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Rescuing Valuable Arctic Vegetation Data for Biodiversity Models, Ecosystem Models and a Panarctic Vegetation Classification

by D.A. Walker, I.G. Alsos, C. Bay, N. Boulanger-Lapointe, A.L. Breen, H. Bültmann, T. Christensen, C. Damgaard, F.J.A. Daniëls, S. Hennekens, M.K. Raynolds, P.C. Le Roux, M. Luoto, L. Pellissier, R.K. Peet, N.M. Schmidt, L. Stewart, R. Virtanen, N.G. Yoccoz and M.S. Wisz

INTRODUCTION

Two workshops held in Roskilde, Denmark, on 29–31 May and 17–19 December 2012, brought together key Arctic vegetation scientists and biodiversity modelers to discuss the rich source of species-distribution information for plant biodiversity modeling studies contained in Arctic vegetation-plot (relevé) data. Georeferenced plot-based vegetation data are needed to understand factors that shape Arctic plant communities, to map distributions of plant species and communities, and to assess vegetation changes over space and time by using predictive models. Such research is especially important now because the Arctic vegetation is responding rapidly to the effects of climate change (Callaghan et al., 2005). The workshops had three main goals: 1) to develop a strategy for harmonizing the relevé data and database approaches available in the various Arctic countries to create an International Arctic Vegetation Database (IAVD, Walker and Raynolds, 2011) and a list of accepted Arctic vegetation species names and their synonyms to be used in that database; 2) to lay the foundation for prototype vegetation databases for Greenland and northern Alaska; and 3) to highlight promising methods for modeling and predicting biodiversity trends from patterns in the plant distribution data. Sponsors for the workshops were the Nordic Network on Climate and Biodiversity (CBIO-NET) project; Conservation of Arctic Flora and Fauna (CAFF), the biodiversity monitoring arm of the Arctic Council; and the University of Aarhus.

CBIO-NET AND DATA NEEDS FOR ARCTIC PLANT SPECIES DISTRIBUTION MODELS

Documenting Arctic plant species and understanding their distributions are important steps toward predicting changes at all trophic levels in Arctic terrestrial ecosystems. CBIO-NET's major objective is to increase our understanding of how climate change affects ecosystems and biodiversity. Ecosystem models and predictive models make up an important part of CBIO-NET's activities. A wide variety of species distribution modeling tools are already available and can be applied to predict historical, present, and future vegetation and plant distributions. These data can help refine predictions of ecosystem change, such as gas exchange between tundra vegetation and the biosphere. New advances in these methods offer the possibility to incorporate information on biotic interactions (Wisz et al., 2013) and phylogeographic history (Espindola et al., 2012) to fill gaps in information about distributions over space and time.

Addressing biodiversity questions in the Arctic is a challenging task, however, because the information on vegetation patterns, which is essential to quantify species-environmental relationships and make ecosystem-level predictions, contains large gaps. The large body of vegetation plot data collected across the Arctic during the past century could provide a key missing link needed to derive predictive models of future distributions under different climate-change scenarios.

THE INTERNATIONAL ARCTIC VEGETATION DATABASE INITIATIVE

The goal of the IAVD (Walker and Raynolds, 2011) is to unite and harmonize the vegetation 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. This open access database would be the first to represent an entire global biome. Arctic vegetation data are especially valuable because of the large time, cost, and even risk associated with their collection in remote areas of the Arctic; however, they are scattered across many institutions in a variety of formats. Some data are maintained in electronic databases managed by various research groups working in the Arctic, while other data have not yet been electronically catalogued. Several of the botanists who collected this uncatalogued information are retired or deceased, so there is an urgent need to add these data to the electronic database before they are lost. The IAVD is a coordinated effort to accelerate the preservation of these data and harmonize them for use in comparative studies.

The concept of the IAVD was first proposed in 1992 at the International Arctic Vegetation Classification Workshop in Boulder, Colorado (Walker et al., 1994). That meeting strongly stimulated international interest in Arctic plant-community research. The idea was revived in 2004, at the Second International Workshop on Circumpolar Vegetation Classification and Mapping in Tromsø, Norway (Daniëls et al., 2005), and in 2007, the CAFF Flora Group endorsed it at the 4th International CAFF Workshop in Tórshavn, Faroe Islands (Talbot et al., 2008). The Circumpolar Arctic Vegetation Map (CAVM) was the first major step toward fulfilling the ideas from the Boulder workshop (Walker et al., 2005). Plot-level plant-community information, which had been gathered for local and national vegetation classifications and maps, was reviewed during the process of making the CAVM. Recent developments in database methods (Schaminée et al., 2009) now make it feasible to assemble an Arctic-wide vegetation database from these data. More than 20 000 relevés are available for inclusion in the database (Walker and Raynolds, 2011, updated).

HARMONIZING SPECIES NAMES, SAMPLING APPROACHES AND DATABASE METHOD

One of the first challenges in developing the IAVD is to produce a single accepted list of all the known vascular plants, lichens, and bryophytes and their synonyms. At the first CBIO-NET – IAVD workshop in Roskilde, Robert Peet (University of North Carolina) presented an overview of the species-name challenges in developing a vegetation database and how this issue has been addressed in VegBank, the plot database used in the United States for the U.S. National Vegetation Classification (Peet et al., 2012). Taxonomists working in conjunction with CAFF have developed lists of currently accepted species names for the vascular plants, lichens, and mosses. At the second CBIO-NET workshop in Roskilde, Amy Breen (University of Alaska Fairbanks, UAF), Helga Bültmann (University of Münster), Martha Raynolds (UAF), Stephan Hennekens (Alterra, Wageningen, The Netherlands), and Skip Walker (UAF) presented the first draft of the PanArctic Species List (PASL v. 1.0), which combined the CAFF lists into a single list of accepted names with their synonyms. A second draft of the checklist will be prepared in time for the next IAVD workshop, scheduled for 14 – 16 April 2013 in Krakow, Poland, and should be generally available and published by late 2013. Members of the species-list team will update the list regularly. Finn Brochsenius (Aarhus University) discussed how the Arctic species database could be linked to the Global Biodiversity Information Facility (GBIF). Simple synonym lists, however, do not allow full integration of plot data collected across many places and many years, so once the initial list of accepted names is developed, it would be highly desirable to map other lists onto it using taxon concept relationships as is done in the VegBank species lists.

Taxonomic issues are not the only challenge: methods for quantifying and inventorying vegetation coverage have also varied over the years and in different places. For example, subjective means of estimating species cover most commonly used in vegetation plot data, such as the seven class Braun-Blanquet cover-abundance scores, can be used for vegetation classification and to derive complete species lists for small plots, but they are of limited value for monitoring quantitative changes in species cover. A variety of point-intercept methods are widely used for this purpose, but these methods have limited value for purposes of classification and developing complete species lists. During the first workshop in Roskilde, Christian Damgaard (Aarhus University) presented a novel method in a Bayesian framework for harmonizing data derived from point-intercept and Braun-Blanquet relevés (Damgaard, 2012). Such methods are promising for bolstering the data available for comparative, long-term studies across the Arctic, where diverse data collection methods have been practiced.

One of the principal products that would be derived from the IAVD is a panarctic vegetation classification system, which is indispensable for further ecological and biodiversity research, predictive modeling, and conservation management in Arctic regions. Two main approaches to Arctic vegetation classification are prevalent. A mainly European approach (Westhoff and van der Maarel, 1978) has been used extensively in both the Eurasian and the American Arctic, but has not been widely accepted elsewhere in North America. An American approach used for the United States and Canadian national vegetation classifications (Faber-Langendoen et al., 2009) is similar to the European approach at the lowest level of the classification hierarchies, but fundamental differences in structure of classification approaches, different traditions and history, and other practical problems make it difficult to make the systems totally compatible. Plant associations described according to the European approach can be included in the American vegetation classification systems, but the reverse is not easily accomplished without considerable additional attention to the naming and publication of the plant communities according to an international code of phytosociological nomenclature (Weber et al., 2000). There is a need to harmonize the European and American approaches (De Cáceres and Wiser, 2012), especially in the Arctic, because the Arctic tundra is now regularly viewed as a single system in many models and circumpolar forums.

A large body of recent international experience for developing national databases will help to make the IAVD a reality. The participants at the first Roskilde workshop agreed that the Turboveg database management system (Hennekens and Schaminée, 2001) is the best option for initial data entry and management because this system is widely used in Europe and worldwide for several national classifications and is compatible with SynBioSys Europe

(Schaminée et al., 2007) and the European Vegetation Archive (EVA), the database initiative of the European Vegetation Survey (Chytrý et al., 2012). The data will be permanently archived in the EVA and VegBank. A protocol for importing information from Turboveg to VegBank will need to be developed using the Veg-X exchange standard (Wiser et al., 2011). The metadata for the IAVD will be entered into the Global Index of Vegetation Plot Databases (GIVD) (Dengler et al., 2011). Members of the CAFF Flora Group will manage the database, and data will be disseminated through the CAFF ArcticData Portal (http://www.arcticdata.is/). Tentative plans are for the IAVD to be maintained in VegBank and also made available through EVA. Vegetation records, community types, and plant taxa may be submitted to VegBank and may subsequently be searched, viewed, annotated, revised, interpreted, downloaded, and cited. Archives such as VegBank and EVA will allow a flexible system for archiving and retrieving the data.

The focus of the IAVD is on vegetation plot data (relevé data), which include complete lists of all species (vascular plants, lichens, and bryophytes) and their estimated cover from plots of known area. Relatively consistent protocols are used across the Arctic. Other valuable types of vegetation data, such as point-intercept data and other types of community and species-specific vegetation data, are in highly variable formats. It was decided at the first Roskilde workshop that these other types of data should be recovered and described in a metadatabase and archived in the GIVD and in a central Arctic data facility, such as that being developed for northern Alaska.

GREENLAND AND ALASKAN PROTOTYPES

One of the first steps in the IAVD effort will be to develop prototype databases for Greenland and Alaska, where a wealth of vegetation plot data collected using the European approach already exists in digital format. Greenland is the Arctic country with the longest north-south coast, resulting in a complete Arctic climatic gradient from the subarctic to the extreme High Arctic along both the east and west coasts, and from the maritime coast to the continental inland ice margins along the extensive fjord systems. These gradients make Greenland particularly well suited for informing climate-change research and the study of changes as plant species shift their ranges. Professor Emeritus Fred Daniëls (University of Münster) described data collected during his 15 expeditions to Greenland since the 1960s. Christian Bay (Aarhus University) presented an overview of other Greenland data sets. During the workshops, Daniëls, Bay, and Bültmann agreed to contribute as many as 2000 Greenland vegetation plots (relevés) to the database. At least 1500 of these will be available in the next year. In North America, Breen, Raynolds, and Walker will assemble about 1000 relevés into a northern Alaska prototype. The Alaska Geobotany Center maintains the Alaska data (http://www.geobotany.uaf.edu/iavd/posters.php). During the second workshop in Roskilde, several participants were invited to submit other datasets for possible inclusion in the database. Esther Lévesque and Noémie Boulanger-Lapointe (Université du Québec à Trois-Rivières) submitted data from northeastern Canada, and Risto Virtanen (University of Finland) submitted data gathered from 1342 plots in the Eurasian Arctic during the 1990–94 Russian-Swedish tundra expedition (e.g., Virtanen et al., 2006). During this exercise, several important issues were identified that need to be addressed in preparation for the next IAVD workshop.

PREDICTIVE MODELS

Quantifying and predicting changes in Arctic ecosystems requires a sound understanding of the processes that sustain biodiversity and ecosystem function over time, and vegetation plots replicated in time and space are crucial to shape this understanding. During both workshops in Roskilde, collaborators from the CBIO-NET project presented methods for integrating spatially explicit vegetation and remote sensing data with new spatial modeling tools such as stacked spatial distribution models (SDMs) and structural equation models. A diverse set of papers described some recent applications of SDMs and other approaches to issues related to Arctic biodiversity. Topics included biological responses controlled by geodiversity, geomorphic processes, herbivory, and climate effects on biodiversity and the tree line (e.g., Luoto and Heikkinen, 2008; Virtanen et al., 2010); Arctic plant distribution changes related to history of glaciation, species origins, plant functional types, and velocities of change (Wisz et al., 2013); applications of DNA metabarcoding in soils to questions of biodiversity (e.g., Yoccoz et al., 2012); and genetic consequences of climate change in northern plants (e.g., Alsos et al., 2012). Consolidation of the existing information about vegetation plots into the IAVD is an essential element required for successful application of the SDMs. Although it will take many years to harvest all the existing data, large amounts of data are relatively accessible now, and good progress is expected in the next few years.

NEXT STEPS

It is important now to involve the full Arctic vegetation-science community to begin the large task of assembling data from the whole Arctic. Other vegetation databases are being developed in Canada and Russia, and these need to be integrated into the Arctic-wide effort. Proposals will need to be developed to ensure that there are funds and personnel for full participation from the widest group of Arctic scientists possible. An Arctic-wide IAVD meeting is planned for the Arctic Science Summit Week in Krakow, Poland, in April 2013. Vegetation scientists from the circumpolar nations will gather to review the status of Arctic vegetation data in their respective countries, update their knowledge of the latest vegetation database technology, and formalize future plans for the IAVD.

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D.A. Walker, M.K. Raynolds, and A.L. Breen (also with the International Arctic Research Center, University of Alaska Fairbanks) are with the Alaska Geobotany Center, Institute of Arctic Biology, University of Alaska Fairbanks; I.G. Alsos is with the Tromsø University Museum, Tromsø, Norway; C. Bay, T. Christensen, L. Pellissier (also with Faculty of Biology and Medicine, Department of Ecology and Evolution, University of Lausanne, Lausanne, Switzerland), N.M. Schmidt (also with the Arctic Research Centre (ARC), Aarhus University, Århus, Denmark), L. Stewart (also, Greenland Climate Research Centre (GCRC), Greenland Institute of Natural Resources, Nuuk, Greenland), and M.S. Wisz (also with ARC and GCRC) are affiliated with the Department of Bioscience, Aarhus University, Roskilde, Denmark; N. Boulanger-Lapointe is with the Department of Geography, University of British Columbia, Vancouver, Canada; H. Bültmann and F.J. Daniëls are at the Institute of Biology and Biotechnology of Plants, University of Münster, Germany; C. Damgaard is with the Department of Bioscience, Aarhus University, Silkeborg, Denmark; S. Hennekens is at Alterra, Wageningen UR, the Netherlands; P.C. Le Roux and M. Luoto are at the Department of Geosciences and Geography, University of Helsinki, Finland; R.K. Peet is at the Department of Biology, University of North Carolina, Chapel Hill, North Carolina, USA; R. Virtanen is at the Department of Biology, University of Oulu, Oulu, Finland; and N.G. Yoccoz is at the Department of Arctic and Marine Biology, University of Tromsø, Norway.

The corresponding author for the IAVD project is D.A. Walker (dawalker@alaska.edu), and the corresponding authors for the CBIO-NET project are Mary Wisz (msw@dmu.dk) and Christian Damgaard (cfd@dmu.dk).