1992 (Walker et al. 1994), reflected on the 21 years of progress in international collaboration and database technology that brought us to the point where such an archive is now achievable. Much of the remainder of the morning was devoted to species-level issues related to maintenance of the CAFF species lists (presentations by Steffi Ickert-Bond and Martha Raynolds) and local floras (Olga Khitun). The CAFF species lists of Arctic vascular plants, lichens, and mosses are key elements of the database that are needed for a list of accepted species names that are used across all the plot samples in the database. These lists have been combined into the Pan Arctic Species List (PASL), which is the list of accepted names of vascular plants, mosses, lichens and liverworts used in the AVA. The group recognized the need for regular updates of the species lists, and a general consensus was reached regarding the mechanism required to accomplish this. More specifics are needed for developing a liverwort list and individuals responsible for the moss list. In the afternoon, the discussion shifted to potential applications of the AVA including as a source for understanding spatial distribution of Arctic biodiversity (Loïc Pellisier and Laerke Stewart) and assessing biodiversity feedbacks to climate change (Gabriela Schaepman-Strub, Maitane Iturrate & Reinhard Furrer).

Day 2: Status of circumpolar vegetation data set and database approaches

In the morning, twelve papers presented the status of circumpolar plot-based vegetation studies, including reviews from Alaska (Amy Breen et al.), Arctic Canada (Esther Levesque et al.), Greenland (Helga Bültmann et al.), Scandinavia (Lennart Nilsen & Dietbert Thannheiser delivered by Fred Daniëls), the boreal tundra region of the North Atlantic and North Pacific (Anna Marie Fosaa et al.), Russia in total (Nadya Matveyeva et al. delivered by Elena Troeva), northwest Yakutia (Michael Teyatnikov et al.) the Kola Peninsula (Natalia Koroleva delivered by Skip Walker), the European sector of the Russian Arctic (Ekaternina Kulyugina), three sectors of Siberian Arctic (Kikolay Lashchinskyi), the Yamal and Gydan Peninsulas (Ksenia Ermokina), and Chukotka (Vladimir Razzhivin, abstract only). In the afternoon, four papers presented the main database approaches that are being used for the European Vegetation Archive (Borja Jiménez-Alfaro), the Canada National Vegetation Classification (Will Mackenzie), the U.S. National Vegetation Classification (Mike Lee) and the Russian database IBIS (Alexander Novakovskiy).

Day 3: Development of a mission statement, workshop resolution, funding possibilities and publications

In the morning three working groups discussed: 1) the mission and applications of the AVA, 2) the geographic scope of the project, and 3) issues related to the database construction. After reconvening a mission statement and workshop resolution were developed by the workshop participants. Prospects for funding, and plans for publication of the workshop outcomes were also discussed and agreed to and the meeting was adjourned.

Major accomplishments of the workshop

The workshop reviewed the status of relevé data and database approaches in each of the circumpolar countries; developed a resolution by the circumpolar Arctic vegetation community to rededicate its members to developing an Arctic Vegetation Archive using an approach that is acceptable to all involved, and took the first steps needed to recruit the people and resources necessary to complete the work.

Mission and justification of the AVA

The mission of the Arctic Vegetation Archive Working Group is to create a database of Arctic plot data, and promote its application to northern issues.

The AVA will be useful for a wide variety of purposes, including: preserving legacy data sets in danger of being lost; designing, locating and extrapolating field experiments at Arctic Observing Stations; identifying research gaps; mapping and remote sensing of vegetation, habitat types, and land cover; assessing Arctic terrestrial biodiversity and biogeographic relationships; modeling functions and ecosystem services of Arctic vegetation; educating scientists, the public and policy makers about the value of Arctic terrestrial systems in relation to local to global systems; industrial and land-use planning; and conserving and managing Arctic terrestrial ecosystems.

Additionally, the AVA is directly relevant to several other circumpolar efforts of the Arctic Council and national Arctic initiatives including:

- **Circumpolar Biodiversity Monitoring Programme** and the **Arctic Biodiversity Assessment**: The AVA is a foundation data set to assess changes in Arctic plant biodiversity and habitat for other trophic levels.
- **Inter-Act**: One of Inter-Act's goals is the discovery and preservation of key legacy vegetation data sets.
- **Back to the Future**: Many of the data sets are from old International Biological Programme (IBP), ongoing Long-Term Ecological Research (LTER) and other large-scale ecosystem studies established in the 1960s to 1990s. These datasets contain information regarding the baseline condition of the Arctic before the modern era of rapid climate change.
- **Arctic Development and Adaptation to Permafrost in Transition (ADAPT) and other permafrost-related initiatives**: Vegetation is the key element of the "buffer layer" that protects the permafrost from catastrophic thawing. A consistent means to characterize this layer would be highly beneficial to permafrost scientists.
- **International Tundra Experiment (ITEX)**: Characterization of control plots and baseline studies would benefit from a consistent means to characterize vegetation across the ITEX network.
- **Arctic Polar Early Career Scientists (APECS)**: The next generation of international terrestrial ecosystem scientists would benefit immensely from a consistent international approach to describing the land cover of the Arctic. The AVA would provide this framework. The AVA will strive to involve young investigators to develop, implement, and use the AVA.

Types of data to be included

The preferred data are published plot data from homogeneous plant communities with tables of cover percentages or cover-abundance scores for all species, including vascular plants, bryophytes, and lichens, preferably with accompanying environmental and geographic location information. Braun-Blanquet or USNVC protocols are ideal. High priority will also be given to datasets that are in danger of being lost.

Geographic framework

The boundaries of the Arctic are those defined by the Circumpolar Arctic Vegetation Map (CAVM Team 2003), which will be modified to include the Arctic portion of the Kola Peninsula in Russia. The database will also include the boreal maritime tundra areas (Aleutian Islands, Iceland, Faroe Islands, Commodore Islands). The group of vegetation scientists working in this region will need to resolve the issues related to boreal species that will be required for the PASL.

Products of the AVA

The AVA will use the Panarctic Flora as a common taxonomical base to develop a comprehensive synthesis of Arctic phytosociological information through the publication of a Prodromus of Arctic vegetation syntaxa (list of plant community types); publication of a bibliography of Arctic vegetation studies, development of a revised syntaxonomical classification for the circumpolar Arctic, and web-portal with descriptions photos, maps, and ancillary information related to the vegetation units. Some early potential applications of the AVA are described a recent publication (Walker et al. 2013), and others were described at this workshop.

Database approaches

A conceptual framework for the database (Walker and Raynolds 2011) was modified with data nodes in each country (perhaps several for Russia). The database Turboveg (Hennekens and Schaminee 2001) will be the standard for initial data entry and the procedures being developed for the European Vegetation Archive (Chytrý et al. 2012) will be used as a preliminary model. Metadata standards will follow in part those of the Global Inventory of Vegetation Databases (Dengler et al. 2011). Protocols for formatting vegetation and environmental data, metadata, and minimum requirements for data are under development in two proto-type databases for Greenland and Arctic Alaska. We will strive for maximum compatibility with databases in other countries, including VegBank in the U.S. (Peet et al. 2012), Vpro in Canada (MacKenzie and Klassen 2004), and IBIS, a database commonly used in Russia. Countries using database approaches other than Turboveg will require vegetation data exchange standards currently under development (Wiser et al. 2011) to conform to the AVA. The PanArctic Species List (Raynolds et al., 2013, this volume) will be the list of accepted plant names. The list will be updated at regular to-be-determined intervals and cross-walked to other synonyms used in the initial plot data and in other national vegetation classification schemes. The IASC data protocols regarding data sharing and credit to database contributors will be used (Parsons et al. 2013). A preliminary framework and dataflow diagram will be used in the beginning. Considerable work remains to address the details of the data protocols. A database group chaired by Marilyn Walker will develop the protocols.

Publication of proceedings of the workshop

The authors of the talks at the workshop agreed to prepare 5-6 page short papers based on their presentations at the workshop. These will be published as a CAFF Proceedings volume. The results will be synthesized into a paper that will be submitted to the journal Applied Vegetation Science or other appropriate journal.

Funding

Funding for the AVA will be pursued by each country. The Alaska portion has been secured through a NASA grant to D.A. Walker that is part of the of the data gathering phase for the Arctic and Boreal Vulnerability Experiment (ABoVE). The Canada High Arctic Research Station (CHARS) has committed to supporting the Canadian portion of the database. The Russian participants will pursue a new mega-grant proposal that will be submitted to the Government of the Russian Federation by Michael Cherosov and a group of Russian colleagues from several institutions. Participants from the EU and other European countries (Czech Republic, Iceland, Norway, Denmark, Germany, Poland) will pursue funding for Greenland, Svalbard, and northern Scandinavia. This is very important because of the long heritage of phytosociological research and large amount of data in these countries that is not archived.

Timeline

A 6-year timeframe is contingent on funding. Years 1-2 will be devoted to organizing national workshops, obtaining international funding, completing AVA prototypes, and collecting the key data sets. During years 2-4, we will assemble data from literature sources at several nodes, build server site software, and build web pages for the data portal. In years 5-6 we will test and release the AVA.

Conclusion

The AVA was conceived 21 years ago at the first International Arctic Vegetation Classification Workshop in Boulder, CO to help consolidate the large amount of plot data from around the Arctic to aid in development of a circumpolar Arctic vegetation classification. The vision from Boulder was revitalized in Krakow with the help of CAFF, IASC, and the CBIO-NET workshops. The great challenge now is to find the funding to complete the task.

Some of the key participants at the 1992 Boulder workshop were present in Krakow and helped to generate a great deal of excitement about the project. Other addresses by members of the international vegetation science community helped everyone realize that times and technology had changed since the 1992 workshop. The need for the AVA is clear, and the project is supported by a strong atmosphere of international collaboration. Furthermore, recent advances in computers, database technology and vegetation classification methods have made vegetation archives much more feasible. Even the daunting task of finding the funds seems achievable.

Krakow Resolution for Preparation of an Arctic Vegetation Archive

Whereas, the distribution, characteristics, and history of Arctic flora and vegetation are of essential importance with regard to (1) knowledge of how circumpolar terrestrial ecosystems interact with climate and contribute to the changing earth system, (2) conservation of the biodiversity of these regions; and (3) increasing exploration and development in the circumpolar nations; and

Whereas, our knowledge of Arctic regions and the environmental constraints on Arctic vegetation has increased;

Whereas, no single existing classification accurately portrays the synthesis of existing knowledge of the vegetation of the circumpolar Arctic;

Whereas an Arctic Vegetation Archive will be useful for a wide variety of purposes, including: Preserving legacy data sets in danger of being lost; classifying and analyzing Arctic vegetation; designing, locating and extrapolating field experiments; identifying research gaps; mapping, remote sensing of vegetation, habitat types, and land cover; assessing Arctic terrestrial biodiversity and biogeographic relationships; modeling functions and ecosystem services of Arctic vegetation; educating scientists, the public and policy makers about the value of Arctic terrestrial systems in relation to the global system; land-use planning, conserving and managing Arctic terrestrial ecosystems.

And whereas the International Arctic Research Committee and the Conservation of Arctic Flora and Fauna have endorsed the concept of an international Arctic vegetation database,

Be it resolved that the international community of Arctic vegetation scientists rededicates itself to the following joint tasks:

1. *Develop an international organizational framework and secure funds for the Arctic Vegetation Archive (AVA).*
2. *Compile vegetation plot data (relevés) into the AVA using the pan-Arctic species lists as a common taxonomical base.*
3. *Develop a syntaxonomical classification for the circumpolar Arctic;*
4. *Publish a compilation of Arctic vegetation types (Prodromus) and a bibliography of Arctic vegetation studies.*
5. *Promote the application of the AVA to northern issues.*
6. *Finally, be it resolved that the undersigned scientists will create a prototype Arctic Vegetation Archive by the 3rd International Conference on Arctic Research Planning (ICARP III) in 2015.*

Signed by 20 members present on the final day of the workshop, 16 April 2013, Krakow, Poland.

Figure 1. From left to right: Back row: Greg Henry, Will MacKenzie, and Christian Bay. Middle row: Skip Walker, Esther Lévesque, Marilyn Walker, Mikhail Cherosov, Fred Daniels, Nikolay Lashchinkskiy, Mike Lee, Elena Troeva, Ekaterina Kulygina, Laerke Stewart, Lynn Gillespie, and Ingibjorg Svala Jonsdottir. Kneeling: Amy Breen, Starri Heiðmarsson, Edie Barbour, Borja Jíménez-Alfaro, Alexander Novakovskyi Maitane Iturrate Garcia, Helga Bültmann, Olga Khitun, and Gabriela Schaepman-Strub. Photo by Kári Lárusson.

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Keynote address: Some reflections on the realization of an international pan-Arctic vegetation classification

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Introduction

With pleasure I address the key-note speech at this important Arctic Vegetation Archive (AVA) meeting. Thanks are due to Skip Walker for the invitation and his kind preface highlighting my contributions to several Arctic projects such as the Boulder Circumpolar Arctic Vegetation Meeting (Walker et al. 1994), the Circumpolar Arctic Vegetation Map (CAVM-Team 2003, Walker et al. 2005), the Circumpolar Vegetation Classification and Mapping meeting in Tromsö 2004, dedicated to Boris A. Yurtsev (Daniëls et al. 2005), the North American Arctic Transect Project (Walker et al. 2008) and some other CAFF activities. I would like to also acknowledge especially Marilyn Walker for involving me early in the international Arctic vegetation classification efforts, and also the present and past staff at the Alaska Geobotany Center of the University of Alaska and its predecessor the Joint Facility for Regional Ecosystem Analysis at the Institute of Arctic and Alpine Research in Boulder, Colorado, for their successful initiatives and skillful leaderships of projects in the field of circumpolar Arctic ecology, vegetation mapping and classification.

Much of my thinking regarding the AVA is already covered in recent joint publications (Walker & Raynolds 2011, Walker et al. 2013) and reading these is strongly recommended. Here, I would mainly like to advocate the application of the Braun-Blanquet approach as an indispensable tool for the analysis and classification of vegetation biodiversity of the Arctic.

Some private history and nostalgia

Before starting my “reflections” I like to say some nostalgic words on my background and phytosociological interest. I am Dutch, born in 1943 in Arnhem, the Netherlands. My first expedition to the Arctic was in 1966. Hans de Molenaar, Jan Jaap Hooft and I were biology students of the Utrecht University (NL). We studied the flora and vegetation of the Angmagssalik district in SE Greenland for four months that first summer. We were just in time to witness the old Greenlandic way of life in a colder climate than now. Hans, and I as staff member of the University of Utrecht, continued our studies in 1968 and 1969 as part of our PhD theses (de Molenaar 1974, 1976, Daniëls 1975, 1982). We revisited our study sites in 1981 and 2007 (Daniëls & de Molenaar 2011). Those first three summers in SE Greenland were paradise-like times. They made me “arctophilous” and broadened my view on life. The acceptance of a professorship in Geobotany at the University of Münster (Germany) 1987 enabled me to focus more intensively on Arctic research. The invitation by Marilyn Walker to attend the Boulder meeting in 1992 came at the right moment and opened the way to circumpolar Arctic cooperation and long lasting friendships. My geobotanical interest and knowledge of the Arctic increased and included now local, regional and global perspectives.

This Boulder meeting was instrumental for new Arctic research activities in a broader context. The resolution from the workshop said we would prepare a circumpolar database, classification, and vegetation map. The vegetation map was published in 2003 and 2005 (CAVM-Team 2003, Walker et al. 2005), however a circumpolar Arctic vegetation database and classification are still due.

Phytosociology requires intensive contact with nature and rewards us with deep species and field knowledge. Maybe that is why making relevés, collecting and identification of plants, structuring vegetation tables and classifying plant communities are among the most exciting activities of my life. Several leading scientists in the fields of lichenology, bryology and vegetation science enriched my knowledge, including Reinhold Tüxen, Jan Barkman, Eddy van der Maarel, Victor Westhoff, Boris Yurtsev and many others. They were instrumental in finding my way in the international and Arctic vegetation science community. Stephen Talbot showed me the Aleutian Islands, Joseph Svoboda and Skip Walker the Canadian Arctic, Nadya Matveyeva and her colleagues of the Komarov Botanical Institute in St. Petersburg introduced me in the Arctic flora and vegetation of Russia. Vladimir Onipchenko was instrumental in showing Marinus Werger and me the taiga and tundra of the Russian Far East. Irina Safronova showed me the vegetation of Kazakhstan. Five of my students conducted their PhD fieldwork in Greenland (Helga Bültmann, Birgit Jedrzejek (Sieg), Birgit Drees, Christoph Lünterbusch, Michael Girnth) and one in Iceland (Thomas Hövelmann).

The Braun-Blanquet approach

“To conduct or publish ecological research without reference to the type of community the work was conducted in is very much like depositing a specimen in a museum without providing a label” (Peet & Roberts 2012). A syntaxonomical classification of vegetation according to the Braun-Blanquet approach groups plant community types in a hierarchical system of syntaxa. The syntaxa have a unique species composition and nomenclature. Their names are derived from plant species with specific suffices reflecting their hierarchical status and have authorship with indication of year of first valid description. This system allows a precise world-wide identification of plant community types and provides a more precise reference of a vegetation type for ecological, modeling and monitoring research. Syntaxonomical units are the most powerful elements in the international scientific communication regarding vegetation types.

"*Simplex sigilum veri*"; the Braun-Blanquet approach is intellectually brilliant in its simplicity and that is why its concept and methodology are applied world-wide (cf. Dierschke 2011). The approach provides classification of vegetation and derived key information on plant community species composition and structure, ecological setting, phytogeography and connectivity within the plant cover.

The basic concept is that floristic variation in plant cover is not random. In the same phytogeographical region and under about the same environmental conditions, similar assemblages of plant species occur. In the field, each particular concrete assemblage of plant species is considered a *plant community*. Plant communities with similar species composition are grouped into abstract "*plant community types*". These phytoceona are classified in a unique inductive (bottom-up), hierarchical system of vegetation types, characterized by diagnostic species, into association, alliance, orders and classes. These hierarchical groups or "syntaxa" have a rank-specific nomenclature similar in principal to rank-based classification approach used to describe organisms, such as that used for plant species, genera, families, orders, and classes. Furthermore, there are rules of nomenclature for the various levels (syntaxa) in the classification system, whereby each described syntaxon is identified by a unique name that contains the first and last author that described the syntaxon and the date of valid publication according to the Rules of the International Code of Phytosociological Nomenclature (Weber et al. 2000). These rules are based on five principles (Moravec 1968). Each syntaxon (with definite rank, position and delimitation) has only one correct name; each name can be correctly used for one syntaxon only; the correct name is established according to the rules based on the priority principle, the *association* is the fundamental nomenclatural unit (syntaxon); and the validity of nomenclatural rules is retroactive. This approach allows distinction and identification of vegetation types and as such provides a world-wide detailed comparison and classification of vegetation types according the same scientific language.

Analytical phase: fieldwork and relevés

The vegetation is analyzed by means of a relevé of a representative vegetation plot, homogenous in floristical composition, vegetation structure, and habitat. In this plot, abundance and cover (scale) of all species, and the structure of the vegetation and environmental conditions are assessed. Unknown species are collected for identification, and soil samples are collected for analyses. Relevé plot sizes depend on vegetation features. Chytrý & Otýpková (2003) suggest plots sizes between of 4m^2 (for aquatic and low grown herbaceous vegetation) and 200 m^2 (for woodlands) based on more than 41,000 relevés from Europe. Examples of relevé protocols with combined estimation of cover and abundance of species and other scales are presented in Westhoff and van der Maarel (1973). Environmental conditions, altitude, geographical position (GPS) and other relevant information are collected for analyses in the laboratory.

Synthesis phase: comparing relevés in tables

Groups of relevés are formed according to their floristic similarity. These groups are conceived as plant community types (or phytocoena) having similar floristic composition, vegetation structure and habitat conditions. In earlier times the rearranging of relevés in a table of all relevés was made manually. Now, many computerized numerical clustering programs are available (for a survey see Peet & Roberts 2012). The characterization of plant community types involves sorting or rearranging the order of the relevés (columns in the table) and the order of species (rows in the table) such that relevés with similar species composition occur together, and species that are more or less preferentially found in each group also occur together. Mathematical rules are used to help in this sorting process to determine of the *fidelity* of each species to the various syntaxa. Diagnostic species include so-called *character species* (or faithful species) – those that differentiate the plant community types against all other plant community types, *differential species* – those that differentiate against a number of other plant community types, such as within a locality or region, and *constant species* – those that occur at some high percentage, say 60%, of the relevés within the plant community type. If character species occur, then the plant community type might be an association, the lowest syntaxon of the system. The association and all other syntaxa are identified by groups of diagnostic species, including character, differential and constant species. For more information about this procedure the reader is referred to Westhoff and van der Maarel (1973), Daniëls (1982), Chytrý & et al. (2002) and the International Association for Vegetation Scientists (IAVS) Vegetation Classification Methods Website: https://sites.google.com/site/vegclassmethods/). For large regional and global classifications based on thousands of relevés, computer programs for classification of very large datasets, such as TURBOVEG by Hennekens & Schaminée (2001) and JUICE by Tichý (2002), are available on the internet.

Syntaxonomical phase: identification and classification of plant communities

This time-consuming phase includes the identification of the syntaxonomical position of the plant community types by comparing it with other syntaxa already described in the existing syntaxonomical literature that have used the Code of Phytosociological Nomenclature (Weber et al. 2000). An example of a hierarchy of syntaxa associated with Arctic saltmarsh vegetation is in Table 1. The use of a prodromus, or checklist, of names of described syntaxa, if one exists, is very helpful in this phase, such as the series *Bibliographia Phytosociologica Syntaxonomica* started and edited by Tüxen (1971-1986) with delivery of 39 classes with their subordinated orders, alliances and associations. For an effective approach to produce a pan-Arctic syntaxonomical vegetation classification system in near future, the development of a pan-Arctic checklist of vascular plant, bryophytes and lichens and regional syntaxonomical checklists are indispensable (see Raynolds et al. 2013, this volume)

Interesting considerations about the class concept in syntaxonomy were presented by Pignatti et al. (1995) taking into account the ecological characterization, coherence of the geographical distribution of character species and the common spatial structure of the vegetation.

Table 1.
Example of syntaxomic classification scheme of saltmarsh vegetation of Arctic Europe.

1. Class *Juncetea maritimae* Br.-Bl. In Br.-Bl., Roussine et Nègre 1952
    1.1. Order *Puccinellietalia phryganodis* Hadač 1946
        1. 1. 1. Alliance *Puccinellion phryganodis* Hadač 1946 (saline)
            1.1.1.1. Association *Puccinellietum phryganodis* Hadač 1946 (low salt marsh)
                1.1.1.2. Association *Festuco-Caricetum glareosae* de Molenaar 1974 (high salt marsh)
        1.1.2. Alliance *Dupontion fisheri* Hadač 1946 (sub-saline)

Feasibility of a pan-Arctic syntaxonomic vegetation classification

Several factors make the Arctic a feasible area to develop a Braun-Blanquet classification for the entire biome. First, the flora of vascular plants, bryophytes and lichens is rather poor, rather well known and still intact. The total number of vascular plant species is about 2,200 (with apomicts the number grows to about 2800 (Daniëls et al. 2013), bryophytes about 900 species (Daniëls et al. 2013), and lichens about 1750 species (Dahlberg & Bültmann 2013). The floristic uniformity is high due to the high percentage of circum-Arctic and circum-boreal species. Vegetation structure is also rather uniform and simple, related to the young postglacial landscapes and harsh environmental conditions. The land surface is still relatively undisturbed by human population and activities, so the tundra and polar desert vegetation are still intact. From a circumpolar view the vegetation is rather uniform as well. Many good vegetation classes have a pan-Arctic distribution. Examples include, the non-acidic sedge and dwarf shrub class – *Carici rupestris-Kobresietea bellardii* Ohba 1974, the acidic dwarf shrub heath class– *Loiseleurio-Vaccinietea* Eggler ex Schubert 1960, and the cryptogam-rich herb class of the polar desert – *Drabo corymbosae-Papaveretea dahliani* Daniëls et al. 2013 ined.).

Albeit there are still many and huge knowledge gaps, much vegetation information is available in global (CAVM; CAVM-Team 2003, Walker et al. 2005), regional (EVM, Bohn & Neuhäusl et al. 2000/2003) and local vegetation surveys and maps. There are very many plot analyses made across Arctic regions and there are several excellent regional vegetation monographs (e.g. Matveyeva 1998, survey in Daniëls et al. 2005, Kohlod 2007, Vonlanthen et al. 2008; for Russia see also the many publications in the journal Vegetation of Russia – Russian Geobotanical Journal ISSN 2073-0659). The activities of the European Vegetation Survey (EVS) resulted in the hierarchical floristic classification system of plant, lichen and algal communities of Europe (Mucina et al. 2013) that could be taken as an example of what we can achieve for the Arctic vegetation. A thorough survey of vegetation classes (27) and subordinate syntaxa for Greenland is close to publication now (Daniëls & Bültmann 2013 in prep.). In my opinion there is enough plot-based information to start first with an inventory of plot analyses; then store this information in archives, and make syntaxonomical checklists in order to produce a first circumpolar vegetation classification scheme in the form of an Arctic-wide prodromus. Let us see what is available so far and then use this material for a pan-Arctic syntaxonomic classification. The production of pan-Arctic checklist with a uniform nomenclature for vascular plants, bryophytes and lichens is "*conditio sine qua non*". Raynolds et al. (2013, this workshop) present a beta version of the pan-Arctic Species List (PASL) that includes vascular plants, bryophytes and lichens. Although this undoubtedly will be modified as we proceed, it is the place to start.

The importance for research and nature management

Regarding the ongoing change in the Arctic (see e.g. Meltofte 2013), an Arctic-wide classification based on the hierarchic syntaxonomic Braun-Blanquet approach would be extremely valuable and beneficial to scientific and applied research for several reasons:

- Since plant species and plant communities are the building blocks and main structural units of terrestrial ecosystems, the Braun-Blanquet approach is an indispensable tool for landscape ecological research. A syntaxonomic-based vegetation survey and map provide key information on the biodiversity and ecological setting of the landscape and landscape quality. Such data are indispensable for quality assessments of habitat types and conservation legislation (cf. EU Habitats Directive). The data can also be used in red-listing of plant species and vegetation types. Habitats are easily identified by their syntaxonomic name, thus by syntaxa!
- Relevé data are easily integrated into species and ecosystem modeling efforts because the data contain relatively consistent detailed plot-based information about species, their abundance/cover, and often geographical and environmental information.
- A phytosociological study of an area is highly beneficial in developing hypotheses in biodiversity and ecological research.

- Phytosociological knowledge is indispensable in the selection of monitoring and surveillance sites for climate-change related studies.
- The syntaxonomical classification system allows generalization and extrapolation of results of experimental ecological research.

Thus the statement of Peet and Roberts (2012) would, in my opinion, be stronger if it focused on syntaxa and read “to conduct or publish ecological research without reference to the **syntaxon** the work was conducted in is very much like depositing a specimen in a museum without providing a label”.

In summary, the Braun-Blanquet plant community classification approach is an excellent tool for assessing plant-species and plant-community biodiversity at local, regional and global scales, and provides a solid base for landscape protection and management.

The AVA

The resolution of the Boulder meeting identified the need to prepare a circumpolar database, classification, and vegetation map. The vegetation map was published in 2003 and 2005 (CAVM-Team 2003, Walker et al. 2005). The circumpolar Arctic vegetation classification and its necessary database still need to be achieved. Here in Krakow we have the opportunity to begin these two other tasks. Conceptual diagrams of the International Arctic Vegetation Database (IAVD) or Arctic Vegetation Archive (AVA) and the data flow were presented in Walker& Raynolds (2011). These diagrams might be used as guidelines for further discussions in the next days in Krakow.

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Short and extended abstracts of papers presented at the workshop

in alphabetical order of the first author

Toward an Alaska prototype for the Arctic Vegetation Archive

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Abstract

We created an Alaska prototype database for the Arctic Vegetation Archive (AVA). A preliminary survey of key vegetation-plot data in Arctic Alaska revealed over 3,000 relevés from sites on the Seward Peninsula, Brooks Range, Arctic Foothills and Coastal Plain. Most of these datasets are high quality and include complete species lists and cover estimates for vascular plants, mosses, and lichens from small, representative areas of homogeneous vegetation. The Alaska Arctic Vegetation Archive (AAVA) utilizes the program TURBOVEG, a comprehensive data management system for vegetation-plot data. We constructed a beta version of the PanArctic Species List for use in TURBOVEG to provide a standard of species nomenclature for the entire Arctic biome and have imported approximately 500 relevés to date. We anticipate a two-year timeline for completion of the AAVA and present the steps we have taken to create the archive and the steps that still remain for use by other regional archive efforts.

Introduction

The goal of the Arctic Vegetation Archive (AVA) is to unite and harmonize relevé data from the Arctic tundra biome for use in developing a pan-Arctic vegetation classification and as a resource for climate-change and biodiversity research (Walker et al. 2013, Walker and Raynolds 2011). The AVA will be an open access database comprised of regional archives from the various Arctic nations that will be the first to represent an entire global biome. Here we present the status of an Alaska prototype for the AVA. We first share our findings from a preliminary survey of key vegetation-plot data from Arctic Alaska. Next, we give an update on the status of the Alaska Arctic Vegetation Archive (AAVA) and propose a list of required and recommended metadata and environmental header data for inclusion in the AVA. Finally, we conclude by outlining the remaining steps toward completion of the AVA.

Preliminary Survey of Relevés from Arctic Alaska

A preliminary survey of key vegetation-plot data revealed over 3,000 relevés from Arctic Alaska (Fig. 1 and Table 1). These data are scattered across many institutions in a variety of formats ranging from spreadsheets, to data reports and publications, to field notebooks. Relevés have been collected along the primary Arctic environmental gradients, including temperature, soil pH, soil texture, and soil moisture. Most of these datasets are high quality and include complete species lists and cover estimates for vascular plants, mosses and lichens from small representative areas usually 1-100 m^2. The more recent vegetation plots are also georeferenced and include supplementary information such as biomass, canopy structure, soils data, and environmental summaries.

The richest history of vegetation-plot data collection in Arctic Alaska is perhaps from sites on the Coastal Plain. This includes early work by Al Johnson (Johnson et al. 1966) at Cape Thompson sponsored by the Atomic Energy Commission to assess the area for the proposed Project Chariot and by Pat Webber as part of the International Biological Programme Tundra Biome project at Barrow (Webber 1978). Pat Webber's students were also quite active studying vegetation on the Coastal Plain. Vera Komárková collected vegetation-plot data at Atqasuk (Komárková & Webber 1980) and

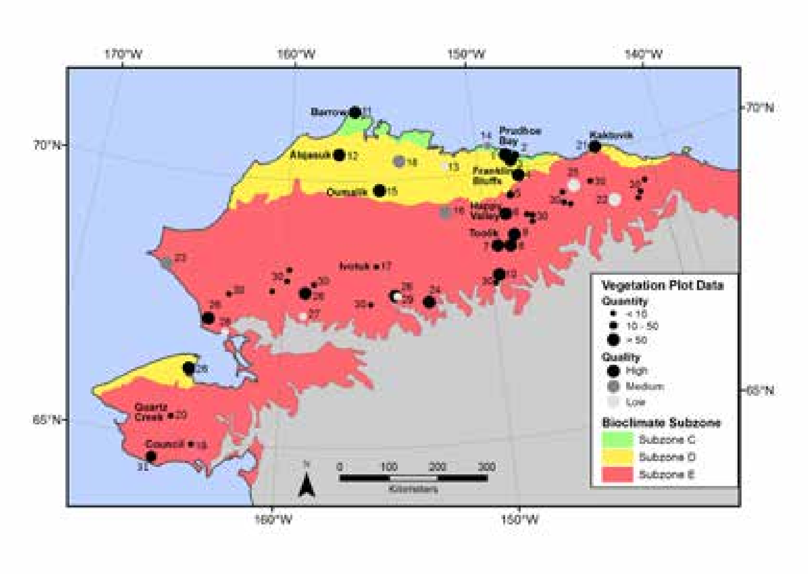

Figure1: Locality of key vegetation-plot data in Arctic Alaska. The three bioclimate subzones (CAVM Team 2003) in Arctic Alaska are shown and the quantity and quality of data are indicated by the size and color of the points. The southern boundary of Subzone E is treeline and the gray area is boreal forest. The numbers on the map for each data set coincide with Table 1.

the Fish Creek Oil Well Site (Lawson et al. 1978 and Komárková 1983), and Jim Ebersole worked at the Oumalik Well Site (Ebersole 1985) as part of the US Geological Service's National Petroleum Reserve-Alaska cleanup activities. In addition, Skip Walker collected vegetation-plot data at the Prudhoe Bay Oilfields (Walker 1985) and Marilyn Walker worked at pingos at multiple study areas on the central Coastal Plain (Walker 1990) for their doctoral research. Two sites on the coastal plain, Barrow and the Oumalik Well Site, were repeat sampled to assess vegetation change after approximately 40 (Villarreal et al. 2012) and 10 years (Forbes et al. 2001), respectively.

Figure 2: Sampling a 1 x 1-m relevé in moist acidic tussock tundra post-fire on the Seward Peninsula in western Alaska.

Relevés have also been collected from several other localities in Arctic Alaska. These sites range from Nome (Hanson 1953), Bering Land Bridge National Preserve (Jorgenson et al. 2009), and Quartz Creek and Council (Raynolds et al. 2002) on the Seward Peninsula to Cape Krusenstern (Jorgenson et al. 2009) and the Kobuk (Racine 1976, Breen 2010) and Noatak Rivers (Young 1974, Breen 2010) in northwestern Alaska. In the Brooks Range, plot data are available from the Arrigetch Peaks (Cooper 1986), Gates of the Arctic National Park and Preserve (Jorgenson et al. 2009) and the Arctic National Wildlife Refuge (Jorgenson et al. 1994 & 2010, Breen 2010). Several studies collected data from long-distance transects including frost boils (Kade et al. 2005) and willow communities (Schickhoff et al. 2002) along a south-north transect following the Dalton Highway from the foothills of the Brooks Range north to the Coastal Plain and from sites that vary in soil pH and moisture (Edwards et al. 2000) along a west-north transect from the Seward Peninsula northwest to Ivotuk and north to Barrow. In the foothills, relevé data are also available from Imnavait Creek (Walker et al. 1987), Toolik Lake (Walker et al. 1991), Happy Valley (Walker et al. 1997) and Umiat (Churchill 1957).

Status of the Alaska Arctic Vegetation Archive

The Alaska Arctic Vegetation Archive utilizes TURBOVEG (v. 2.100; Hennekens and Schaminee 2001) which is a comprehensive data management system for vegetation-plot data. TURBOVEG was developed for storing, editing and selecting of relevés for the task of producing a national vegetation classification for The Netherlands. Since then, the program has evolved to become the standard for data storage for the European Vegetation Archive which is an initiative aimed at establishing and maintenance of a single data repository of vegetation-plot observations (http://euroveg.org/eva-database).

The first step toward creating the prototype was to construct a species list to provide a standard of species nomenclature for the entire Arctic biome (Murray 1994). We have now completed this task and the beta version of the PanArctic Species List (PASL) is available for use and review (Raynolds et al. 2013, this workshop). The PASL was developed from the checklists of vascular plants, lichens, mosses, and liverworts by taxonomists within the Conservation of Arctic Flora and Fauna Working Group.

The second step was to import the most readily available high quality vegetation-plot data into TURBOVEG databases for proof of concept. The first relevés we imported into the prototype were from Marilyn Walker's PhD dissertation studying pingos on the Coastal Plain (Walker 1990, 293 relevés) which is appropriate given her leadership role in the 1995 Boulder Workshop that lead to the resolution to create the Arctic Vegetation Archive nearly 20 years ago (Walker et al. 1995). The other data sets in the prototype to date include relevés from Toolik Lake (Walker 1991, 81 relevés), Imnaviat Creek (Walker 1987, 84 relevés), and Happy Valley (Walker 1997, 56 relevés) in the Arctic Foothills.

Once we imported the first vegetation-plot data into the AAVA, the next step that is ongoing is to standardize required project metadata and header data included in the environmental matrix. We will ask that all contributors submitting relevés to the AVA meet these standards. This is a necessary and important task as it will assure the data included are of high quality and can eventually be included in a circumpolar classification of Arctic vegetation. The proposed metadata and header data standards are presented in Tables 2 & 3 for review. We view these standards as a starting point for discussion and anticipate these will be refined and improved as we move forward with the AVA.

The most recent step we have taken is to register the AAVA in the Global Index of Vegetation-Plot Databases (GIVD; Dengler et al. 2011). The GIVD is an internet resource aimed at registering metadata on existing vegetation databases worldwide. The status of the AAVA is listed as emerging and has been assigned a unique identifier (NA-US-014). We anticipate each of the regional archives in the AVA will register independently and update their status as their archives evolve.

Timetable for Completion of the AAVA

We recently received funding from the National Aeronautics and Space Administration to assemble the AAVA in preparation for NASA's next major field campaign called the Arctic Boreal Vulnerability Experiment (ABoVE; http://cce.nasa.gov/terrestrial_ecology/above/). Table 5 outlines our anticipated 2-year timetable for completing the major tasks toward creating the AAVA. The Boulder Workshop scheduled for October 2013 will focus on the Alaska and Canada portions of the Arctic. The major goal of the workshop is to review the status of relevé data from Arctic Alaska and begin the task of assembling these data into the AAVA with consistent format and metadata. We anticipate beginning analysis to classify plant communities and preparing a manuscript from the results once the AAVA is complete.

Table 1

Preliminary list of key vegetation-plot data from Arctic Alaska.

Point on Map	Author(s) (Date)	Location	Published Relevés	Unpublished Relevés	Relevé Size (m^2)	Species Data			Environmental Data	Plant Communities Identified	Georeferenced	Format	Applicable to the AVA
						vascular plants	bryophytes	lichens					
1	Walker, D. A. (1985)	Prudhoe Bay Oilfield	93	-	1-10	yes	yes	yes	yes	yes	yes	PDF	yes
1, 9	Walker M. D., (1990)	Pingo communities on the Central Arctic Coastal Plain (Kuparuk, Prudhoe Bay, Toolik River, Kadleroshilik study areas)	293	-	12.5 (2 m diameter)	yes	yes	yes	yes	yes	yes	Turboveg	yes
2, 3, 4, 5, 6	Kade, A., D. A. Walker & M. K. Raynolds (2005)	Frost boils along the Northern Alaska Arctic Transect (Howe Island, Deadhorse, Franklin Bluffs, Sagwon Uplands, Happy Valley)	117	-	1	yes	yes	yes	yes	yes	yes	Excel	yes
6	Walker, D.A., N. A. Auerbach, T. K. Nettleton, A. Gallant & S. M. Murphy (1997)	Happy Valley	56	-	19.6 (5 m diameter)	yes	yes	yes	yes	yes	yes - most	Excel	yes
7	Walker, D. A. & N. Barry (1991) and Walker, M. D., D. A. Walker & N. A. Auerbach (1994)	Toolik Lake	73	-	19.6 (5 m diameter)	yes	yes	yes	yes	yes	yes	Turboveg	yes
8	Walker, D. A., N. D. Lederer & M. D. Walker (1987) and Walker, M. D., D. A. Walker & N. A. Auerbach (1994)	Imnaviat Creek	81	-	19.6 (5 m diameter)	yes	yes	yes	yes	yes	yes	Turboveg	yes
9, 10	Schickhoff, U., M. D. Walker & D. A. Walker (2002)	Willow communities along the Dalton Highway	85	-	50 or 100	yes	yes	yes	yes	yes	yes	PDF	yes

Point on Map	Author(s) (Date)	Location	Pub-lished Relevés	Unpub-lished Relevés	Relevé Size (m^2)	Species Data			Environ-mental Data	Plant Communi-ties Identi-fied	Georef-erenced	Format	Appli-cable to the AVA
						vascular plants	bryo-phytes	lichens					
11	Webber (1978) and Villarreal, S., R. D. Hollister, D. R. Johnson, M. J. Lara, P. J. Webber & C. E. Tweedie (2012)	Barrow	430 (1978) + 330 (2012)	-	1 (1972) + 0.1 (2012)	yes	no	yes	yes	yes	yes	Excel	yes
11, 12	Peterson, K. M. (1978)	Barrow and Atqasuk	-	-	-	yes	no	no	no	no	no	Hard Copy	no
11, 12,15, 17	Edwards, E. J., A. Moody & D. A. Walker (2000)	Western Alaska Arctic Transect (Barrow, Atqasuk, Oumalik, Ivotuk)	15	-	100	yes	yes	yes	yes	yes	yes - most	Hard Copy	yes
11, 21	Elias, S. A., S. K. Short, D. A. Walker & N. A. Auerbach (1996)	Barrow and Barter Island	59	-	80	yes	yes	yes	yes	yes	no	Hard Copy	yes
12	Komárková, V. & P. J. Webber (1980)	Atqasuk	73	-	unknown	yes	no	no	yes	yes	unknown	Hard Copy	yes
13	Lawson, D. E., J. Brown, K. R. Evertt, A. W. Johnson, V. Komárková, B. M. Murray, D. F. Murray & P. J. Webber. (1978) and Komárková, V. (1983)	Fish Creek	15	-	0,2	yes	no	no	yes	yes	unknown	Hard Copy	yes
14	Jorgenson, M. T., J. E. Roth, E. R. Pullman, R. M. Burgess, M. K. Raynolds, A. A. Stickney, M. D. Smith & T. M. Zimmer. (1997)	Colville River Delta	293	-	2.500	yes	yes	yes	yes	yes	yes	unknown	yes
15	Ebersole, J. J. (1985)	Oumalik - undisturbed	87	-	25	yes	yes	yes	yes	yes	no	Hard Copy	yes
15	Ebersole, J. J. (1985)	Oumalik - disturbed	61	-	25	yes	no	no	yes	yes	no	Hard Copy	yes
16	Churchill, E. D. (1955)	Umiat	80	-	1	yes	no	no	no	yes	no	PDF	yes
18	Komárková, V.& J.D. McKendrick (1988)1	National Petroleum Reserve-Alaska Sand Region	608		25	yes	un-known	un-known	yes	yes	unknown	unknown	un-known

Point on Map	Author(s) (Date)	Location	Published Relevés	Unpublished Relevés	Relevé Size (m^2)	Species Data			Environmental Data	Plant Communities Identified	Georeferenced	Format	Applicable to the AVA
						vascular plants	bryophytes	lichens					
19, 20	Raynolds, M.K., C. R. Martin, D. A. Walker, A. Moody, D. Wirth, C. Thayer-Snyder (2002)	Council and Quartz Creek	52	.	100	yes	yes	yes	yes	yes	yes	Excel	yes
22	Jorgenson, J. C., J. M. Ver Hoef. & M. T. Jorgenson (2010)	Arctic National Wildlife Refuge	60	-	120	yes	yes	yes	unknown	yes	yes	PDF	yes
22	Jorgenson, J. C., P. E. Joria, T. R. McCabe, B. R. Reitz, M. K. Raynolds, M. Emers & M. A. Wilms (1994)	Arctic National Wildlife Refuge	132	-	3.600	yes	yes	yes	yes	yes	yes	unknown	yes
23	Johnson, A. W., L. A. Viereck, R. E. Johnson, and H. Melchior (1966)	Cape Thompson	54	-	4,046.9 (1 acre)	yes	yes	yes	yes	yes	no	unknown	yes
24	Cooper (1986)	Arrigetch Mountains	372	-	1-30 (varies)	yes	yes	yes	yes	yes	no	Hard Copy	yes
25	Batten (1977)	Lake Peters	-	-	-	yes	no	no	no	yes	no	Hard Copy	no
26	Jorgensen, M. T., J. E. Roth, P. F. Miller, M. J. Macander, M. S. Duffy, A. F. Wells, G. V Frost & E. R. Pullman (2009)	Arctic Network of National Parks, Preserves and Monuments	793	-	315 (20 m diameter)	yes	yes	yes	yes	yes	yes	unknown	yes
27	Racine (1976)	Kobuk River Valley	-	-	-	yes	no	no	no	no	no	Hard Copy	no
28	Young (1974)	Noatak River	-	-	-	yes	no	no	no	no	no	Hard Copy	no
29	Murray, D. F. (1974)	Killik River	-	-	-	yes	no	no	no	no	no	Hard Copy	no
30	Breen, A. L. (2010)	Balsam poplar stands in the Arctic Foothills and western Alaska	25	-	varies depending upon the size of the stand	yes	yes	yes	yes	yes	yes	Excel	yes
31	Hanson, H. C. (1953)	Nome	70	-	1	yes	no	no	no	yes	no	PDF	yes

[1] *The status of Vera Komárková's relevés from the National Petroleum Reserve-Alaska is unknown and likely cannot be recovered after her death in 2005. Our main point of contact is her first husband,Dr. Jiří Komáre at the Department of Botany, Faculty of Science, University of South Bohemia, České Budějovice, Czech Republic.*

Table 2

Project metadata for the Arctic Vegetation Archive. The proposed fields required for inclusion in the AVA are indicated with an asterisk. All other fields are recommended for inclusion.

Project Metadata				
Field name	**ID[1]**	**Source[2]**	**Type[3]**	**Description**
Project description				
Project name*	PROJ_NAME	AVA	C	Project title.
GIVD code*	PROJECT	TV	C	Global Index of Vegetation Databases code, will be included in header data.
Project description	PROJ_DESC	AVA	C	Brief description of the study.
Author name*	AUTH_NAME	TV	C	Relevé primary author(s).
Locality*	LOCALITY	AVA	C	Specific project locality, will be included in header data.
Country*	COUNTRY	TV	C	Country, will be included in header data.
Number of relevés*	RELEVE_NO	AVA	N	Number of relevés in the dataset.
Number of classified relevés	CLASSIF_NO	AVA	N	Number of relevés in the dataset for which syntaxon is known.
Reference*	REFE_NAME	TV	C	If data are published, include primary reference(s).
Data quality				
Taxonomic expertise*	EXPERT	AVA	C	Pop-up list: **expert, collections made and sent to experts for determination, moderate, poor.**
Permanently marked	MARKED	AVA	C	Are relevés permanently marked? (yes or no)
Marking method	MARK_METH	AVA	C	If relevés are permanently marked, specify methods.
Collection*	COLLEC	AVA	C	Pop-up list: **relevé, other.**
Collection method	COLL_METH	AVA	C	If did not use relevés, specify collection method and source.
Minimum area	MINI_AREA	AVA	C	Relevé minimum area requirements satisfied? (yes or no)
Homogeneity	HOMOGEN	AVA	C	Homogeneity requirements satisfied? (yes or no)
Mosses*	MOSS_IDENT	TV	C	At least 80% of mosses identified? (yes or no)
Liverworts*	LIV_IDENT	AVA	C	At least 80% of liverworts identified? (yes or no)
Lichens*	LICH_IDENT	TV	C	At least 80% of lichens identified? (yes or no)
Georeference*	GEOREF	AVA	C	Are the relevés georeferenced? (yes or no)
Site description	SITE_DESC	AVA	C	Are the relevés accompanied by a description of the site? (yes or no)
Vegetation description	VEGE_DESC	AVA	C	Are the relevés accompanied by a description of the vegetation? (yes or no)
Soils description	SOIL_DESC	AVA	C	Are the relevés accompanied by a description of the soils? (yes or no)
Quality score*	QUALITY	AVA	C	Pop-up list: **very high quality**: acceptable for most applications including vegetation classification and environmental analysis (complete vascular plant, moss, and lichen species lists; cover abundance or percentage cover for all species; good environmental data that includes all the minimum header data, including soil data; good georeference at landscape level (GPS coordinates)), **intermediate quality a-e**: acceptable for some applications (specify weak points in the data set (a. incomplete species list, b. serious problems with plant taxonomy, c. no or weak environmental data, d. no or weak soil data, e. no or weak georeference), **unacceptable quality a-d**, not useful for most vegetation classifications or analyses (a. not plot data, b. very incomplete species list, c. no environmental or header data, d. no georeference).

[1] *For consistency, we suggest column headers across the various prototypes. Column headers are limited to ten characters.*

[2] *The source of the proposed fields is either Turboveg (TV) or the AVA. Turboveg includes many fields as standard within the program.*

[3] *Fields are either characters (C) or numbers (N).*

Table 3

Environmental header data for the Arctic Vegetation Archive. The proposed fields required for inclusion in the AVA are in bold and indicated with an asterisk. All other fields are recommended for inclusion.

Relevé header data1				
Field name	**ID[1]**	**Source[2]**	**Type[3]**	**Description**
Relevé description				
Relevé number*	RELEVE_NR	TV	N	Relevé number is generated automatically in Turboveg.
Field relevé number	FIELD_NR	AVA	C	Relevé number used in the field by the author(s).
Locality*	LOCALITY	AVA	C	From project metadata. Should be a specific locality for the plot.
Country*	COUNTRY	AVA	C	From project metadata.
Author*	AUTHOR	TV	C	From project metadata. Should be plot collector.
Date*	DATE	TV	C	Date of collection (yyyy/mm/dd).
Relevé size*	SURF_AREA	TV	N	Size of the releve (m^2).
Stand size	STAND_ AREA	AVA	N	Size of the stand (m^2).
Cover abundance scale	COVERSCALE	TV	C	Pop-up list: **percentage, Braun/Blanquet (old), Braun/ Blanquet (new), Londo, presence/absence, Ordinale scale (1-9), Barkman, Doing & Segal, Doing, constancy classes, Domin, Colin, Tansley, Didukh, Numbers (< 65025), Numbers (< 24000).**
Plant community name	COMM_ NAME	AVA	C	Syntaxon name, formal or other. Will specify the source of the name in the next field.
Source of plant community name	COMM_ SOUR	AVA	C	Pop-up list: **Braun-Blanquet syntaxon name, USNVC name, CNVC name, Russian nomenclature system, field community name, other.**
Other source of plant community name	COMM_ OTHE	AVA	C	If other source for plant community name, specify.
Locality				
Georeference*	GEOREF	AVA	C	Is the relevé georeferenced? (yes or no) If yes, provide subsequent fields.
Georeference source*	GEO_SOURC	AVA	C	Pop-up List: **GPS, Google Earth, map, aerial photograph**.
Latitude	LATITUDE	TV	N	Latitude (decimal degrees).
Longitude	LONGITUDE	TV	N	Longitude (decimal degrees).
Geodetic datum	GEO_DATUM	AVA	C	If relevés are georeferenced using a GPS or map, include the datum.
Altitude	ALTITUDE	TV	N	Altitude of relevé (m).
Site description				
Slope	INCLINATIO	TV	N	Slope of relevé (degrees).
Aspect	EXPOSITION	TV	N	Aspect of relevé (degrees).
Habitat*	HABITAT	AVA	C	Pop-up list: **moderate to well-drained uplands (including zonal sites),wetland, riparian, snowbed, rocky barrens, zoogenic, saline, dune.**
Snow duration	DUR_SNOW	AVA	C	Pop-up list: **snow free all year, snow free most of the winter but some snow cover persists after a storm that is blow free soon afterward, snow free prior to melt out but with snow most of winter, snow free immediately after melt out, snow bank persists 1-4 weeks after melt out, very short snow free period, deep snow all year.**
Exposure	EXPOSURE	AVA	C	Pop-up list: **protected from winds, moderate exposure to winds, exposed to winds, very exposed to winds**

[1] For consistency, we suggest column headers across the various prototypes. Column headers are limited to ten characters.

[2] The source of the proposed fields is either Turboveg (TV) or the AVA. Turboveg includes many fields as standard within the program.

[3] Fields are either characters (C) or numbers (N).

Relevé header data1				
Field name	**ID[1]**	**Source[2]**	**Type[3]**	**Description**
Stability	STABILITY	AVA	C	Pop-up list: **stable, subject to occasional disturbance, subject to prolonged but slow disturbance such as solifluction, annually disturbed, disturbed more than once annually**.
Disturbance*	DISTURBAN	AVA	C	Pop-up list: **natural vegetation or anthropogenically disturbed. What about type of distubance? What about concentrated animal use? Burned? Flooding, Soils distubance...etc**
Soils description				
Soil classification	SOIL_CLASS	AVA	C	Pop-up list: **US Soil Survey, Canadian Classification, Russian Classification, FAO-UNESCO, other, none. If other, specify.**
Soil classification method	SOIL_METH	AVA	C	If other soil classification method, specify method and source.
Soil type	SOIL_TYPE	AVA	C	Description of the soil. This will be specific to the classification system used.
Organic layer depth	ORG_DEPTH	AVA	N	Depth of organic layer (cm).
Soil pH	SOIL_PH	AVA	N	pH of the soil.
Soil moisture*	SOIL_MOIST	AVA	C	Pop-up list: **dry, moist, wet, aquatic.**
Vegetation Description				
Cover total	COV_TOTAL	TV	N	Total vegetation cover (%).
Cover shrubs	COV_SHRUBS	TV	N	Shrub cover (%).
Cover dwarf shrubs	COV_DSHRUB	AVA	N	Dwarf shrub cover (%).
Cover graminoids	COV_GRAMIN	AVA	N	Graminoid cover (%).
Cover herbs	COV_HERBS	TV	N	Herb cover (%).
Cover bryophytes	COV_BRYOP	AVA	N	Bryophyte cover (%).
Cover lichens	COV_LICHEN	TV	N	Lichen cover (%).
Cover algae	COV_ALGAE	TV	N	Algae cover (%).
Cover soil	COV_SOIL	AVA	N	Soil cover (%).
Cover rock	COV_ROCK	TV	N	Rock cover (%).
Cover water	COV_WATER	TV	N	Water cover (%).
Cover litter	COV_LITTER	TV	N	Litter cover (%).
Mean canopy height	MEAN_CANOPY	AVA	N	Mean height of the canopy within the stand.
Maximum canopy height	MAX_CANOPY	AVA	N	Maximum height of the canopy within the stand.
Vascular plants	NO_VPLANT	AVA	N	Species number of vascular plants.
Mosses	NO_MOSS	AVA	N	Species number of mosses.
Liverworts	NO_LIVER	AVA	N	Species number of liverworts.
Lichens	NO_LICHEN	AVA	N	Species number of lichens.
Species	NO_SPECIES	AVA	N	Total number of species.
Other				
Remarks	REMARKS	TV	C	Comments.

[1] *For consistency, we suggest column headers across the various prototypes. Column headers are limited to ten characters.*

[2] *The source of the proposed fields is either Turboveg (TV) or the AVA. Turboveg includes many fields as standard within the program.*

[3] *Fields are either characters (C) or numbers (N).*

Table 4

Timetable for recovery of key vegetation-plot data from Arctic Alaska and creation of an Alaska Arctic Vegetation Archive.

Tasks for Recovery of Key Plot Data for the Alaska Arctic Vegetation Archive	Start Year	Planned Completion[1]
Task 1. Alaska AVA Workshop in Boulder		
- Participants will include authors of vegetation datasets	2013	31.Oct.13
- Ask participants to bring their data to standardize and format for inclusion in the AAVA during the workshop		
Task 2. Develop prototype AVA database for Arctic Alaska		
2.1 Inventory and assess the quality of available vegetation datasets	2013	31. Oct.13
2.2 Send out inventory for external review	2013	31. Oct.13
2.3 Standardize project metadata and header data	2013	31.Aug.13
2.4 Standardize PASL revisions & updates	2013	31.des.14
2.5 Prioritize vegetation datasets for inclusion in the AAVA	2013	31. Aug.13
2.3 Recover vegetation data including:	2013	31.Dec.14
- format to meet standards	-	-
- enter or format data that is only available as a PDF or hard copy	-	-
- compile other plot related files (eg, photographs, soil profiles, maps, PDFs of original reports or publications) to include in Geobotanical Catalog	-	-
2.4 Update entry in Global Index of Vegetation Databases (GIVD)	2013	Ongoing
2.5 Export vegetation data from TURBOVEG to archive in VegBank	2014	01-June-15
2.6 Make AAVA publically available as a downloadable Turboveg file via CAFF and the Geobotanical Catalog	2014	01-June-15
Task 3. Analyze and classify plant communities in Arctic Alaska		
3.1 Analyze and classify plant communities in Arctic Alaska	2015	01-June-15
3.2 Prep manuscript to report results of the analysis	2015	1. Aug.15
3.3 Submit manuscript for publication	2015	31. Dec.15
[1] *dates for task completion are based on a start date of 1-Jul-2013 and end date of 30-Jun-2015.*		

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Greenland data stored in the Arctic Vegetation Archive (AVA) in Münster

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Introduction

The status of the Greenland vegetation database, stored in Münster, Germany, is reviewed here. The database is kept in Turboveg, a program written by Stephan Hennekens (Hennekens & Schaminée 2001). It is widely used for vegetation data in Europe (e.g. Schaminée et al. 2009). Recently the European Vegetation Archive, EVA, was established as an umbrella to coordinate the national databases (http://euroveg.org/eva-database). The need for an Arctic vegetation database was originally formulated at the Boulder meeting in 1992 (Walker et al. 1994), but only recently the importance and urgency of activity were resumed (Walker & Raynolds 2011, Walker et al. 2013) also triggered by the need of vegetation datasets for large scale spatial modelling of species assemblages (Pellissier & Stewart in this volume) and ecosystem modeling (Shaepman-Strub et al. in this volume). The Arctic Vegetation Archive (AVA) is under construction now and the Greenland vegetation data will be a part of it.

Status of the database

To begin, data that were already stored in different versions of Turboveg in Münster were assembled and revised. This database includes mostly relevés from diploma and Ph.D. theses, which were written in the group of the second author at the University of Münster. The present database comprises 3217 digitized original relevés from these sources from different parts of Greenland and different vegetation types. Only parts of the studies are published. These relevés include detailed environmental data, and the cryptogams were usually studied with scrutiny. More relevés have been sampled, but as 30-50 species of bryophytes and lichens in a relevé are not uncommon and the identification of cryptogam species by microscopy and thin layer chromatography takes time for so many species, their identification is not yet finished, and the relevés are only partially digitized. We aim to complete cryptogam identification and enter the data into Turboveg, at least for those areas and vegetation types with the largest knowledge gaps in Greenland, within this year.

Figure 1 shows the number of relevés made in the different parts of Greenland. W Greenland is well represented while E and N Greenland are less well known except for the Ammassalik District. The surroundings of the Zackenberg Station are also well studied, however the plot analyses are not yet included in our datasets. The largest number of digitized data, 1880 total samples, were collected for a study of altitudinal vegetation zonation in Greenland (AZV), a project to test the assumption that altitudinal belts in the Arctic correspond with the latitudinal Arctic subzones from south to north (see CAVM Team 2003). The studies were carried out in W Greenland from 2000-2010 in the Kangerlussuaq Area from sea level up to over 1200 m altitude. The data were collected mainly by Birgit Sieg, Birgit Drees, Carsten Sult, Ole Morgenstren and Fred J. A. Daniëls. The database includes 786 digitized relevés and transects with 253 small plots with detailed environmental data, and the cryptogams are identified with care. Most plots are georeferenced by GPS. An additional georeferenced dataset was assembled by Jörg Hüls in Kangerlussuaq with 125 digitized relevés and transects with 235 small plots. Michael Girnth studied the altitudinal zonation in the context of the oceanity gradient from Sisimiut to Kangerlussuaq. His dataset includes 481 digitized relevés, including environmental data, but the locations are not georeferenced by GPS. The macrolichens and dominant mosses were included. Most relevés from these large datasets are published in the PhD theses of Birgit Sieg (2006), Birgit Drees (2008) and Michael Girnth (2011) and additionally in Sieg & Daniëls (2006), Drees & Daniëls (2009) and Sieg et al. (2009).

A dataset from the Umanak District in NW Greenland was collected from 1997-2000 by Fred Daniëls, Helga Bültmann, Ortrun Lepping and Christoph Lünterbusch. Finalized and digitized are 522 relevés, 232 and a transect of 21 small plots in vegetation types dominated by Dryas integrifolia, 139 from coastal and ruderal vegetation and 52 relevés mainly from mire vegetation. Vascular plants and header data are digitized for another 121 relevés in snow bed, heath, steppe and scree vegetation. More than 43 relevés are not yet digitized, and the sampled cryptogams still need to be identified. The dataset includes detailed environmental data, and the cryptogams are studied in particular.

Figure 1: Distribution and number of relevés for the vegetation datasets of Greenland stored in Münster (red numbers: digitized original relevés, blue: not digitized, green: digitized from literature only; ++ & +++: several & many, not counted).

The localities are noted but not georeferenced by GPS. Many of the relevés are published in the PhD. thesis of Christoph Lünterbusch (2002) and in Lünterbusch & Daniëls (2004) and Lepping & Daniëls (2007).

A larger number of relevés was sampled in the Ammassalik Area, SE Greenland, from 1966-2010 by Fred Daniëls, Helga Bültmann, Christoph Lünterbusch, Hans De Molenaar, Hedzer Ferwerda, Kok van Herk and Jan Knaapen. Most relevés are older than 20 years and published in Daniëls (1975, 1980, 1982) and De Molenaar (1974, 1976), but not yet digitized. The 727 digitized relevés from the Ammassalik Area: 153 from fjellfield vegetation by Hedzer Ferwerda in 1980, 135 and 2 transects with 45 small plots from scree, alluvial and fjellfield vegetation by Christoph Lünterbusch 1995, and 152 from terricolous lichen dominated vegetation by Helga Bültmann 1995. Environmental data are noted in detail and cryptogams carefully studied, the localities were not georeferenced by GPS. Fred Daniëls and Hans De Molenaar revisited Ammassalik in 2007 and recorded 110 relevés and 22 transect plots corresponding to the same plots, vegetation stands and vegetation types from 40 years ago. The relevés from 2007 are digitized together with the corresponding relevés from 40 years ago. The relevés from 2007 are georeferenced by GPS. Parts of the datasets are published in Lünterbusch et al. (1997), Bültmann (1999), Bültmann (2005), Daniëls et al. (2011) and Daniëls & De Molenaar (2011).

Relevés from N Greenland are rare and a valuable set of 76 relevés was collected by Fred Daniëls in 1995. It is digitized, but without GPS data.

Another small dataset was collected in 2009 in S Greenland by Helga Bültmann and Fred Daniëls. The vascular plants and header data of 12 relevés are digitized, but the cryptogams have to be determined. About 20 additional relevés are not digitized.

The authors collected more than 200 relevés on two expeditions to W Greenland in 1992 and 1993, which are partly digitized. Cryptogams were collected, but identified only for a smaller part. The environmental factors are completely digitized, however the localities are not georeferenced by GPS.

Also stored in the Turboveg database are 795 relevés from Böcher from W Greenland (Böcher 1954: 386 rel., 1959: 83 rel., 1963: 326 rel.).

Table 1

Distribution of relevé data in vegetation classes in the regions of Greenland (S: South, W: West, NW: Northwest, SE: Southeast, N: North; red: digitized, blue non-digitized; + to +++: increasing amount of relevés).

	S	W	NW	SE	N
Juncetea maritimi - Coastal salt marsh vegetation	+		++	++	
Ammophiletea - Dry coastal beach and sand dune vegetation			++		
Cakiletea maritimae - Therophytic strandline vegetation			+		
Potamogetonetea - Rooted floating or submerged macrophyte vegetation of meso-eutrophic waters			+	++	
Phragmito-Magnocaricetea - Swamp vegetation of tall sedges, herbs and grasses					++
Salicetea purpureae - Riparian willow shrub vegetation		++			
Isoeto-Littorelletea - Small rush vegetation on temporarily moist-wet soil			+	++	
Scheuchzerio palustris-Caricetea fuscae - Sedge grass and dwarf shrub mire and fen vegetation		++	+++	++	++
Asplenietea trichomanis - Fern and herb vegetation of rock fissures and ledges				++	
Thlaspietea rotundifolii - Talus slope, debris and alluvial vegetation	+	++	++	+++	
Drabo corymbosae-Papaveretea dahliani - high Arctic polar desert vegetation of forbs, rushes, bryophytes and lichens					++
Salicetea herbaceae - Snowbed vegetation		++	+++	+++	
Loiseleurio-Vaccinietea - Dwarf shrub heath and low shrub vegetation on acidic poor substrate	++	+++	+++	+++	
Carici-Kobresietea - Achionophytic dwarf shrub and graminoid vegetation on non-acidic substrate		+++	+++	++	++
Saxifrago-Calamagrostietea purpurascentis - Boreal and low Arctic steppe vegetation of the inland on dry, warm substrate		+++	+		
Juncetea trifidi - Xerophytic graminoid vegetation on acidic sandy-gravelly substrates				+++	
Mulgedio-Aconitetea - Tall forb and shrub vegetation on mesic-moist soil				++	
Vaccinio-Piceetea - Scrub and low forest of Betula pubescens ssp. czerepanovii	+				
Molinio-Arrhenatheretea - Anthropogenic pastures and meadows on fertile soil	+				

Table 1 shows that in spite of the oversampling of W Greenland (see figure 1), the dataset represents many different vegetation types and their distribution: vegetation from at least 19 classes is included. The common dwarf shrub and graminoid vegetation of chionophytic and achionophytic type and on acidic and calcareous substrate are well represented. The less common azonal vegetation types are correspondingly less frequently recorded.

The database in the present state includes 4012 digitized relevés, 3217 from sources within the working group in Münster and 795 from literature sources.

Remarks on header data and richness

The environmental data are briefly exemplified by the two largest consistent datasets, AZV and NW Greenland. In addition to project codes and relevé numbers, the header data include date, location and coordinates, the latter in different degrees of accuracy, relevé size (usually between one and four square meters), altitude, aspect, slope, and position in landscape. The cover of vegetation, also separately for different layers, of soil, humus, rocks etc. is estimated together with vegetation height and stand size. The vegetation type is always indicated, but in various ways, for the published relevés to association level. Different ordinal scales are used to estimate wind protection, snow cover, water, erosion, and cryoturbation. The soil type and texture are described and usually soil samples are analysed for pH, specific conductivity, and loss on ignition, for the NW Greenland dataset also K, Na, Mg, Ca, C, N, P, Cl.

Figure 2 shows the frequency of species richness per plot for the two large datasets: Altitudinal Zonation AZV (left) and the NW Greenland relevés from Dryas integrifolia-dominated vegetation by C. Lünterbusch (right). The former shows a typical distribution of a large dataset mainly from acidic soil with a richness maximum in the lower parts, while the latter is typical for calcareous or base-rich substrate, with almost all relevés with more than 30 species per plot. Frequency diagrams of the larger datasets can help to estimate the completeness of cryptogam vegetation in the relevés. Here we want to stress once more the importance of cryptogams as the main diversity contributors in most Arctic vegetation types (e.g. Dahlberg & Bültmann 2013). The observation of high small-scale richness has been stated in several papers (e.g. Lünterbusch & Daniëls 2004, Bültmann 2005, Sieg et al. 2009). A comparison of 700 species-rich relevés from all over the world also showed, that richness in Arctic vegetation is comparable with the richest calcareous dry grasslands or limestone pavements or subtropical savannas, but only if the bryophytes and lichens are treated in full (Bültmann 2008, 2011).

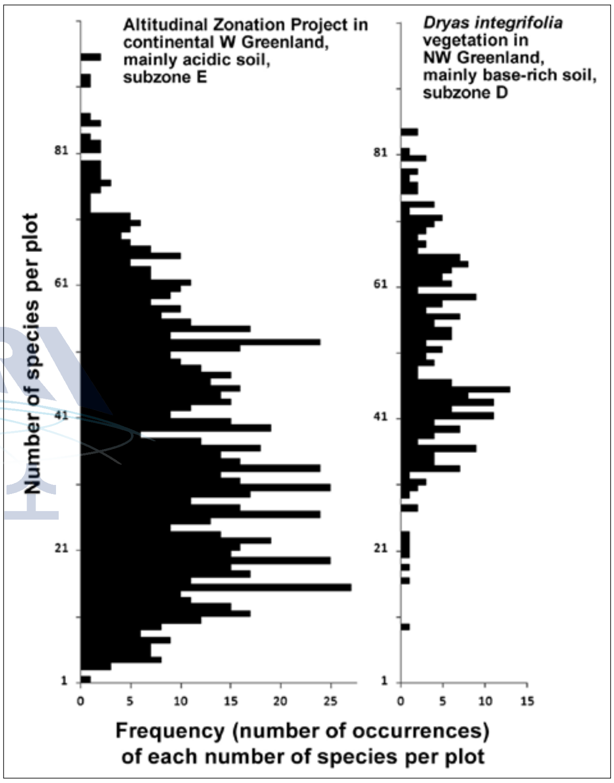

Figure 2: Frequency of species richness values (a diversity) for the datasets Altitudinal Zonation AZV (left) (n=885; except transects and the relevés of M. Girnth) and Dryas integrifolia *vegetation from NW Greenland by C. Lünterbusch (right) (n=242).*

Outlook

4012 relevés are stored already in digitized form in Turboveg or are ready to be imported to Turboveg from digital spread sheets. More relevés will be added in the course of this year with a focus on those relevés, which are not already published.

The environmental data are heterogeneous (e.g. different ordinal scales even within a project). A standard format is desirable for calculations, however it is necessary to keep the original information. As a first step a data form will be filled in for each set of relevés, which includes the basic information in an easily accessible way, for example the project, authors, number of relevés, the applied methods and scales and quality evaluation. We will also try to render as precisely as possible the geographic information of those relevés, which are not georeferenced by GPS.

After we complete that work, we will start to import data from the literature. A large number of published and unpublished relevés has been assembled by Christian Bay in Copenhagen and will be added to the Turboveg database.

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Phytosocioloy of the Western Canadian Arctic

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The study area is a part of the western Canadian Arctic and includes Banks Island, Victoria Island, King William Island, the Boothia Isthmus and sites on the northern mainland (Bathurst Inlet and Tuktoyaktuk). Figure 1 shows the research area with 18 field stations, from where the research was carried out in the years 1971,1973,1983,1984, 1986 1987, 1988 and 1998.

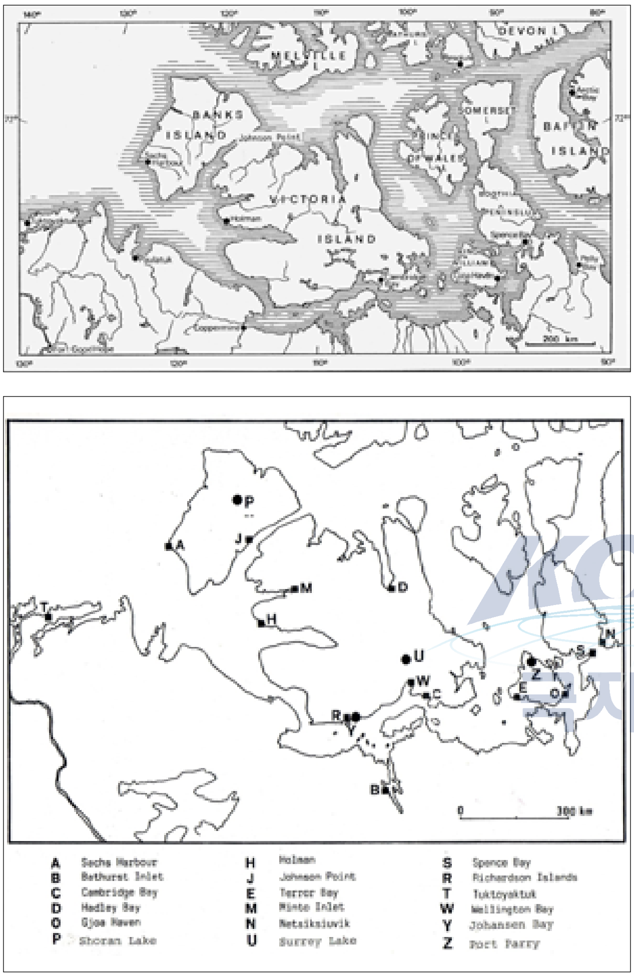

Figure 1. The 18 research areas of D. Thannheiser including 5 field stations (A-O) in 1971, 1973, 1983, 1984, 1986, 1987, 1988 and 1998.

The structure and composition of the vegetation in the Arctic varies due to a South-North as well as a coast-inland climate gradient.

The study areas comprise three bioclimatic subzones (C-E) of the Arctic Vegetation Map (CAVM 2003).

The northern parts of Banks Island, Victoria Island, and King William Island belong to subzone C. Plant cover ranges here from 5 % to-50 %. The vegetation is rich in cryptogams, herbs, grasses and dwarf shrubs and its height reaches up to 20 cm. The *Dryas integrifolia* heath is very characteristic. The southern part of Victoria Island consists of a continuous vegetation cover and this area belongs to subzone D of the CAVM (2003). The vegetation cover varies from 80 to 100 %. The shrubs *Betula* and *Salix* dominate this subzone and attain a height of 40 to -60 cm. The dwarf shrubs (*Cassiope*, *Empetrum* and *Vaccinium*) and sedges (*Carex*) are very prominent over large areas. In addition, there are many waterlogged areas in the lowlands with sedges, grasses (*Dupontia* and *Arctophila*) and mosses. The neighboring mainland in the South belongs to subzone E.

Since 1971 more than 1900 relevés have been made by the second author during eight field seasons. A small part of these have been published by the second author (see Table 1).

Currently, only a deficient plant sociological overview exists for the vegetation of the western Canadian Arctic, but it will be necessary in the future to establish a complete synopsis of all plant communities in the Canadian Arctic. Still, it is possible to collect plenty of plot-based information from different publications. However trans-regional overviews based on similar approaches are highly needed because the vegetation surveys and their evaluations were made by different authors and were based on dissimilar methods.

Table 1.
Vegetation types of the western Canadian Arctic Achipelago. Includes 1916 relevés from Dietbert Thannheiser Hamburg/Münster; numbers of relevés in brackets.

Saltmarshes		
1	Puccinellietum phryganodis	46
2	Caricetum subspathaceae	36
3	Caricetum ursinae	34
4	Caricetum glareosae	8
5	Caricetum mackenzei	8
6	Puccinellietum pauperculae	5
7	Puccinellia andersonii community	6

Grass heaths		
1a	Carex rupestris community	59
1b	Carex rupestris-Dryas integrifolia community	11
3	Kobresia hyperborea community	16
4	Carcietum nardinae	7
Dryas dwarf shrub heaths		
1	Dryas integrifolia-Saxifraga oppositifolia community	105
2	Dryas integrifolia-Oxytropis maydelliana community	30

Coastal dune vegetation		
1	Mertensietum maritimae	13
2	2. Honckenyo diffusae-Elymetum mollis	42
Tidal mark vegetation		
1	Suaeda calceoliformis community	5
2	Matricaria ambigua community	10
3	Potentilla egedii community	5
Freshwater and litoral vegetation		
1	Arctophiletum fulvae	41
2	Hippuris vulgaris community	10
3	Pleuropogon sabinei community	15
4	Ranunculus hyperboreus community	13
5	Ranunculus trichophyllum community	5
6	Ranunculus gmelini community	10
Moss vegetation along water runnels		
1	Bryum pseudotriquetrum community	8
2	Bryum cryophilum community	5
Mire vegetation		
1	Bryo-Dupontietum fischeri	60
2	Carex atrofusca community	19
3	Eriophorum triste community	9
4	Caricetum stantis 1972	108
5	Carex physiocarpa community	39
6	Carex membranacea community	47
7	Hierochloe pauciflora community	6
8	Carex saxatilis community	5
Vegetation on alluvial gravel and stone fields		
1	Epilobium latifolium community	20
Discontinuous tundra vegetation (barrens)		
1	Oxytropis arctobia community	17
2	Saxifraga tricuspidata community	49
3	Saxifraga oppositifolia community	16
4	Puccinellia angustata community	13
5	Puccinellia agrostidea community	19
6	Potentilla rubricaulis community	6
7	Koenigia islandica community	5
8	Potentilla vahliana community	11
9	Salix arctica community	35
Snowbed vegetation		
1	Salix polaris community	47
2	Deschampsia brevifolia community	15
3	Cassiope tetragona community	57
4	Ranunculus pygmaeus community	8
5	Cetraria delisei community	5
6	Phippsia algida community	6
7	Cerastio regelii-Poetum alpinae	7

3	Dryas integrifolia-Cetraria nivalis community	55
4	Dryas integrifolia-Carex rupestris community	71
5	Dryas integrifolia-Salix arctica community	22
6	Dryas integrifolia-Carex misandra community	40
7	Dryas integrifolia-Carex membrancea community	8
8	Dryas integrifolia-Carex stans community	26
9	Dryas integrifolia-Astragalus alpinus community	27
10	Dryas integrifolia-Oxytropis arctobia community	29
11	Dryas integrifolia-Cetraria delisei community	11
12	Dryas integrifolia-Kobresia hyperborea community	5
13	Dryas integrifolia-Oxytropis arctica community	17
14	Dryas integrifolia-Kobresia myosuroides community	
15	Dryas integrifolia-Astragalus richardsonii community	
16	Dryas integrifolia-Hedysarum alpinum community	18
17	Dryas integrifolia-Hedysarum mackenzii community	9
18	Dryas integrifolia-Salix reticulate community	11
19	Dryas integrifolia-Schistidium apocarpon community	
20	Dryas integrifolia-Cassiope tetragona community	7
21	Dryas integrifolia-Salix Polaris community	12
22	Oxytropis arctica community	5
23	Astragalus alpine community	10
Moss and Lichen heaths		
1	Rhacommitrium lanuginosum community	9
2	Tomenthypnum nitens community	11
3	Cetrarietum nivalis	5
Dwarf shrub tundras		
1	Vaccinium uliginosum community	13
2	Arctostaphylos alpinus community	5
3	Salix arctica community	30
4	Arctostaphylos rubra community	30
5	Salix reticulata community	13
6	Rhododendron lapponicum community	5
7	Empetrum nigrum community	10
8	Ledum decumbens community	5
Shrub vegetation		
1	Salix lanata ssp. richardsonii community	18
2	Salix alaxensis community	16
3	Betuletum glandulosae	7
Anthropogenous vegetation		
1	Puccinellia vaginata community	21
2	Descuriana sophioides community	17
3	Puccinellia deschampsioides community	6
4	Matricaria matricaroides community	7
5	Puccinellia borealis community	24
6	Senecio congestus community	6
7	Poa alpigena community	5
Zoogenous vegetation (Bird cliffs and weasel dens)		
1	Festuca rubra ssp. richardsonii community	5
2	Poa glauca community	14
3	Alopecurus alpinus community	5
4	Puccinellia andersonii community	5

The attached survey of the Canadian Arctic's plant communities and its classification (Table 2) is preliminary and needs revision in future.

Table 2.
Preliminary syntaxonomic and nomenclature survey of Canadian Arctic vegetation.

- **Juncetea maritimi Braun-Blanquet 1931**
  - **Glauco-Puccinellietalia Beeftink & Westhoff 1968**
  - (syn. Spergularietalia canadensis Knapp 1964)
    - **Puccinellion phryganodis Hadač 1946**
    - (syn. Armerion maritimae Braun-Blanquet & De Leeuw 1936
      - Puccinellietum phryganodis Hadač 1946
      - Caricetum subspathaceae Hadač 1946
      - Caricetum ursinae Hadač 1946
      - Puccinellietum pauperculae Blouin & Grandtner 1971
      - Caricetum glareosae de Molenaar 1974
      - Caricetum mackenzei Nordhagen 1974

- **Honckenyo peploides-Elymetea arenarii Tüxen. 1966**
  - **Honckenyo-Elymetalia (arenarii) Tüxen 1966**
    - **Honckenyo (peploidis)-Elymilion arenarii Galiano 1959**
      - Mertensietum maritimae (Nordhagen 1940) Thannheiser1981
      - Honckenyo diffusae-Elymetum mollis (Tüxen 1970) Thannheiser 1983

- **Cakiletea maritimae Tüxen & Preising 1950**
  - **Cakiletalia edentulae Tüxen 1950**
  - (syn. Thero-Suadetalia Braun-Blanquet & De Bolos 1957 em. Beeftink 1962)
    - **Cakilion edentulae Tüxen 1950**
    - (syn. Thero-Suaedion Braun-Blanquet em Tüxen 1950)
      - Matricaria ambigua community
      - Agropyro-Rumicion crispi (Nordhagen 1940) Tüxen 1950
      - Potentilla egedii community

- **Thlaspietea rotundifolii Braun-Blanquet 1948**
  - **Thlaspietalia rotundifolii Braun-Blanquet ap. Braun-Blanquet & Jenny 1926**
    - **Papaverion dahliani Hofman ex Daniëls 2013**
  - (syn. Arenarion norvegicae Nordhagen 1935)
      - Puccinellietum angustatae Möller 2000
      - Potentilletum pulchellae Möller 2000
      - Papaveretum radicati Dierßen 1992
      - Armerio-Silenetum acaulis Hadač 1972
  - **Androsacetalia alpinae Braun-Bl-anquet. ap. Braun-Blanquet & Jenny 1926**
    - **Saxifrago stellaris-Oxyrion digynae Gjærevoll 1950**
    - [syn. Luzulion arcuatae all. prov. Elveb. 1985, Ranunculo-Oxyrion Nordhagen1936 Incl. Cerastio-Saxifragion cernuae Hartmann1980]
      - Deschampsietum alpinae (Samuelsson 1913) Nordhagen 1943
      - Oxyrio-Trisetetum spicati (Hadač 1946) 1989
      - Saxifrago-Oxyrietum digynae (Nordhagen1943) Gjærevoll1950
  - **Epilobietalia fleischeri Moor 1958**
    - **Epilobion fleischeri** G. Braun**-Blanquet & J. Braun-Blanquet 1931**
      - Epilobium latifolium community

- **Montio-Cardaminetea Braun-Blanquet & Tüxen 1943 ex Klika & Hadač 1944**
  - **Montio-Cardaminetalia (Braun-Blanquet 1925) Pawlowski et all.1928**
    - **Cardamino-Montion Braun-Blanquet 1926**
      - Calliergono-Bryetum cryophili Hofman 1968
      - Bryum pseudotriquetrum community

- **Salicetea herbaceae Braun-Blanquet 1948**
  - **Salicetalia herbaceae Braun-Blanquet ap. Braun-Blanquet & Jenny 1926**
    - **Saxifrago-Ranunculion nivalis Nordhagen 1943 em. Dierßen 1984**
    - (syn. Drepanoclado-Poion alpinae Hadač 1946, Saxifrago oppositifolio-Oxyrion digynae Gjærevoll 1956 p.p., Salicion polaris Du Rietz 1942 n.n., Ranunculo-Oxyrion Nordhagen 1936, Salicion pseudopolaris Lambert 1968)

Salicetum pseudopolaris Lambert 1968
Cerastio regelii-Poetum alpinae Dierßen 1992
Luzulenion arcticae (Nordhagen 1936) Gjærevoll 1950
[syn. Luzulion nivalis Nordhagen 1936, Ranunculo-Oxyrion Nordhagen 1936 p.p.]
Tomenthypnetum involuti Hadač 1946
Salicetalia arcticae Barrett & Krajina 1972
Luzulo-Salicion arcticae Barrett & Krajina 1972
Pogonato-Luzulo-Salicetum arcticae Barrett & Krajina 1972
Phyllodoco-Cassiopetialia Brooke,Petersen & Krajina 1970
Cassiopion tetragonae Barrett & Krajina 1972
Sphaerophoro-Rhacomitrio-Cassiopetum tetragonae Barrett & Krajina 1972
Arabidetalia Braun-Banquet 1948
Phippsion algidae Barrett & Krajina 1968
Catascopio-Ranunculo-Phippsietum algidae Barrett & Krajina 1968
Phippsietum algidae-concinnae Nordhagen1943

Scheuchzerio-Caricetea nigrae (Nordhagen1936) Tüxen 1937
Scheuchzerietalia palustris Nordhagen 1936
(syn Arctophiletalia fulvae Lambert 1968)
Caricion lasiocarpa Vanden Berghen ap. Lebrun et al. 1941
(syn. Eriophorion Prsg. ap. Oberd. 1957, Arctophilion fulvae Lambert 1968)
Arctophiletum fulvae (Lambert 1968) Thannheiser 1976
Eriophoretum angustifoliae Lambert 1968
Drepanoclado-Ranunculetum hyperborei Hadač 1989
Caricetalia nigrae (Koch 1926) Nordhagen1936 em. Braun-Banquet. 1949
Caricion aquatilis Lambert & Krajina 1968
(syn. Caricion nigrae Koch 1926 em. Klika 1934, Caricion canescenti-goodenowii Nordhagen 1936; inkl. Eriophorion scheuchzeri Hadac 1939, Drepanocladion exannulati Krajina 1933,Sphagn(et)o-Tomenthypnion Dahl 1956)
Bryo-Dupontietum fisheri (Hadač 1946)
Caricetum stantis Barrett & Krajina 1968
Carici maritimae-Juncetum baltici Vanden Berghen 1969
Caricetalia davallianae Braun-Blanquet 1949
Tofieldietalia Prsg. ap. Oberdofer 1949, Drepanoclado-Caricetalia Succow 1974)
Caricion atrofusco-saxatilis Nordhagen 1943
Calliergono-Caricetum saxatilis (Nordhagen 1928) Dierßen 1982
Petasitetalia frigidae Lambert & Krajina 1968
Arctagrostidion latifoliae Barrett & Krajina 1968
Eriophoro-Salico-Arctagrostidetum latifoliae Barrett 1972

Carici rupestris-Kobresietea bellardii Ohba 1974
Dryadetalia(octopetalae-integrifoliae) Barrett et Krajina 1972
(syn. Kobresio-Dryadetalia (Br.-Bl. 1948) Ohba 1974
Dryadion integrifoliae Ohba ex Daniëls 1982
Tetragono-Draydetum integrifoliae Barrett 1972
Pedicularo-Dryadetum integrifoliae Barrett & Krajina 1972
Rhacomitrio-Oxaryio-Dryadetum Barrett & Krajina 1972
Caricetum nardinae Nordhagen 1935

Nardo-Callunetea Preising 1949
[syn. Calluno-Ulicetea Braun-Blanquet & Tüxen 1943]
Nardetalia strictae Oberdorfer 1949 ex Preising 1949
Nardo-Caricion bigelowii Nordhagen (1936) 1943
[incl. Deschampsio-Anthoxanthion Du Rietz 1942]
Cetrarietum delisei (Resvoll-Holmen 1920) Dahl 1956
Caricetum bigelowii-lachenelii Nordhagen1943
Alectorietalia Barrett & Krajina 1972
Dryado-Alectorion Barrett & Krajina 1972
Nardino-Dryado-Alectorietum Barrett & Krajina 1972

Cetrario-Loiseleurietea Suzuki.-Tokio & Umezu 1964
Cetrario-Loiseleurietalia Suz.-Tokio & Umezu 1964
Loiseleurio-Diapension (Braun-Blanquet, Sissingh. & Vlieger 1939) Daniëls 1982
Empetrum nigrum ssp. hermaphroditum community

Vaccinio-Piceetea ?
Ledo decumbentis-Betuletalia glandulosae Rivas-Martinez, Sánchez- Mata & Costa 1999
Salici pulchrae-Betuletion glandulosae Rivas-Martinez, Sánchez-Mata & Costa 1999
Vaccinio microphylli-Betuletum glandulosea Rivas-Martinez, Sánchez-Mata & Costa 1999

The oldest vegetation studies using a plant sociological approach were by Barrett (1972), Kershaw (1974), Schweingruber (1977) and Thannheiser (1976, 1979). Other vegetation studies in the Canadian High Arctic (especially Ellesmere Island) were selectively published by Bliss & Svoboda (1984) and Bergeron & Svoboda (1989).

During the last 10 years a number of comprehensive local plant sociological studies were published by Vonlanthen et al. (2008) and Walker et al. (2011). The present contribution includes a list of plant sociological surveys with published and unpublished relevés (see Table. 3).

Table 3. *Phytosociological relevés from the Canadian Arctic.*

Authors	Location	Publ.	Not publ.	Relevé size m²	Envir. data	Digital data	Map	Notes
Babb, T.A. & L.C. Bliss (1974)	Queen Eliszabeth Isl.	8						
Barrett, P. A. (1972)	Devon Island	66		25-100				
Batten, D.S & J. Svoboda (1994)	Ellesmere Island	7		0,5				
Bergeron, J.F.S. & J. Svoboda (1989	Ellesmere Island	62		2,5				
Bliss, L.C. et al. (1994)	Devon & Ellesmere Island	19		1-12				
Bliss, L.C. & J. Svoboda (1984)	High Canadian Arctic	30		2,5				
Breen, K. & E. Lévesque (2006)	Ellesmere Island	20						
Bournerias, M. (1978)	Noveau-Québec	31		5-100				
Corns, G.W. (1974)	Mackenzie-Delta	6			X			transect; frequency
Edlund, S. (1982)	District of Keewatin	9			X		X	
González, G. et al (2000)	Canadian Arctic	28						
Kershaw, K.A. (1974)	Hudson Bay	236						
Kojima, S. (1991)	Corwallis Island	7						Constancy table
Kojima, S. (1994)	Ellesmere Island	57						Constancy table, transect
Muc, M. et al. (1989)	Ellesmere Island	6		0,5				
Nams, M.L. & B. Freedman (1987)	Ellesmere Island	8						
Pakarinen, P. & D.H. Vitt (1973)	Devon Island	3						Moss communities
Rivas, Martinez, S. et al. (1999)	Yukon	5						
Rowe, J.S. et al. (1977)	Rankin Inlet	13						
Sasse, E. & D.Thannheiser (1988)	Western Canadian Arctic	81		1-10				
Schweingruber, F. (1977)	Banks Island	99		4-50			X	
Sheard, J.W. & D:W. Geale (1983)	Bathurst Island	7						
Thannheiser, D. (1975)	Canadian Artkic Archipelago	5 23		1-10				23 constancy
Thannheiser, D. (1976)	West. Can. Arctic-Archipelago	40		1-100				
Thannheiser, D. (1979)	Canadian Arctic-Archipelago	50		1-10				
Thannheiser, D. (1987)	Western Can. Arctic-Archipelago						4	3 transects
Thannheiser, D. (1988)	Victoria Island	1					X	Constancy table
Thannheiser, D. (1989)	Banks Island	1					X	Constancy table
Thannheiser, D. (1971-1989)	Western Canadian Arctic		2000	1-100				manuscript
Thannheiser, D. & B. Geesink (1990)	Western Canadian Arctic Archipelago	17					X	Constancy table
Thannheiser, D. & T. Willers (1988)	Western Canadian Arctic Archipelago	18						Constancy table and transects
Vonlanthen, C.M. et al. (2008)	Canadian High Arctic	75		1				
Walker, D.A. et al. (20011)	Western Canadian Arctic	5		1				constancy
Wüthrich, C., I Möller & D. Thannheiser (2000)	Victoria Island	1						constancy
Sum of published and unpublished relevés		2956						

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Yamal and Gydan vegetation datasets

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Numerous relatively recent plot-based (relevé) datasets are available from the Yamal and Gydan peninsulas region of northwestern Russia (Table 1). Other investigators from earlier years have also collected abundant floristic information including: O. Rebristaya (2000) and Rebristaya & Khitun (1994, 1998), flora of the Yamal and Gydan regions; S. Pristyazhnyuk (1994), disturbed habitats; mainly lichens and vascular plants), N. Andreyashkina & Peshkova (1995), mainly vascular plants; M. Boch et al. (1971a, b), mainly wetlands, mainly vascular plants and bryophytes; S. Gribova (1985) and Gribova and Potemkin (1988), mainly vascular plants and bryophytes; L. Meltser (1977), mainly vascular plants; Czernyadjeva (1993, 2001), mosses; and Magomedova et al. (2006), Yamal vegetation. Not all of these data are appropriate or publically available for inclusion in the proposed database.

The datasets reviewed here (Table 1) are considered the most available data for the Yamal involving the collection of complete species-cover estimates from study plots. The datasets often also include other environmental information and biomass data. This overview includes: number of relevés at key sites, completeness of species lists, additional environmental and community data, format and quality of the stored information.

Table 1.
Vegetation datasets of Yamal and Gydan peninsulas.
PU – Polar Urals, SY – Southern Yamal, MY – Middle Yamal, NY – Northen Yamal, G – Gadan, FJL – Franz Josef Land

Datasets holders	Institutes	Groups	№ of key sites / releves	Area
S. Ektova & L. Morozova	Institute of Plant and Animal Ecology UB RAS, Yekaterinburg	vascular plants, bryophytes**, lichens, phytomass data	690 relevés	PU, SY, MY, NY
K. Ermokhina	Earth Cryosphere Institute SB RAS, Moscow	vascular plants, bryophytes, lichens, environmental, phytomass data	>450 relevés	PU, SY, MY, NY, G
D.A. Walker et al.	Institute of Arctic Biology, UAF, Alaska, USA	vascular plants, bryophytes, lichens soils, environmental, phytomass and spectral data	79 relevés	SY, MY, NY, FJL
M. Telyatnikov	Central Siberian Botanical Garden SB RAS, Novosibirsk	vascular plants, bryophytes, lichens	680 relevés	PU, SY, MY, NY
***only dominant species*				

Svetlana Ektova and Lyudmila Morozova, Institute of Plant and Animal Ecology, UB RAS (Yekaterinburg), have one of the largest datasets (more than 690 relevés). Their research was carried out in the Polar Urals and the Southern, Middle and Northern Yamal Peninsula in 1990-2012 (Fig. 1). The data have been used in a number of publications mostly focused on lichens and the effect of reindeer overgrazing on vegetation (e.g., Ektova and Ermokhina 2012; Golovatin et al. 2010, 2012; Kryazhimskii et al. 2011). Their relevés include full lists of vascular plants and lichens and dominant bryophyte species. The datasets include additional information on 13 key sites with detailed description of lichen synusias (1600 plots). Eleven sites have phytomass data. The relevés have coordinates and some some environmental information.

Ksenia Ermokhina, Earth Cryosphere Institute SB RAS (Moscow) has a dataset containing more than 600 relevés with full lists of species (vascular plants, lichens and bryophytes) from the Polar Urals, Southern, Middle and Northern Yamal Peninsula, and Gydan peninsula (Figure 2). Much of these data have been used for analysis of disturbed sites on the Yamal Peninsula (Ermokhina and Myalo, 2012a, b; Ektova and Ermokhina 2012; Yermokhina and Myalo 2012). Additional information includes GPS coordinates, cover of species, height of trees and shrubs (when applicable), environmental data (data on soils, permafrost, relief, exogenous processes, etc.). Forty-five plots have phytomass data, and about 200 plots have LAI data. The research was carried out in 2002-2012. In addition to the relevés dataset there is a set of 4607 photos taken from helicopters, which is held by Ksenia Ermokhina and Anna Mikheeva of Lomonosov Moscow State University. All photos include GPS coordinates and orientation data in ARCGIS project file.

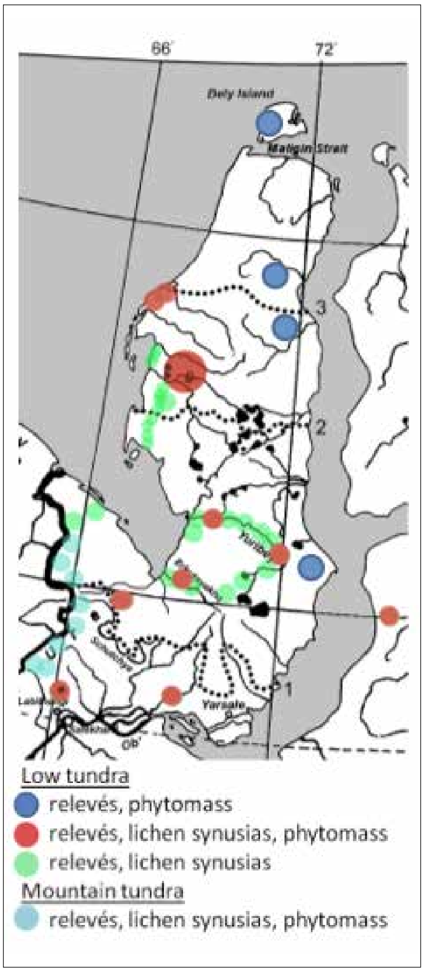

Figure 1. Key sites of Svetlana Ektova and Lyudmila Morozova

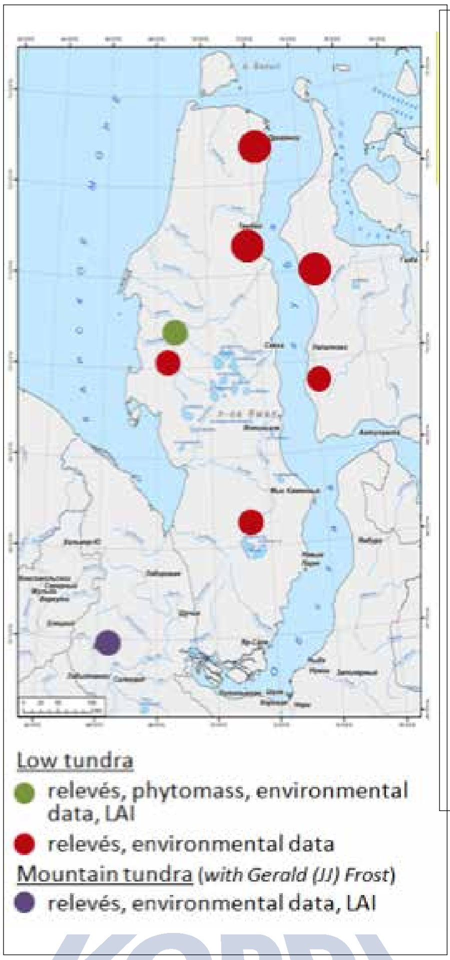

Figure. 2. Key sites of Ksenia Ermokhina

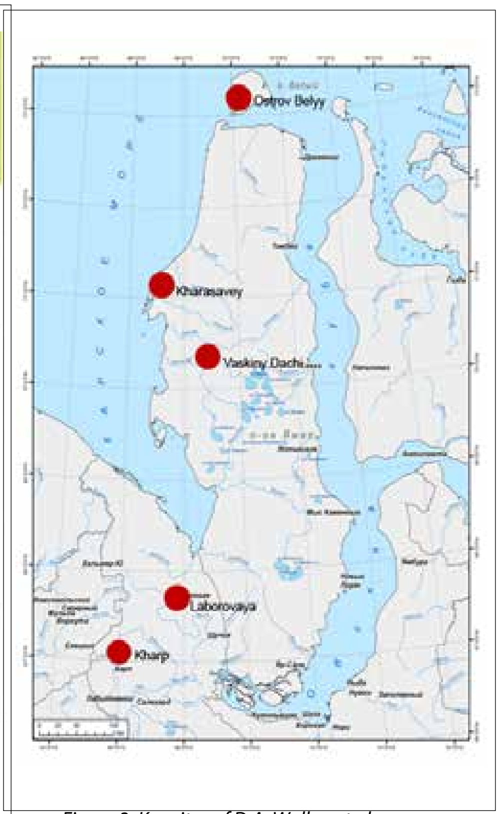

Figure 3. Key sites of D.A. Walker et al.

Additionally, 333 relevés were subjected to a preliminary classification analysis using Braun-Blanquet approach (Table 2). Four associations were assigned to two new alliances and three independent associations with unknown affinities to previously described alliances were identified. All of the described associations and alliances are new. Communities of Equiseto-Salicion glaucae alliance are typical for the areas disturbed by the cryogenic landslides in different extent and periods of time. Alliance Luzulo–Festucion rubrae occupies lichen polygonal tundra on subhorizontal plains of marine terraces covered by sand deposits. Association Vaccinio–Betuletum nanae represents sublimax dwarf birch tundra on clay marine terrace slopes and subhorizontal plains. Communities of Luzulo–Polytrichetum juniperinum association are grass-moss tundra of snow patches on marine terrace slopes.

Table 2.
Preliminary classfication of Yamal vegetation sampled by Ermokhina and Maylo (2012).

Alliance Luzulo–Festucion richardsoni, diff. species: *Festuca richardsonii, Luzula confusa, Equisetum arvense*

Association Rumicietum graminifolius, diff. species: *Rumex graminifolius*

Subass. Polytrichetosum hyperboreum, diff. species: *Polytrichum hyperboreum, Luzula confusa,*

Subass. Cerastietosum arvense, diff. species: *Equisetum arvense, Cerastium arvense, Bryocaulon divergens*

Association Salicetum nummulariae, diff. species: *Salix nummularia, Bryocaulon divergens, Thamnolia vermicularis, olytrichum hyperboreum*

Subass. Tanacetosum bipinnatum. diff. species: *Armeria maritima, Tanacetum bipinnatum, Conostomum tetragonum*

Subass. Arctoetosum alpinae. diff. species: *Arctous alpina, Cladonia uncialis*

Subass. Oxytropietosum sordidae. diff. species: *Oxytropis sordida, Cerastium arvense*

Subass. Polytrichastrietosum alpinum. diff. species: *Polytrichastrum alpinum var. fragile*

Subass. Salicetosum polaris. diff. species: *Solorina crocea, Salix polaris, Racomitrium lanuginosum*

Subass. typicum. diff. species: *Salix nummularia, Festuca richardsonii, Equisetum arvense, Bryocaulon divergens*

Subass. Ledetosum decumbens. diff. species: *Empetrum subholarcticum, Ledum decumbens, Vaccinium vitis-idaea, Armeria maritima, Hierochloe alpina, Luzula confusa, Pedicularis oederi, Polytrichum piliferum, Racomitrium lanuginosum, Alectoria ochroleuca, Cetraria nigricans, Cladina arbuscula, Cladonia uncialis, Flavocetraria cucullata, Flavocetraria nivalis, Ochrolechia frigida, Peltigera scabrosa, Sphaerophorus globosus*

Alliance Equiseto–Salicion glaucae, diff. species: *Salix glauca, Equisetum arvense* ssp. *boreale*
Association Poo–Caricetum concolor, diff. species: *Carex concolor, Poa alpigena ssp. colpodea, Ranunculus borealis*
Subass. Salicetosum polaris. diff. species: *Salix polaris, Poa arctica, Dryas octopetala, Polytrichum juniperinum*
Subass. Calamagrostietosum holmii. diff. species: *Calamagrostis holmii*
Subass. Drepanocladetosum uncinati. diff. species: *Drepanocladus uncinatus*
Subass. Veratretosum lobeliani. diff. species: *Veratrum lobelianum*
Subass. Caricetosum arctisibiricae. diff. species: *Carex arctisibirica*
Subass. typicum. diff. species: *Salix glauca, Equisetum arvense* ssp. *boreale, Carex concolor, Polemonium acutiflorum*
Subass. Caricetosum lachenalii. diff. species: *Carex lachenalii*
Association Bistorto-Betulion nanae, diff. species: *Betula nana, Vaccinium vitis-idaea* ssp. *minus, Bistorta viviparum, Dicranum elongatum*
Subass. typicum. diff. species: *Salix glauca, Betula nana, Dicranum elongatum, Vaccinium vitis-idaea* ssp. *minus*
Subass. Festucetosum rubrae. diff. species: *Alopecurus pratensis, Festuca rubra* ssp. *arctica, Ranunculus borealis*
Subass. Peltigeretosum aphthosae. diff. species: *Polemonium acutiflorum, Aulacomnim turgidum, Peltigera aphthosa*
Subass. Veratretosum lobeliani. diff. species: *Veratrum lobelianum*
Subass. Poetosum articae. diff. species: *Poa arctica, Carex arctisibirica*
Subass. Eriophoretosum vaginati. diff. species: *Nardosmia frigida, Eriophorum vaginatum, Stellaria palustris*
Subass.–Calamagrostietosum holmii. diff. species: *Poa alpigena* ssp. *colpodea, Calamagrostis holmii*
Alliance ??
Association Vaccinio–Betuletum nanae, diff. species: *Betula nana, Vaccinium vitis-idaea ssp. minus*
Alliance ??
Association Luzulo–Polytrichetum juniperinum, diff. species: *Luzula confusa, Polytrichum juniperinum*
Alliance ??
Association Alopecuretum pratensis, diff. species: *Alopecurus pratensis*

D. A. (Skip) Walker and colleagues collected 79 5x5-m relevés from six locations along a North-South bioclimate transect of the complete Arctic bioclimate gradient that included the Yamal Peninsula and Franz Josef Land as part of a project sponsored by the U.S. National Aeronautics and Space Administration (Walker et al. 2012). Study locations were at Nadym, Laborovaya, Vaskiny Dachi, Kharasavey, Ostrov Belyy, and Hayes Island (FJL). Complete vegetation, soil and environmental are in data reports produced by the Alaska Geobotany Center (Walker et al. 2008, 2009, 2011; Frost et al. 2012). The data contain GPS coordinates of all plots, Br.-Bl. cover-abundance values and quantitative percentage cover for all vascular plants, bryophytes, and lichens, biomass (sorted by plant growth forms), mean Normalized Difference Vegetation Index (NDVI), leaf area index (LAI), soil physical and chemical data [percent sand, silt, clay, gravel, soil bulk density, soil moisture (gravimetric and volumetric), cation exchange capacity, soil pH, Ca, Mg, Na, K (meq/100g)] soil descriptions, environmental data (active layer thickness, tree shrub & herb height, moss layer thickness, soil organic layer thickness, microrelief height, landform, surficial geomorphology, subjective estimates of site moisture, soil moisture, topographic position, snow persistence, disturbance regime, site stability, exposure to winds) and photographs of all plots, soils and landscapes. Additional relevé data were gathered at Kharp in 2011 and are being processed.

Mikhail Telyatnikov of Central Siberian Botanical Garden SB RAS (Novosibirsk) holds the dataset of 680 relevés with full lists of species (vascular plants, lichens and bryophytes). The research was carried out in the Central Yamal (Telyatnikov, 2003) and on Polar Urals, South, Middle and North Yamal in 1987-1995 (Telyatnikov & Prystyazhnyuk, 2012) (Fig. 4). The additional information in dataset include GPS coordinates, projective cover of species, height of trees and shrubs (when appliable) and characteristics of the relief and soils.

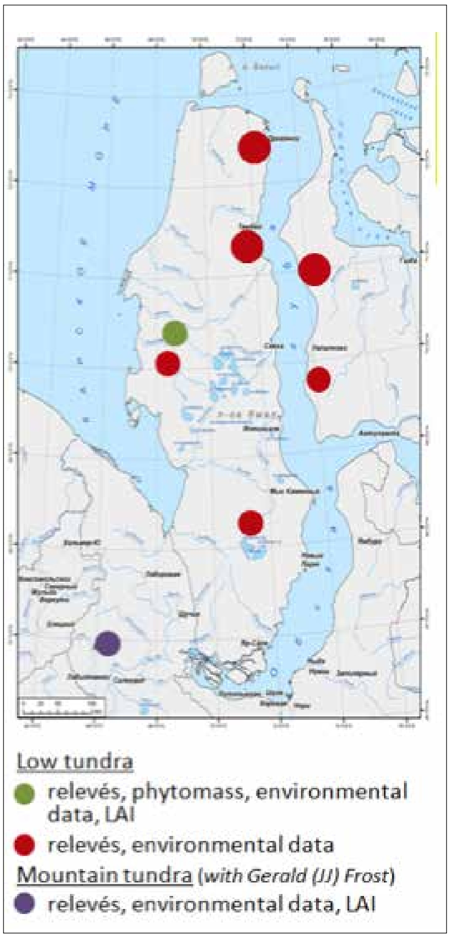

Figure 4. Key sites of Mikhail Telyatnikov.

Braun-Blanquet classification of intrazonal grass communities was made by Mikhail Telyatnikov and Sergey Pristyazhnyuk (2012a). 212 relevés of the dataset were involved. This part of the research was published in 2012 in Russian. Intrazonal grass vegetation of the research territory are represented by two groups of plant communities. Communities of short-grass cryophitic meadows are presented by three new associations (Cerastio maximi–Salicetum nummulariae ass. nova hoc loco, Antennario lanatae–Arctoetum alpinae ass. nova hoc loco and Diantho repentis–Festucetum ovinae ass. nova hoc loco) which belongs to new alliance Oxytropido sordidae–Tanacetion bipinnati all. nova hoc loco. Sub-Arctic meadows are presented by one new association (Polemonio acutiflori–Veratretum lobeliani acc. nova hoc loco) which is included in new alliance Polemonio acutiflori–Veratrion lobeliani all. nova hoc loco.

Class *Thlaspietea rotundifolii Br.-Bl.* 1948
Order *Androsacetalia alpinae Br.-Bl. ap. Br.-Bl. et Jenny* 1926
Alliance *Oxytropido sordidae–Tanacetion bipinnati all. nova hoc* loco
Ass. *Cerastio maximi–Salicetum nummulariae ass. nova hoc* loco
Ass. *Antennario lanatae–Arctoetum alpinae ass. nova hoc* loco
Ass. *Diantho repentis–Festucetum ovinae ass. nova hoc* loco
Class *Mulgedio–Aconitetea Hadac et Klika* 1944
Order *Schulzio crinitae–Aquilegietalia glandulosae Ermakov* et al. 2000
Alliance *Polemonio acutiflori–Veratrion lobeliani all. nova hoc* loco
Ass. *Polemonio acutifl ori–Veratretum lobeliani ass. nova hoc* loco
Subass. *typicum subass. nova hoc* loco
Subass. *artemisietosum tilesii subass. nova hoc* loco

Also, a Braun-Blanquet classification of dwarf shrub and moss tundras was made by Mikhail Telyatnikov and Sergey Pristyazhnyuk (2012b). 246 relevés of the dataset were involved. This part of the research was published in 2012 in Russian. The dwarf shrub and moss tundras of research territory are presented by 4 associations. They belong to the class Loiseleurio-Vaccinietea Eggler 1952. Three associations are described for the first time. In sub-Arctic tundra of Yamal and east foothills of Polar Ural Mountains communities of associations Festuco ovinae – Dryadetum octopetalae ass nova hoc loco and Sphagno-eriophoretum vaginati Walker et al. 1994 are widespread. Communities of the first association occupy convex slopes of watersheds with good drainage. Communities of the second association occupy flat sites of watersheds. Sometimes they participate in formation of tundra-marsh complexes. Two other associations Sphaerophoro fragilis – Arctagrostetum latifoliae ass. nova hoc loco and Tephrosero atropurpureae – Vaccinietum vitis-idaeae ass. nova hoc loco are spreading only in subzone D of Yamal. Association Sphaerophoro fragilis – Arctagrostetum latifoliae occupy gently concave slopes of watersheds. Slopes have a moderate drainage. They are formed by sandy loams and sand. Association Tephrosero atropurpureae – Vaccinietum vitis-idaeae occupy gently convex parts of watersheds which are formed by loams.

Class Loiseleurio-Vaccinietea Eggler 1952
Order Rhododendro-Vaccinietalia Br.-Bl. in Br.-Bl. et Jenny 1926
Alliance Loiseleurio-Diapension (Br.-Bl., Siss. et Vlieg. 1939) Daniels 1982
Ass. Festuco ovinae – Dryadetum octopetalae ass. nova hoc loco
Ass. Sphaerophoro fragilis – Arctagrostetum latifoliae ass. nova hoc loco
Ass. Sphagno-eriophoretum vaginati Walker et al. 1994
Ass. Tephrosero atropurpureae – Vaccinietum vitis-idaeae ass. nova hoc loco

Information from the available Russian Arctic Local Floras datasets (Khitun 2002, Rebristaya 2000, Rebristaya and Khitun 1994, 1998) indicate that there is relatively good floristic coverage of much of the Yamal, but still large areas with little geobotanical information from almost all the Gydan and Tazovskiy peninsulas, northwest and central parts of Nothern Yamal, central parts of Middle Yamal and southeast and northwest parts of South Yamal (Fig. 5).

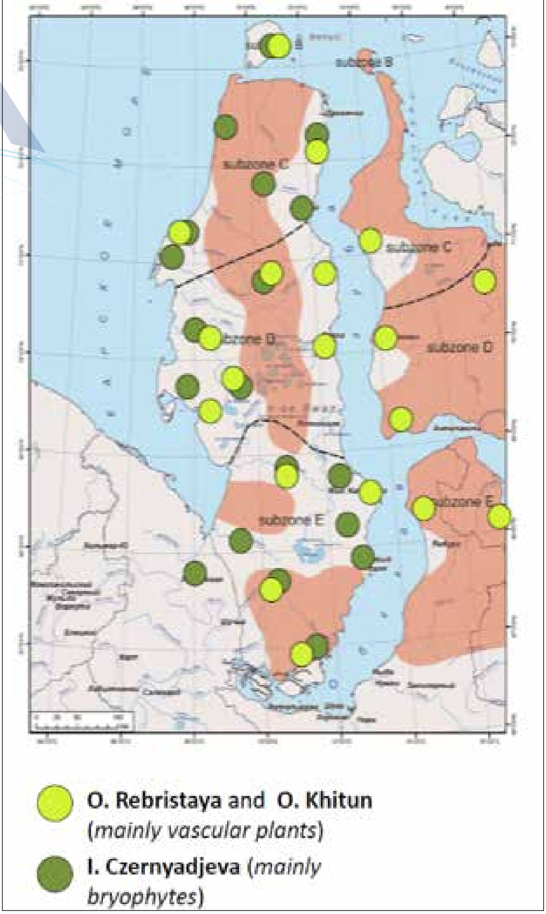

Figure 5. Local flora data sets in the Yamal-Gydan region.

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Walker, D.A., H.E. Epstein, M.K. Raynolds, P. Kuss, M.A. Kopecky, G.V. Frost, F.J.A. Daniels, M.O. Leibman, N.G. Moskalenko, G.V. Matyshak, O.V. Khitun, A.V. Khomutov, B.C. Forbes, U.S. Bhatt, A.N. Kade, C.M. Vonlanthen, and L. Tichý. 2012. Environment, vegetation and greenness (NDVI) along the North America and Eurasia Arctic transects. *Environmental Research Letters* 7:015504.

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Vegetation data from boreal tundra of the North Atlantic and North Pacific regions

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Figure 1. North Atlantic and North Pacific regions.

The oceanic Atlantic area of the Faroe Islands, Iceland, southwestern Greenland and the ecologically homologous regions within the North Pacific area of southwestern Alaska (Fig. 1) are included within the Conservation of Arctic Flora and Fauna (CAFF) area. We present an overview of available data on its vegetation, focusing on treeless tundra, which is in the sub-Arctic transition zone between the Arctic and the boreal zone. In the Atlantic area, oceanicity increases from the west to east with the Faroe Islands being most oceanic. Atlantic vegetation is characterized by dwarf shrub and moss heaths, grasslands, alpine tundra, and with the exception of the Faroe Islands, mountain birch woodlands. In the North Pacific area of North America, oceanicity increases from east to west. The vegetation of the southwestern Alaska mainland and Kodiak Island is dominated by crowberry heaths, alder thickets, bluejoint meadows, and alpine tundra, while the Aleutian Islands are dominated by crowberry heaths, forb meadows, and alpine tundra. The boreal tundra flora of southwestern Alaska is rich in amphi-Beringian species with similarities to the Russian Far East. We review and assess the quality of available relevé, or similar plot data, and its accompanying environmental data. The purpose of presenting the vegetation from the area is to explore the possibilities of including this area in the Arctic Vegetation Archive (AVA).

Description and classification of boreal tundra vegetation in the region

Faroe Islands

The vegetation in the Faroe Islands was sampled in various projects during the last 14 years.

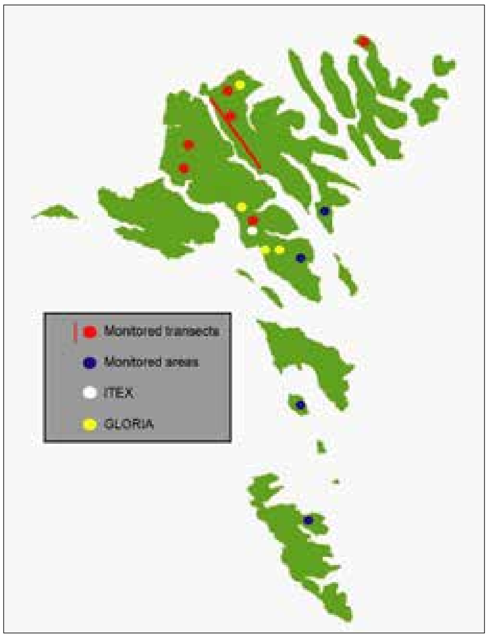

Figure 2. Location of the major site sampled in the Faroe Islands.

The location of the area sampled is mainly in the northern part of the islands, Viðoy, Eysturoy, Streymoy and on the southern part Skúvoy and Suðuroy, these areas are indicated in Fig 2. The vegetation of these sites is *Calluna vulgaris* and *Empetrum hermaphroditum* dwarf shrub and grassland in the lowland and moss heaths, grasslands, alpine tundra in the alpine area. The whole area has been treeless since the last ice age (10,000 years ago).

At each locality the plots were laid out in as homogeneous vegetation as possible, so as to represent conspicuous variation in plant communities. The vegetation for most of the localities was sampled in 100 m^2 quadrats (macro-plots). In each macroplot, 8 smaller (0.25 m^2) quadrats (mesoplots) were placed randomly. The mesoplots were subdivided into 25 (0.01m^2) microplots and the presence/absence of each plant species was noted for each mi- croplot. In each mesoplot, all the vascular plant species, most mosses and lichens were sampled. The vegetation cover was estimated as percentage cover for each mesoplot and the slope was measured in degrees. Also in each mesoplot (in all the altitudinal transects), one soil core, 5 cm in diameter and 10 cm deep, was sampled after the top vegetation layer had been removed. Soil samples were analyzed for: Loss on ignition, pH, Exchangeable cations (Ca, Mg, Na, K), total Kjeldahl-N, total P, exchangeable H (H_3O+). These data are available in all the altitudinal plots and soil temperature data are available from altitudinal transects, measured 1 cm below the soil surface at 50 m altitudinal intervals, hourly for three years.

Most of the data are stored in a Turboveg database (Hennekens and Schaminée 2001). Below, the number of micro-plots for each site is shown in parentheses. Studies with detailed environmental data are indicated with an asterisk. Published studies are indicated below with the number of sampled macroplots, others are published in reports or actively sampled for later publication (e.g. ITEX and GLORIA):

***Viðoy, Villingardalsfjall**- Mountain transects from sea level to alpine (115, soil temperature and soil data, published in *Fróðskaparrit*, 51: 200-211)
***Eysturoy, Gráfelli**- Mountain transects from sea level to alpine (113, soil temperature and soil data published in *Fróðskaparrit*, 51: 200-211)
***Eysturoy, Eiði-Selatrað**- A transect along the island (96, soil data, published in *Applied Vegetation Science* 13: 249-256)
Eysturoy, Toftavatn- (48)
Eysturoy, Sandfelli-GLORIA site (16)
***Streymoy, Ørvisfelli, Mosarøkur** and **Sornfelli**- Mountain transects from sea level to alpine (88, 118 and 114, soil temperature and soil data published in *Fróðskaparrit*, 51: 200-211)
***Streymoy, Stóratjørn**- (64, soil data)
Streymoy, Sornfelli-ITEX site (30).
Streymoy, Lambafelli, Tungliðufjall and **Sornfelli**-GLORIA site (64)
Skúvoy-(56)
Suðuroy, Hvannhagi-(32)

Iceland

Steindór Steindórsson was the first to provide a complete list of Icelandic vegetation types based on the hierarchical classification of the Central European school (e.g. Steindórsson 1974). Since then the Braun-Blanquet relevé approach has mainly been applied by central European vegetation scientists, occasionally visiting Iceland (e.g. Tüxen 1969, 1970, Hadac 1970, Thannheiser 1987), as well as in the PhD theses by Gunnlaugsdóttir (1985) and Bjarnason (1991).

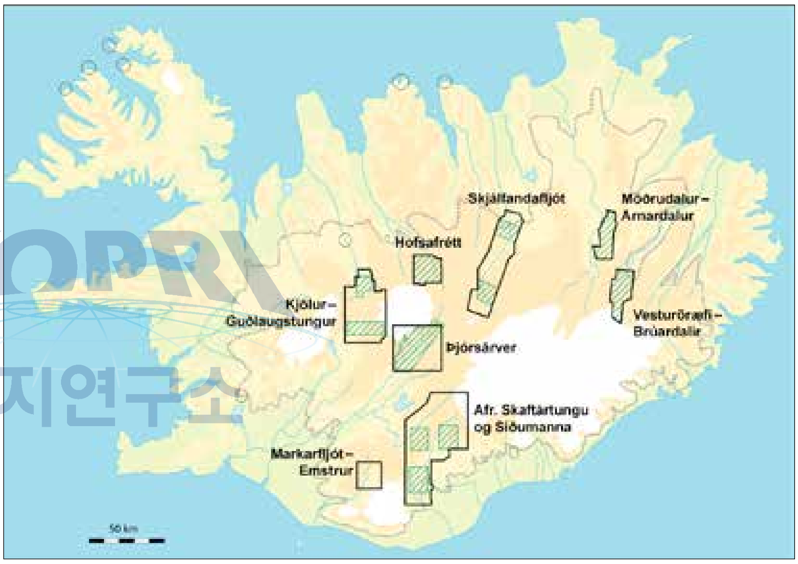

Figure 3: Map of Iceland showing areas where vegetation data are available. Using data from inside the squares, the central highlands (area depicted by dotted line) have been mapped according to EUNIS classification. Circles depict other areas where datasets are available. (Picture from Magnússon et al. 2009).

Vegetation data have, however, been collected by many groups in Iceland during the last decades, using various approaches, usually for other reasons than purely description (Figure 3). The Icelandic Institute of Natural History has probably collected the most extensive plot data in relation to mapping of habitat types in the central highlands according to the EUNIS (European Nature Information System) classification (Davies et al. 2004). More than 3000 plots were sampled along almost 400 randomly chosen transects. In each 100x33 cm plot, cover of vascular plant species, bryophytes and lichens were recorded. Several environmental variables were recorded for each transect (soil pH, soil depth, slope, etc.) Altogether 24 habitat types have been recorded in the central highlands and published in a summary report (Magnússon et al. 2009). In addition the institute has some monitoring projects where cover and abundance of plants is recorded regularly as in the GLORIA-sites in Eyjafjörður in N-Iceland and in nunataks in the southern parts of Vatnajökull glacier.

Jónsdóttir (1984) compared ungrazed (by sheep) and grazed vegetation along six transects across meso-topographic gradients in a highland tundra by using the point intercept method in 50x50 cm plots along the transects. All plant species were included and soil parameters were assessed in selected plots. Selected plots were re-analysed 30 years later and publication is in preparation. Vegetation at two sites is being monitored in 75x75 cm permanent plots within the International Tundra Experiment (ITEX) using the point intercept method, 50 plots in total (Jónsdóttir et al. 2005, Elmendorf et al. 2012a and b). All species are included and soil and temperature data is available for most plots.

There are two additional examples of on-going vegetation studies and monitoring that may be of interest for the database. Detailed vegetation (all species) and soil data have been collected in six valleys situated within the Arctic bioclimatic zone in the north western and northern costal areas of Iceland, as a part of PhD and Master's degree projects, addressing the scale of plant community differentiation under different grazing and fertility conditions (supervised by Ingibjörg Svala Jónsdóttir and others). About 400 40x40 cm plots have been analysed. In the glacial river floodplains of Skeidarársandur in South Iceland Thóra Ellen Thórhallsdóttir and Kristín Svavarsdóttir are monitoring 50 permanent plots in grids related to studies on plant community succession.

In addition, a wealth of vegetation data (most focusing on vascular plants) has been collected by various researchers in relation to specific management or restoration projects. These data are either unpublished or published in internal institutional reports, some of which can potentially be made available for the vegetation database.

South Greenland

A few detailed plot-based vegetation analyses have been completed in the boreal inland of South Greenland using to the Braun-Blanquet approach (Westhoff and van der Maarel 1973) The PhD thesis of Stumböck (1993) contains 213 relevés of 1-200 square meters from altitudes between 5 m and 875 m, all from the close neighbourhood of Narsarsuaq. However header data are incomplete, GPS data are lacking and cryptogams are not considered at species level.

Another 32 relevés were made in 2009 by Bültmann and Daniëls, however not published so far. A fair number of plot based vegetation analyses have been made by several investigators (a.o. Feilberg), not for detailed vegetation description and classification, but mainly for global monitoring, mapping and land-use purposes. These studies have not been published so far in scientific literature. For further information see a.o. Fredskild and Odum 1990, Feilberg and Høegh 2008, and Daniëls 2010.

Boreal tundra of Southwest Alaska

Over a 20 year period we collected observational data on the structure and composition of the boreal vegetation of western Alaska. During this period a number of scientists joined in the effort; they include Wilf Schofield, Sandra L. Talbot, and Fred J. A. Daniels, Ayzik Solomeschch, and John Myers. Their knowledge and insight enriched these studies.

The location of our major phytosociological study sites are in the boreal Aleutian Islands, Alaska Peninsula and its adjacent islands, Kodiak Island and also in the low Arctic of northwestern Alaska, Selawik NWR; these sites are indicated in Fig. 4. The vegetation of these sites is essentially treeless and are comprised of heaths, alpine tundra, meadows, deciduous thickets, and mires. Some treed vegetation occurs in Alaska Peninsula/Becharof National Wildlife Refuge (NWR), Kodiak NWR, and Selawik NWR. Relevés were recorded according to Braun-Blanquet methods (Westhoff and van der Maarel 1973).

Plots were laid out in units of homogeneous vegetation so as to represent conspicuous variation in plant communities usually over a topographic gradient. Relevé sizes were 25 m^2 for heaths, meadows, and mires; 100 m^2 for thickets; and 400 m^2 for forests, which were minimal areas for comparable types (Westhoff and van der Maarel 1973). Cover-abundance was estimated for all vascular plants, bryophytes, and lichens according to the nine-point ordinal scale of Westhoff and van der Maarel (1973). Voucher specimens were prepared for all species, reviewed by taxonomic specialists, and archived in major herbaria. Taxonomic nomenclature generally follows the USDA Plants Database.

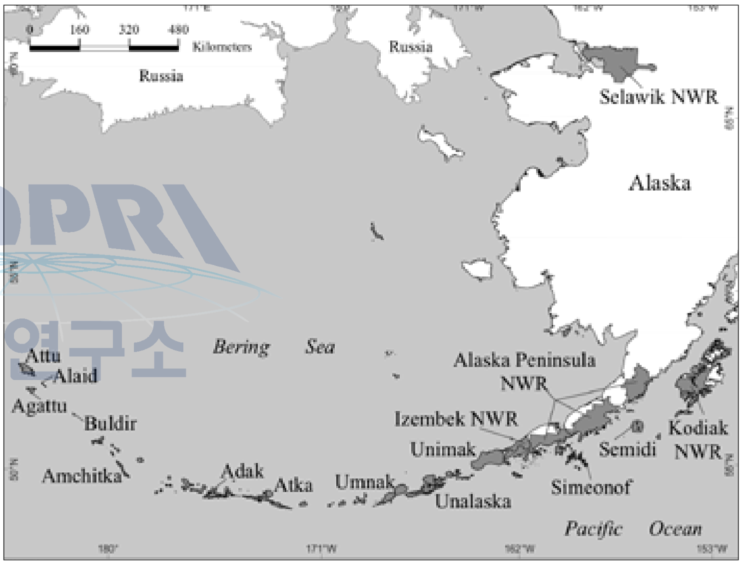

Figure 4. Location of the major sites sampled on the Alaskan Peninsula and Aleutian Islands.

In addition to the floristic information of the plant communities, the vegetation structure within each relevé was also recorded as the percent cover of each layer according to the following classes: tree with three subclasses: (1) > 20 m, (2) 10-20 m, (3) 5-10 m; shrub with two subclasses: (1) 2-5 m, (2) 0.5-2 m; herb with three subclasses—(1) graminoid, (2) forb, and (3) dwarf shrub (< 0.5 m); and bryoid with two subclasses— (1) bryophyte, (2) lichen.

We recorded latitude and longitude for all sites by GPS using WGS84 datum. Environmental factors recorded were aspect (degrees), elevation (m), litter cover (%), slope inclination (degrees), ecological moisture regime (ordinal values: 1, xeric; 2, subxeric; 3, submesic; 4, mesic; 5, subhygric; 6, hygric; 7, subhydric; and 8, hydric), and mesotopography (Luttmerding et al. 1990).

When funding permitted we collected a soil sample from the rooting zone in the center of each relevé at a depth of 15-20 cm. Laboratory analyses of these samples tested for organic matter content, pH, electrical conductivity, NO_3-N, NH_4-N, P, SO_4-S, B, Zn, Mn, Cu, Fe, K, Ca, Mg, Na, total bases, and texture.

Data are stored in a Turboveg database (Hennekens and Schaminée 2001). The number of relevés for each site is shown in parentheses and given below. Studies with detailed environmental are indicated with an asterisk. Published studies are indicated below; others are actively being analyzed for publication:

Aleutian Islands, Eastern Aleutian Islands: Fox Islands — Adugak (6), Akutan (5), Chagulak (3), Egg (6), Kaligagan (8), Ogchul (4), Rootok (3) Sanak (1), Tangik (3), Tigalda (6), Ugamak (5), Umnak (7), *Unalaska (70, Talbot et al. 2010); + 5), Unalga (4), *Unimak (70), Vsevidof (6); Islands of the Four Mountains — Chagulak (3), Kagamil (4), Uliaga (4).

Aleutian Islands, Central Aleutian Islands: Adreanof Islands — *Adak (123), Amlia (12), Argonne (1), Atka (2), Crone (4), Eddy (1), Egg (6), Gareloi (3), Great Sitkin (3), Igitkin (8) Kanu (6), *Kasatochi (50) Kavalga (15), Seguam (7), Tagadak (10), Tagalak (4), *Tanaga (50), Tanaklak (1), Ulak (3), Umak (2); Rat Islands — Amchitka (5), Davidof (8), Khvostof (11), Kiska (7), Little Kiska (5), Rat (4), Tanadak (11); Buldir Island — *Buldir (13)

Aleutian Islands, Western Aleutian Islands: Near Islands — Agattu (8), Alaid (3), *Attu (65 + 76, Talbot & Talbot 1994), Nizki (10), Shemya (8)

***Alaska Peninsula/Becharof National Wildlife Refuge (NWR)** — Mountain transects from sea level to alpine (357 + 6 – 16 environmental variables, including alder communities, Talbot et al. 2005).

Neighboring Islands of the Alaska Peninsula — *Deer (15), *Simeonof (30, published in Talbot et al. 2004), *Semidi (48), *Wosnesenski (24)

***Izembek NWR** — Coastal vegetation (123 + 16 environmental variables)

Kodiak NWR — Mountain transects from sea level to alpine, Spiridon Peninsula (263 + 4 environmental variables)

***Selawik NWR** — Mountain transects from sea level to alpine (159 + 20 environmental variables)

Conclusion

There are two reasons data from the subarctic (boreal) tundra should be included in an Arctic Vegetation Archive. First, its physiognomy and ecology are similar to the true Arctic tundra. Second, large responses to climate change are to be expected in this ecotone between the Arctic and the boreal forest zone. From this brief overview it is apparent that there are substantial amount of sub-Arctic boreal tundra vegetation data available that could be compiled into the Arctic Vegetation database, thus enabeling large scale tundra vegetation monitoring along a high Arctic, sub-Arctic gradient.

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Unifying and analyzing vegetation-plot databases in Europe: the European Vegetation Archive (EVA) and the Braun-Blanquet project

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Introduction

Vegetation-plot databases have enormous potential for biodiversity research and for developing systems of vegetation and habitat classification (Chytrý et al. 2011). In Europe there are about 2 million of vegetation-plot records stored electronically (Schaminée et al. 2009). However, this information is relatively unexploited and geographically focused on national or sub-national scales. It is therefore an urgent task for vegetation scientists and biodiversity managers to develop international synergies addressing supra-national and continental scales.

Here we present two projects that are being pursued by the European Vegetation Survey (EVS) Working Group of the International Association of Vegetation Science (www.euroveg.org).

The European Vegetation Archive (EVA)

The main purpose of the European Vegetation Archive (EVA) is to create the conceptual background for the development of pan-European analyses based on national vegetation databases (http://euroveg.org/eva-database). EVA represents a key infrastructure for unifying vegetation-plot data, aiming at establishment of a centralized European vegetation database and stimulating international feedbacks between database managers and potential users.

EVA is conceived as a dynamic system for sharing data among national databases while they would continue their normal, country-focused activities. The EVA consortium has developed Data Property and Governance Rules that guarantee the rights of the data contributors are respected. Thus, individual data contributors can decide on the mode of data availability from restricted to open access, and different options of data sharing can be agreed for particular projects developed between EVA and external partners.

A new version of the software TURBOVEG (Hennekens & Schaminée 2001) and complementarities with the SynBioSys Europe information system (Schamineé et al. 2007) are being developed as the management software for EVA. These tools will allow us to combine the species cheklists linked to national vegetation databases into standarized taxonomical lists to be used in the analysis of vegetation data. Given the complexity of managing the taxonomy of large datasets, this system provides a dynamic feedback to regularly update the links between species names of the original databases.

The Braun-Blanquet project

The European Vegetation Survey is developing projects to benefit from EVA infrastructure but also to involve other collaborators beyond the consortium. An example is the Braun-Blanquet Project (http://euroveg.org/projects), the main aim of which is the compilation and analysis of floristic and geographical information related to European phytosociological alliances as defined in the new European syntaxonomical overview (EuroVegChecklist, Mucina et al.).
This project is dedicated to Josias Braun-Blanquet, whose legacy has been the inspiration for collecting most of the data that will be analyzed (Westhoff & van der Maarel 1973). At the moment 22 extensive datasets from 18 European countries are involved in this project. Thanks to the relatively homogeneous information provided at the plot level, c. 60% of the samples included in the vegetation databases can be characterized at the level of alliance. This information will be summarized in the form of constancy-based synoptic tables, and will be essential for offering a parameterized overview of European vegetation types and for developing further research at habitat level.

In order to make all this information useful for conservation managers, the European Vegetation Survey team is working with the European Environment Agency to supply real data and scientific background to the EUNIS habitat classification. This classification is currently used as a crucial tool of nature conservation survey, planning and reporting in Europe in Europe (http://eunis.eea.europa.eu/).

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Application of Russian Arctic local flora database to the issues of Arctic biodiversity conservation

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The concept of local flora

The global problem of biodiversity conservation along with the possible effects of global climate changes and anthropogenic influences on northern ecosystems require formal systematic methods for inventory, comparative analysis, and monitoring of Arctic plant biodiversity. The concept of a *local flora* was initiated by A.I. Tolmatchev in 1930s and contributed greatly to the development of comparative floristics in Russia (Yurtsev, 2004). Tolmatchev initially used the term *concrete flora*, to describe the flora of a natural existing region in nature, in contrast to a flora contained within an artificial political boundary such as a state or administrative district, which can contain several concrete floras (Tolmatchev, 1931, 1932). The term meant the complete flora or total floral diversity within a representative region surrounding a given locality, and this unit could then be used to compare the diversity with other localities. Tolmatchev (1974) stressed that the area of a concrete flora should be small enough so that the species occurring within habitats are mainly determined by local environmental factors and not major differences in geography, climate or history. The composition and size of a concrete flora depends on the characteristic set of habitats within the local area. The size of the area should be big enough to reveal *all possible habitat types* and can vary in different geographic areas. "The constancy of species composition in similar habitats throughout the area of a concrete flora serves as the criterion of homogeneity" (Tolmatchev, 1974).

Boris Yurtsev developed the concept of concrete floras further and suggested a narrower understanding corresponding to the flora of a representative defined landscape surrounding the locality (Yurtsev, 1975, 1982, 1987, 1997, 2004; see also: Lukicheva & Saburov, 1969 and Khitun, 2010). In the field, we do not search for the boundaries of the concrete flora. Instead, we perform a selective floristic sampling of habitats within the vicinity of some locality. Yurtsev (1975) suggested it is a "sample of the floristic situation at a geographic point", or "the flora in the vicinity of a geographic point", but these terms were too bulky and never got wide recognition. Shelyag-Sosonko (1980) proposed a shorter name for it, *local flora*, which became the more widely used term. In other words, a local flora is roughly the minimum-area required to sample the complete theoretical concrete flora of a locality (Fig. 1). In the Arctic, the minimum area of a local flora is approximately 100 km^2 in lowlands and 300 km^2 in mountainous regions; in taiga it is approximately 600 km^2 (Tolmatchev, 1974; Schmidt, 1972; Yurtsev, 1987). Worldwide this concept is poorly known, probably due to the language barrier, but in Russia it is widely used in different regions. Just to name a few, these include the NW and NE of the European part of Russia (Baranova et al., 1971; Bubyreva, 1998; Shmidt, 2005; Martunenko, Gruzdev, Kanev, 2008; Rebristaya, 1977); Yamal (Rebristaya, 2013); Southern Siberia (Revushkin, 1988; Naumenko, 2008), Udmurtiya (Baranova O.G., 1994) and many others.

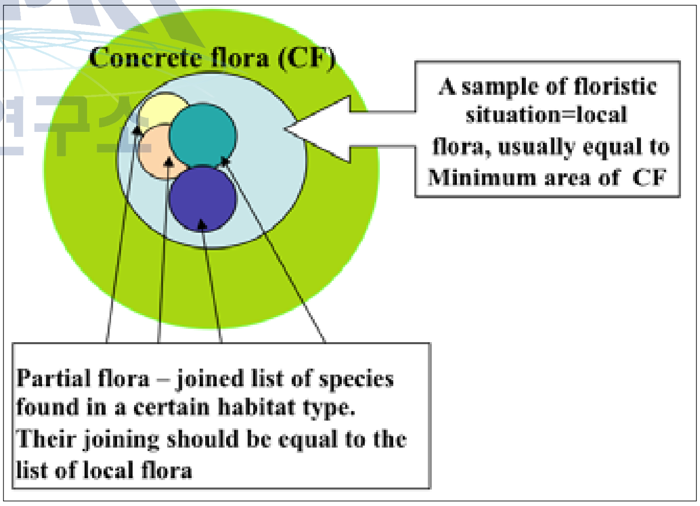

Figure 1. Conceptual relationship of concrete, local, and partial floras.

Method of local flora provides unique information about species populations

The method of creating a local flora involves thoroughly examining the area around a base location by radial routes about 6-7 km long during 2-3 weeks, compiling species lists for all existing habitat types in the area; recording presence of species and collecting information about their distribution in the area, their ecology, commonness or rarity, also record distribution of different habitats. A thorough search through the study area results in many rare species which otherwise could be missed. Although the complete (100%) local flora is probably never achieved, such detailed study gives a very good approximation. Partial floras (Yurtsev, 1987) are the sets of species occurring in ecologically similar subdivisions of the landscape, i.e., habitat types (Khitun, 1989). In working with local floras Yurtsev (1968) introduced the concept of species *activeness*, also a commonly used term in Russian floristic literature. It is an estimate of species behavior within a landscape, based on estimation of breadth of ecological range, abundance and frequency of the species within the local flora (Table 1). Yurtsev suggested five grades of activeness: I, nonactive; II, low activity; III, medium activity; IV, highly active; V, especially active. In the majority of papers dealing with local floras species activeness is also estimated. Data about species activeness can be very useful both for monitoring purposes and for conservation. Most of information on the ecology of species in the *Arctic Flora of the USSR* was obtained from the study of local floras.

Table 1.
Grades of species activeness (after: Yurtsev, 1968, modified by Yurtsev, 1994 and Khitun, 1998).

Abundance	**Breadth of ecological amplitude**									
	Occur in >80% of all habitat types present in the area		**Occur in 50-80% of all habitat types**		**Occur in 21-49% of habitat types**		**Occur in <20% of all habitat types present in the area**			
	Every-where	**Sporadic**	**Every-where**	**Sporadic**	**Every-where**	**Sporadic**	**Common habitats**		**Rare habitats**	
							Constant	**Non-const.**	**Constant**	**Non-const.**
Copious (>10%)	V	V	IV	IV	III	II	III	II	II	I
Sparse (2-10%)	IV	IV	III	III	III	II	III	I	I	I
Solitary (<2%)	III	II	II	II	II	I	II	I	I	I

A network of biodiversity monitoring sites in the Russian Arctic

Scientists of the Far North Vegetation Laboratory of the Komarov Botanical Institute, Russian Academy of Science, have used the local flora method for more than 50 years. Detailed information has been gathered for more than 400 local floras in the Asian Arctic. The availability of such data led Yurtsev (1997) to suggest the idea of monitoring of biodiversity at the level of local floras. A local floras database was started in the Integrated Botanical Information System (IBIS) (Zverev, 1995, 2007). The IBIS library has approximately 7000 plant names including accepted names and synonyms; the taxonomy follows the Arctic Flora of the USSR.

Criteria for selecting floras for the network were pointed out with list of the first 130 local floras included into the net (Yurtsev et al., 2001; translated by Balandin, 2008). Today, biodiversity monitoring at the level of the local floras network contains 258 local floras from all parts of the Russian Arctic (we expanded it into European Arctic and also included some northern taiga local floras to highlight the ecotone between tundra and taiga) (Fig. 2). At present the different subprovinces of the Arctic (Yurtsev et al., 1978) are unevenly represented, but work is on-going and now we also use existing literature data on local floras, critically checking species lists and herbarium to fill the gaps.

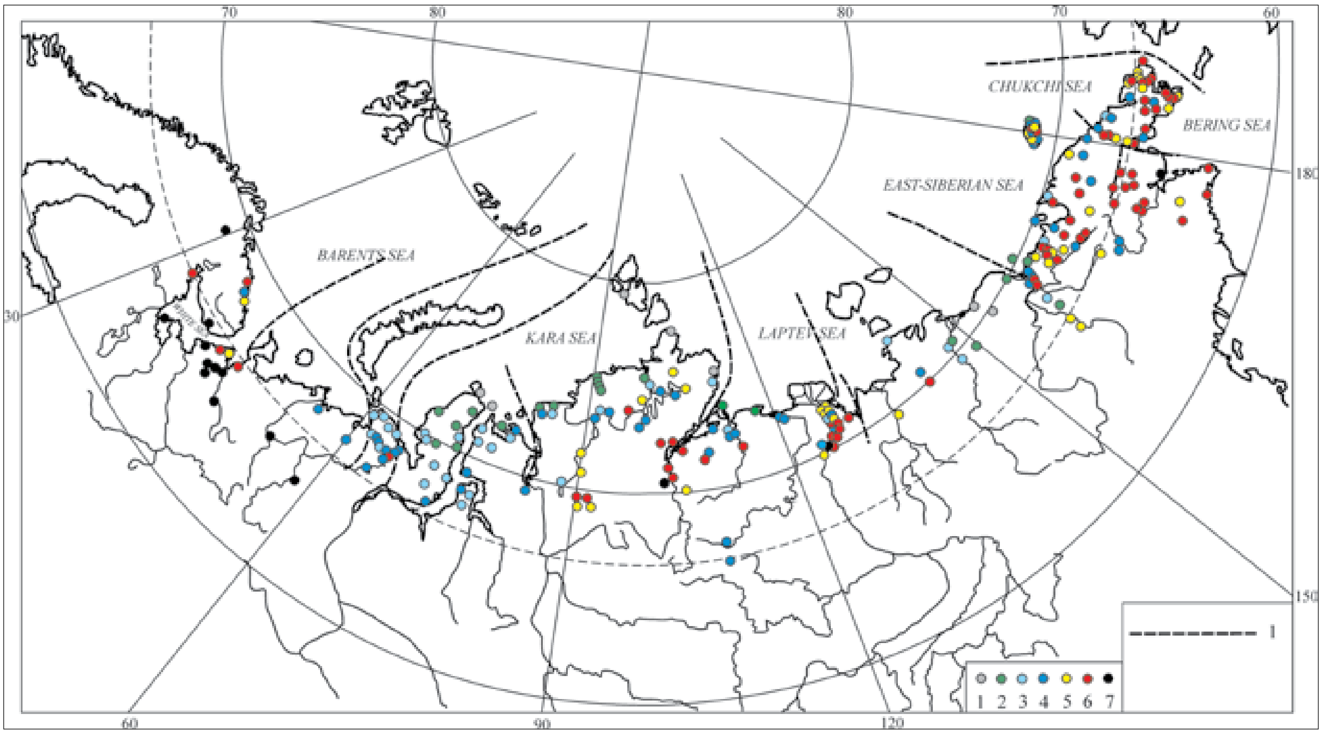

Figure 2. Biodiversity monitoring network based on local floras in the Russian Arctic. Circles of different color indicate local floras with different species richness. Grey circles (1) – 46-100 species; green circles (2) – 101-150 species; blue circles (3) – 151-200 species; dark-blue circles (4) – 201-250 species; yellow circles (5) – 251-300 species; red circles (6) – 301-400 species; black circles (7) – >400 species; dotted lines (1) – boundaries of subprovinces.

The initial idea of monitoring has a serious obstacle – lack of finances. So far only five sites have been re-visited 20-70 years after initial study. As an example, the reinventory of "Yamu-Nery" in the Taimyr studied by Tolmatchev in 1932, revealed 30 new species and apparent changes in the frequency for other species (12 species decreased and 37 increased, mainly thermophilous species) (Pospelov, Pospelova, 2001). Re-inventory of Tiksi (Sekretareva, Sytin, 2006) also revealed changes. Of the 277 species found initially (Tikhomirov et al., 1966), 227 were re-found; 15 new species were recorded, including 6 ruderal; several typical snowbed species were not found (*Trisetum agrostideum, Phippsia algida, Carex lachenalii, Ranunculus pygmaeus* etc); and there was some increase in the activeness of willows (*Salix alaxensis, S. lanata, S. hastata, S. reptans*).

Analysis of spatial changes in floristic parameters

The network of floras collected using the same method allows us to study spatial gradients of different floristic parameters. Some of the common parameters calculated include *species richness* (including the number of species, genera, and families in local and regional floras; average ± standard error, min, max for each region; and the ratio (%) of species richness of certain local to respective regional flora); systematic structure (average; min; max number of species in a family or in a genus, the same –for genera in families; number and portion of single species genera and families; number and portion of differential species and genera; number of species in 5 and 10 richest families and their portion in the flora; ratio Asteraceae/Poaceae, Cyperaceae/Poaceae; presence, number and portion of rare species in local floras of phytochoria; *similarity of local floras by species composition* (Sørensen similarity index); *biomorphologic structure* (proportion of woody plant species, presence and composition of trees); *geographic structure* (number and ratio of longitudinal and latitudinal groups and fractions; similarity of local floras by geographical structure) and some others. The results are published (Yurtsev et al., 2002, 2004; Koroleva et al., 2008, 2011, 2012 and many others).

Many parameters (for example number of species, genera, families) exhibit zonal trends but in different phytogeographic sectors their ranges and intensity is different. Other parameters are quite stable in different subzones but their values are specific for each sector. For example, the average number of species in a family, portion of single species families, the portion of species diversity of certain local flora in the total flora of subprovince is more or less constant in the same subzone. Species richness increases from north to south, and also from west to east (Fig.2). Lowland Yamal and Gydan local flora number 100-200 species. The richest floras in the southern Taimyr contain 200-300 species, whereas the majority of Chukotka local floras contain more than 300 species. The mean species richness values for Chukotka local floras are 1.5 to 2 times greater than those in the Yamal and Taimyr regions. The highest values of the proportions of Yamal's local floras (mean number of species in the families) are the same as the lowest in Chukotka. The high species diversity of the East-Asian floras is caused by the relief diversity, the history of the formation of the floras and their close proximity to the ancient centers of speciation – Angarida and Beringia.

The ranges of richness which are typical for certain regions and subzones, and can also serve as estimates of how completely a local flora in a certain region is studied (if data are collected by other authors). For example, species diversity of local floras in the southern hypoarctic tundra of the Yamal Peninsula varies between 175-190, in the same subzone in Gydansky and Tazovsky peninsulas it is 185-215 depending on diversity of available habitats; in the northern hypoarctic tundra species richness ranges are 136-160 in the Yamal and 160-180 in the Gydansky and Tazovsky peninsulas. And in Arctic tundra subzone the difference is even higher: 115-130 species in Yamal's mainland vs 150-170 in Gydansky.

Analysis of geographical structure of local floras and gradients in distribution of geographical groups of species as a tool for floristic regionalization

The weighting of any species as a typological element of a given flora is a necessary procedure for the evaluation of the rank of the flora and demarcating its natural boundary (Yurtsev, 1982, 1987). Each regional flora is structured as a set of local floras. Each species in the database was referred to certain longitudinal and latitudinal fraction and grouped according to the system elaborated on the basis of species distribution in the tundra zone, unified for all sectors of the Arctic and containing five longitudinal fractions and 18 groups, three latitudinal fractions and seven groups. Distribution of each group and fraction within the territories of subprovinces has been analyzed and existence of more or less sharp gradients in their presence and abundance was revealed. We consider them as markers of floristic boundaries. They partly coincide with the boundaries suggested in the scheme of regionalization of the Arctic floristic region (Yurtsev et al., 1978) but also show some other boundaries (of uncertain rank yet) which were not reflected in that scheme. The following new boundaries were revealed: approximately in the middle of the Gydansky peninsula, separating the eastern part of the Yamal-Gydan subprovince; along the Pyasina river, which separates the western parts of Taimyr from the rest of peninsula; and at the base of the Chukchi peninsula and separating its Beringian coast. Longitudinal spectra of local floras were compared pair-wise using modified Sørensen-Chekanovskii's similarity index (Yurtsev, Semkin, 1980), cluster analysis was performed and revealed groups of floras of similar composition. Boundaries between different clusters did not completely coincide with previous boundaries found by distribution of different groups, but areas with concentration of boundaries found by different analysis were identified (Koroleva et.al, 2008, 2011). The latitudinal structure (Koroleva et al., 2012) reflects mainly subzonal but not subprovincial position. The latitudinal trend can be observed in all groups and fractions. It is more pronounced in the Yamal-Gydan and Taimyr subprovinces and with a more complex pattern in the Chukotka subprovince due to the mountainous relief and proximity of the two oceans.

Importance of studying local floras for recognition of differential species and phytogeographical reconstructions

The local flora database allows us to provide additional information about distribution of rare species and endemics. In some cases a species status should be changed. One such example is *Castilleja arctica*, a species listed in the Red Data Book of Russia and considered as a very rare endemic of the Yamal-Gydan subprovince. It was found in several local floras in the Taimyr subprovince (see: www.byrranga.ru) and even in the Anabar subprovince, it is not rare in the Yamal either; where it was found practically in all studied hypoarctic floras. Recent research also provided new information about species ranges for many species mentioned as differential for subprovinces in the proposed scheme of floristic delimitation of the Arctic (Yurtsev et. al, 1978). Many of these so-called differential species have been found later in neighboring regions, and the respective lists need to be updated. This is especially true for the Kharaulakh subprovince, where several species formerly regarded as differential (e.g., *Taraxacum semitubulosum, Gorodkovia jacutica, Stellaria jacutica*) were found also in the Anabar-Olenëk subprovince. Another examples from the Yamal-Gydan region is *Lychnis sibirica* subsp. *samoedorum* which was mentioned as eastern co-differential with its western border in Gydan, but found in East-European Arctic (Narjan-Mar), also *Aconitum czekanowskyi* was mentioned as differential for this subprovince but found also in the Taimyr.

A thorough inventory of local floras allowed us to better identify rare species and improved our knowledge of species origin and migration. Thus, *Draba oblongata* was considered as endemic of Greenland and the Canadian Arctic (Porsild, 1957), but it was found in several Asian Arctic local floras (Fig. 3). Probably, this species migrated from Arctic America westwards along the dry shelf's margin. We can expect more similar findings on the Siberian coast. A similar situation was found with *Gastrolychnis ostenfeldii*, also considered earlier as a Canadian Archipelago endemic (Porsild, 1957). It was found first on Wrangel Island, later on Aion island, then in the Kolyma lowlands and finally in the Taimyr Peninsula! Now we refer this species to the Chukotkan-West American group and can expect new findings in Yana-Indigirka lowlands (Petrovsky et al., 2010). Another example, *Oxytropis wrangelii* was regarded as progressive endemic of Wrangel island where it is widespread, but recently two relict populations of this species were found on the coast of the Chukotka peninsula also. A similar situation occurs with *Puccinellia colpodioides*, but for the latter there is even information of findings on Banks Island (Elven, 2007). Such findings allow us to reconstruct the steps of formation of modern floristic complex, suggesting areas where these species can be also found.

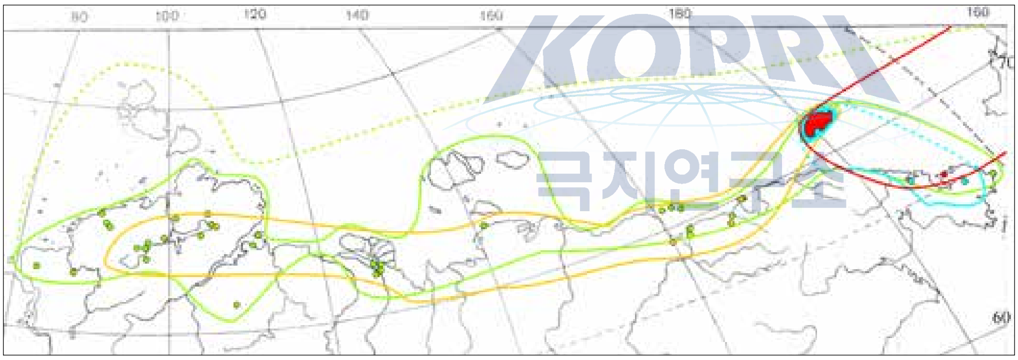

Figure 3. New findings of species earlier regarded as endemics. Circles indicate local flora locations. Lines indicate flora distribution ranges; dotted lines – hypothetical historic range during period of exposed coastal shelf; green color – Draba oblongata R.Br (=Draba groenlandica E.Ekman); blue – Oxytropis wrangelii Jurtz.; red – Puccinellia colpodioides Tzvel.; orange – Gastrolychnis ostenfeldii (A.E.Porsild) Petrovsky.

The network of local floras can be useful for the aims of regionalization, monitoring and conservation of flora of the Russian Arctic, the data obtained gives valuable information also for the evaluation of conditions of vegetation cover in the situation of global change and anthropogenic pressure.

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A syntaxonomic analysis of the northwest to southwest vegetation gradient in the western part of European Russia Arctic

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Introduction

Syntaxonomic data take into account flora and ecological properties of plant cover and are suitable for representation of biogeographical patterns at local, regional and circumpolar scales. They can provide background for assessment of plant-cover biodiversity and aid in selection of rare plant communities and areas of special conservation interest. An Arctic vegetation database would therefore be useful for many European projects, such as the network of special areas of conservation Natura 2000 established under the 1992 Habitats Directive, (Council Directive, 1992) and Emerald network of Areas of Special Conservation Interest (ASCI's) under Resolution 4 on the Berne Convention, revised in 2010 (Council of Europe, 2010).

Plant cover of Kola tundra zone makes up a substantial part of the biodiversity of the European Arctic. An analysis of the changes in the gradient in tundra vegetation on the Kola Peninsula is important for understanding of the integrity in the European and circumpolar Arctic ecosystems.

Materials and methods

Although the Circumpolar Arctic Vegetation Map (CAVM 2003), shows no Arctic tundra on the Kola Peninsula, there is a band of tundra up to 80 km wide. The *Map of Vegetation of the Kola Peninsula*, at 1:1 000 000 scale shows the position and boundaries of the tundra zone of the Kola Peninsula (Chernov, 1954) (Fig. 1). This map was the foundation for all regional vegetation maps of the Kola Peninsula that followed; including small-scale maps of the vegetation of USSR and Russia (Koroleva & Loshkareva, 2013).

Gradients in species composition and structure of tundra vegetation were examined on the using the Braun-Blanquet classification approach and data from of 390 vegetation descriptions from areas along a transect from the northwest to the southeast of the Kola Peninsula. These data were compared with information from northern Scandinavia and Bolshesemel'skaja and Malozemel'skja Tundra in Nenets District of Russia (Andreyev, 1932; Dedov, 2006). Plant communities (103 relevés) with a dominance of widely-distributed dwarf shrubs, such as E*mpetrum hermaphroditum, Betula nana, Vaccinium myrtillus*, and *V. uliginosum*, were analyzed by means of a clustering program called GRAPHS, which used the Sørensen-Chekanovsky coefficient, and average distance as a measures of similarity (Novakovsky, 2006). The resulting clusters of relevés were interpreted as Braun-Blanquet syntaxa (associations or plant community types).

Figure. 1. Map of vegetation of Kola Peninsula, scale 1:1 000 000, showing extent of the tundra in blue (Chernov, 1954).

Results

The following discussion summarizes the transitions that occur from northwest to southeast in the tundra zone of Kola Peninsula in the major habitat groups: tundra heathlands and barrens, coastal marshes and beaches, and bogs and fens. Grasslands and meadows also show well-expressed gradient from northwest to southeast, but their syntaxonomy is still under consideration.

Tundra heathlands and barrens. The gradient from northwest to southeast is displayed at the level of subassociations of the Alliance ***Loiseleurio-Diapension*** (Br.-Bl. et al. 1939) Daniels 1982. Polygonal tundra vegetation in the eastern part of Kola belongs to subass. ***Loiseleurio–Diapensietum salicetosum nummulariae*** Koroleva 2006. Diagnostic taxa (DT) are *Salix nummularia* (on the east of Kola lies west limit of its distribution), *Flavocetraria nivalis, Bryocaulon divergens, Sphaerophorus fragilis*, and *Ochrolechia frigida*. The ***Loiseleurio-Diapensietum*** subass. ***typicum*** is widely distributed in western part of Fennoscandia, mainly along the Norwegian Sea on exposed stony shores. DT include *Loiseleuria procumbens, Racomitrium lanuginosum* (D - Dominant), *Sphaerophorus fragilis*, and *Ochrolechia frigida*.

The most typical and widely distributed for all Fennoscandian tundra are the dwarf-shrub-dominated plant communities of ***Empetro-Betuletum nanae*** Nordh. 1943, subass. ***typicum***, DT *Cladonia arbuscula, C. stellaris, C. uncialis*; and subass. ***pleurozietosum***, DT *Hylocomium splendens, Pleurozium schreberi.* Association ***Arctoo-Empetretum hermaphroditi*** (DT *Arctous alpina, Chamaepericlymenum suecicum, Ptilidium ciliare*) is characteristic near sea shores along the Fennoscandian sub-Arctic coast. The community type ***Calluna vulgaris – Racomitrium lanuginosum*** (DT *Calluna vulgaris* (D), *Hylocomium splendens, Racomitrium lanuginosum*) is common in the western part of Fennoscandian tundra.

Syntaxa of All. ***Phyllodoco-Vaccinion myrtilli*** Nordh. 1936 do not change their composition on the northwest to southeast along the gradient. Communities of All. ***Cassiopo–Salicion herbaceae*** Nordh.1936 are well-represented in the western part of Kola Peninsula and become sparse and patchy towards the eastern part of the Kola Peninsula, where only the association ***Veratro lobeliani–Salicetum herbaceae*** Koroleva 2006 is described in sea-exposed early-melting snow-beds (Koroleva, 2006).

Communities of the Alliance ***Caricion nardinae*** (Nordh. 1935) Dierssen 1992, DT *Saxifraga oppositifolia, Cassiope tetragona, Kobresia myosuroides, Carex rupestris, C. hepburnii* prefer calcium-containing substrata and are more common on some islands and on the shore of Norwegian Sea, as well as on Spitsbergen, but are rare in the north of East-European tundra. On the Kola Peninsula, they are represented only in the northwestern part of area, on the Rybachij (Fisher) Peninsula and are considered rare among the Murmansk Province plant communities (Koroleva, 2011). Dendrogram and dendrite diagrams showing similarities of *Dryas octopetala*-dominated communities (Alliance *Caricion nardinae*) from Greenland, Spitzbergen, the Kola Peninsula-Fennoscandinavia region, and the north of East-European Russia, indicate that Spitsbergen and Greenland likely belong to different Alliances than those in northern Scandinavia and on the north of East-European Russia (Fig. 2).

Coastal marshes and beaches. Seashore zones of the European Arctic are well-defined based on seashore vegetation syntaxa spectra. The Arctic seashores (i.e. on Spitsbergen and Novaja Zemlja) are characterized by All. ***Puccinellion phryganodis*** Hadač (1946) 1989 (DT *Puccinellia phryganodes, Carex subspathacea, Plantago schrenkii*) and ***Caricion glareosae*** Nordh. 1954 (DT *Carex glareosa, Artanthemum hultenii, Primula finmarchica, Potentilla egedii*). In the zone of sub-Arctic seashores (including Barents and White Sea' shores) communities of these Alliances occur on marshes. The Alliance ***Honckenyo–Elymion arenariae*** (Fernandez-Galiano 1954) Tx. 1966 (DT *Leymus arenarius, Lathyrus aleuticus, Mertensia maritima, Honckenya oblongifolia, Festuca arenaria, Tripleurospermum hookeri, Conioselinum tataricum*) occurs on the rocky and sandy shores and beaches (Koroleva et al., 2011).

Bogs and fens. Communities of 'pounikkos', flat and dome palsas on the Kola Peninsula belong to Alliance ***Oxycocco-Empetrion hermaphroditi*** Nordh. 1936 ex Neuhäusl 1969 (DT *Eriophorum vaginatum, Rubus chamaemorus, Oxycoccus microcarpus, Sphagnum fuscum, Mylia anomala*) and are common through all European Arctic and sub-Arctic, as well as boreal bogs. Poor fens are placed in Alliance ***Caricion rotundatae*** (Kalliola 1939) stat. nov. (non ***Scheuchzerion palustris*** Nordh. 1937), with DT *Carex concolor, C. rariflora, C. rotundata, Baeothryon cespitosum, Eriophorum polystachion, E. russeolum, Sphagnum lindbergii, S. compactum, Warnstorfia exannulata, Sarmentypnum sarmentosum, Straminergon stramineum*. Moderately rich to rich mires were ascribed to Alliance ***Sphagno warnstorfii–Tomenthypnion*** Dahl 1957, DT: *Salix myrsinites, Potentilla erecta, Comarum palustre, Saussurea alpina, Pinguicula alpina, P. vulgaris, Bartsia alpina, Molinia caerulea, Selaginella selaginoides, Equisetum palustre, Aulacomnium palustre, Sphagnum warnstorfii, Lophozia longiflora* (Koroleva, 2013, in print).

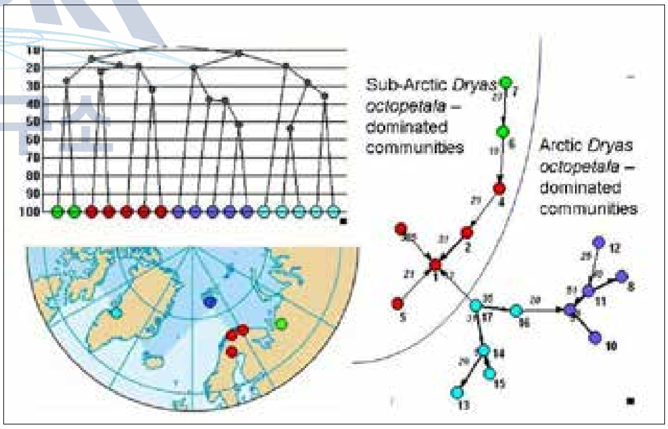

Figure 2. Dendrogram and dendrite diagram showing similarity of Arctic and sub-Arctic syntaxa of Dryas octopetala, Carex hepburnii, Cassiope tetragona-dominated plant communities using GRAPHS clusterization (Novakovsky, 2006).

Conclusion

Plant communities of the tundra zone on the Kola Peninsula demonstrate affinity to those of northern Fennoscandia as well as to east-European tundra. The vegetation databases for the Kola permits a regional analysis of perspective syntaxonomical background, which together with satellite images and topographical maps provides valuable data about the relationship of vegetation with geographical environment, role and proportion of syntaxa and their complexes in plant cover of the territory, and valuable habitats and areas to be protected in the Arctic.

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Vegetation of the Vasyakha River Basin (Yugorsky Peninsula, Pai-Hoy Ridge) – a case study of vegetation diversity in the European sector of the Russian Arctic

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Introduction

Investigations of different aspects of biological diversity are some of the main scientific endeavors of the Institute of Biology, Komi Scientific Center, Russian Academy of Science (RAS). Recently, we can see an increasing focus on studies of arctic territories. In our region these studies are supported by the projects of the Ural Branch (UB) of RAS - 12-4-7-006-Arctic - "Complex Assessment of Natural Ecosystems of the East-European Arctic Sector for Developing Areas of High Environmental Value" and by the UNDP/GEF project "Strengthening the Protected Areas System of the Komi Republic to Conserve Virgin Forest Biodiversity in the Pechora River Headwaters Region" (2008-2013). The goals of these projects are to inventory modern Protected Areas of the Komi Republic and to find new areas to be protected, including tundra and mountain tundra regions. The data obtained in these projects complement and extend the long-term research carried out by the Institute of Biology scientists in the European Arctic. There are certain reasons for such an "Arctic background" of our investigations: 1) there is a lack of protected areas in the tundra zone, including the western slopes of the Ural Mountains; 2) large areas of tundra are still not well investigated, and research within the projects support field work in remote Arctic areas of the Russian European North-East; 3) there are currently many mining companies (coal, oil, gas, gold, bauxite) working in the region and disturbing vulnerable Arctic ecosystems. Recent investigations were carried out in the Polar Urals, Pay-Khoy Ridge and Bolshezemelskaya tundra and covered such interesting regions as the Nya-yu River, the Sylova-Yakha River and Malaya Pyadeya Mountains. The area described in this work is located in the central part of the Yugorsky Peninsula in the eastern part of the Bolshezemelskaya tundra, in the Vasyaha River basin near the Malaya Pyadeya Mountains of the Pay-Khoy Ridge (Fig. 1).

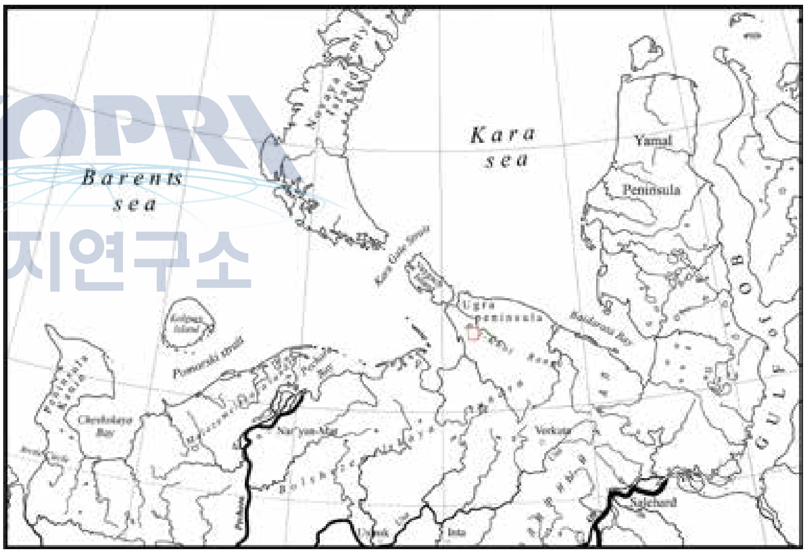

Figure 1. Location of study area (red rectangle) (the Vasyaha River basin near the Malaya Pyadeya Mountains of the Pay-Khoy Ridge).

During the 20th century many botanists visited the eastern part of the Bolshezemelskaya tundra and its outskirts (Kertselli, 1911; Gorodkov, 1935; Andreev, 1935; Ruoff, 1960; Dorogostayskaya, 1963; Rebristaya, 1977; Gribova, 1977, 1980; Druzhinina & Myalo, 1990; Lavrinenko, 2010). However, the vegetation cover of this region is still not well investigated due to its remoteness. The publication of V.N. Andreev (1935) is the most complete description of the vegetation cover diversity. It presents zonal features and geobotanical zoning, community descriptions and their proportional area. This publication was the basis for our investigations of the present state of vegetation cover. The aim of our work was to describe the diversity of vegetation communities, their composition, structure, and ecotopic preferences.

Methods

Field investigations were carried out in the summer of 2010 within the Pay-Khoy Ridge complex, during an expedition of the Institute of Biology, UB RAS. Standard methods were used to describe vegetation cover within 25-m sites. In total, 78 relevés were made. Relevés were classified using the Braun-Blanquet approach. We used Excel and "GRAPHS" module for the data analysis (Novakovskyi, 2006). Remote sensing data (Landsat) were also used (Elsakov & Kulyugina, 2011).

Vegetation of the Vasyakha River basin

According to the geobotanical zoning of V.D. Alexandrova (1977), the territory belongs to the Ural-Paykhoy subprovince of the East-European-West-Siberian province of the sub-Arctic tundra. The sub-Arctic tundra is middle tundra (Alexandrova, 1977), or typical tundra (Matveeva, 1998). The investigated area is characterized by severe climatic conditions, large quantities of mires, hilly relief, and permafrost. This region is located within an old section of the Pay-Khoy Ridge. It is formed of crystalline and sedimentary arenated rocks, chalky clays and limestones. These factors create specific vegetation communities. The elevation of the vegetation communities ranged from 190 to 330 m.

We differentiated plant communities and now provide the results. We described phytocoenons (groups of relevés), their preliminary relation to higher units, and the proportion of the area of plant communities at the sample sites (Table 1).

Table 1.
Proportion of area of plant communities in sample sites.

Community type	Percent of total area
Herb-shrub-moss-lichen	6
Sedge-shrub-lichen-moss	19
Open herb-moss willows	21
Willow-herb-moss	23
Sedge-moss communities	11
Coastal-water communities	3
Herb-sedge-moss meadows	3

Sedge-shrub-moss communities (200-215 m above sea level) - type ***Carex arctisibirica-Dryas octopetala-Tomentypnum nitens*** occupy low hills with cryoturbated peats. Height of plants is minimal - up to 20 cm. *Carex arctisibirica, Salix polaris, Salix reticulata, Dryas octopetala* dominate here. Mosses (*Hylocomium splendens, Aulacomnium turgidum, Tomentypnum nitens*) dominate in lower layer. Diagnostic species are *Saxifraga hirculus, Festuca ovina, Tomentypnum nitens, Peltigera canina, Luzula nivalis, Hedysarum arcticum, Pyrola grandiflora*. These communities were classified as ***Carici Rupestris-Kobrisietea Bellardii*** Ohba 1974, order ***Kobresio-Dryadetelia*** Ohba 1974, ***Carici arctisibiricae-Dryadion octopetalae*** all. nov. prov., developed for east-European tundra for sandy and loamy moraine hills (Koroleva, Kulyugina, 2010). Diagnostic species of this alliance are *Dryas octopetala, Thalictrum alpinum, Saxifraga hieraciifolia* and *Pedicularis oederi*.

Herb-shrub-moss-lichen tundra communities (type ***Salix nummularia-Racomitrium lanuginosum-Sphaerophorus globosus***) occupy the driest ecotopes: tops of hills, high banks of rivers and lakes, terraces and southern slopes (201-330 m above sea level). Cryoturbated spots are common. The height of plants in such ecotopes is minimal - up to 15-20 cm. Specific features of this kind of tundra are the dominance of lichens (up to 50-80 %) and the occurrence of *Betula nana*. In other sites, this species was not found. Communities are polydominant. Shrubs (*Dryas octopetala, Salix nummularia, Salix polaris*) and herbs (*Carex arctisibirica, Equisetum arvense*) are the most abundant species. Green mosses and lichens form a ground layer. Diagnostic species include: *Salix nummularia, Racomitrium lanuginosum, Sphaerophorus globosus, Polytrichum hyperboreum, Dicranum spadiceum, Tephroseris atropurpurea, Cetraria aculeata, Hierochloë alpina, Cladonia crispata, Pertusaria panyrga, Solorina crocea*. These communities were classified as class ***Loiseleurio-Vaccinetea*** Egler ex Schubert 1960, order ***Rhododendro-Vaccinietalia*** Br.-Bl. ex Däniels 1994, all. Loiseleurio-Diapension Braun-Blanqet, Sissingh et Vlieger 1939, and included the following diagnostic species: *Empetrum hermaphroditum, Thamnolia vermicularis, Vaccinium vitis-idaea, Cladonia arbuscula, Betula nana, Flavocetraria nivalis, Alectoria ochroleuca, Arctous alpina, Bryocaulon divergens, Dactylina arctica, Bryoria nitidula*.

Willow communities include two groups: herb-moss-willows (type ***Salix lanata-Tephroseris integrifolia***) and open herb-moss-willows (type ***Salix lanata-Arctocetraria andrejevii***). They occupy different ecotopes in relief. Herb-moss-willows (community type ***Salix lanata-Tephroseris integrifolia***) are concentrated in low sloping spaces between hills, in the lower parts of slopes and along rivulets and lakes. The tallest shrubs (1-1.7 m) and most dense (0.8-0.9) occur here. Sedges, herbs and mosses dominate under the willows. The most coenotically important species are *Salix glauca* and *S. lanata*. Diagnostic species are *Festuca richardsonii, Saxifraga cernua, Plagiomnium ellipticum, Cerastium arvense, Tephroseris integrifolia*. Open herb-moss-willows (community type ***Salix lanata-Arctocetraria andrejevii***) occur on gentle slopes. These communities have a high diversity of herbal plants. Shrubs heights are 50 to 60 cm, and density is 0.6. Herbs, grasses and mosses are abundant in the lower vegetation layers. Dominant species are *Salix glauca, S. lanata, S. phylicifolia*, with significant roles of *Salix reticulata, Salix polaris*. Diagnostic species are *Arctocetraria andrejevii, Taraxacum croceum, Nostoc commune*. For both phytocoenons, such diagnostic species as *Valeriana capitata, Parnassia palustris, C. lachenalii, Luzula frigida, Pachypleurum alpinum, Solidago lapponica, Viola biflora*, and *Carex juncella* were found. Communities were classified as ***Salicetea purpureae*** Moor 1958, ***Salicetealia purpureae*** Moor 1958, ***Salicion phylicifoliae*** Dierssen 1992. Syntaxa include stream communities of willows and herbs (Koroleva, Kulugina, 2010; Mirkin, Naumova, 2012). Alliance diagnostic species are *Salix phylicifolia, Salix lanata, Veratrum lobelianum, Polemonium acutiflorum*.

Herb-sedge-moss meadows - community type ***Grass-sedge-moss meadow*** occur on flat watersheds between hills (type Carex concolor -Polemonium acutiflorum), on the banks of lakes as well as along water courses (type ***Carex concolor -Galium uliginosum***). Height of plants reaches 30-50 cm. Depending on relief, dominant species complexes can be different. On the watersheds, dominants are *Carex concolor, Polemonium acutiflorum, Calamagrostis holmii, and mosses Polytrichum commune* and *Sanionia uncinata*. Similar communities - sedges with significant abundance of *Polemonium acutiflorum* were described earlier (Andreev, 1935). Grasses (*Alopecurus pratensis, Poa pratensis*) dominate near the rivulets. Diagnostic species are *Alopecurus pratensis, Myosotis palustris, Epilobium alpinum, Viola epipsila, Galium uliginosum, Marchantia polymorpha, and Veronica alpina*. These are also the diagnostic species for the alliance ***Salicion phylicifoliae*** Dierssen 1992. On the other hand, dominance of *Carex concolor* brings them together with communities of the class ***Phragmo-Magno-Caricetea Klika*** in Klika et Novák 1941, and large amounts of meadow diagnostic species indicate their belonging to meadow vegetation.

Sedge-mosses communities (type ***Carex stans -Calliergon cordifolium***) occupy large areas in relief depressions, often in wet conditions. They occur on extended flat spaces between hills and on the thermokarst lake banks. Plants height is from 40 to 50 cm. The main dominants are *Carex concolor* and green mosses - *Warnstorfia exannulata* and *Calliergon cordifolium*. A similar, often swampy phytocoenosis with sedges was found earlier (Andreev, 1935). We classify these communities as ***Scheuchzerio-Caricetea fuscae*** Tx. 1937, order ***Caricetealia fuscae*** Koch 1926, alliance ***Caricion stans*** Matveeva 1994. Its diagnostic species were *Carex concolor, Eriophorum scheuchzeri, Caltha arctica, Epilobium palustre, Warnstorfia exannulata*. At the same time these wet communities are close to the association ***Caricetum aquatilis*** Sambuk 1930, alliance ***Magnocaricion eletae*** W.Koch. 1926 order ***Magnocaricetalia*** Pignatii 1953 – communities with dominance of *Carex* species, from the class ***Phragmo-Magno-Caricetea Klika*** in Klika et Novák 1941.

Coastal-water communities with *Arctophila fulva* (community type ***Arctophila fulva -Warnstorfia exannulata***) occur on the edge of lakes, streams and cover small waterlogged plots. Plants reach 60 cm in height. These communities have an extremely low level of species diversity and belong to the order ***Arctophiletalia fulvae*** Pestryakov et Gogoleva 1989, class ***Phragmo-Magno-Caricetea Klika*** in Klika et Novák 1941 – communities of lakes, meanders and swampy hollows with dominance of *Arctophila fulva*.

Vegetation units of the Vasyaha River basin (Yugorsky Peninsula, Pay-Hoy Ridge) are as follows:

- Class ***Carici Rupestris-Kobrisietea Bellardii*** Ohba 1974
    - Order ***Kobresio-Dryadetelia*** Ohba 1974
        - Alliance ***Carici arctisibiricae-Dryadion octopetalae*** Korolerva 2010
            - Community type **Sedge-shrub-moss tundra** (*Carex arctisibirica-Dryas octopetala-Tomentypnum nitens*)
- Class ***Loiseleurio-Vaccinetea*** Egler ex Schubert 1960
    - Order ***Rhododendro-Vaccinietalia*** Br.-Bl. ex Däniels 1994
        - Alliance ***Loiseleurio-Diapension*** Braun-Blanqet, Sissingh et Vlieger 1939
            - Community type **Herb-shrub-moss-lichen tundra** (*Salix nummularia-Racomitrium lanuginosum-Sphaerophorus globosus*)
- Class ***Salicetea purpureae*** Moor 1958
    - Order ***Salicetealia purpureae*** Moor 1958
        - Alliance ***Salicion phylicifoliae*** Dierssen 1992
            - Community type **Herb-moss willow** (*Salix lanata-Tephroseris integrifolia*)
            - Community type **Open herb-moss willow** (*Salix lanata-Arctocetraria andrejevii*)
- Class ***Scheuchzerio-Caricetea fuscae*** Tx. 1937
    - Order ***Caricetealia fuscae*** Koch 1926
        - Alliance ***Caricion stans*** Matveeva 1994
            - Community type **Sedge-moss communities** (*Carex stans -Calliergon cordifolium*)
- Class ***Phragmo-Magno-Caricetea*** Klika in Klika et Novák 1941
    - Order ***Arctophietalia fulvae*** Pestryakov et Gogoleva 1989
        - Alliance ***Arctophiletalia fulvae*** Pestryakov et Gogoleva 1989
            - Community type **Coastal water communities** (*Arctophila fulva -Warnstorfia exannulata*)
- Class ?
    - Order ?
        - Alliance?
            - Community type **Grass-sedge-moss meadow on the watershed** (*Carex concolor -Polemonium acutiflorum*) **along water courses** (*Carex concolor -Galium uliginosum*)

Synthesis of the results of investigations in the European sector of Russian Arctic

We are currently collecting additional field materials, analyzing the data and preparing publications. It should be noted that including an association in higher syntaxonomic units is still a challenge and we still do not have enough data to generalize (Koroleva & Kulyugina, 2010). The following regions of the tundra zone of the Russian European Northeast were partly investigated: Malozemelskaya tundra (eastern part), Bolshezemelskaya tundra (western, central and eastern parts), Polar Urals (west macroslope), Pay-Khoy Ridge. In total, we have 654 releves. Certain releves are still in paper form, some were transformed to digital tables, some were published (Kulyugina, 2008).

Acknowledgements

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Spatial vegetation structure of southern tundra from three sectors of the Siberian Arctic

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Figure 1. Location of test locations (marked by stars).

Within the framework of The CryoCARB Project (http://www.univie.ac.at/cryocarb/), spatial structure and syntaxonomical diversity of southern tundra vegetation were studied in three locations of the Siberian Arctic: Shalaurovo (East Siberia sector), Logata (Central Siberia sector) and Tazovskiy (West Siberia sector) (Fig. 1). At each location, test polygons were established in zonal positions, areas of flat terrain that are weakly drained by small temporary creeks. The size of each polygon was approximately 2 by 2 kilometers. Some environmental characteristics at each study polygon are summarized in Table 1.

Table 1.
Environmental site characteristics of the study polygons.

Environmental Parameter	Logata	Shalaurovo	Tazovskiy
Latitude	73°26	69°26'	67°16'
Longitude	98°22'	161°42'	78°50'
Altitude (m)	38	26	29
Relief	Drained plain	Drained plain	Drained plain
Substrate	Loam	Loam	Loam or sandy loam
Substrate origin	Marine	Eolian	Marine or fluvial
Subsoil	Soft rock	Bedrock	Sandy loam or sand

In field seasons of 2010-2012 standard geobotanical relevés were made within each polygon in order to cover all vegetation types. The total number of releves for all polygons was about 350. We combined traditional vegetation field descriptions with analysis of high-resolution satellite images (Quick Bird). For each polygon, diversity of plant communities was described according to their mesorelief position. Floristic composition of higher vascular plants, abundance and distribution of certain species and communities were compared between locations. The dominant land-cover classes and their vegetation characteristics for the each polygon are given in Table 2.

Based on satellite images and ground information, the main relief features were determined for all sites. In general, all of them could be presented as generalized profile across small creek valley (Fig. 2). The vegetation changes along these profiles showed some similarities and also some unique characteristics. Even slight changes in relief can create new habitats with characteristic microhabitat and plant communities.

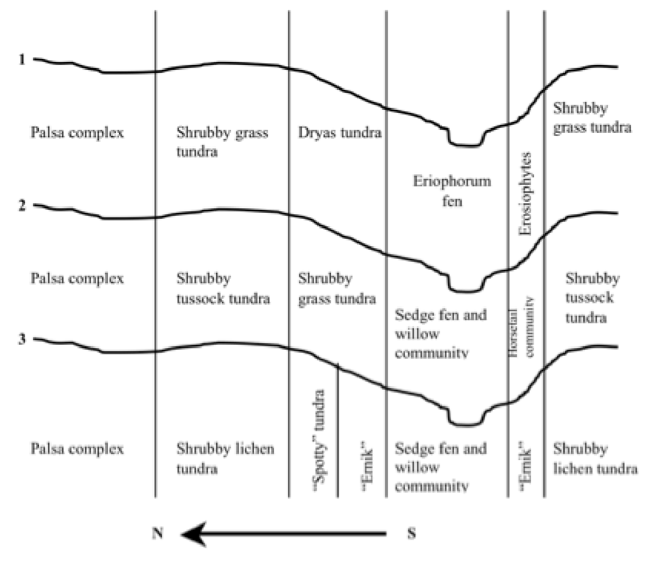

Figure 2. Distribution of land-cover classes along the generalized profile containing the main relief features: 1, Logata; 2. Shalaurovo; 3, Tazovskiy.

Some conclusions can be made based on this comparative study:

1. Each location has its own characteristic set of higher vascular plant species. There are species in common for all locations, and some unique to each sector of the Siberian Arctic (West, Central and East Siberia).
2. Each location has its own set of dominant species. The biggest difference in dominant species is between the Tazovskiy sites, dominated by lichens and others, dominated by mosses.
3. Floristic composition and spatial structure mainly depend on longitude (history?), composition of substrate, relief structure, and soil erosion intensity.

Table 2.

Dominant Braun-Blanquet class and characteristic species within land-cover classes at each study location.

Land-coverclass	Syntaxonomy(Braun-Blanquetclass)	Characteristic species
Logata		
Shrubbygrass tundra	*Loiseleuria-Vaccinietea*	*Pinguicula villosa, Pedicularis lapponica*
Dryas tundra	*Loiseleuria-Vaccinietea*	*Dryas punctata, Trisetum sibiricum, Cerastium maximum*
Palsa bog	*Oxycocco-Sphagnetea + Scheuchzerio-Caricetea nigrae*	*Polytrichum strictum, Rubus chamaemorus*
Sedge fen	*Scheuchzerio-Caricetea nigrae*	*Carex stans, Comarum palustre, Carex chordorrhiza, Hierochloe pauciflora, Caltha palustris*
Erosiophytes	*?*	*Descurainia sophoides, Taraxacum taimirense*
Eriophorum fen	*Scheuchzerio-Caricetea nigrae*	*Eriophorum scheuchzeri, E. polystachyon, Dupontia fisheri*
Shalaurovo		
Shrubby tussock tundra	*Loiseleuria-Vaccinietea*	*Eriophorum vaginatum, Tomentypnum nitens, Aulacomnium palustre, Eriophorum polystachyon*
Shrubby grass tundra	*Loiseleuria-Vaccinietea*	*Bistorta elliptica, Aconogonon tripterocarpum, Rhytidium rugosum, Anemonastrum sibiricum, Hedysarum hedysaroides, Claytonia acutifolia*
Palsa bog	*Oxycocco-Sphagnetea + Scheuchzerio-Caricetea nigrae*	*Polytrichum strictum, Rubus chamaemorus*
Sedge fen	*Scheuchzerio-Caricetea nigrae*	*Carex aquatilis, Comarum palustre, Salix fuscescens, Pedicularis sudetica, Hierochloe pauciflora, Sphagnum squarrosum, Caltha palustris*
Willow community	*Loiseleuria-Vaccinietea(?) + Scheuchzerio-Caricetea nigrae*	
	Warnstorfia sp., Calamagrostis langsdorffii, Aconitum productum	
Horsetail community	*Salicetea herbaceae*	*Bistorta vivipara, Equisetum arvense, Carex lachenalii, Trisetum spicatum, Polemonium boreale, Salix reticulata, Salix lanata, Poa paucispicula, Stellaria irrigua*
Tazovskiy		
Shrubby lichen tundra	*Loiseleuria-Vaccinietea*	*Carex globularis, Pedicularis labradorica, Cladonia stellaris*
"Spotty" tundra	*Loiseleuria-Vaccinietea*	*Alectoria nigricans, A. ochroleuca, Flavocetraria cucullata, Carex glacialis*
"Ernik" (Dwarf birch community)	*Loiseleuria-Vaccinietea*	*Pleurozium schreberi*
Palsa bog	*Oxycocco-Sphagnetea + Scheuchzerio-Caricetea nigrae*	*Polytrichum strictum, Rubus chamaemorus*
Sedge fen	*Scheuchzerio-Caricetea nigrae*	*Carex stans, C. rostrata, Comarum palustre*
Willow community	*Mulgedio-Aconitetea(?)*	*Aconitum baicalense, Salix lanata*
Wet grassland	*Phragmito-Magnocaricetea (?)*	*Calamagrostis langsdorffii, Polemonium boreale*

VegBank: a permanent online repository for international plot and relevé data

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Introduction

VegBank is a public, online, vegetation-plots data archive accessible over the internet at http://vegbank.org. The purpose of VegBank is to provide a public repository for vegetation plot data that researchers may use to freely access, view, search, download, and cite vegetation plots. There are no geographical restrictions for data submission to VegBank, but the initial geographical focus was North America. As of April 2013, VegBank held about 73,000 plots covering much of North America. Only limited coverage of Arctic vegetation plots is included in this total (a few hundred plots in Alaska). However, VegBank could serve as an effective means for storage and dissemination of most forms of Arctic vegetation-plot data.

History

The VegBank project was initially created by a subcommittee of the Vegetation Panel of the Ecological Society of America to foster large-scale analysis and to provide a tool for documentation of vegetation data used in such analyses in much the same fashion as GenBank plays a core archival role for genetics research. The National Center for Ecological Analysis and Synthesis (NCEAS) in Santa Barbara, California, USA provided technical leadership and housed the development team that created the VegBank database and website from 1999-2004. The principal investigators were Robert K. Peet (University of North Carolina), Michael D. Jennings (U.S. Geological Survey), Dennis Grossman (NatureServe), and Marilyn D. Walker (USDA Forest Service). Don Faber-Langendoen (NatureServe), David Roberts (Montana State), and Matt Jones (NCEAS) were primary collaborators. Michael Lee served as project manager. John Harris, Gabriel Farrell, Mark Anderson, and Chad Berkley were the programmers. Many groups provided critical support and funding: the Ecological Society of America (ESA), the National Center for Ecological Analysis and Synthesis (NCEAS), NatureServe, the Federal Geographic Data Committee (FGDC), the US Geological Survey (USGS) Gap Analysis Program, the National Biological Information Infrastructure (NBII), and the National Science Foundation (NSF). Many of these groups were interested in providing a plots database to support the US National Vegetation Classification (US-NVC), so VegBank focuses strongly on community classification, but classification of plots is not required. Between 1999 and 2004 some 30 meetings and workshops were held with over 100 participants from around the world to make sure the data framework and business rules would support the wide range of plot data collected in various places. Feedback from these meetings was critical to designing an approach that would work both technically and politically.

What Makes VegBank Different?

While other plot-databases exist for many reasons, few others (if any) have all these advantages:

- **Public** – Not only are the data open access, but so is the plot submission process.
- **Open source** – The data architecture and underlying code are open source so that they can be adopted or adapted by other parties.
- **Confidentiality** – Protection for sensitive data is ensured by reducing geo-coordinate precision for plots that have species that might be prone to damage if their exact locations were known. Temporary embargoes can remove plots from public view while the initial analysis of these plots is completed and published.
- **Longevity** – Many databases have a short-term lifespan or purpose. VegBank is designed to last and be supported in the long-term.
- **Search, view, and download** – Many databases can export a single large dataset; VegBank allows finer control on what you see or download.
- **Citable** – Any plot or set of plots may be cited with a unique link, that can be used to view those data subsequently.
- **Flexible plot design** – Most methodologies for plot sampling are supported, and a robust user-defined data structure ensures full data support.
- **Many data sources** – Data are accepted from a wide variety of sources, increasing the availability of data and the possibility of large-scale analysis and collaboration.
- **Flexible plant and community taxonomy** – VegBank does not require users to conform to a single taxonomic standard, but rather uses concept-based taxonomy for both plants and community taxa so that multiple taxonomic standards can potentially be used interchangeably.
- **FGDC compliant** – The archive was designed to accommodate requirements of the U.S. National Vegetation Classification as mandated by the U.S. Federal Geographic Data Committee.
- **Annotations supported** – Users may annotate plots to new community types, and plant occurrences may be annotated to correct errors or as plant taxonomy changes.
- **True archive** – Nothing is ever deleted so earlier, time specific views of plots can be recreated.

Metadata

Most databases have hard-coded, implied methodologies. It is assumed that the users "just know" that, for example, lichens were not sampled, or mosses were sampled, or only woody stems were sampled, or only dominant species were sampled. A stratum method or cover method are often hard-coded without explicit documentation. Because these types of information are critical to quick determination of whether plots are adequate or appropriate for a specific analysis, it is not sufficient to store this information in long text fields that must be read plot-by-plot before someone can undertake a study involving thousands of plots. The following fields are provided in VegBank to quickly filter out plots that do not meet the requirements for a particular analysis:

- Stratum Method (if applicable, plots do not need to implement strata)
- Cover Method: what cover classes were used?
- Vascular, bryophyte, and lichen sampling effort: was a complete list made, was sampling hurried or incomplete, or was a particular class ignored completely?
- Plot size, shape, and configuration of any subplots
- Stem sampling method (if shrub or tree stems were counted or measured)

Ambiguous Plant Names

A central problem in harmonizing data from many different places, times, and investigators is attaching consistent meanings to plant names. Many people mistakenly assume that this problem is solved because plant names are standardized into Latin scientific names with lists of synonyms available to facilitate data integration. However, the problem remains because the meaning of a particular scientific name can vary across datasets, especially datasets collected at different places, different times, or following different taxonomic authorities.

Consider, for example, the high-elevation fir trees of the western United States and Canada. According to the current US Department of Agriculture (USDA) and ITIS plant lists, *Abies lasiocarpa* is a widespread species extending north along the Rocky Mountains from Arizona and New Mexico north into Canada and then west to the Pacific coast and back south in the Cascade Mountains of Washington and Oregon. The populations in Arizona, New Mexico, and southern Colorado are recognized as Abies lasiocarpa var. arizonica, whereas the populations across the remainder of the range are recognized as the nominal variety, *Abies lasiocarpa* var. *lasiocarpa*. An illustration of the USDA's treatment is shown on the left side of Figure 1.

However, there is another widely accepted taxonomic standard in the United States and Canada, the Flora of North America (FNA). FNA views the high-elevation fir trees in most of British Columbia, Washington, and Oregon as *Abies lasiocarpa*, whereas populations in the larger, Rocky Mountain portion of the range are given the name *Abies bifolia*, and the variety arizonica populations are simply lumped into *A. bifolia*. This very different view is illustrated on the right side of Figure 1.

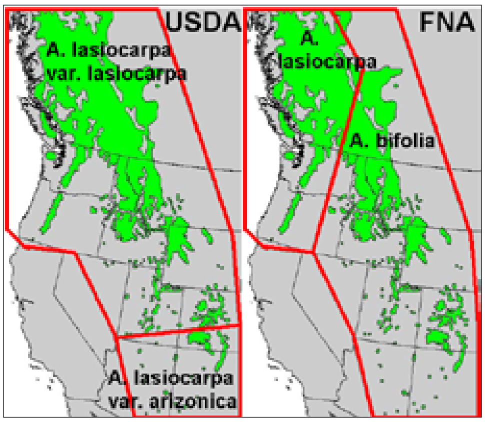


Figure 1. Taxonomic ambiguity of Abies lasiocarpa and/or A. bifolia deriving from different treatments according to USDA (left) and FNA (right). CREDIT: Range maps from USGS (http://esp.cr.usgs.gov/data/little/).

In order to combine data from different sources following these different taxonomic treatments into a single dataset, how can the different meanings of these names be handled? If one simply stores the name attached to a plant, some plots will appear to be quite dissimilar, as the *Abies bifolia* in one source may well be the same tree as those marked *Abies lasiocarpa* in another source. Or, trees marked *Abies lasiocarpa* in one source may be different from those with the same name in the other source.

VegBank moves toward a solution to this challenging problem by using **concept-based taxonomy.** This approach creates a **plant concept** by combining a plant name with a reference in which that name is described (indicated as sec, short for secundum, or according to). This approach is consistent with the TDWG Taxonomic Concept Transfer Scheme (2008) and is roughly equivalent to Berendsohn's (1995, 1997) "potential taxon."

The next step in harmonizing data is to establish relationships between plant concepts. Relationships consist of the two plant concepts in question and a set-theory correlation between them: included in (≤), equals (=), includes (≥), overlaps (><), does not overlap (|). For example:

Abies lasiocarpa sec. Flora North America ≤ Abies lasiocarpa var. lasiocarpa sec. USDA Plants
Abies lasiocarpa sec. Flora North America | Abies lasiocarpa var. arizonica sec. USDA Plants

Unfortunately, the fir example just described is relatively simple compared to some of the more challenging taxa. Taxonomic treatments do not always have such relatively well-defined geographic boundaries on species delineations. Nor is the problem always confined to two or three different names at a time. Furthermore, many datasets exist where only naked plant names are included in occurrence data with the consequence that the taxonomic authority used to identify plants is unknown. For an example that is much more challenging, *Andropogon virginicus s.l.* as viewed across a chronosequence of 8 important taxonomic authorities includes between 1 and 9 distinct taxa in a treatment, with 17 unique concepts represented by 27 scientific names. These are illustrated in Table 1 below.

Protecting Data

One of the primary concerns expressed by parties interested in submitting data to VegBank relates to protecting data from misuse. Two approaches are commonly used for protecting records of threatened and endangered species in databases: 1) deleting the threatened or endangered species from the list of plants on the plots when sharing data, or 2) withholding the precise geo-coordinates and location information so that sensitive species cannot be poached or damaged by discovering their exact location. VegBank implements the second approach for several reasons. The first solution, omitting species when displaying or downloading data, leaves data incomplete by changing the fundamental composition of the plot. We find this to be contrary to the main goals of the database. It also proves an inadequate solution, as in many cases it may be simple to infer which rare species may have been present, but omitted, based on the type of vegetation and environment.

The second solution, withholding precise geo-coordinates, preserves the original plot composition and provides general location that is quite useful to most analyses. This protects the plot without invalidating the data. Users may choose 10, 100, or 1000 km reduced precision levels depending on the nature of the species and its location. Data on private lands where the owner wishes to remain anonymous are handled in the same manner.

Some researchers are also concerned that other researchers may pose similar questions to those they themselves are asking, and that this could result in someone else publishing on the topic with the same data before the person who collected the data. To eliminate this possibility, one may upload data to VegBank and place a temporary embargo on the plots for up to three years to allow sufficient time for the initial publication based on the data. The alternative of waiting until after publication to send data to VegBank could easily lead to the data never being deposited, as the publishing process often leaves little time for data management and submission.

Long-term Implications and Future Directions

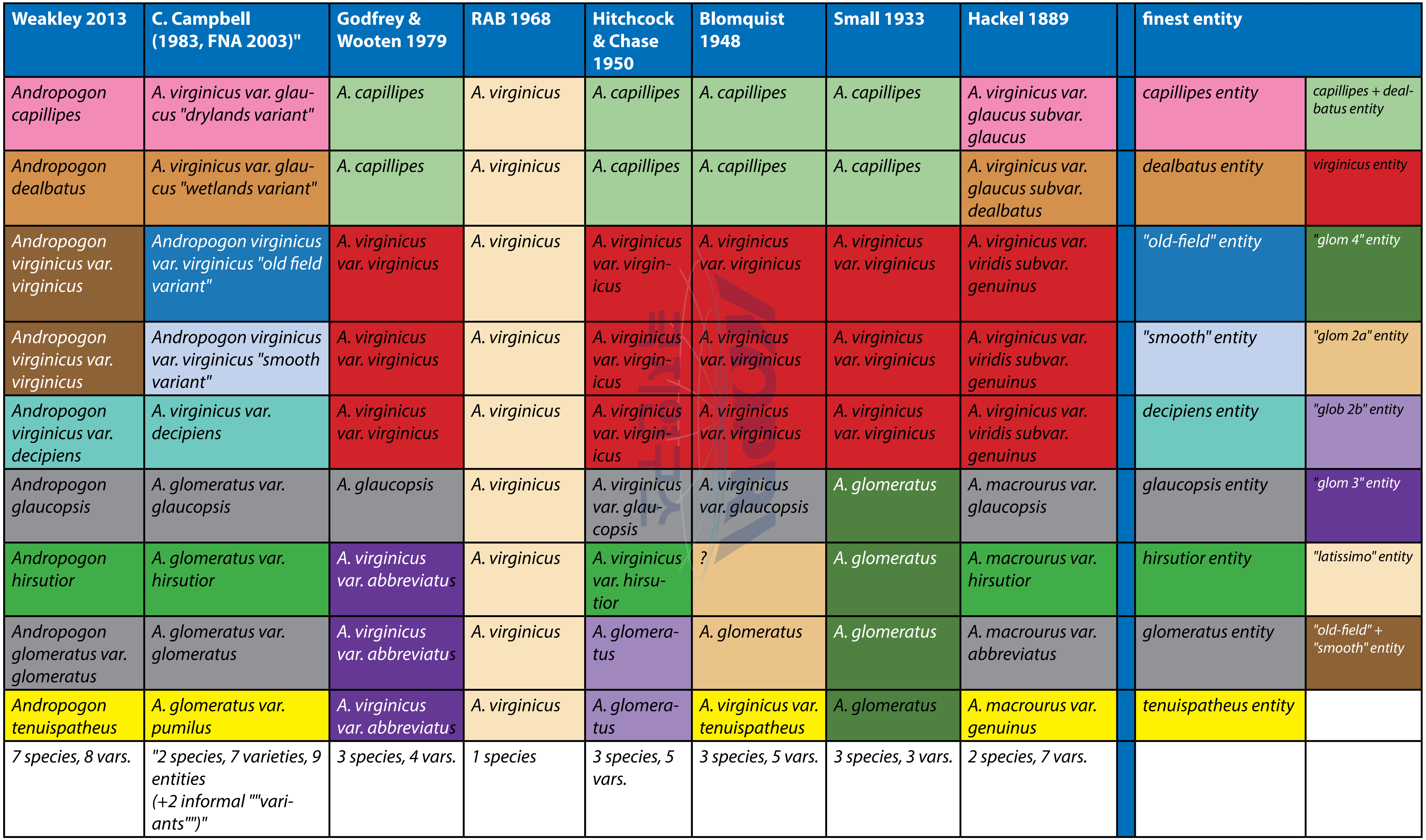
A perfect archive never deletes data, but rather retains previous values so that views of data can be reconstructed for any arbitrary point in the past. This approach allows plot data to conform to new taxonomic information, include corrections of errors, and adhere to new community classifications without losing the original and intermediate views of the data, views that need to be preserved if they are cited in literature. A key component of archiving in VegBank is allowing annotations of species occurrences to plant concepts, and of plots to community concepts. No previous annotations are overwritten, which allows different users to have different opinions about plots and taxonomy without the need to regulate these and indicate a final "correct" answer.

A potential standard for plot data exchange called Veg-X has emerged in recent years (Wiser et al. 2011), with the product based substantially on the VegBank data model. Our expectation is that after the next significant upgrade VegBank will support this standard for both import and export of data, as well as direct data exchange with the next version of TurboVeg.

A new database product called VegBIEN is being developed by the iPlant Collaborative. This database of both specimen-based occurrence records and plot co-occurrence records is built on a modified version of the open-source VegBank data model. This should expand the user-base of VegBank-like products, and perhaps lead to development of other offshoot products to serve slightly different user-groups. VegBank could also be modified to serve as a data-provider engine for groups like the Arctic Vegetation Archive (AVA), where the programming and data of VegBank could be used and embedded in the AVA website without the need to reproduce and house the servers and software separately. The public aspect of VegBank may represent the most effective link to the AVA, as none of the other databases considered for the AVA have an outward-facing public interface, and using an existing tool like VegBank offers many advantages and would be far less costly than creating a new custom database implementation.

Table 1

Andropogon virginicus complex. Each column represents a different treatment, and colors are used to distinguish between identical concepts, with a key to colors and concepts on the right. CREDIT: Franz et al. 2008.



Weakley 2013	**C. Campbell (1983, FNA 2003)"**	**Godfrey & Wooten 1979**	**RAB 1968**	**Hitchcock & Chase 1950**	**Blomquist 1948**	**Small 1933**	**Hackel 1889**		**finest entity**	
Andropogon capillipes	*A. virginicus var. glaucus "drylands variant"*	*A. capillipes*	*A. virginicus*	*A. capillipes*	*A. capillipes*	*A. capillipes*	*A. virginicus var. glaucus subvar. glaucus*		*capillipes entity*	*capillipes + dealbatus entity*
Andropogon dealbatus	*A. virginicus var. glaucus "wetlands variant"*	*A. capillipes*	*A. virginicus*	*A. capillipes*	*A. capillipes*	*A. capillipes*	*A. virginicus var. glaucus subvar. dealbatus*		*dealbatus entity*	*virginicus entity*
Andropogon virginicus var. virginicus	*Andropogon virginicus var. virginicus "old field variant"*	*A. virginicus var. virginicus*	*A. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. viridis subvar. genuinus*		*"old-field" entity*	*"glom 4" entity*
Andropogon virginicus var. virginicus	*Andropogon virginicus var. virginicus "smooth variant"*	*A. virginicus var. virginicus*	*A. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. viridis subvar. genuinus*		*"smooth" entity*	*"glom 2a" entity*
Andropogon virginicus var. decipiens	*A. virginicus var. decipiens*	*A. virginicus var. virginicus*	*A. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. virginicus*	*A. virginicus var. viridis subvar. genuinus*		*decipiens entity*	*"glob 2b" entity*
Andropogon glaucopsis	*A. glomeratus var. glaucopsis*	*A. glaucopsis*	*A. virginicus*	*A. virginicus var. glaucopsis*	*A. virginicus var. glaucopsis*	*A. glomeratus*	*A. macrourus var. glaucopsis*		*glaucopsis entity*	*"glom 3" entity*
Andropogon hirsutior	*A. glomeratus var. hirsutior*	*A. virginicus var. abbreviatus*	*A. virginicus*	*A. virginicus var. hirsutior*	*?*	*A. glomeratus*	*A. macrourus var. hirsutior*		*hirsutior entity*	*"latissimo" entity*
Andropogon glomeratus var. glomeratus	*A. glomeratus var. glomeratus*	*A. virginicus var. abbreviatus*	*A. virginicus*	*A. glomeratus*	*A. glomeratus*	*A. glomeratus*	*A. macrourus var. abbreviatus*		*glomeratus entity*	*"old-field" + "smooth" entity*
Andropogon tenuispatheus	*A. glomeratus var. pumilus*	*A. virginicus var. abbreviatus*	*A. virginicus*	*A. glomeratus*	*A. virginicus var. tenuispatheus*	*A. glomeratus*	*A. macrourus var. genuinus*		*tenuispatheus entity*	
7 species, 8 vars.	*"2 species, 7 varieties, 9 entities (+2 informal ""variants"")"*	*3 species, 4 vars.*	*1 species*	*3 species, 5 vars.*	*3 species, 5 vars.*	*3 species, 3 vars.*	*2 species, 7 vars.*			

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Vegetation data available for classification of Canadian Arctic sites

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Introduction

Arctic terrestrial ecosystems in Canada range over more than 30° in latitude and 60° in longitude, from tall shrub tundra near the treeline to polar deserts on the Queen Elizabeth Islands in the High Arctic. Within Canada, northern terrestrial systems are found in five of the 15 terrestrial ecozones across the country (Wiken 1986). Tundra landscapes cover nearly 30% of Canada, and span the five bioclimate subzones of the Circumpolar Arctic Vegetation Map (CAVM 2003). Gould et al. (2003) delineated 17 different tundra vegetation units in Arctic Canada that could be mapped at the landscape scale from satellite data which were used in the CAVM (Walker et al. 2005). Vegetation maps have been produced for smaller areas of interest to researchers and land managers, such as national and territorial parks. Most of these maps involved detailed sampling of plant communities and statistical classification of the species composition and abundance data (e.g. Muc and Bliss 1977; Bergeron 1988; Muc et al. 1989; Larter et al. 2009). Here we report on the current state of vegetation data sets from Arctic Canada that could be used in a national and circum-Arctic vegetation classification.

Vegetation Classification in Canada

The Canadian National Vegetation Classification (CNVC) is a national initiative to define and describe the vegetation of Canada at various levels of generalization, using standardized criteria and terminology (CNVC 2013). The CNVC is based on, but separate from, the various provincial and territorial classification systems within Canada, with links to international classification systems. It is closely linked with the USVC in the United States, to provide a continent-wide classification (CNVC 2013). It is based within the Canadian Forest Service but is coordinated by a working group of ecologists from most provinces and territories. While the initial focus of CNVC is on forest communities, there has been a concerted effort to expand the database to include all other plant communities.

As part of the Canadian International Polar Year project CiCAT (Climate Impacts on Canadian Arctic Tundra Ecosystems: Multi-scale and Interdisciplinary Assessments, Henry et al. 2012), Catherine Kennedy, vegetation ecologist and habitat biologist for the Yukon government, coordinated the collection and compilation of available vegetation datasets and studies. The objective was to begin compilation of vegetation data from the Canadian Arctic to be included in the CNVC. The quality and spatial distribution of these data sets varied as they were collected for various projects, not specifically for vegetation classification purposes. The archived list of publications and studies was examined to identify those containing satisfactory vegetation plot data (de Groot et al. 2011).

The standard Arctic vegetation plot data compiled in the CNVC can directly contribute as the Canadian component of the Arctic vegetation archive (AVA) and will be referred to as the Canadian AVA.

Arctic vegetation data compilation and gap analysis

To date, 482 projects, theses, and reports have been reviewed, and 82 of these with suitable data were acquired. The criteria for inclusion included relatively complete species list (vascular species and at least lichen and moss estimates), and acceptable plot size and sampling method. Line-intercept data were not included and micro-plots were generally excluded, but in some cases nested micro-plots were converted into a single vegetation plot with mean cover value per species. Various cover classes were used and these were converted to mid-point percent cover values to produce a uniform dataset using percent cover in all cases.

Collection and presentation of environmental data in projects were variable. Generally, environmental data were not presented by plot but were summarized by classification unit or not presented at all. More complete individual environmental plot data may exist with the authors of the studies.

Additional projects with suitable data have been identified and will be acquired and integrated when they are available. For example, the relevé data collected by Dietbert Thannheiser and colleagues in the western and central Canadian Arctic, perhaps as many as 2350 relevés (Thannheiser 1984), have not been added to the Arctic CNVC data base to date.

In total, 4762 plots have been collected to date as part of the Arctic component of the CNVC, distributed among the five bioclimate subzones of the Canadian Arctic as shown on the CAVM (CAVM 2003) (Figure 1). The spatial distribution of these plots shows there are areas that are well represented in the data sets such as northwestern Yukon, the Mackenzie Delta region, southern Hudson Bay coast, and Bylot Island. However, most of the terrestrial areas in the Canadian Arctic have not been studied. As an indication of sampling intensity we calculated the ratio of the total number of vegetation plots to the total area of each floristic province and bioclimate subzone (Table 1). The maximum ratio of 1.1 plots/100 km^2 is in the Northern Alaska and Yukon region, which has the smallest area and the largest number of plots. The ratio is only an indication of sampling adequacy, as adequacy also depends on the size of the plots and their distribution among plant communities. However, it seems reasonable that a minimal threshold value of 1-2 plots/100 km^2 would be desirable for vegetation classification. The sampling intensity in all other floristic provinces and bioclimate subzones were well below this threshold. Hence, while it is worthwhile to begin to test classification on the available data sets in Arctic Canada (especially in the N-Alaska Yukon region), there should be a continued search for more data and encouragement of more sampling throughout the region.

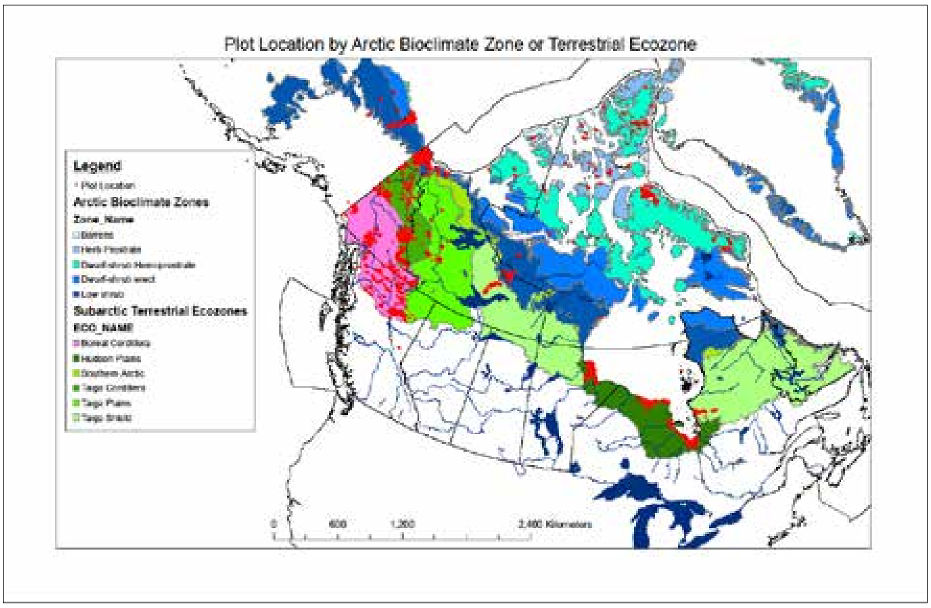

Figure 1. Distribution of available northern vegetation datasets in Canada within the terrestrial ecozones.

Table 1.
Distribution of Arctic vegetation plots currently included in the Canadian National Vegetation Classification in relation to Arctic bioclimate subzones and floristic provinces (CAVM 2003).

	Floristic Province								
Bioclimate Subzone	**N-Alaska Yukon**	**Central Canada**	**West Hudsonian**	**Baffin-Labrador**	**Ellesmere N-Greenland**	**Total number of plots**	**Bioclimate Subzone Area km²**	**Proportion of total Arctic Canada**	**Number of plots/ 100 km²**
A	n/a	104	n/a	n/a	0	104	58.059	2%	0,18
B	n/a	92	3	n/a	69	164	370.568	13%	0,04
C	203	101	544	87	349	1.284	969.266	34%	0,13
D	592	21	0	64	n/a	677	751.838	26%	0,09
E	1.578	726	229	0	n/a	2.533	742.239	26%	0,34
Total # plots	2.373	1.044	776	151	418	4.762			
Floristic Province Area km²	216.709	999.481	737.698	536.402	401.682				
Proportion of total Arctic Canada	7%	35%	26%	19%	14%				
Number of plots/ 100 km²	1,10	0,10	0,11	0,03	0,10				

Preliminary classification results

A preliminary CNVC Arctic vegetation classification using 3985 plots from the compiled Canadian AVA allowed the description of 66 proto-associations within six broad hierarchical groupings: four CNVC Orders, that are defined by specific floristic assemblages and two CNVC Groups that represent "habitat types" but are more diverse floristically without a commonly shared species group.

These are the groupings, by order of plot abundance in the dataset (commonality):

IV. Order – *Dryas – Cassiope tetragona* (1144 plots)
⇨ Associations of this Order occur in bioclimate subzones B-E on dry to moist, calcareous to weakly basic sites. Seventeen Associations are currently recognized.

V. Order – **Betula – Ledum – Vaccinium** (1132 plots)
⇨ This Order occurs in bioclimate subzones C-E on dry to very moist acidic sites. Twelve Associations are currently described.

VI. Order – *Carex aquatilis – Eriophorum angustifolium* (776 plots)
⇨ This Order occurs in all bioclimate subzones and represents very moist to wet sites, especially fens and marshes and some incompletely described willow-sedge swamp ecosystems. It includes some related but floristically distinct graminoid marsh types. Thirteen Associations are currently described.

VII. Group – Barrens (419 plots)
⇨ This group includes ecosystems of extreme climates with low vascular vegetation cover. Predominantly from bioclimate subzones A and B but also at higher elevations or very exposed sites in other subzones. Ten Associations are currently described.

VIII. Order *Salix arctica – Alopecurus alpinus – Arctagrostis latifolia* (360 plots)
⇨ This Order describes mesic to moist tundra in bioclimate subzones A-C largely from the eastern Canadian Arctic. Nine associations are currently described.

IX. Group Shorezone (154 plots).
⇨ This group of ecosystems are floristically varied but represent saline ecosystems of beaches, estuaries, and the spray zone. Five associations are currently described.

For the purpose of developing a circumpolar vegetation classification, complete species data are important. However, the data compiled for the Canadian AVA includes studies of variable quality. The majority of included project data have complete vascular species list but only partial data for bryophytes and lichens, hence the units presented here are generally defined by vascular plant species composition. In some cases the published data available for the compilation does not represent the detailed original plot data list and these could possibly be completed by obtaining original data from the author. Where projects were non-academic, plot quality may be of lower standard but were included where it appeared that thorough species lists and taxonomic identification were completed. Many of the reviewed projects that were not included in the Canadian AVA have incomplete plot data or present only descriptions of ecosystems. These data will be useful to validate the spatial distribution of vegetation types. The quality of the datasets should be verified through analyses and, where possible, meta-data and other information from the authors.

Summary and Conclusions

With the impetus of the Canadian IPY program, an initial database of plant community data for the Canadian Arctic was established to be included in the CNVC, and currently has nearly 4800 plots from ca. 82 studies. There are data sets from all floristic provinces of the Canadian Arctic and from each of the five bioclimate subzones of the CAVM. Preliminary classification of the plot data identified six broad hierarchical groupings. However, there are important gaps in the coverage that will impede a complete vegetation classification. In addition, there are still many studies with plot and relevé data that have not been compiled. The Arctic database for the CNVC will be coordinated through the Monitoring Program of the new Canadian High Arctic Research Station, which will help to ensure the quantity and quality of the vegetation data for the CNVC and for international efforts, such as the Arctic Vegetation Archive.

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A data compilation of Canadian Arctic vegetation relevé data and preliminary classification

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The ecosystem plot database program, VPro (MacKenzie and Klassen 2013), was created to manage vegetation-plot data (currently 55,000 relevés) and resulting hierarchical classifications for the Biogeoclimatic Ecosystem Classification system of British Columbia, Canada (BEC Program 2013). VPro uses Microsoft ACCESS for all database functions and EXCEL for most reporting functions. This relational database stores ecosystem data in linked vegetation, site, and soils tables and relates to taxonomic and environment code libraries. Single level and hierarchical classification structures are also managed within this system and data summaries and exports can be made using any level of the classification. The program and database design are simple and flexible to improve usability for users with limited knowledge of databases.

In 2006, Natural Resources Canada initiated a Canadian National Vegetation Classification (CNVC) program with the aim to harmonize provincial forest classifications and provide a national classification product. The boreal forest was the first biome to be included in the CNVC as it spans almost all provinces. The CNVC adopted VPro as the tool to compile and harmonize separate provincial plot data sets and vegetation associations (CNVC 2013).

Funding acquired by the Yukon Territorial government through the International Polar Year (IPY) was used to compile existing plot data from the Canadian Arctic and sub-Arctic following similar protocols to the CNVC project. The initial Arctic data compilation included approximately 9,000 relevés derived from historical and contemporary published and unpublished sources (de Groot et al. 2011). Approximately 3,000 of the relevés were used to generate an association classification for the Canadian Arctic broadly following Braun-Blanquet tabular methods.

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The Russian input to the Arctic Vegetation Archive and an example of the value of plot data for assessing climate change on the Taymyr Peninsula

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Introduction

The plant cover diversity of the Russian Arctic is great due to the huge area (about 27,000,000 km^2) and large variety of landscapes stretching between the Kola and Chukotka peninsulas. The widest part is situated in its longitudinal center on the Taymyr Peninsula where the complete range of latitudinal subzones from treeline to polar desert landscapes is represented. The study of plant cover started in the 1930s and intensified gradually reaching its peak in the 1970s and 1980s. There were initially very few phytocoenologists who sampled vegetation using a relevé approach and even less who published these with enough repetition. However, the famous tundra ecologists B. N. Gorodkov, A. A. Dedov and V. D. Aleksandrova were among those who did. Some Russian phytosociologists used the formal methods of the Braun-Blanquet approach in more southern biomes in the late 1970s, but only at the beginning of 1990s did the approach begin to be applied in the Russian Arctic. As a result, according to the preliminary Prodromus (Telyatnikov, unpubl.), about 80 associations have been recorded within 35 alliances of 18 orders and 14 classes while about 40 new associations have not been placed into higher units.

There are 18 researchers who have published Arctic data according to the Codex of Phytosociological nomenclature (Weber et al. 2000). This pool contains close to 5 000 relevés. These are the best source that is ready for entry into the AVA. Most of these are stored in Excel tables by their owners in botanical institutions in six cities (Saint-Petersburg, Syktyvkar, Kirovsk, Novosibirsk, Yakutsk, Magadan). Some authors used the programs "Turboveg" by S. Hennekens and "IBIS" by A. Zverev, for treating and storing the data, and "Graph" by A. Novakovskyi, for preliminary sorting both species and relevés. Many more data are still in field notebooks and boxes with incompletely identified cryptogam specimens.

There are various degrees of knowledge regarding syntaxa diversity both in different geographic regions and within the higher syntaxa. There are only four locations (Fig. 1, red dots) where the entire range of plant communities within a landscape has been characterized. These include three large islands in the Arctic Ocean - Alexandra Land (Franz Josef Land), Bolshevik Island (Severnaya Zemlya) and Wrangel Island. However, the Arctic vegetation data are formally published using the Braun-Blanquet approach in only two of these (Matveyeva, 2006; Kholod, 2007). The vegetation of Alexandra Land (Aleksandrova, 1983) and Sivaya Maska (European North) (Katenin, 1972) is characterized by using other classification approaches.

Areas studied

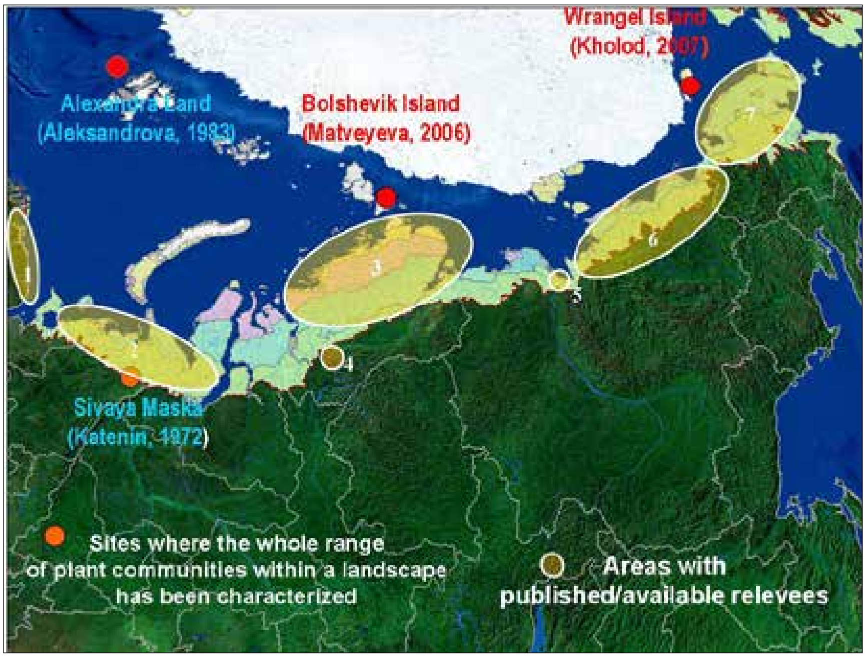

Figure 1. Areas and sites where the plant cover is analyzed using different classification methods. 1 – Kola Peninsula; 2 – East European North (including Kolguev Island, Malozemelskaya and Bolshezemelskaya Tundras, Dolgyi and Vaigach islands, Yugor Peninsula, Polar Ural) and Yamal Peninsula; 3 – Taymyr Peninsula; 4 – Putorana Plateau; 5 – Tiksi Bay; 6 – Arctic Yakutia; 7 – Chukotka.

The following regions have been the focus of Russian syntaxonomic interests (Fig. 1):

Kola Peninsula (Fig. 1, 1): This area was not included in the Circumpolar Vegetation Map (CAVM Team, et al., 2003); however, we are sure that the treeless strip along the Barents Sea should be included. S. Chinenko (2008, 2013) convincingly demonstrated this with regard to the vascular plant flora. Also plant communities of different types belong to the same syntaxa as the true tundra ones (Koroleva, 2013, this volume).

East European North (Fig. 1, 2): This area includes Kolguev Island, Malozemelskaya and Bolshezemelskaya Tundras, Dolgyi and Vaigach islands, Yugor Peninsula, and the Polar Ural mountains.

For regions 1 and 2 containing the western part of the Russian Arctic, the data of various community types (e.g., salty marshes, sparse vegetation on sands, and Dryas and Arenaria fell-fields) in the northern Kola Peninsula and in the Bolshesemelskaya Tundra were published recently (Kuljuguna, 2008; Koroleva, 2011; Koroleva et al., 2011; Matveyeva, Lavrinenko, 2011; Matveyeva, et al., 2013), while a lot of information on sedge mires and lichen peat mounds (palsa) is forthcoming.

Yamal Peninsula (Fig. 1, 2): Plot data from the Yamal Peninsula have been obtained by O. Rebristaya, O. Khitun, K. Ermokina, and others (see Ermokhina this volume), but so far few data have been published. For example, there were no primary tables in monograph on Yamal typical tundra subzone vegetation by M. Telyatnikov (2003), but recently he began to use the Braun-Blanquet approach and already has published a few syntaxa for southern tundras (Telyatnikov & Pristyazhnyuk, 2012 a, b).

Taymyr Peninsula (Fig. 1, 3): The study of zonation on Taymyr Peninsula provided data for vegetation of different classes and allowed examination of the changes in association composition along the latitudinal gradient and to distinguish subzonal vicariants within the main associations (Matveyeva, 1994, 1998). Although not a large dataset for such a vast and diverse territory, the data do provide a relatively representative set of syntaxa. A similar study for colorful grass-herb meadows on south facing slopes and for zoogenic grass stands was made within the tundra zone on the Taymyr Peninsula and in polar deserts on Bolshevik Island by L. Zanokha (2009). However the amount of unpublished data still exceeds the published.

Putorana Plateau (Fig. 1, 4): The Putorana is a large tundra area at higher elevations situated just south of the latitudinal tree line. A few associations have been described by N. Matveyeva(2002) and M. Telyatnikov (2009, 2010).

Tiksi Bay vicinity (Fig. 1, 5): No tables with tundra relevés are known from the Lena River basin, but there is a hope that at least some data obtained by N. Sekretareva from the Tiksi Bay east of the Lena River delta will be available soon.

Yakutia (Fig. 1, 6): The monograph by V. Perfil'eva and co-authors (1991) includes the scrupulously described Arctic portion of Yakutia. Although the authors did not follow Braun-Blanquet approach in classification, the vegetation descriptions contain many tables with numerous relevés. The data can be easily adapted for the Arctic Vegetation Archive. Unfortunately, the relevés lack site information.

Sequences of communities disturbed under human impact in northern Yakutia were described and classified according to the Braun-Blanquet approach (Cherosov et al., 2005).

Chukotka (Fig. 1, 7): The vascular plant flora of Chukotka has been studied most thoroughly under Boris Yurtsev's leadership. The vegetation, however, is not thoroughly described. Among the published materials, V. Razzhivin, I. Kucherov & F. Daniels have described associations of the snow-bed vegetation and Dryas fell-fields according to Braun-Blanquet (see details in V. Razzhivin, this volume). Tundra steppes on dry south facing slopes (Slinchenkova, 1994; and others) and series of herb and moss stands around the hot springs (Katenin, 1981) were described in another system but were accompanied by tables with relevés

Willow communities: The willow shrub stands were classified along the large longitudinal gradient from the Polar Urals to Chukotka with many units within the association and a few new alliances (Sekretareva, 1994, 2003, and others).

Anthropogenically disturbed vegetation: The diversity of restored vegetation on industrial disturbed sites at Vorkuta, Yamal and Norilsk up to Wrangel Island was the focus of the long-term investigation by O. Sumina (1994, 2000) and her students (Sumina & Koptseva, 2004; and others).

Summary of described syntaxa

About half of associations are known for classes Loiseleurio-Vaccinietea Eggler 1952 em. Schubert 1960, Carici rupestris–Kobresietea Ohba 1974 and Salicetea herbaceae Br.-Bl. 1948 that undoubtedly does not reflect the whole diversity of these types of vegetation on the vast territoty of the Russian Arctic. Even less information is available for classes Scheuchzerio Caricetea nigrae (Nordh. 1936) Tx. 1937 and Oxycocco Sphagnetea Br.-Bl. et R. Tx. 1943 that cover large areas in wet depressions on the large plains in particular in Yakutia. Fortunately a lot of information on sedge mires and lichen peat mounds (palsa) for European North is forthcoming (by O. Lavrinenko) and will be soon published in the journal *Vegetation of Russia*.

The vegetation of salt marshes within class Juncetea maritimi Br.-Bl. 1931 is described relatively completely from a few regions of the East European North, but the huge mass of salt marshes known east of Varandei in Bolshezemelskaya Tundra has so far been closely observed only from a helicopter. There are data from Chukotka, but in recent monograph on salt marshes by L. Sergienko (2008) no tables with relevés are given. A few associations have been described on the Kola Peninsula within the class Honckenyo Elymetea arenariae R. Tx. 1966 (Koroleva et. al, 2011). There are also data from Pechora Bay coast and Kolguev Island. Sparse vegetation on the interior sands in Bolshesemelskaya Tundra also belong to this class as well as to the class Koelerio Corynrphoretea Klika in Kliká et Novak 1941 (Kuljuguna, 2008).

Other classes are represented more poorly. Syntaxa of at least five classes known for Spitsbergen and Greenland are still not described in Eurasian part of the Arctic. The necessity of describing new higher units including even classes is strongly felt by all participants taking part in the elaboration of Arctic syntaxonomy. This is particularly urgent for the polar desert region where the very specific vegetation is referred to the class Thlaspietea rotundifolii Br.-Bl. 1948 based only its very sparse cover. Also even formally the zonal vegetation of the northernmost regions of the tundra zone is still placed into Loiseleurio-Vaccinietea.

Twenty-one years ago at the at the International Workshop on Classification of Arctic Vegetation in Boulder, CO, we talked about the necessity to make a circumpolar Arctic vegetation map and to write the monograph where at least the main types of circumpolar vegetation have to be described not only in words but also in tables. The first task of this program has been successfully fulfilled due to the intensive activity by an international team led by Skip Walker (CAVM Team, et al., 2003). Now is the time to turn to the second, no less intricate, goal – to develop a syntaxonomic classification framework for the whole Arctic. The great challenge and the time to begin is now! Let us hope the AVA will be really the most appropriate step to do this. The syntaxonomic data are ground-based documents that are necessary for monitoring and change detection and for reducing the subjectivity associated with change interpretation from remote-sensing means. They are relatively easy to collect are done in similar ways by investigators across the Arctic. The AVA initiative combined with the pressing need for quantitative assessments of change is also a strong impetus for intensifying syntaxonomical field research, but regrettably Russian field work in the Arctic recently became much more problematic than in the second part of last century in the USSR.

Revisits to areas of previous syntaxonomic studies on the Taymyr Peninsula reveal large landscape transitions

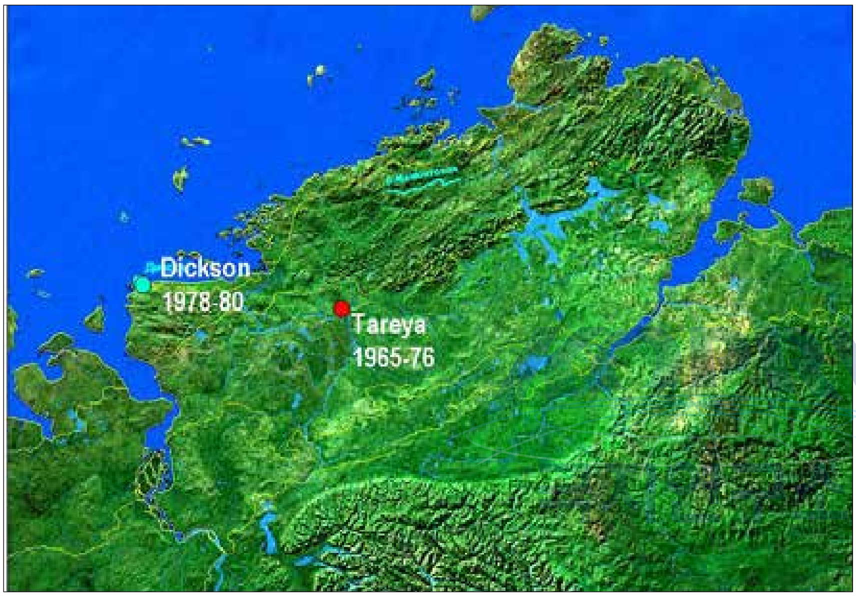

Figure 2. Study areas on the Taymyr Peninsula.

Recently, within the project "Back to the Future" Five Russian scientists revisited Tareya and two revisited Dickson on the Taymyr Peninsula where complex ecological studies were done in the late 1960s and 1970s during the International Biological Programme (IBP). Tareya is in the mid course of the Pyasina River and was resampled in 2010. Dickson is at the west corner of peninsula and was resampled in 2012 (Fig. 2). We found similar types of landscape transformation at both locations.

Previously level, smooth surfaces of the interfluves between small valleys had been polygonized (fragmented) into thousands of mounds and trenches (Fig. 3). At Tareya, this was documented using a published vegetation map (Matveyeva, 1978) (Fig. 4), and at Dickson using unpublished material including photos and personal experience of the investigators. There were some other transformations in the micro- and nanorelief, such as sinking of polygon rims in areas of low-centered-polygon mires, the formation of hummocky surfaces on the slopes, and landslide activity, but the polygonization of the interfluves was the most spectacular transformation that took place over large areas within a short period of time. Evidence from aerial photographs indicate that the events took place between 1994 and 2003 at Tareya and not earlier than 1988 and before 2007 at Dickson. The well-developed high-centered polygons on the interfluves were not evident at either location during the first sampling in the IBP years. We can decisively document large-scale landscape transformations for these two locations (Fig. 5). The occurrence of extensive areas of high-centered polygons that are visible on other high-resolution Quick-Bird images from nearby areas indicate the transformation is regionally extensive.

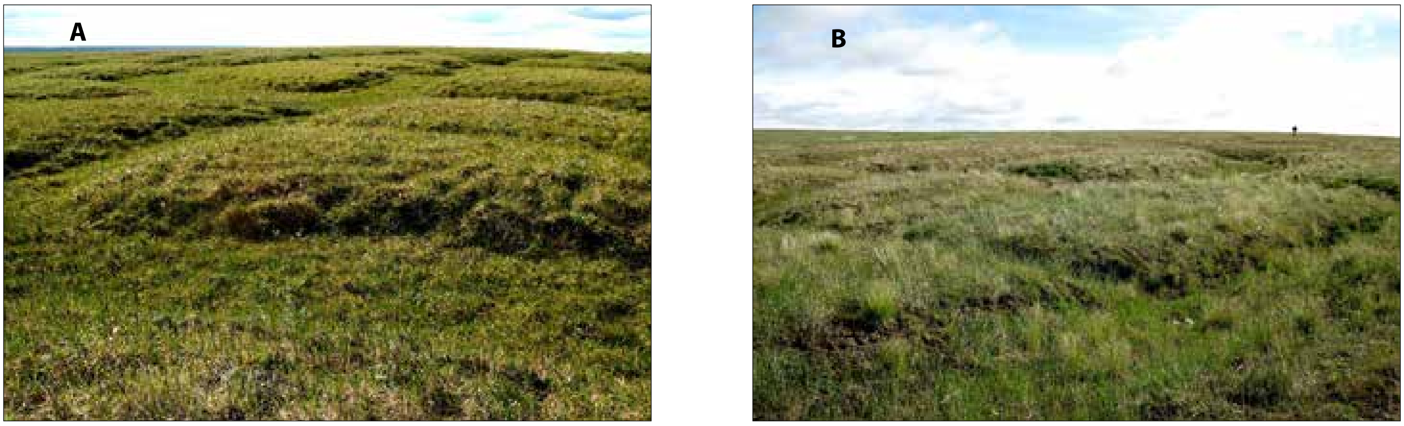

Figure 3. Polygonized interfluves in Tareya (a) and Dickson (b).

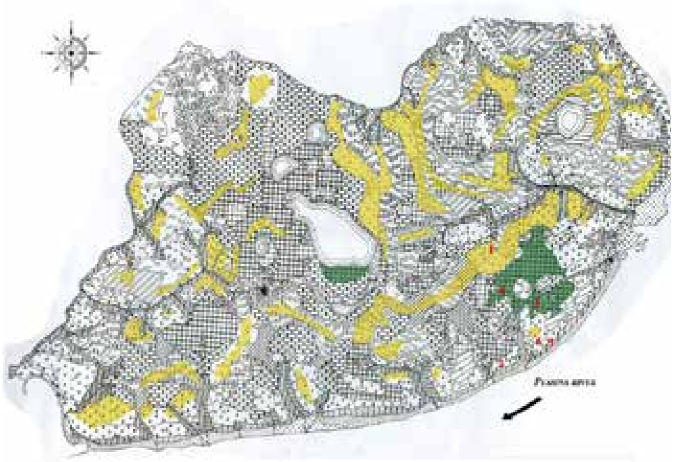

Figure 4. Map of vegetation (original map scale: 1:10,000) at Tareya in 1970 (Matveyeva, 1978). Yellow areas are newly polygonized interfluvial areas observed in 2010. Green areas are low-centered polygons where the rims have become less prominent, but have largely retained the vegetation that was observed in first sampling.

We leave the explanation of this phenomenon to experts in geocryology. Our task was to objectively assess what kinds of changes in plant cover have followed such wide-scale landscape transformations. The only *true evidence* but not a simple *impression* of change to the vegetation is from numerous relevés that were sampled 40-32 years ago and recently resampled. Phytosociological relevés are a simple and fairly precise documentation of species-composition change. At Tareya, many sampled stands were marked on the aerial photos and could be reassessed by one of the participants 40 years after the first sampling. At Dickson, it was more problematic because the memory of even two researchers for relocating the plots appeared to be not too reliable, but at least a few permanent sample plots were relocated. In both regions, we were impressed that the plant cover appeared to be remarkably stable, regardless of the large and even dramatic landscape transformations. This state is documented by recurrent relevés! The detailed analysis of all obtained data lies ahead. Here we only want to attract attention to the unique phenomenon and to tell about the potential prognostic value of the relevé data.

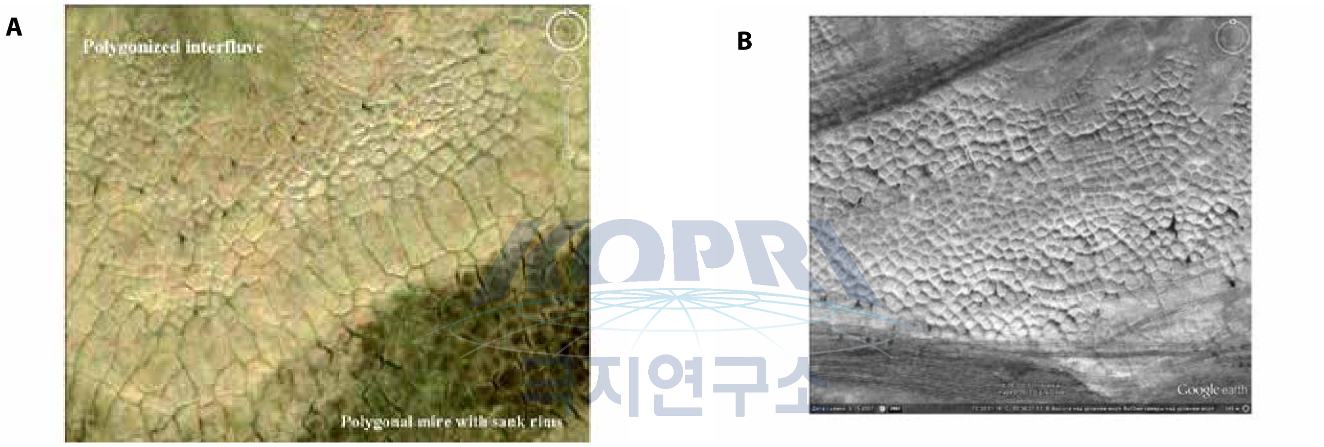

Figure 5. Quickbird satellite images: (a) Tareya showing strongly polygonized upland area and area where the low-centered polygons have become less pronounced. (b) Polygonized upland near Dickson (b).

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Phytosociology of the Svalbard Archipelago including Bjørnøya and Jan Mayen

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Botanical investigations of the Svalbard Archipelago started out early in the 18th century mainly focusing on revealing new species and documenting their distribution on the islands. The first comprehensive documentation of plant habitats and their floristic content stems from Elton, C.S. and Summerhayes, V.S. (1928). Very few of the habitat types found in Svalbard occur on the Norwegian mainland. In the total area there are 180 native vascular plant species and 68 of these are not known from mainland Norway, but are found in either Greenland or the Russian Arctic, or in both areas. So far 18 introduced plant species seem to have established populations able to survive the Arctic winter on the archipelago in or close to permanent settlements. In 2010 Svalbard had 50 species and 15 sub-species on the redlist of vascular plants (a listing of rare plants).

Botanist very early became aware of Svalbard as a kind of Arctic oasis, with an exceptionally warm climate and lush vegetation considering its northern latitude. Yearly average precipitation is from 150 mm (Eastern Spitsbergen) to 400 mm (Western Spitsbergen). Still, the tundra is dominated by humid conditions, because temperature-induced evaporation is low and, at the same time, permafrost causes waterlogged soils. Average July temperature varies between 1 and 6 degree Celsius. Different systems have been applied to divide Svalbard into bioclimatic zones, according to the island's heterogeneous environmental conditions.

The Svalbard Archipelago with its main island Spitsbergen has a landmass of 61,000 km^2 and is 60% covered by ice. In Spitsbergen (including Northeast Land, Barentsøya and Edgeøya) four different vegetation zones were distinguished (Fig. 1) as part of the plant geographical classification (Thannheiser 1996). The Arctic Polar Desert Zone (APWZ) includes Northeast Land and the eastern coast of Spitsbergen. Due to the lack of summer heat (no influence of the Gulf Stream, frequent summer fog) only a few plants can establish themselves (e.g. *Papaver dahlianum, Phippsia algida*). The Northern Arctic Tundra Zone (NATZ) supersedes the APWZ in Eastern Spitsbergen and stretches along the northern coast to the western coast. The vegetation cover is between 10% and 25% and is characterized by snow bed conditions and plant species like *Salix polaris* and *Saxifraga oppositifolia*. The Middle Arctic Tundra Zone (MATZ) is represented by *Dryas octopetala* and can reach up to 50% vegetation cover. In the Inner Arctic Fiord Zone (IAFZ), which is less frequently covered by fog and clouds, temperature sum during growth season is at the peak, allowing 75% of all plants in Svalbard to grow there, among others *Empetrum nigrum* ssp. *hermaphroditum* and *Cassiope tetragona*.

Currently, only a deficient plant sociological overview exists for Svalbard's vegetation, but it will be necessary in the future to establish a complete synopsis of all plant societies in Svalbard including Jan Mayen. Still, it is possible to collate plenty of information from different publications. However, comparisons and trans-regional overviews are nevertheless made difficult because the vegetation surveys and their evaluations were made by authors from different countries and were based on diverse methods. The oldest vegetation studies using a plant sociological approach were produced by Hadac (1946). After 1945 plant sociological field work was mainly carried out in the interior areas of fiords by Rønning (1965) and Eurola (1968). But areas outside the inner fiords also were surveyed at selected locations by Hofman (1967) and Philippi (1973). During the last 30 years a number of comprehensive plant sociological treatises of individual test sites were published, such as by Hartman (1980), Dubiel and Olech (1990), Möller (2000), Möller and Thannheiser (1997) and Nilsen et al. (1999). After searching through botanical literature from Svalbard and Jan Mayen we were able to generate a list of plant sociological surveys with published and unpublished relevés (Table 1).

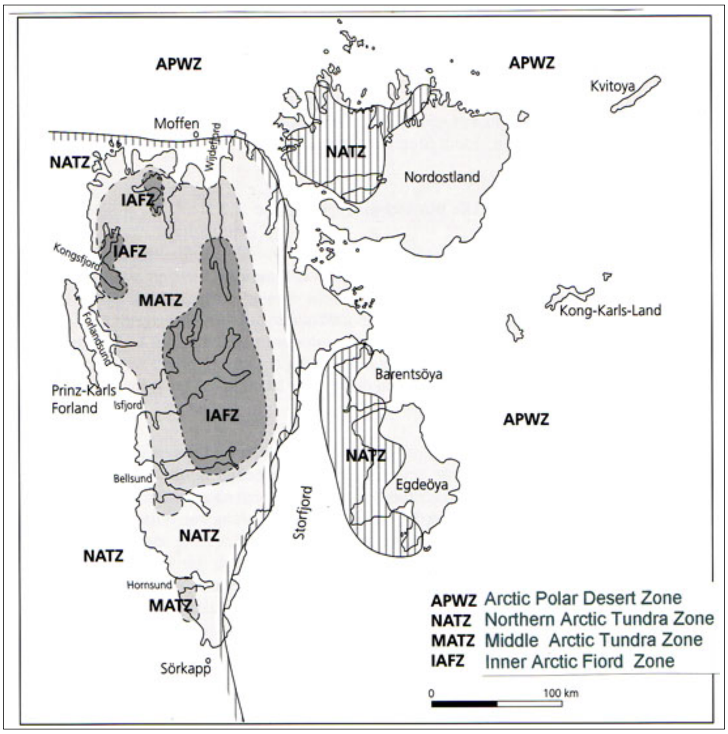

Fig: 1: The vegetation zones of Svalbard archipelago. The map is redrawn from Thannheiser (1996).

Below is an overview of Svalbard's plant communities and their classification, which is based on the study by Möller (2000) carried out in Northern Spitsbergen. The Northern and Central European plant sociological system was used as a reference, but this approach needs to be revised for future surveys in Svalbard.

Syntaxanomical survey of Spitsbergen

Cl.: Juncetea maritimi Br.-Bl. 1931
Ord.: Glauco-Puccinellietalia Beeft. & Westh. 1968
All.: Puccinellion phryganodis Hadač 1946
Ass.: Puccinellietum phryganodis Hadač 1946
Ass.: Caricetum subspathaceae Hadač 1946
Ass.: Caricetum ursinae Hadač 1946

Cl.: Honckenya peploides-Elymetea arenarii Tx 1966
Ord.: Honckenyo peploides-Elymetalia arenarii Tx 1966 em. Géhu & Tx. ap. Géhu 1975
All.: Honckenyo peploides-Elymion (Galiano 1959) TX. 1966
(= Agropyron-Rumicion Nordh. 1940)
Ass.: Mertensietum maritimae (Nordh. 1940) Thannh. 1981

Cl.: Thlaspietea rotundifolii Br.-Bl., Emb. & Mol. 1947
Ord.: Thlaspietalia rotundifolii Br.-Bl. Ap. Br.-Bl & Jenny 1926
All.: Papaverion dahliani Hofm. 1968 ex Daniëls 2013
(= Arenarion norvegicae Nordh. 1935)
Ass.: Puccienellietum angustatae Möller 20000
Ass.: Papaveretum dahliani Hofm. 1968
Ord.: Androsacetalia alpinae Br.-Bl. ap. Br.-Bl. & Jenny 1926
All.: Cerastio-Saxifragion cernutae Hartm. 1980
(= Saxifrago stellaris-Oxyrion digynae Gjærev.l 1950
Luzulion arcuatae all. prov. Elvebakk 1985, Ranunculo-Oxyrion Nordh. 1936)
Ass.: Deschampsietum alpinae (Samuelsson 1913) Nordh.1943
Ass.: (Anthelio-) Luzeletum arcuatae Nordh.1928
Ass.: Sphaerophoro-Racomietum lanuginosi (Hadač 1946) Hofm. 1968
Ass.: Oxyrio-Trisetum spicati Hadač (1946) 1989

Cl.: Montio-Cardaminetea Br.-Bl. & Tx 1943 ex Klika & Hadač 1944
Ord.: Montio-Cardaminetalia (Br.-Bl. 1925) Pawl., Sokl. & Wall. 1928
All.: Cardamino-Montion Br.-Bl. 1926
Ass.: Drepanoclado-Ranuculetum hyperborei Hadač 1989
Ass.: Calliergono-Bryetum cryophili Hofm. 1968

Cl.: Salicetea herbaceae Br.-Bl., Emb. & Mol. 1947
Ord.: Salicetalia herbaceae Br.-Bl.ap. Br.-Bl. & Jenny 1928
All.: Saxifrago-Ranunculion nivalis Nordh. 1943 em. Dierßen 1984
(= Drepanoclado-Poion alpinae Hadač 1946, Saxifrago oppositifoli-Oxyrion digynae Gjærevoll 1956
p.p.,Salicion Polaris Du Rietz 1942 n.n., Ranunculo-Oxyrion Nordh.1936 p.p.)
Ass.: Phippsietum algidae-concinnae Nordh. 1943
Ass.: Salicetum polaris Gjærev. 1950
Ass.: Cerastio regelii-Poetum alpinae Dierßen 1992
SubAll.: Luzulenion arcticae (Nordh. 1936) Gjærev.1950.
(= Luzulion nivalis Nordh. 1936, Ranunculo-Oxyrion Nordh. 1936 p.p.)
Ass.: Tomenthypnum involuti Hadač 1946

Cl.: Scheuchzerio-Caricetea nigrae (Nordh. 1936) Tx. 1937
(= Caricetea limosae Malmer 1968, Tofieldietea Malmer 1968)
Ord.: Scheuchzerietalia palustris Nordh. 1936
(= "Apiculatetalia" Du Rietz 1954)
All.: Caricion lasiocarpae van den Berghen ap. Lebrun et a. 1949
(= Eriopohorion gracilis Prsg. Ap. Oberd. 1957)
Ass.: Arctophiletum Lambert 1968) Thannh. 1976
Ass.: Caricetum stantis Barret & Krajina 1972
Ord.: Caricetalia nigrae (Koch 1926) Nordh. 1936 em. Br.-Bl. 1949
All.: Caricion nigrae Koch 1926 em. Klika 1934
(= Caricion canescentis-goodenowii Nordh. 1936; incl. Eriophorion scheuchzeri Hadač 1939,
Drepaocladion exannulati Krajina 1933, Sphagn(et)o-Tomenthypnion Dahl 1956)
Ass.: Drepanoclado-Ranunculetum hyperborei Hadač 1989
Ass.: Bryo-Dupontietum pelligerae Hadač (1946) 1989
Ass.: Calliergono-Caricetum saxatilis (Nordh.1928) Dierßen 1982
Ord.: Caricetalia davallianae Br.-Bl.. 1949

(= Tofieldietalia Prsg. Ap. Oberd. 1949, Drepanoclado-Caricetalia Succow 1974)
All.: Caricion atrofuscae-saxatilis Nordh. 1943

Cl.: Carici-Kobresietea bellardii Ohba 1974
Ord.: Kobresio-Dryadetalia (Br.-Bl. 1948) Ohba 1974
All.: Caricion nardinae Nordh. 1935
(= Elynion bellardii Nordh. 1936, Kobresio-Dryadion 1936)
Ass.: Caricetum nardinae Nordh. 1935
Ass.: Carici rupestris-Dryadetum octopetalae Rønning 1965
Ass.: Dryadetum minoris Hadač 1946
Ass.: Dryado-Cassiopetum tetragonae (Fries 1913) Hadač 1946

Cl.: Nardo-Callunetea Prsg. 1943
(= Calluno-Ulicetea Br.-Bl. & Tx. 1943)
Ord.: Nadetalia strictae Oberd. 1949 ex Prsg. 1949
All.: Nardo-Caricion bigelowii Nordh. (1936) 1943
(incl. Deschampsio-Antoxanthion Du Rietz 1942)
Ass.: Cetrarietum delisei (Resvoll-Holmen 1920) Dahl 1956

Cl.: Cetrario-Loiseleurietea Suz.-TTok. & Umezu 1964
Ord.: Cetrario-Loiseleurietalia Suz.-Tok. & Umezu 1964
All.: Loiseleurio-Diapension (br.-Bl.,Siss. & Vlg. 1939) Daniëls 1982

Table 1:
Phytosociological relevés recorded from the Svalbard Archipelago including Björnöya and Jan Mayen.

Authors	Location	Publ.	Not publ.	Relevé size m²	Environmental data	Digital data	Map	Notes
Aarrestad, P.A. et al. (2010)	Endalen, Spitsbergen		50	0,25	Yes	Yes		Monitoring of permanent plots. Incl. mosses and lichen
Barkman, J.J. (1987)	Edgeøya	14						
Brandshaug, R. (1982)	Lågnesflya, Brøggerhalvøya, Spitsbergen		110	1				Master thesis, NTNU
Brattbakk, I. (1979)			538	1			Yes	Master thesis, NTNU
Brattbakk,I. (1983)	Brøggerhalvøya, Spitsbergen	25					Yes	
Brossard, T. et al. (1984)	Brøggerhalvøya, Spitsbergen	70		1	No			
Dahle, O. (1983)	Reinsdyrflya, Spitsbergen	107		1	Yes			
Dierßen, K. (1990)	Kongsfjorden, Liefdefjorden, Spitsbergen		100					
Dierßen, K. (1992)	Liefdefjorden, Spitsbergen	4						
Dubiel, E. and Olech, M. (1990)	Sørkapp, Spitsbergen	258						
Dubiel,E. and Olech, M. (1992)	Hornsund, Spitsbergen	27					Yes	
Elvebakk, A. (1979)	Bröggerhalvöya, Spitsbergen		140	1,0				Master thesis, NTNU
Eurola, S. (1968)	Hornsund, Spitsbergen	58		25				
Eurola, S. (1971 a)	Reindalen, Spitsbergen	11		1				
Eurola, S. (1971 b)	Sveagruva, Spitsbergen	20		1				
Eurola, S. and Hakala, A. (1977)	Spitsbergen, Nordaustlandet	29			Yes			
Gugnacka-Fiedir, W. and Noryskiewicz, B. (1982)	Kaffiøyra, Spitsbergen	?						
Hadač, E. (1946)	Sassendalen, Spitsbergen	75						

Authors	Location	Publ.	Not publ.	Relevé size m^2	Environmental data	Digital data	Map	Notes
Hadač,E. (1989)	Isfjorden, Van Meijenfjorden, Spitsbergen	95		1	Yes			
Hartmann, H. (1980)	Spitsbergen	47						*const.tab.
		20*						
Heinemeijer, H. D. and van Dijk, A. J. (2004)	Rosenbergdalen, Edgeøya	119		1	No		Yes	
Hermansen, J.E. (1979)	Bröggerhalvöya, Spitsbergen		75	1				Master thesis, NTNU
Herstad, P. (1981)	Bolterdalen, Spitsbergen		200	1				Master thesis, NTNU
Hjelmstad, R. (1981)	Barentsøya	26						
Hofmann, W. (1967)	Edgeöya, Barentsöya		200					
Hofmann, W. (1969)	Spitsbergen	13						
Kapfer, J. (2012)	Jan Mayen	200		1	Yes	Yes		
Kobayashi, K. et al. (1990)	Bohemansflya, Isjord, Spitsbergen	56		1	Yes			
Koroleva N. (1995)	West coast of Spitsbergen	8						
Kuper, J.H. et al. (1972)	Edgeøya	48						
Lid, J. (1964)	Jan Mayen	327		1	No			
Lid, J. (1967)	Spitsbergen	200						
Lund, N. (1979)	Brøggerhalvøya, Spitsbergen	135		1		Yes		
Möller, I. and Thannheiser, D. (1997)	Billefjorden, Spitsbergen	149						const.tab.
Möller, I. et al. (1998)	West Spitsbergen	284						const.tab.
Möller, I. (2000)	North West Spitsbergen	580						
Möller, I. et al. (2001)	Eidembukta, Spitsbergen	106						const.tab.
Möller, I. and Thannheiser, D. (2003)	Woodfjorden, Spitsbergen	40						const.tab.
Nilsen, L. (1992)	Uversøyra, Spitsbergen		222	1	Yes	Yes	Yes	
Nilsen, L. et al. (1999)	Brøggerhalvøya, Spitsbergen	266		100	Yes	Yes	Yes	
Phillippi, G. (1973)	Barentsøya, Edgeøya	187					Yes	
Prach, K. and Rachlewicz, G. (2012)	Petuniabukta, Ragnarbreen, Spitsbergen	60		25	No	Yes		
Prach, K. et al. (2012)	Petuniabukta, Ragnarbreen, Spitsbergen	53			Yes	Yes	Yes	
Rønning, O.I. (1965)	Spitsbergen	193		1	Yes			
Schuhwerk, F. (1991)	Liefdefjorden, Spitsbergen		50					lichens
Thannheiser, D. (1969)	Kongsfjorden, Krossfjorden, Spitsbergen		80					
Thannheiser, D. (1975)		18						const.tab.
Thannheiser, D. (1976)		4						
Thannheiser, D. and Hofmann, W. (1977)	Kongsfjorden, Krossfjorden, Spitsbergen	21						
Thannheiser, D.(1992)	Liefdefjorden, Spitsbergen						Yes	
Thannheiser, D. (1994)	Liefdefjorden, Spitsbergen.	150					Yes	constancy

Authors	Location	Publ.	Not publ.	Relevé size m^2	Environmental data	Digital data	Map	Notes
Thannheiser, D. (1995)	Liefdefjorden, Spitsbergen	1					Yes	const.tab.
Thannheiser, D. and Wüthrich, C. (1999)	St. Johnsfjorden, Spitsbergen	2					Yes	const.tab.
Thannheiser, D. et al. (2001)	Sassendalen, Spitsbergen	20						const.tab.
Vanderpuye A.W. et al. (2002)	Sassendalen, Spitsbergen	7				Yes		Const.
Virtanen, R. and Eurola, S. (1997)	Kjellstrømdalen, Agardbukta, Spitsbergen	56		25	No			Relevé size 5 x 5 m,
Virtanen, R. et al. (1996)	Jan Mayen	31		0,64				Relevé size 0.8 x 0.8 m
Wegener, C. et al. (1991)	Stuphallet, Dyrevika, Spitsbergen	50		1	Yes	Yes		
Wollesen, D. 1997	Liefdefjorden, Spitsbergen	120						
Zonnefeld,I.S. set al. (2004)	Edgeöya	126		70 and 300			Yes	
Sum of published and unpublished relevés		**6281**						

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Approaches for storing and analyzing geobotanical data

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Introduction

The main objective of the Arctic Vegetation Archive (AVA) is to create a global database of vegetation plots for the whole territory of the Arctic. This area includes Russia, Canada, USA and Scandinavian countries. A large part of the Arctic territory includes Russia. Therefore, it is especially important to know how many and where exactly vegetation plots were made in Russia. Also, some technical questions are of interest such as the format of databases used for data storage in Russian scientific institutes, and methods of processing and analysis of collected data.

This paper is focused on the vegetation-plot data collected by specialists at the Institute of Biology of the Komi Scientific Centre. The Institute of Biology was founded in the middle of 20th Century and specialists in geobotany started their field investigations from those very first days. Experts regularly participated in different expeditions to collect field data mainly in the Komi Republic. Data were collected from the boreal forests in the foothills of Ural Mountains to polar tundra on the tops of mountains. Moreover, researchers worked in more northern region such as the Nenets district, which is located on the Arctic shore. More recently, such regions as the Bolshezemelskaya Tundra, the delta of the Pechora River and the Polar Urals were investigated (Fig. 1).

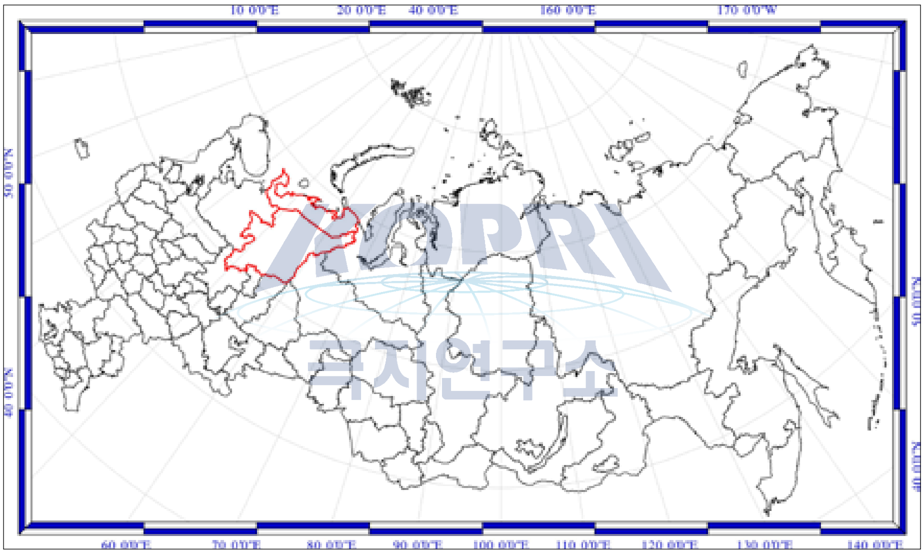


Figure 1. Area of the data collection.

Archiving relevé data

Initially, only a hard copy paper format was used for storing botanical data. In general, in the field specialists filled in datasheets containing information about the vegetation plot. Then these relevés are converted into a digital form. But, until the 1990s we didn't have any computers and special programs to do the conversion from paper to digital format. Therefore, the earlier relevés are still stored only as hard copies in paper format. There are about 5,000-6,000 hard copies of releves collected by the Institute of Biology. Today, much effort is required to convert these data to a digital format because during the last 50 years the taxonomy of many species has changed. Moreover, today, scientists use different cover abundance scales than 50 years before.

In the early 1990s, Andrei Zverev (2012) from Tomsk State University designed the first data-base of Vegetation Plots in Russia – IBIS (Fig. 2). This system allows entering, storing and analyzing vegetation plot data. In addition, it is possible to make pivot tables, floristic lists and to calculate similarity matrices. The use of IBIS is quite widespread in botanical institutes in Russia from Siberia to Saint Petersburg, the Komi Republic, and other regions. Today, there are about 60-80,000 vegetation plots stored in this system. IBIS was made with CA-Clipper, so it is a DOS program, which causes some problems for users. For example, IBIS does not support the use of a "mouse" in its interface. Nevertheless, it is possible to convert data from the IBIS format to others, for example Microsoft Excel or Turboveg.

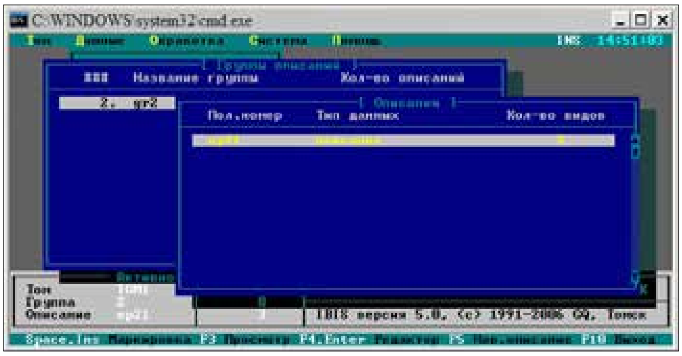


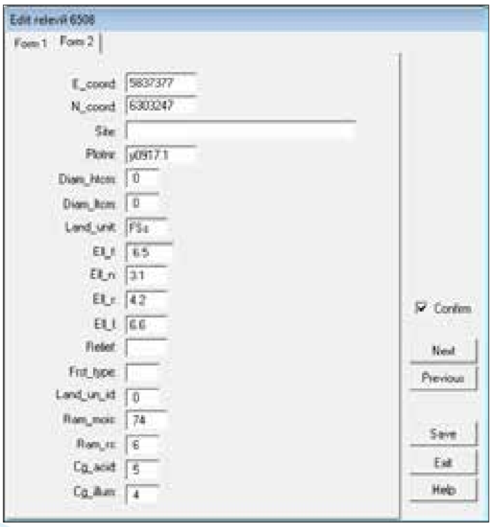
Figure 2. Appearance of the IBIS database.

Since 2000, most relevés collected were converted into a digital format. Initially, we used a Microsoft Excel format. Of course, these tables are not real databases. However, this kind of data storage allowed us to make some basic analyses including estimating the average abundance or species fidelity, calculating biodiversity indices, building synoptic tables and so on. This for-mat is now used only as an intermediate between different databases and programs for data analysis, as we now archive most vegetation plots in the Turboveg format (Hennekens & Schaminee 2001). We have about 3,500 releves, which were made during the last 5-7 years, stored in Turboveg databases. We have added some extra fields to the standard header list in Turboveg (Fig. 3).

These fields include:

- **E_coord, N_coord** – latitude and longitude
- **Plotnr** – unique identification code. This code contains brief information about the author (first letter), the year of creation (two digit numeric key) and the author's plot number. We put this code in every selection and it allows us to identify releves and to get a brief description of it without any additional effort.
- **Land_unit** – index of vegetation type.
- **Ell_f, Ell_n, Ell_r, Ell_l, Ram_mois, Ram_rs, Cg_acid, Cg_illum** – Ellenberg, Ramensky and Ciganov ecological scale values (moisture, nitrogen, reaction and light). The last two ecological scales were developed for local vegetation and are widely used in Russia. Obviously, this secondary information can be calculated using the species list of certain vegetation plot. But, it is more efficient to calculate it once, add to database and use when needed.

It should be noted that only about 10-15% of the vegetation plots mentioned above occur in the Arctic region. Ekaterina Kuljugina (2004, 2008) and Aleksey Dedov (2006) collected most of them. The other relevés relate to the boreal zone of the Komi Republic or the Ural Mountains region.


Edit relevé 6508

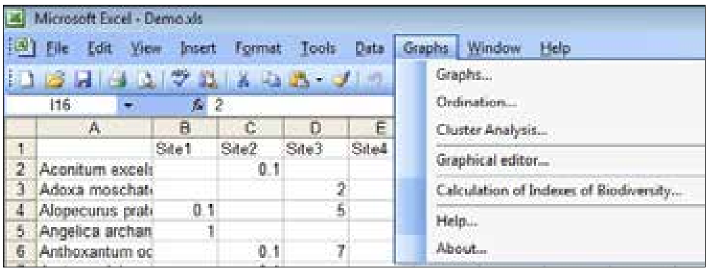
E_coord 5837377
N_coord 6303247
Site
Plotnr y0917.1
Diam_hcov 0
Diam_lcov 0
Land_unit FSa
Ell_f 6.5
Ell_n 3.1
Ell_r 4.2
Ell_l 6.6
Relief
Frst_type
Land_un_id 0
Ram_mois 74
Ram_rs 6
Cg_acid 5
Cg_illum 4
☑ Confirm

Figure 3. List of extra fields used in Turboveg.

Analysis of relevé data

The second part of this paper concerns the issue of geobotanical data analysis. Today, there are many computer programs developed for statistical analysis and data visualization ranging from large, complicated and expensive packages, such as STATISTICA and SPSS, to relatively small and inexpensive packages, such as PC-ORD (Jongman et al. 1987) and CANOCO (Leps 2003). In addition, there are some freeware statistical programs. The "R" package is one of the most well known freeware statistical programs (Seefeld & Linder 2007). Often, researchers (especially in the ecology and biology fields) have difficulties using these kinds of software including: a) preparing data for analysis (programs often use special data formats not compatible between each other), b) interpreting results of statistical analysis, and c) using program with unusual or unclear interfaces. It is very helpful to have some tools to make statistical analysis as easy as possible without a lot of effort.

We designed the software module "GRAPHS" to help our scientists in statistical data proceedings. This module is an Excel add-on and after its installation a new Excel submenu appears (Fig. 4). Full compatibility allows the user all the standard Excel functions to convert data or to prepare them for analysis.



I16 2

	A	B	C	D	E
1		Site1	Site2	Site3	Site4
2	Aconitum excels		0.1		
3	Adoxa moschat			2	
4	Alopecurus prat	0.1		5	
5	Angelica archan	1			
6	Anthoxantum oc		0.1	7	

Figure 4. The Excel submenu "GRAPHS."

The data source for this submodule is a classical geobotanical table where rows are releves (objects) and columns are species (their properties) or other ecological parameters. For the user's convenience, ranges, which contain data, can be defined automatically. However, to avoid errors in determining ranges it is advisable to follow some simple rules including: 1) only one (first) row should contain information about object captions, 2) only one (first) column should hold property names, and 3) in all other cells, only numeric values should be presented. In addition, the "GRAPHS" menu provides three different types of methods for analysis: cluster analysis, ordination and graph theory.

The first group includes cluster analysis methods. There are two groups of options in the dialog window for cluster analysis. The first option, similarity indices, is used for making a table of similarity distances between objects. In the module, we have developed some of the most common similarity indices used in in botany (e.g., Jaccard, Sorensen, Ohiai, Inclusions measurement), correlations and rank correlations (Pearson, Kendell), and conjugations between species and Euclidean Distance (Legendre & Legendre 1998, Mueller-Dombois & Ellenberg 2003). The second option is the method of objects grouping. Right now, there are three methods developed which include: nearest neighbor method, unweighted pair group method with arithmetic mean (UPGMA), and Ward's method of clustering (Fig. 5A, Ward 1963).

The second group of analysis methods refers to ordination. In the module “GRAPHS” three or-dination methods are implemented: principal components analysis (PCA), correspondence analysis (CA) and multidimensional scaling (NMS, Fig. 5B). There is a lot of literature devoted to the subject of ordinations (Jongman et al. 1987, McCune et al. 2002, Ter Braak 1986, Prentice 1977).

The last group of methods is according to graph theory. Like in the cluster analysis, the user selects a similarity index to calculate a matrix of distances between objects and a form of presenting this matrix. Now, the following forms of presentation are implemented: 1) circle form (all objects are located in a circle and line thicknesses shows the value of similarity, 2) the higher coefficient of similarity the thicker line), 3) weighted tree (only the highest similarities are shown), 4) star form, and 5) splitting graph into connected components (Fig. 6., Bondy & Murty 1982). This approach allows the user to present fewer objects than the other methods, specifically no more than 30-40 objects. However, specialists can easily interpret this form of graphical representation of data. For more information about module "GRAPHS" visit the website http://m-graphs.com/index.php/en

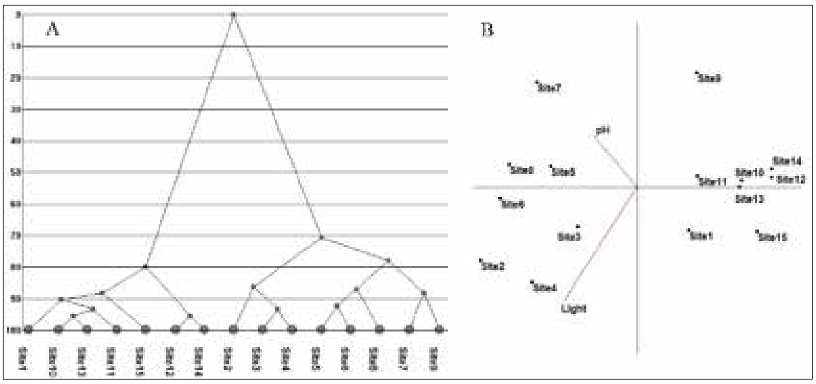


Figure 5. An example of the resulting output from “GRAPHS.” A) cluster analysis (Ward clustering), and B) ordination (NMS method).

Conclusion

Since the beginning of the Institute of Biology, vegetation specialists have accumulated more than 10,000 vegetation plots and a lot of other floristic information. Some of the vegetation-plot data is converted to a digital form, while many relevés are still only in a paper format. It is estimated that 5,000-6,000 vegetation plots are stored in the paper format, 1,000-1,500 plots in Excel format, 2,000-3,000 relevés in IBIS format (mostly aquatic vegetation) and about 3,500 relevés have been converted and stored in Turboveg.

Acknowledgements

This work was funded by the Ural Division of Russian academy of Science scientific program "Reaction of ecosystems of the European North and Western Siberia cryolitozone to climatic fluctuations of the last tens of years" (12-C-4-1018) and Russian Foundation for Basic Research "Ecological, morphological and functional characteristics of vascular plants in relation to the implementation of different types of life strategies in the north and the extreme northern taiga" (13-04-98829).

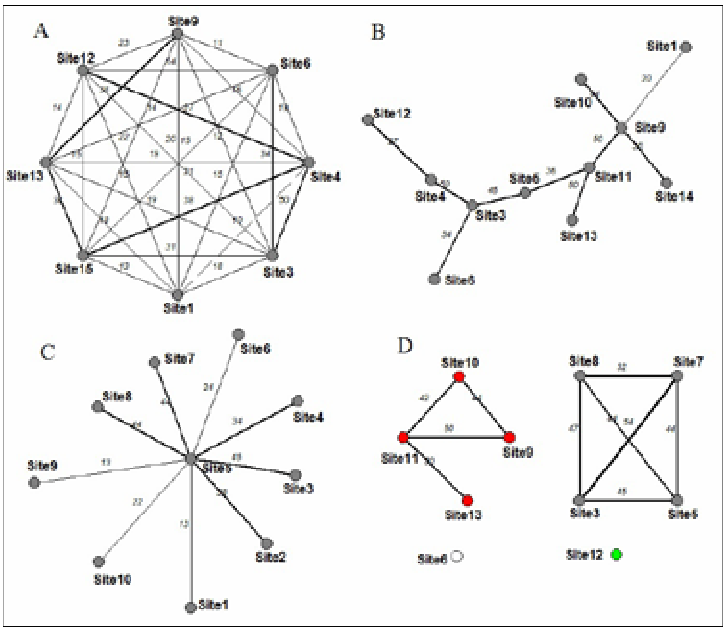


Figure 6. Different forms of graph theory presentation output from “GRAPHS.” A) circle graph, B) tree graphs (connected graph with no cycles), C) star graph, and D) connected components.

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The Pan-Arctic Species List (PASL)

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Abstract

The Pan-Arctic Species List (PASL *beta* 1.0) was created from lists of accepted taxa for different groups in the Arctic: vascular plants, mosses, liverworts, lichens and lichenicolous fungi, compiled by members of the Conservation of Flora and Fauna (CAFF) Flora Working Group. The vascular plant list, from the Annotated Pan-Arctic Flora (PAF) (Elven 2011), contains 2789 accepted vascular plant taxa and 4118 synonyms. The moss species list, compiled by René Belland for North America, contains 735 accepted moss taxa and 3934 synonyms. The liverwort taxa were extracted from the *Checklist of liverworts (Marchantiophyta) of Russia* (Konstantinova et al 2009), containing 222 accepted Arctic liverwort taxa and 393 synonyms. The list of Arctic lichens, compiled by Hörður Kristinsson, Mikhail Zhurbenko and Eric Steen Hansen (Kristinsson 2010), includes 1699 accepted lichen and lichenicolous fungi taxa and 240 synonyms. Comparison of the lists with the Taxonomic Resolution Service resulted in 89, 98, 79, and 66 % exact matches for vasculars, mosses, liverworts and lichens respectively. Stephan Hennkens combined the four lists into one TurboVeg species list. Participation of the CAFF Floral Working Group will be critical to maintaining, updating and publishing the Pan-Arctic Species List.

Introduction

The Conservation of Flora and Fauna (CAFF) Flora Working Group members have been compiling lists of accepted taxa for different groups in the Arctic: vascular plants, mosses, liverworts, lichens and lichenicolous fungi. These lists were combined into the first, *beta*-version of the Pan-Arctic Species List (PASL *beta* 1.0). The goal is to have the PASL serve as the definitive source for Arctic taxonomist and global species databases, to be used as the basis for the rare species Red Lists, and for harmonizing Arctic vegetation plot data into an international Arctic vegetation database, the Arctic Vegetation Archive (AVA) (Walker and Raynolds 2011). The vision is to have the PASL curated and updated on a regular basis by members of the CAFF Flora Working Group, and this information made available through the internet on the CAFF Data Portal.

The species lists for vascular plants, mosses, liverworts and lichens, as available in 2012, were converted by Martha Raynolds and Amy Breen at the University of Alaska Fairbanks to a common spreadsheet format, then combined into a TurboVeg species list by Stephan Hennekens. Specific details of the sources and dates of the lists are discussed below for each group. The numbers of taxa and synonyms included in the PASL for each group are listed in Table 1.

The species lists were checked with other international vegetation databases using the Taxonomic Resolution Service (http://tnrs.iplantcollaborative.org). The search compared each taxon with lists from the Missouri Botanical Garden's Tropicos database, The National Center for Biotechnology Information's Taxonomy ITIS database, the US Department of Agriculture's PLANTS database, and the Global Compositae Checklist. Most of the PASL taxa were found in either the Tropicos or PLANTS databases. The results of the taxonomic resolution search are shown in Table 2.

In order to make the Pan-Arctic Species List the definitive list for the Arctic, it will be critical to identify the people who will take responsibility for maintaining and curating the species lists for vascular plants, mosses, liverworts and lichens and the combined PASL. It will also be important to make the PASL available to researchers and the public through the internet. The CAFF Flora Working Group with the support of the CAFF Secretariat could fill this important role.

Vascular Plants List

The Annotated Pan-Arctic Flora (PAF) Checklist is a compilation of accepted names and synonyms, and an evaluation of all vascular plant taxa at ranks of family, genus, species, subspecies, varieties, and hybrids (but only those with an independent existence), occurring regularly within the Arctic as circumscribed for the Checklist. The sources include published floras and checklists for different regions. The PAF Editorial Board (Reidar Elven, David Murray, and Boris Yurtsev (until his death in 2004)) was responsible for final decisions as to which taxa to include, their taxonomic ranks, and names. Each taxon has notes regarding taxonomic and nomenclatural problems, arguments for the choices made, prospects of future work, and also cases where the Editorial Board did not reach agreement on treatments and why. The PAF checklist was made available on the web in 2011 (Elven 2011). Detailed information about the methods is included in the introduction on the website (http://nhm2.uio.no/paf/introduction).

Reidar Elven emailed the complete list of the taxa in the Pan-Arctic Flora (PAF) in a text document to Amy Breen in June 2012. The text included the PAF numbers and hierarchy, including family, genus, accepted taxa (including species, subspecies and varieties), authorities for accepted taxa, and synonyms and their authorities. Martha Raynolds converted this text file into a spreadsheet file in August 2012 by importing it into Microsoft Excel and parsing each line into columns. The final file is composed of three worksheets, one for families and synonyms, one for genera and synonyms and their authorities, and a third for species, subspecies and varieties that includes synonyms and authorities. It contains 2789 accepted taxa and 4118 synonyms (Table 1).

Table 1.
Numbers of species of each lifeform in the Pan-Arctic Species List (PASL beta 1.0).

Species	Number of accepted families	Number of family synonyms	Number of accepted genera	Number of genus synonyms	Number of accepted taxa	Number of taxon synonyms
Vascular	91	30	426*	194*	2789*	4118*
Mosses	57	0	192*	0	735*	3934
Liverworts	34*	0	72*	8	222*	393*
Lichens	-	-	266*	19*	1699*	240
*with authorities						

A comparison of the parsed vascular species list with the Taxonomic Resolution Service on October 2012 for the 6907 taxa (accepted and synonyms) found 6121 (89%) exact matches (Table 2). The remaining 786 taxa were checked with a fuzzy match. 204 taxa had fuzzy match scores of 0.99, indicating minor spelling discrepancies. An additional 174 had fuzzy match scores > 0.9, mostly issues as to whether a subspecies designation is necessary. David Murray and Reidar Elven went through the list of taxa that had no exact matches. Reidar Elven identified 74 taxa with spelling errors in the initial PAF list, which were then corrected by Martha Raynolds for the PASL. Most of the remaining 712 discrepancies were correct in the initial PAF list in Reidar Elven's opinion, though several needed further research to identify the correct nomenclature. He recognized 55 taxa with spelling errors in the Tropicos list, and 360 taxa missing from the Tropicos list.

Table 2.
Results of Taxonomic Resolution Service (TRS) search (http://tnrs.iplantcollaborative.org).

Species	Exact matches in TRS (%)	Discrepancies found by TRS	Fuzzy matches > 0.9 in TRS*	Discrepancies resolved (%)
Vascular	6121 (89%)	786	204	74 (9%)
Mosses	4556 (98%)	112	30	0
Liverworts	485 (79%)	130	21	2 (2%)
Lichens	1276 (66%)	662	65	16 (2%)
*Likely simple spelling errors in either PASL or match database				

The next step for this portion of the PASL will be to address the Taxonomic Resolution Service discrepancies.

Moss List

The moss species list for North America was compiled by René Belland of the University of Alberta, Edmonton, Canada. René Belland sent Excel spreadsheets to Amy Breen in February and August 2012. These included a list of accepted taxa with authorities, region and country, and a list of synonyms. Amy Breen formatted these into the PASL format with three worksheets, one with families, one with genera and authorities, and a third with the accepted species (with authorities) and synonyms (no authorities). It contains 735 accepted taxa and 3934 synonyms (Table 1).

A comparison of the moss species list with the Taxonomic Resolution Service in October 2012 for the 4668 taxa (accepted and synonyms) found 4556 (98%) exact matches (Table 2). The remaining 112 taxa were checked with a fuzzy match. 30 had a fuzzy match score of 0.99, indicating a minor spelling discrepancy. An additional 64 had fuzzy match scores > 0.9, mostly issues as to whether a subspecies designation is necessary.

The next step for this list will be to add any additional Arctic species listed in the "Check-list of mosses of East Europe and North Asia" (Ignatov et al. 2006). This will require converting the article to text in a spreadsheet, parsing the lines, extracting the Arctic species, and comparing these with the existing PASL moss list.

Liverworts List

The liverwort taxa were extracted from "Checklist of liverworts (Marchantiophyta) of Russia" (Konstaninova et al. 2009). Michael Lee with the U.S. VegBank did the initial conversion from pdf to spreadsheet and parsing into columns in May 2012. He e-mailed the resulting spreadsheet to Amy Breen. Martha Raynolds extracted the species that occurred in the Arctic, and put the spreadsheet into PASL format with three worksheets, one with families and authorities, one with genera with authorities and synonyms, and a third with the accepted species and synonyms with authorities for both. It contains 222 accepted taxa and 393 synonyms (Table 1).

A comparison of the liverwort species list with the Taxonomic Resolution Service in October 2012 for the 615 taxa (accepted and synonyms) found 485 (79 %) exact matches (Table 2). The remaining 130 taxa were checked with a fuzzy match. 21 had a fuzzy match score of 0.99, indicating a minor spelling discrepancy. An additional 3 had fuzzy match scores > 0.9. Nadezda Konstantinova looked at these and found two spelling errors in the PASL (which were corrected) and four in the Tropicos list.

The next step for this data set is to add species from other parts of the Arctic, particularly information on liverworts of Alaska (Worley 1970, Steere and Inoue 1978, Potemkin 1995), data from the Canadian Arctic (Hong and Vitt 1977, Damsholt 2007, etc.), Svalbard (Frisvoll and Elvebakk 1996, Konstaninova and Savchenko 2012, etc.), Greenland (Schuster and Damsholt, 1974; Schuster, 1988, etc.), work by Kristian Hassel in eastern Greenland, and others. Species as well as intraspecies taxa (subspecies, varieties, forma, etc.) should be extracted. Taxonomic discrepancies should be compared with global databases.

Lichen and Lichenicolous Fungi List

The list of Arctic lichens was compiled by Hörður Kristinsson, Mikhail Zhurbenko and Eric Steen Hansen. It was published as a CAFF Technical Report (Kristinsson et al. 2010). The list was compiled from publications from North America, Greenland, Iceland, Svalbard, Norway and Russia, as well as unpublished data from the Russian Arctic and Greenland. The report is available electronically on the CAFF Arctic Data Portal, and data in spreadsheet format can also be downloaded there (http://www.abds.is/publications/view_category/75-lichens-data).

The list in the PASL is from an Excel spreadsheet file sent by Hörður Kristinsson in April 2012. Martha Raynolds formatted the data to match the PASL, with one worksheet for accepted genera and synonyms with authorities for both, and one worksheet for accepted species with authorities and synonyms (no authorities). It contains 1699 accepted lichen and lichenicolous fungi taxa, and 240 synonyms (Table 1).

A comparison of the lichen species list with the Taxonomic Resolution Service in October 2012 for the 1939 taxa (accepted and synonyms) found 1276 (66 %) exact matches (Table 2). The remaining 663 taxa were checked with a fuzzy match. 65 had a fuzzy match score of 0.99, indicating a minor spelling discrepancy. An additional 69 had fuzzy match scores > 0.9.

The next step for this data set is to include more recent, common synonyms. Amy Breen is working on this. The list also needs to incorporate recent work by Helga Bueltmann on the lichens of Greenland. The discrepancies with nomenclature from global databases need to be further resolved.

Combining the lifeform lists into one Pan-Arctic Species List

Martha Raynolds emailed the spreadsheets with the lifeform lists to Stephan Hennekens in October 2012. Stephan Hennekens combined the lists and formatted them into a TurboVeg species list. Amy Breen has been testing the PASL *beta* 1.0, using it to import relevé data from Northern Alaska into TurboVeg.

The next steps for the PASL are to address the Taxonomic Resolution Service discrepancies for the vascular species, add additional Arctic moss species from Eurasia, add liverwort species from Arctic North America, Greenland and Svalbard, and add lichen synonyms and species from Greenland. It will be critical to identify the people who will take responsibility for maintaining and curating the species list for each group and the combined PASL, and making the PASL available to researchers and the public through the internet. The CAFF Flora Working Group with the support of the CAFF Secretariat, could help fill this important role.

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Vegetation datasets for Chukotka (Russia)

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Extensive field studies of vegetation in Chukotka were started in the 1930s both in the northernmost Wrangel Island by B. Gorodkov (1958 a,b) and in the southernmost tundra-forest ecotone by L. Tyulina (1936) and V. Vasiljev (1936, 1956). B. Gorodkov characterized the most extreme northeastern part of Wrangel Island. L. Tyulina and V. Vasiljev described vegetation of the Anadyr River basin including larch open forests, stlanik (*Pinus pumila* tall shrub) and tundra vegetation. These three monographs included numerous tables of relevés. V. Vasiljev (1956) also published two provisional vegetation maps of the Markovsky and Anadyrsky administrative districts.

Regular field studies of the flora and vegetation of Chukotka started in the late 1960s. The major case studies of vegetation in Chukotka were as follows:

- Detailed mapping of characteristic sites, based on fairly large sets of unpublished relevés (hundreds per study site) (Katenin 1974, 1981, 1984, 1988, Kholod 1984, 1989, 1994).
- Composition, structure, environments, vegetation classification and mapping of landscapes of the relict cryo-xeric (Pleistocene tundra-steppe) vegetation which were focused on cryo-xeric plant communities but also many relevés represent surrounding vegetation and transitional ecotones (Kholod 1983, Kozitskaya & Razzhivin 1985, Slinchenkova 1984, 1994, Yurtsev 1974a,b, 1981, 1986).
- Composition, structure and syntaxonomy of willow and alder shrub vegetation (Sekretareva 1982, 1989, 1990, 1991, 1992, 1994, 1995, 1999, 2001, 2003, Sinelnikova 2001).
- Composition, structure and syntaxonomy of halophytic vegetation (Sergienko 1988, 1989, 2008).
- Syntaxonomy of the tundra vegetation surrounding Lake Elgygytgyn and the mid-Amguema River (Sinelnikova 1992, 1993).
- Various case studies of vegetation accompanied with mostly unpublished relevé datasets.

Figure 1. Detailed vegetation mapping in Chukotka.
1 - characteristic sites in the eastern Chukotka Peninsula,
2 - hot springs sites in the Chukotka Peninsula,
3 - landscapes with relict cryo-xeric (Pleistocene tundra-steppe) vegetation,
4 - Studies of composition, structure, environments of the relict cryo-xeric communities, with vegetation classification and mapping.

Detailed vegetation mapping of the characteristic sites and surroundings of hot springs by A. Katenin (Fig. 1) represents common landscapes of the Chukotka Peninsula (Katenin, 1974, 1981, 1984, 1988, Katenin & Rezvanova 1998). Mapping of each study site was based on hundreds of relevés which were usually marked on aerial photographs and can be georeferenced. The dominant approach was used for vegetation classification but only the names of associations and their dominant species were published, without the relevé tables. Vegetation mapping of Wrangel Island (Kholod 1989, 1994, etc.) and of continental Chukotka (Kholod 1983, 1984) accompanied the complex study of the vegetation and environments of landscapes with relict cryo-xeric (tundra-steppe) vegetation on gentle south-facing slopes. Common vegetation types were also characterized, sometimes with the full list of recognized taxa.

Studies of composition, structure, and environments of the relict cryo-xeric tundra-steppe vegetation, its classification, and mapping of the surrounding landscapes (Fig. 1) also included many relevés representing the surrounding vegetation and transitional ecotones. Two books which included the original relevés were published by B. Yurtsev (1981, 1986). A series of papers also included original relevé data, but most of the collected data remain unpublished (Kholod 2000, Kozitskaya & Razzhivin 1985, Sekretareva, 1998, Slinchenkova 1984, Yurtsev 1974a,b, etc.). The most detailed description of vegetation of Somnitelnaya Bay (Yurtsev 1993) included a vegetation map, detailed descriptions of transects, horizontal structure of communities and many original relevés.

Special attention was paid to composition, structure and syntaxonomy of willow and alder shrub vegetation (Fig. 2). N. Sekretareva published a series of papers on willow shrubs in the eastern part of the Chukotka Peninsula (Sekretareva 1982, 1989, 1990, 1991, 1992) using floristic classification with diagnostic tables of relevés. She continued to study shrub vegetation using the Braun-Blanquet approach in other parts of Chukotka (Sekretareva 1994, 1995, 1999, 2001, 2003), and also in the Polar Urals, the Kharaulakh Range, etc. Two papers on willow and alder shrub vegetation were published by N. Sinelnikova

(2001, Sinelnikova et al. 2001). She also classified tundra vegetation in the area surrounding Lake Elgygytgyn and the mid-Amguema River (Sinelnikova 1992, 1993, 2000).

Coastal flora and vegetation were studied by L. Sergienko (Fig. 2). She published a syntaxonomical overview of the Chukotka halophytic plant communities (Sergienko 1988, 1989, 2008). Several treatments were published describing ecological units like snowbed vegetation (Razzhivin 1994) and the vegetation of anthropogenically disturbed sites (Sumina 1991, 1994, 1995). Extensive study of the Chukotka flora using the "local flora" approach was accompanied by short characterization of the vegetation of the studied localities using common relevé approach with visual estimation of each species' abundance. About 300 local floras were studied during the 1960s to 1990s in the tundra subzones of Chukotka (Fig. 3). Finally, the case study of vegetation in acidic and limestone landscapes of the northeastern Chukotka Peninsula (in the vicinity of Yanrakynnot village) should be mentioned. Occurrence of plants along a soil pH gradient was estimated using more than 300 relevés with environmental data on soil pH, calcium content, soil moisture and snow depth. Some results were published (e.g. Razzhivin 1994), but the original relevés remain mostly unpublished.

The most complete syntaxonomic treatment was published by S. Kholod (2007) on the vegetation of Wrangel Island, which included 29 associations (25 of them are newly described), 1 community type, 18 subassociations, 8 variants and 5 facies. Currently Wrangel Island is the best studied territory of Chukotka, with numerous papers about the vegetation of the island.

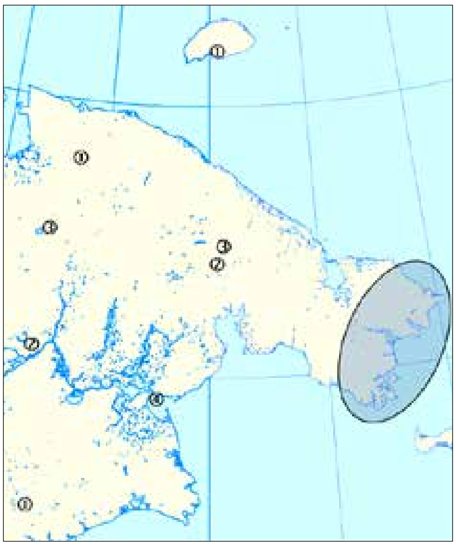

Figure 2. Case studies in Chukotka. 1- and shaded ellipse - composition, structure and syntaxonomy of willow and alder shrubs by N. Sekretareva, 2- syntaxonomy of willow and alder shrubs by N. Sinelnikova, 3 - syntaxonomy of tundra vegetation surrounding Lake Elgygytgyn and the mid -Amguema River by N. Sinelnikova, 4- and shaded ellipse – syntaxonomy and environments of coastal vegetation by L. Sergienko.

In terms of putting Chukotka relevés into a common database, the following difficulties should be taken into account:

- It is difficult to estimate the number of unpublished relevés in the above mentioned case studies and the floristic studies using the "local flora" approach.
- Most of the relevés are archived in field books and standardized field protocols and usually have valuable comments, which are impossible to formalize for databasing but it would be very useful to "attach" scanned images of handwritten pages to the databased relevés.
- A lot of relevés have incomplete lists of cryptogams, but can still be used for e. g. estimating the distributional range of syntaxa;
- Almost all relevé datasets have no coordinates and can only be georeferenced with low accuracy;
- There are almost no published data on the most common zonal low shrub and tussock vegetation communities of Chukotka and it is very important to fill this gap in the nearest future.

The major relevé datasets from Chukotka are currently archived in the Department of Vegetation of the Far North of the Komarov Botanical Institute.

Figure 3. Network of local floras (red stars) studied during the 1960s to 1990s in Chukotka.

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Towards assessing biodiversity feedbacks to climate in the Arctic - future application of the AVA

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Terrestrial ecosystems interact with climate at the local, regional and global scale (e.g., Nobre et al., 1991; Oechel et al., 1993). While climate affects terrestrial ecosystems composition and functioning, vegetation exerts significant feedbacks on atmospheric processes through land-atmosphere exchange of energy and matter (e.g. Feddema et al., 2005; Konings et al., 2011). Land surface schemes of climate models embody these interactions by implementing processes such as the absorption of photosynthetically active radiation, and latent and sensible heat fluxes.

Large scale vegetation changes (tundra to shrubland to forest conversion) and their effects on the shortwave albedo and evapotranspiration in the Arctic are expected to generate strong positive feedbacks to climate warming (Chapin et al., 2005; Swann et al., 2010). However, little is known about the role of vegetation patches and of biodiversity in the land surface energy balance. In the framework of a new research priority programme on global change and biodiversity at the University of Zurich, we will investigate the interactions of biodiversity and energy balance components at the local to pan-Arctic scale using physically based radiation modeling and statistical approaches. The main research question is whether vegetation type and biodiversity influence the radiation fluxes (e.g. albedo, fraction of absorbed photosynthetically active radiation) through structural characteristics such as leaf angle, canopy height, and biomass.

We will investigate this question using field measurements and a 3D radiative transfer model (DART - Discrete Anisotropic Radiative Transfer). The core research site 'Kytalyk' (70°49'28" N, 147°29'23" E) is located in the Indigirka lowlands, Northeastern Siberia (Fig 1). In summer 2013 we established two 1.5 m-tall towers measuring shortwave radiation fluxes over dwarf birch and wet-sedge dominated vegetation patches. These observations will be used to analyze the impact of small-scale vegetation patches (about 10 m diameter) on the radiation balance. Further, plant and bryophyte species and associations are currently being determined. Using vegetation maps of the area based on high-resolution satellite imagery (Geo-Eye), we will upscale energy fluxes and biodiversity measures to the larger site area and compare upscaled results with medium-resolution satellite products.

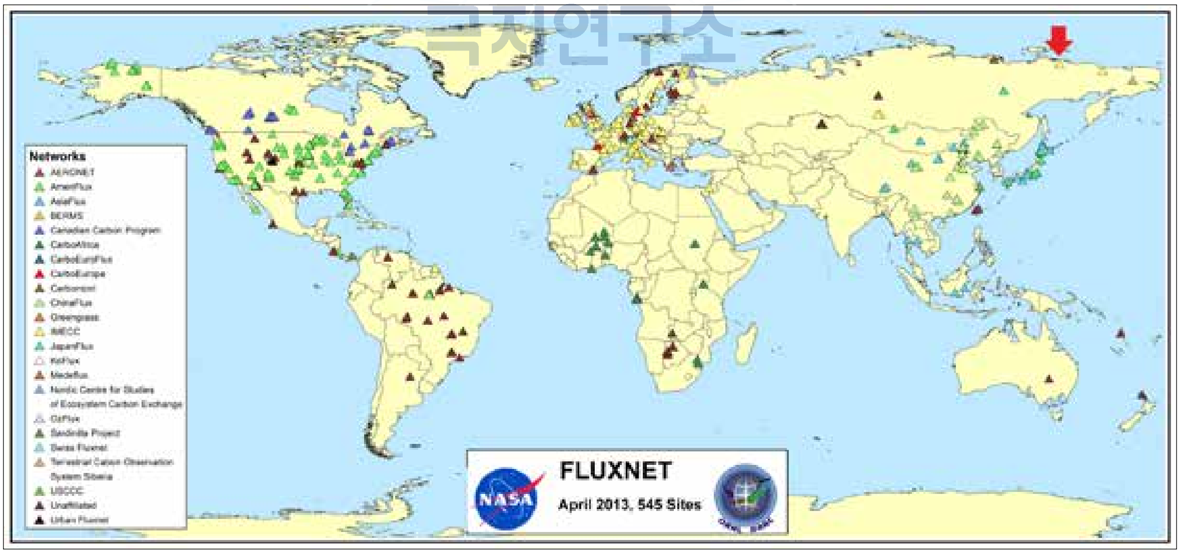

Figure 1. Location of the core research site 'Kytalyk' in NE Siberia. Map courtesy: Oak Ridge National Laboratory Distributed Active Archive Center (ORNL DAAC). 2013. FLUXNET Maps & Graphics Web Page. Available online [http://fluxnet.ornl.gov/maps-graphics] from ORNL DAAC, Oak Ridge, Tennessee, U.S.A. Accessed September 09, 2013.

The second part of our study will focus on the correlations of energy balance components (albedo, evapotranspiration, and their seasonal and interannual variation) with biodiversity measures at pan-Arctic scale. While we hope to contribute with the Kytalyk relevés to the AVA database, we foresee a great potential of the Arctic Vegetation Archive for providing point data on biodiversity. Using spatio-temporal Bayesian hierarchical models, sparse point data will be correlated to spatially continuous fields of energy balance components as inferred from satellite observations. We hope to find interesting results on if and how vegetation patterns and biodiversity influence essential climate variables (ECVs) at local to pan-Arctic scale.

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The Arctic Vegetation Archive as a source for understanding spatial distribution of Arctic biodiversity

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Climate change, species distribution and Arctic ecosystems

Populations of organisms are non-randomly distributed in space, and understanding the distribution of plants and animals on Earth has long fascinated biogeographers (Wallace 1876, MacArthur & Wilson 1967). The accelerating climate change observed in recent years (IPCC 2007) has increased the need for understanding current species' distributions and spatial patterns of community assemblage, to predict the possible consequences of climate change on ecosystems. There is now compelling evidence of ongoing climatic change, and observed changes are predicted to drastically increase in magnitude during this century. In particular, the Arctic is warming faster than any other place on Earth (IPCC 2007, AMAP 2011). Biological impacts are thus expected to be greater in those regions where the rate and magnitude of climate change are greater (Ackerly et al. 2010). Recorded ecological impacts of climate change on the Arctic ecosystem are widespread and encompass not only geographic range shifts of plants (Sturm et al. 2001, Tape et al. 2006, Danby & Hik 2007) and animal species (Killengreen et al. 2007, Vors & Boyce 2009), but also changes in phenology and trophic interactions (Post et al. 2009).

Because anticipation of changes improves our capacity to properly manage landscapes and ecosystems, it becomes increasingly urgent to understand the current drivers of species distributions to forecast species' potential responses to a changing climate. The Arctic is one of the most extreme environments on the planet, with low and variable temperatures, and a short growing season. Arctic species have developed numerous adaptations to tolerate the high stress associated with such a severe environment, often at the expense of competitive abilities (Callaghan et al. 2004). Also, the trophic guilds in arctic food webs are relatively specialized, and therefore changes in the abundance of single key species can have very large impacts on other species in the food web (Schmidt et al. 2012). Despite the hardiness of arctic species, these ecosystems are therefore highly vulnerable to climate change.

Changes in arctic vegetation in response to increasing temperatures over the past decades has already been detected (Callaghan et al. 2005). For instance, in many places shrubs are increasing both in height and cover at the expense of herbs, bryophytes and lichens (Walker et al. 2006, Pajunen et al. 2011, McManus et al. 2012). Once shrubs are established, their success is ensured through positive feedbacks associated with the change in plant functional types (Sturm et al. 2005). Forests are also responding to higher temperatures as well, and trees from the forest/tundra ecotone are shifting northwards into the tundra (Suarez et al. 1999, Lloyd 2005, Danby & Hik 2007). This increase of woody vegetation may cause a reduction in the diversity of plant and animal species adapted to open tundra habitats, especially those species that are iconic of arctic ecosystems (Pellissier et al. 2013). Species that are adapted to arctic climate may be replaced by species from lower latitudes, resulting in a biodiversity turnover and reshuffling of communities, at the expense of typical arctic species (Normand et al. 2013).

Animals are also expected to be affected by climate change. Lemmings, a key herbivore for the functioning of the terrestrial arctic ecosystem, are dependent on a stable snow cover in winter in order to reach high spring densities, which allow specialized arctic predators (e.g. snowy owl and stoat) to breed. With climate change and warmer winters, characteristic lemming cycles have faded out in several regions of the Arctic, with detrimental consequences for their predators (Ims et al. 2008, Gilg et al. 2009). In addition to predators, birds breeding in the tundra, such as waders and geese, are affected by the fading out of lemming cycles, as they constitute alternative prey (Summers et al. 1998, Blomqvist et al. 2002). Such changes affecting the species composition of the different components of the tundra ecosystem, plants, herbivores and predators, are likely to have major impacts on ecosystem functioning. Those changes are expected in turn to affect the services the ecosystems provide to resident human populations.

Species distribution modelling

While field experiments are an ideal tool to isolate individual effects and allow a causal understanding of the natural world, setting up experiments is highly time consuming and often not realistic in complex ecosystems or in vast desolate areas. Collecting data through multiple observations of an event (e.g., occurrence of a species) in nature and relating it to environmental parameters using statistical techniques, even if it cannot allow inferring causal mechanisms, can still be highly useful to understand the system. Species Distribution Models (SDMs) are empirical models relating field observations to environmental predictor variables, based on statistically-derived response surfaces that best fit the realized niche (Hutchinson 1957) of species (Franklin 1995, Guisan & Zimmermann 2000, Guisan & Thuiller 2005). Species data can be simple presence, presence-absence or abundance observations based on random or stratified field sampling. Environmental predictors, for example climatic and edaphic variables, are preferably factors expected to have a causal effect on the species fitness (Austin 2002). SDMs allow spatial predictions indicating locations of the most suitable environment for the species. By changing the input climatic maps in the models, various climate change impact scenarios can be derived. Then, projections may show the locations of future colonization and extinction events. SDMs constitute valuable tools to study the most likely impact of climate change on the distribution of species (Iverson & Prasad 1998, Thomas et al. 2004, Thuiller et al. 2005, Engler et al. 2011), communities (Brzeziecki et al. 1995, Kienast et al. 1998) or diversity (Saetersdal et al. 1998, Bakkenes et al. 2002).

Recent large-scale projections based on SDMs suggest that, in some areas under the most severe climate change scenarios, as much as 60% of species may turnover or be lost in mountain areas (Thuiller et al. 2005, Engler et al. 2011). High species extinction and turnover rates are also predicted by local models in mountain areas (Guisan & Theurillat 2000, Dirnbock et al. 2003, Randin et al. 2010, Engler et al. 2011). Using occurrence data from vegetation and animal surveys in the Arctic, SDMs will aid in similar large-scale projections for the fate of vegetation and of the animals that interact with it under global warming scenarios. Recent projections of the forest coverage in the Arctic following global warming suggest that the arctic tundra may lose an important portion of its current surface causing large biodiversity loss (Gamache & Payette 2005, Roderfeld et al. 2008, Normand et al. 2013). However, observed changes appear to be slow, showing that there is much left to understand in order to get more reliable predictions. There is thus an urgent need to assess how species, as well as assemblages of interacting species such as within food webs, may be affected by climate change in the Arctic.

The Arctic Vegetation Archive as a source for Species Distribution Models

A good spatial coverage of species and communities allows a sound evaluation of how not only species, but also communities and ecosystems, may respond to climate change. Several ecosystem monitoring or research stations exist around the Arctic providing detailed data about ecosystem components and processes at these particular places (e.g. Zackenberg (Jensen 2012), Bylot Island (Cadieux et al. 2008)). However, extreme costs and logistical challenges of field work seriously limit the number of stations. The low number of monitoring stations does not allow for generalizing results found at those locations to the whole Arctic. Long-term monitoring may thus benefit from short-term surveys replicated over large spatial scales.

Biological expeditions to the Arctic are often carried out in the frame of individual research projects, most of which conduct field-work for one to several years in a particular locality. Data are collected for a certain purpose, and no system exists to systematize the generated knowledge on species distributions. In addition, the Arctic is situated in several countries and exchanges or merging of data has not been easy. Some of the data are old and risk being lost if not properly archived and documented. The Arctic Vegetation Archive (AVA) (formerly International Arctic Vegetation Database (IAVD), (Walker & Raynolds 2011)) was started with one of its main goals to unite and harmonize these data and make them available in an open access database (Walker et al. 2013). By merging the vegetation-plot data collected from the Arctic into a common database and complementing it with fieldwork, a large and accessible source of data will be created for investigating and understanding the consequences of climate change on arctic ecosystems more deeply. During several workshops arctic vegetation scientists, database managers and biodiversity modelers have come together and made substantial progress toward reaching this goal. Already several datasets (especially from Greenland and Alaska) have been entered into the database and great effort has been made to track down and identify older data in need of preservation. In addition, the first modeling studies are under way (Walker 2013).

Vegetation data spanning large areas across the Arctic is particularly useful in combination with remote sensing data and climate models. Combining remote sensing data (NDVI, snowcover, surface temperature, topography), climatic information derived from meteorological stations and climatic models (e.g. temperature and precipitation, http://worldclim.org/ (Hijmans et al. 2005)) and plant community data allow better understanding of the drivers of species distribution and assemblage across the Arctic. The observed occurrence of the species at a given site is related to ecologically relevant remote sensing variables (Mac Nally 2000), to model the species' realized niche. This model can then be used to assess which sites in the landscape have conditions that fit the species niche and thus provide potential habitat for the species.

Along with providing the fundamental data needed to quantify species-environmental relationships for predicting future communities, datasets of arctic plant species will provide a window into the historical aspects that have shaped the ecological communities we see today. Because of the strong impact of Pleistocene glaciations on the configuration of faunas and floras in northern regions, species richness is relatively low in many arctic territories (Callaghan et al. 2005). This is notably the case of islands such as Novaya Zemlya or the Svalbard archipelago, which were recurrently overrun by ice, and whose vascular plant flora comprises 185 (Aleksandrova 1988) and 178 (Rønning 1996) species, respectively. Species richness is much higher in several areas in Beringia, which were little affected by the glaciations and are thought to be persistent refugia, harbouring the highest rates of endemism in the Arctic (Murray et al. 1994, Astakhov 2013). For instance, Wrangel Island (that was very little glaciated during the Pleistocene) harbours more than 400 vascular plants, of which 23 are endemics (Petrovskii 1985, Yurtsev 1987). In comparison the whole Canadian archipelago only harbours 349 vascular plants (Aiken et al. 2007). Hence, species distribution and richness depends not only on climate and other environmental conditions, but also on colonization and speciation history, which should be accounted for when explaining species' distributions and richness. Thus, the AVA may also provide information on the historical factors that shaped plant diversity across the Arctic. In addition, because it includes data on species cover and not just presence-absence data, AVA can contribute to understanding the role of some important biotic interactions in shaping plant communities (Wisz et al. 2013)

Modelling studies in the Arctic

Compared to other parts of the world, few modelling studies have been carried out in the Arctic, and they are generally focused on a smaller part of the region. Svalbard is a region in the Arctic with a well-known flora and with plentiful ancillary data layers available. Nilsen et al. (2013) modelled vascular plant diversity based on data from 184 sites distributed around the archipelago. Using forward stepwise multiple regression, they showed that the best predictors of vascular plant diversity are growing season temperature, mean July precipitation and 'normalized difference vegetation index' (NDVI). Also working in Svalbard, Beck et al. (2005) modelled the occurrence and abundance of a single species, *Dryas octopetala* around the fjord Kongsfjorden. Temperature, topographical exposure and inclination of a site seemed to promote both occurrence and abundance. Occurrence was negatively influenced by snow and water cover and they argue that models predicting local distribution of plant species in the Arctic would greatly benefit from data on the distribution and duration of snow cover. In Fennoscandia, modelling studies have highlighted the role of plant competition in shaping the plant species distribution (Pellissier et al. 2010, le Roux et al. 2012, le Roux et al. 2013). A study modelling range shifts of the Arctic fox in Fennoscandia (Hof et al. 2012) has likewise shown that incorporating biotic interactions in their model, increased the ability to predict the species range. Plant distribution data coupled with environmental predictors and statistical techniques shows great promise to similarly provide valuable information to increase our understanding of the Arctic ecosystem.

Species distribution models may also shed light on past and future dynamics of species under climate change on a larger scale. Normand et al. (2013) used potential treeline and climatic niche modelling of 56 Greenlandic, North American and European tree and shrub species to project shifts in areas climatically suitable for tree growth. Their results show that a majority of non-native species find climatically suitable habitats in certain parts of Greenland today. The projected climatic scope for future expansions is strongly limited by dispersal, and human spread could have potentially large impacts on the Greenlandic flora (Normand et al. 2013). Espindola et al. (2013) modelled the range of *Trollius europeaus* through time since the last glacial maximum and showed that reconstruction of colonization routes allows forecasting the spatial distribution of the species' genetic structure.

To our knowledge, so far no studies have been able to model the Arctic as a whole based on plot data covering this entire biome. When finished, the AVA will be a milestone providing unique opportunities for modelling species distributions and richness patterns on a circumpolar scale, since this database will be the first to represent an entire global biome (Walker et al. 2013).

Conclusion

By bringing together circumpolar georeferenced data on plant occurrences, cover of plant functional types and physical site characteristics such as aspect, slope, and soil properties, the AVA has the potential to aid us in understanding arctic diversity patterns, both alpha, beta and gamma. It can also help us to better understand plant community ecology, and thereby also give insights into plant-herbivore interactions by providing information on where food sources are available. If supplemented with extant spatial genetic structure, the AVA could also assist in inferring how climate change impacts species genetic structure. With the creation of the AVA we will be able to hind cast species distributions to past climate in order to better understand re-colonization patterns, and last but not least we will be able to forecast how species, communities and ecosystems will respond to the ongoing climate changes, which can help us manage landscapes and ecosystems.

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Plant communities of southern hypoarctic tundra of the Anabar River basin (North-West Yakutia)

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Introduction

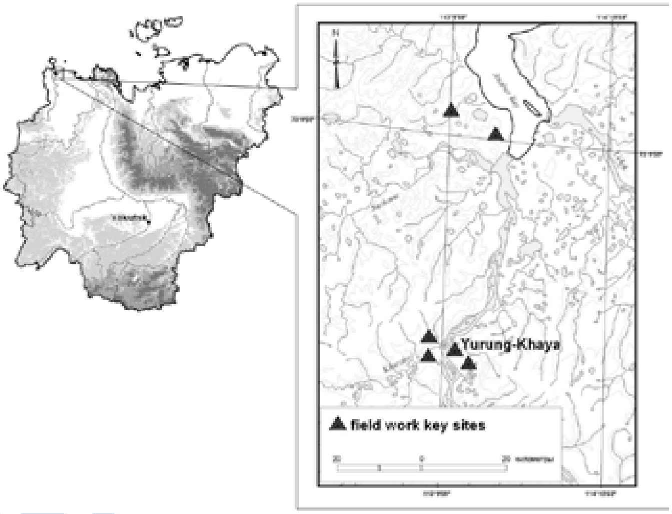

Figure 1. The Yurung-Khaya study area.

During the summer of 2011, a complex study of hypoarctic tundra ecosystems was conducted at the monitoring site Yurung-Khaya. This site is located 7.5 km south of the Yurung-Khaya settlement, Anabar Region, North-West Yakutia (Fig. 1). According to the *Map of Vegetation Zones and Altitudinal Zonation Types of Russia and Adjacent Territories* by Ogureeva (1999), the study area belongs to the Subzone of the Middle Siberian southern hypoarctic (shrub) tundra (northern stripe) and Subzone of Middle Siberian (Taimyr) northern hypoarctic (typical) tundra. The main objective of our research was to conduct studies of syntaxonomy and to map vegetation.

The previous generation of investigators reported on patterns of vegetation cover in the Yakutian part of the Arctic using the ecological-phytocoenotic method of vegetation classification (Perfilyeva et al., 1991). More recently, the participants of North-East Federal University's grant program on the Arctic conducted work on a classification based on the Braun-Blanquet approach. The vegetation diversity of the Anabar tundra is represented by 8 associations and 2 subassociations belonging to 3 classes of ecological-floristic classification (*LOISELEURIO-VACCINIETEA* Eggler ex Schubert 1960, *SALICETEA HERBACEAE* Br.-Bl. 1948, and *CARICI RUPESTRIS-KOBRESIETEA BELLARDII* Ohba 1974). The position of a new association ***Triseto sibirici-Astragaletum umbellati*** Telyatnikov, Lashchinskiy, Troeva ass. nova hoc loco is still undetermined. All associations and subassociations were distinguished for the first time. A new alliance ***Carici concoloris-Aulacomnion turgidi*** was also distinguished belonging to order ***Rhododendro-Vaccinietalia*** of class *LOISELEURIO-VACCINIETEA* (Telyatnikov et al., 2013). The authors base their work upon the results of previous studies of tundra vegetation in Taymyr Peninsula conducted by Dr. N.V. Matveyeva (Komarov Botanical Institute, Saint-Petersburg), as well as on an up-to-date conspectus of the vegetation of Russia (Ermakov 2012).

Prodromus

The prodromus of the studied vegetation of the Anabar tundra is as follows (Telyatnikov et al., 2013):

Class *Loiseleurio-Vaccinietea* Eggler 1952
Order *Rhododendro-Vaccinietalia* Br.-Bl. in Br.-Bl. et Jenny 1926
Alliance *Carici concoloris-Aulacomnion turgidi* all. nova hoc loco
Ass. *Carici concoloris-Hylocomietum splendentis* ass. nova hoc loco
Subass. *typicum* subass. nova hoc loco
Subass. *orthilietosum obtusatae* subass. nova hoc loco
Ass. *Pedicularido oederi-Aulacomnietum turgidi* ass. nova hoc loco
Alliance *Loiseleurio-Diapension* (Br.-Bl., Siss. et Vlieg.1939) Daniels 1982
Ass. *Alectorio nigricantis-Diapensietum obovatae* ass. nova hoc loco

Class ?
Order ?
Alliance ?
Ass. *Triseto sibirici-Astragaletum umbellati* Telyatnikov, Lashchinskiy, Troeva ass. nova hoc loco

Class *Salicetea herbaceae* Br.-Bl. 1948
Order *Salicetalia herbaceae* Br.-Bl. in Br.-Bl. et Jenny 1926
Alliance *Salicion polaris* Du Rietz 1942 em. Hadac 1989
Ass. *Eutremo edwardsii-Sanionietum uncinatae* ass. nova hoc loco
Ass. *Saxifrago tenuis-Salicetum polaris* ass. nova hoc loco

Class *Carici rupestris-Kobresietea bellardii* Ohba 1974
Order *Kobresio-Dryadetalia* (Br.-Bl. 1948) Ohba 1974
Alliance *Oxytropidion nigrescentis* Ohba 1974
Ass. *Rhytidio rugosi-Dryadetum punctatae* Matveyeva 1998
Subass. *artemisietosum furcatae* subass. Telyatnikov, Lashchinskiy, Troeva subass. nova hoc loco
Ass. *Rhodiolo roseae-Astragaletum alpini* ass. nova hoc loco

Distribution of plant communities

The confinement of plant communities of the above mentioned associations to various landform types is represented in Figure 2.

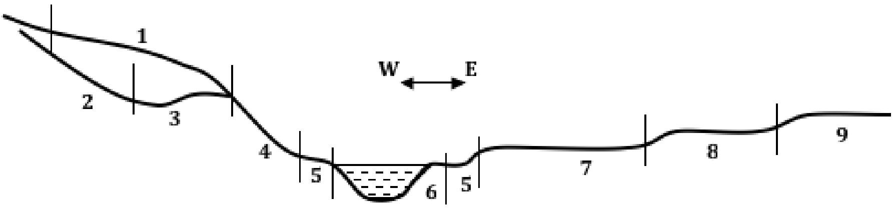

Figure 2. Topographical transect showing distribution of plant communities in Anabar tundra. Communities are represented by the following associations: 1 - Rhytidio rugosi-Dryadetum punctatae; 2 - Saxifrago tenuis-Salicetum polaris; 3 - Eutremo edwardsii-Sanionietum uncinatae; 4 - Rhodiolo roseae-Astragaletum alpini; 5 - Triseto sibirici-Astragaletum umbellati; 6 – sedge and cotton-grass communities of class Phragmiti-Magnocaricetea; 7 - Carici concoloris-Hylocomietum splendentis; 9 - Pedicularido oederi-Aulacomnietum turgidi; 10 - Alectorio nigricantis-Diapensietum obovatae.

Dryas tundra communities of *Rhytidio rugosi-Dryadetum punctatae* (Association 1, Fig. 2) are confined to edges of valley slopes, convex parts of watershed areas featuring proper drainage, shallow snow cover in winter time, and strong snow and wind corrosion throughout the whole studied territory. Willow-forb meadow-tundra (ass. *Saxifrago tenuis-Salicetum polaris*) (Association 2, Fig. 2) are characteristic for the middle and lower parts of gentle and steep (up to 35°) concave slopes with an eastern aspect. Snowbed swamped meadow-tundra with predomination of *Salix polaris* and green mosses (ass. *Eutremo edwardsii-Sanionietum uncinatae* (Association 3, Fig. 2) are located on lower and middle parts of concave slopes (facing southwest and west) within the typical tundra subzone. In the same subzone, upper and middle parts of well-drained watershed slopes feature grass-forb meadow-tundra communities of ass. *Rhodiolo roseae-Astragaletum alpini* (Association 4, Fig. 2). Coenoses of ass. *Triseto sibirici-Astragaletum umbellati* (Association 5, Fig. 2) represent riparian shrubby grass-forb-Sanionia cryophytic meadows framing the lower parts of moderately steep slopes of channel and creek valleys in the southern tundra subzone. Flat landforms both in southern and typical tundra bear polygonal-ridge complexes of cryogenic origin. Newly developed ridges are the habitat for shrub-sedge-lichen-green moss tundra communities of ass. *Carici concoloris-Hylocomietum splendentis* (Association 7, Fig. 2) that feature participation of hygro- and hygromesophytic species. Herb-lichen-green moss-*Dryas* tundra of ass. *Pedicularido oederi-Aulacomnietum turgidi* (Association 8, Fig. 2) are characteristic for typical tundra subzone and occur on gentle slightly convex slopes (basically facing west) of watersheds with moderate drainage. They may replace the communities of the previously mentioned association in a natural succession series. Dwarf shrub-green moss-lichen tundra communities of ass. (Association 9, Fig. 2) cover moderately steep and slightly convex slopes (mainly northwest aspect) or flat hills in tundra-bog complexes (Tleyatnikov et al., 2013).

Concluding remarks

There are also data on azonal vegetation types (*VACCINIO-PICEETEA* Br.-Bl. in Br.-Bl. et al. 1939; *ASPLENIETEA TRICHOMANIS* (Br.-Bl. in Meier et Br.-Bl. 1934) Oberd. 1977; *THLASPIETEA ROTUNDIFOLII* Br.-Bl. 1948; *SCHEUCHZERIO-CARICETEA FUSCAE* Tx. 1937; *OXYCOCCO-SPHAGNETEA* Br.-Bl. et Tx. ex Westhoff et al. 1946; *PHRAGMITI-MAGNOCARICETEA* Klika in Klika et Novák 1941; *MATRICARIO-POETEA ARCTICAE* Ishbirdin 2002; *PUCCINELLIO-HORDEETEA JUBATI* Mirkin in Gogoleva et al. 1987) which are still under discussion.

In 2012, the authors supplemented their work with new field data on the vegetation of the Kolyma River basin and the Lena River Delta. These data are at the sample analysis stage and therefore not presented herein.

Plant species determination (higher vascular plants, mosses, lichens), required for vegetation classification issues, were made by the specialists of Komarov Botanical Institute, Russian Academy of Science (Saint-Petersburg), Central Siberian Botanical Garden, Siberian Branch of the Russian Academy of Science (Novosibirsk), and the Institute for Biological Problems of Cryolithozone, Siberian Branch of the Russian Academy of Science (Yakustk).

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