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Cover photo: Arrigetch Peaks, Brooks Range, Alaska, location of the first application of the Braun-Blanquet approach to vegetation classification and analysis in northern Alaska. Photo: David Cooper

Back cover photo: David Cooper, Tom Cottrell, and Bill Newmark, members of the 1979 Arrigetch Peaks Expedition. Photo: David Cooper.

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CAFF Designated Area

A rich nonacidic tundra plant community, Sagwon Upland, Northern Alaska, Dryado integrifoliae-Caricetum bigelowii Walker et al. 1994 var. Lupinus arcticus, described by Anja Kade. Common species include: Anemone parviflora, Arctagrostis latifolia, Arctstaphylos rubra, Astragalus umbellatus, Aulacomium turgidum, Cardamine hyperborea, Carex bigelowii, C. membranacea, C. scirpoidea, C. vaginata, Cassiope tetragona, Castilleja caudata, Cetraria islandica, Cladonia pyxidata, C. posillum, Dactylina arctica, Dicranum spadacium, Distichium capillaceum, Ditrichum flexicaule, Dryas integrifolia, Eriophorum angustifolium ssp. triste, E. vaginatum, Equisetum arvense, E. variegatum, E. scirpoidea, Flavocetratia cucullata, F. nivalis, Hedysarum alpinum, Hylocomium splendens, Hypnum bambergeri, Kobresia myosuroides, Lupinus arcticus, Minuartia arctica, Oxytropis maydelliana, Papaver macounii, Parrya nudicaulis, Pedicularis capitata, P. kanei, P. langsdorfii, Polygonum bistorta ssp. plumosum, Polygonum viviparum, Pyrola grandiflora, Rhododendron lapponicum, Salix glauca, S. lanata ssp. richardsonii, S. arctica, S. reticulata, Saussurea angustifolia, Saxifraga hieracifolia, Senecio atropurpureus, S. resedifolius, Stellaria longipes, Tofieldia pusilla, Tomentypnum nitens, Rhytidium rugosum, Thamnolia subuliformis. Photo: D.A. Walker.

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Acknowledgements

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Preface

D.A. (Skip) Walker

Alaskan Arctic vegetation scientists met in Boulder, Colorado, 14-16 October 2013, to discuss an Alaska Arctic Vegetation Archive (AAVA). The archive will contain species and environmental data for most of the documented vegetation plots in northern Alaska, and is one of two prototype databases being made in preparation for building an Arctic-wide Vegetation Archive (AVA) (Walker et al. 2013).

This volume contains 20 abstracts from papers presented at the meeting. Most of the abstracts describe details of datasets collected by the authors in Arctic Alaska and Canada. Several others describe database approaches that have been used in the US, Canada, and Europe that potentially could be useful for the AAVA. The first abstract by Amy Breen and coauthors describes the current state of the AAVA, and provides the workflow and latest version of the data dictionary that is being used.

The AAVA will be an open-access community resource. We will strive to insure continued involvement of the original authors of the data, encourage them to publish their own papers using the data, and strongly encourage others to include the original data collectors as authors on papers that use their data. I am sorry we could not have invited more vegetation scientists who have collected Arctic Alaska data. We had only a small grant for travel funds, but we will continue identifying potentially useful data sets, and hopefully not miss any key data.

A highlight of the meeting was Dr. David Cooper's keynote talk. Dr. Cooper was the first to apply the Braun-Blanquet approach to vegetation analysis for his Ph.D. studies in the Arrigetch Mountains, AK (Cooper 1986). The cover of this volume shows this spectacular group of mountains and the three members of his 1979 expedition.

The meeting was held in Boulder, Colorado because several of the participants live and work in the Front Range region or nearby, thus minimizing transportation costs. Also, the idea for making an Arctic vegetation database was first discussed at the International Workshop on Classification of Arctic Vegetation, held 21 years ago in Boulder. Marilyn Walker was the leader of the 1992 Workshop and she also arranged the 2013 AAVA meeting. Thanks, Marilyn! We are indebted to many other very early Alaska-vegetation-research pioneers who collected some of the foundation datasets.

References:

Cooper, D. J. 1986. Arctic-alpine tundra vegetation of the Arrigetch Creek Valley, Brooks Range, Alaska. *Phytocoenologia* 14:467–555.

Walker, D. A., A. L. Breen, M. K. Raynolds, and M. D. Walker (Eds.). 2013. Arctic Vegetation Archive Workshop, Krakow, Poland April 14-16, 2013. CAFF Proceedings Report #10.

Walker, M. D., F. J. A. Daniels, and E. Van der Maarel. 1994. Circumpolar arctic vegetation: Introduction and perspectives. Special Features in Journal of Vegetation Science 5:757–920.

Abstracts

in alphabetical order of the first author

Progress toward an Alaska prototype for the Arctic Vegetation Archive: Workflow and data dictionary

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Introduction

The creation of an Alaska prototype for the Arctic Vegetation Archive is underway. A survey of key vegetation-plot data from Arctic Alaska is complete. The vegetation-plot, or relevé, data that are appropriate for classification and analysis using the Braun-Blanquet approach were obtained directly from the author, or from the literature, and are now nearly all digitized (Table 1).

The basis for the archive is TURBOVEG (v. 2.99; Hennekens & Schaminée 2001), a comprehensive data management system for vegetation-plot data. Two essential elements to harmonize disparate datasets for use of TURBOVEG are an archive-specific species list and data dictionary. We therefore constructed the PanArctic Species List to provide a standard for species nomenclature (Raynolds et al. 2013). We also recently reached agreement on common data standards and constructed a data dictionary (described herein).

The Alaska Arctic Vegetation Archive (AAVA) will be made available to the public through the Arctic Alaska Geoecological Atlas web portal (Wirth et al. 2014, this workshop). We established a workflow to outline the steps we will take to go from gathering data, to importing vegetation-plot data into databases, to populating the plot archive on the Atlas. Herein, we present the archive workflow and the standards developed for the data dictionary.

Archive Workflow

The Alaska Arctic Vegetation Archive workflow is dynamic, and not necessarily linear (Fig. 1). The main products derived from the process are a TURBOVEG database and the web portal used to visualize and obtain vegetation-plot data available from across Arctic Alaska. In addition, we will create an archive bibliography, deposit plot data into VegBank and write associated metadata. We will also provide access to raw species and environmental tables, publications and data reports, and ancillary datasets (eg, biomass and spectral data). The individual steps that comprise the workflow are listed below.

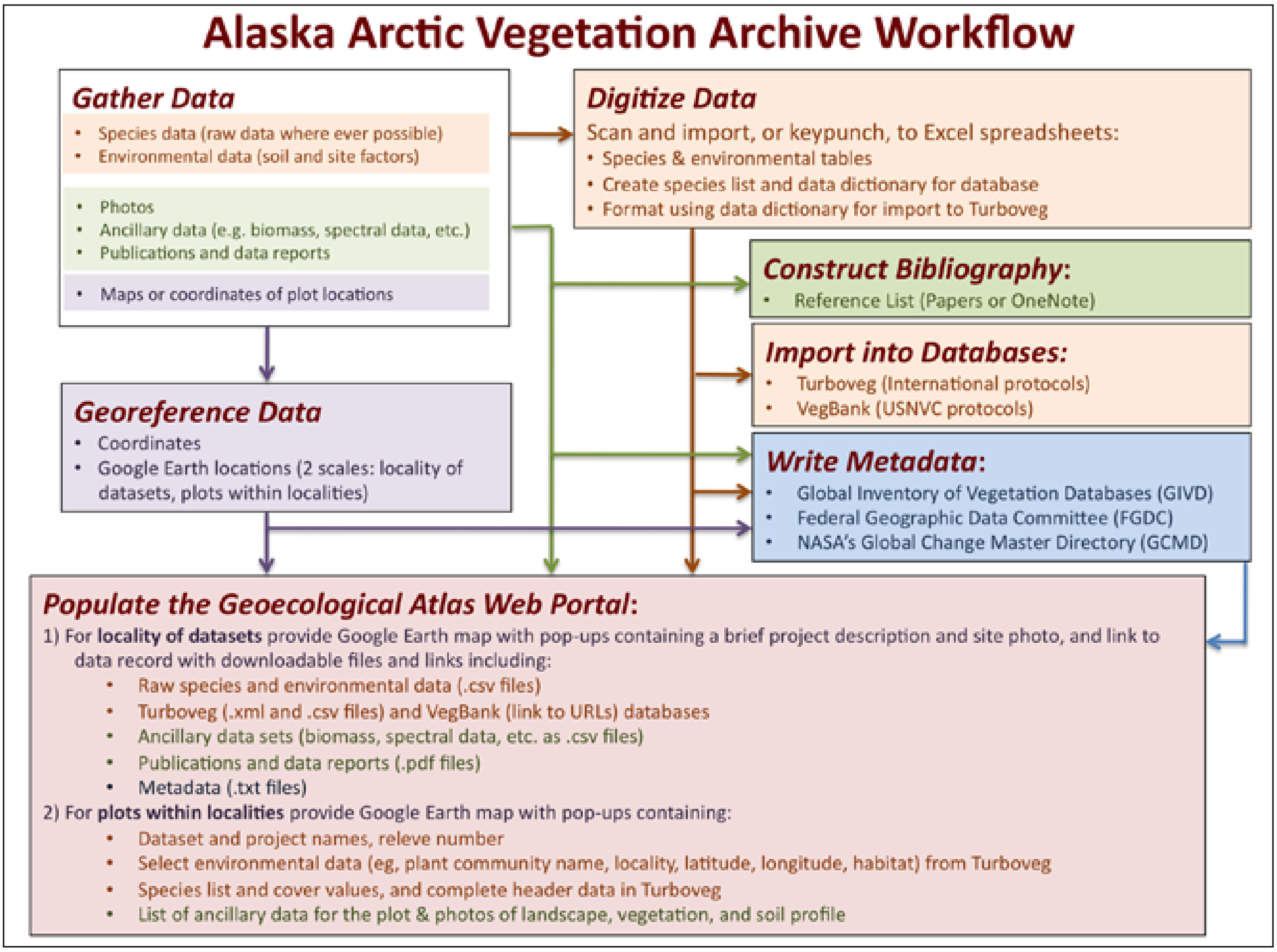

Figure 1. *The Alaska Arctic Vegetation Archive Workflow..*

1) Gather data

This step involves not only data gathering, but also data discovery. We began the creation of the AAVA by surveying the literature and experts about vegetation-plot data available from Arctic Alaska. Once the vegetation-plot data are discovered, the ease to gather data varies depending upon: 1) accessibility of the species and environmental tables, 2) how well the methods were documented in terms of collection of vegetation and environmental data, photographs and ancillary data, and 3) whether the plots were georeferenced in the field. In general, the more recent the vegetation study the better the ease of gathering data. For example, recent studies will likely have data readily available and entered in spreadsheets, plots will have been georeferenced in the field with a GPS, and photos will have been taken with a digital camera.

2) Digitize data

The vegetation-plot data included in the AAVA are in various forms. If the species and environmental tables are only available in their print form, or as hard copies, these data must be entered manually or scanned and exported into a spreadsheet program such as Microsoft Excel. If necessary, ancillary data must be digitized as well, including scanning photographs. To import relevés into TURBOVEG, an archive-specific species list and a data dictionary must be created. Once these are created, we then format the raw data in Excel to import the speciesand environmental tables into TURBOVEG.

3) Georeference data

The step of georeferencing data, or more specifically locating main study areas and plots within localities, will vary depending upon how recently a study was conducted as mentioned in the data gathering step above. If a study pre-dates the use of hand-held GPS, coordinates were likely derived from a map or aerial photographs and are coarse. The accuracy of the coordinates can be improved upon if the original map or photographs are available and plots can be located on satellite imagery via Google Earth or a similar program. For many older studies, however, plot maps are not available. For these studies, we choose a single coordinate for the locality of the main study area and indicate the plots were not georeferenced.

4) Construct bibliography

The construction of an AAVA bibliography is independent of the creation of the database. The bibliography contains a full list of the citations associated with each vegetation-plot dataset, while the database contains the primary source(s) for the species and environmental tables. For example, the citations from a single vegetation-plot dataset may include a data report, dissertation and numerous publications that will all be listed in the bibliography. The database, in contrast, may only list the publication in which the plant communities were described and formally named. We are constructing the AVA bibliography using the software program Papers for Mac.

5) Import into databases

Once the data are digitized, the next step is to import the species and environmental tables into databases. The basis for the AAVA is the TURBOVEG program. For the import, we use the AAVA data dictionary and the PanArctic Species List. We bring the species table and the associated header data in directly via an import from Microsoft Excel. In addition to creating an AAVA in TURBOVEG, we also aim to submit our vegetation-plot data to VegBank. VegBank is the online vegetation plot database of the Ecological Society of America's Panel on Vegetation Classification (Peet et al. 2012). To accomplish this task, we plan to export our data from TURBOVEG using the plot data exchange tool Veg-X that is currently under development (Wiser et al. 2011).

6) Write metadata

We will write metadata in a variety of formats. We registered the Alaska AVA in the Global Index of Vegetation-Plot Databases (NA-US-014; Dengler et al. 2011), which is a metadatabase that provides an overview of existing vegetation data worldwide. The status of the AAVA is listed as emerging and we will update the database record as we progress. We will also utilize the option to include standard project metadata in a relational table in TURBOVEG v. 3.0 that will be available at the end of 2014. To reach the larger earth science community, we will also write metadata according to the best data management practices of Oak Ridge National Laboratory's Distributed Active Archive Center for Biogeochemical Dynamics (ORNL-DAAC). The AAVA will then be discoverable through the ORNL-DAAC and NASA's Global Change Master Directory (GCMD).

7) Populate the web portal

The step of populating the AAVA plot archive via the Arctic Alaska Geoecological Atlas web portal will be accomplished with the assistance of the Geographic Information Network for Alaska at the University of Alaska Fairbanks (Wirth et al. 2014, this workshop). We plan to include two spatial scales to visualize available vegetation-plot data in Google Earth. These scales include: 1) at the level of the locality of a dataset, or project, and 2) at the level of plots within localities. At each of these scales, we will populate pop-ups, either datasets or plots, with background information to familiarize the user with available vegetation-plot and ancillary data (See Fig. 1). We will also populate data records for each dataset in the Atlas. Data records will include a brief description of each project, site photo and links to downloadable files in various formats and metadata.

Common Data Standards

We archive available vegetation-plot data according to common data standards. These standards comprise our data dictionary for use in TURBOVEG (Tables 2-4). The step to cross-walk our header data among our datasets assures we are poised for analytical phases upon completion of the AAVA.

We presented draft standards at both the Krakow Arctic Vegetation Archive and the Boulder Alaska Arctic Vegetation Archive Workshops. The result is a data dictionary applicable to the Circumpolar Arctic with 71 header-data fields, 20 of which are required (starred fields in Table 2). Our hope in including the recommended header fields is that these will spur common data standards for recording relevés in future field surveys. Nearly all of the required header fields should all be readily available (e.g., relevé number, date, relevé area, cover abundance scale, author, reference, etc.).

Conclusion

The creation of an Alaska prototype for the Arctic Vegetation Archive is well underway with an anticipated launch date of July 2015. We completed a survey of key vegetation-plot data from Arctic Alaska, obtained these data from their authors or the literature, and are currently formatting high priority datasets for import into TURBOVEG using the archive-specific PanArctic Species List and data dictionary we created. The Alaska Arctic Vegetation Archive will be made available to the public through the Arctic Alaska Geoecological Atlas web portal. We established a workflow to outline the steps for gathering data, importing vegetation-plot data into databases, and populating the plot archive. The workflow is dynamic, and will be adapted over time as we work toward completion of the archive.

Acknowledgements

This status update on the Alaska Arctic Vegetation Archive is the result of fruitful and lively discussions with the participants of both the Krakow Arctic Vegetation Archive Workshop and the Boulder Alaska Arctic Vegetation Archive Workshop. In particular, we thank Borja Jimenez-Alfaro, William MacKenzie, Michael Lee, Robert Peet, Helga Bültmann and Fred J.A. Daniëls for their contribution to the proposals contained in this paper.

Table 1. *Key vegetation-plot data in Arctic Alaska. The* Priority *column refers to the order in which we will import data into the AAVA and is listed based on the most readily available data. The* Current Format *column indicates whether data are digitized or not, and if so, in what computer program files reside. The electronic files are primarily stored as spreadsheets in Microsoft Excel or as databases in Microsoft Access. VPro is a program created by the British Columbia Ministry of Forests' Forest Science Program that runs within the Microsoft Access (MacKenzie, 2014; this workshop). Vegetation-plot data that are applicable to the AAVA were collected according to the Braun-Blanquet or equivalent approach.*

Priority	Author(s) (Date Published)	Location(s)	Relevés	Current Format	Applicable to the AAVA
1	Walker, D. A. (1985)	Prudhoe Bay Oilfield	93	VPro, Excel	yes
1	Walker M. D. (1990)	Pingo communities on the Central Arctic Coastal Plain (Kuparuk, Prudhoe Bay, Toolik River, Kadleroshilik study areas)	293	VPro, Excel	yes
1	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	Excel	yes
1	Walker, D.A., N. A. Auerbach, T. K. Nettleton, A. Gallant & S. M. Murphy (1997)	Happy Valley	56	VPro, Excel	yes
1	Walker, D. A. & N. Barry (1991) and M. D. Walker, M. D., D. A. Walker & N. A. Auerbach (1994)	Toolik Lake	73	VPro, Excel	yes
1	Walker, D. A., N. D. Lederer & M. D. Walker (1987) and Walker, M. D., D. A. Walker & N. A. Auerbach (1994)	Imnaviat Creek	81	VPro, Excel	yes
1	Schickhoff, U., M. D. Walker & D. A. Walker (2002)	Willow communities along the Dalton Highway	85	VPro, Excel	yes
1	Breen, A. L. (2010)	Balsam poplar stands in the Arctic Foothills and western Alaska	25	Excel	yes
2	Webber, P. J. (1978) and Villarreal, S., R. D. Hollister, D. R. Johnson, M. J. Lara, P. J. Webber & C. E. Tweedie (2012)	Microtopography grid in Barrow, AK	136 (1971) + 136 (2000) + 136 (2008)	Access	yes
2	Edwards, E. J., A. Moody & D. A. Walker (2000)	Western Alaska Arctic Transect (Barrow, Atqasuk, Oumalik, Ivotuk)	15	Excel	yes
2	Elias, S. A., S. K. Short, D. A. Walker & N. A. Auerbach (1996)	Barrow and Barter Island	59	Excel	yes
2	Komárková, V. & P. J. Webber (1980)	Atqasuk	73	Access	yes
2	Ebersole, J. J. (1985)	Undisturbed control plots at Oumalik	87	Excel	yes
2	Raynolds, M.K., C. R. Martin, D. A. Walker, A. Moody, D. Wirth & C. Thayer-Snyder (2002)	Council and Quartz Creek	52	Excel	yes
2	Cooper, D. (1986)	Arrigetch Mountains	372	VPro - partial, Hard Copy	yes

Priority	Author(s) (Date Published)	Location(s)	Relevés	Current Format	Applicable to the AAVA
2	Webber, P. J. (1978) and Villarreal, S., R. D. Hollister, D. R. Johnson, M. J. Lara, P. J. Webber & C. E. Tweedie (2012)	Barrow, AK	430 (1978) + 330(1999) +330 (2008) 330 (2010)	Access	yes
2	Komárková, V. & P. J. Webber (1980) and Villarreal, S., D. R. Johnson, M. J. Lara & C. E. Tweedie (Unpublished)	Atqasuk, AK	60 (1975) + 32 (2000) + 31 (2009)	Access	yes
3	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	Hard Copy	yes
3	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	Access	yes
3	Ebersole, J. J. (1985)	Disturbed plots at Oumalik	61	Excel	yes
3	Churchill, E. D. (1955)	Umiat	80	VPro	yes
3	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	763	Access	yes
3	Hanson, H. C. (1953)	Nome	70	Excel	yes
3	Jorgenson, M. T., J. E. Roth, P. F. Miller, M. J. Macander, M. S. Duffy, et al. (2009)	Selawik National Wildlife Refuge	275	Access	yes
3	Jorgenson, M. T. (2000)	Yukon-Kuskokwim Delta	65	Access	yes
3	Jorgenson, M. T., J. E. Roth, M. Emers, S. Schlentner, D. K. Swanson, et al. (2003)	National Petroleum Reserve-Alaska	84	Access	yes
3	Hollister R.D., C. E. Tweedie, et al. (Unpublished)	Barrow, AK	50 (2010)	Access	yes
3	Hollister R.D., C. E. Tweedie, et al. (Unpublished)	Atqasuk, AK	50 (2010)	Access	yes
3	Hollister R.D., C. E. Tweedie, et al. (Unpublished)	Atqasuk, AK	35 (2010)	Access	yes
3	Hollister R.D., C. E. Tweedie, et al. (Unpublished)	Atqasuk, AK	36 (2010)	Access	yes
4	Webber (1971) and Villarreal, S., D. R. Johnson, M. J. Lara, P. J. Webber & C. E. Tweedie (Unpublished)	Baffin Island, Canada	82 (1964) + 79 (2009)	Access	yes
4	Boucher, T.V., et al. (In prep)	NPR-A	50+ transects	Not yet available	yes
4	Lipkin, R. & M. Carlson (In prep)	NPR-A	50	Not yet available	yes
4	Boggs, K., A. Garibaldi, J. Stephens & T. Helt (1999)	Gates of the Arctic National Park and Preserve	137	US DoI National Park Service Database	yes

Priority	Author(s) (Date Published)	Location(s)	Relevés	Current Format	Applicable to the AAVA
4	Johnson, D.R., M. J. Lara, G. R. Shaver, G. O. Batzli, J. D. Shaw, & C. E. Tweedie (2012)	Herbivory exclosures at Barrow, AK	24 (2002) + 24 (2010)	Access	yes
4	Boggs, K., T. Boucher, et al. (In prep)	Across North Slope west of the Arctic National Wildlife Refuge	195	Access	yes
5	Peterson, K. M. (1978)	Barrow and Atqasuk	-	Hard Copy	no
5	Komárková, V. & J.D. McKendrick (1988)	National Petroleum Reserve-Alaska Sand Region	608	Unknown	unknown
5	Jorgenson, J. C., J. M. Ver Hoef. & M. T. Jorgenson (2010)	Arctic National Wildlife Refuge	60	Excel	no
5	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	Excel	no
5	Johnson, A. W., L. A. Viereck, R. E. Johnson & H. Melchior (1966)	Cape Thompson	54	Hard Copy	no
5	Racine, C. (1976)	Kobuk River Valley	-	Hard Copy	no
5	Young, S. (1974)	Noatak River	-	Hard Copy	no
5	Young, S. (1971)	Saint Lawrence Island	-	Hard Copy	no
5	Murray, D. F. (1974)	Killik River	-	Hard Copy	no
5	Elmendorf, S., et al. (2012a, 2012b)	International Tundra Experiment point-frame vegetation plots across northern Alaska and the Arctic region	-	"Archived at www.polardata.ca	
5	Batten (1977)	Lake Peters	-	Hard Copy	no

Table 2. *Data dictionary for the Alaska Arctic Vegetation Archive. Required fields are shown in bold with an asterisk. The remaining fields are recommended for inclusion in the archive. The* Field Name *column contains consistent header names and are limited to ten characters. The* Source *column indicates whether the field is standard from Turboveg (TV) or added for the AVA. The* Type *column indcates whether fields are alphabetic characters (C), or numbers (N), or a combination (C/N). The* Width *column indicates the number of characters allowed within the field and the* Decimal *column indicates how many of these characters can occur after the decimal.*

Relevé Header data						
Header	**Field Name**	**Source**	**Type**	**Width**	**Decimals**	**Field Description**
Relevé description						
Relevé number*	RELEVE_NR	TV	N	6	0	Turboveg generated identifier assigned to each unique plot during import. Can set start and end number.
Field relevé number	FIELD_NR	AVA	C	15	0	Author's plot number or code if it differs from the reference for the species table.
Date*(yyyy/mm/dd)	DATE	TV	C	8	0	Date of collection (yyyy/mm/dd). At a minimum, enter year of collection.
Relevé area* (m^2)	SURF_AREA	TV	N	7	2	Area of the relevé (m2). -1 is used to indicate the plot had no boundaries or no estimate of the sampled area.
Relevé shape	SHAPE	AVA	C	1	0	Shape of the relevé area. Necessary for judgements on 'edge effects'. From pop-up list: **square (S), rectangle (R), linear/band-forming (L), circular (O), irregular (I), more subplots combined (C), unknown (not-recorded) (N).** (Mucina et al. 2000)
Cover abundance scale*	COVERSCALE	TV	C	2	0	Cover abundance scale. **From pop-up list: Percentage (%) (00); Braun/Blanquet (old) (01); Braun/Blanquet (new) (02); Londo (03); Presence/Absence (04); Ordinal scale (1-9) (05); Barkman, Doing & Segal (06); Doing (07), Constancy classes (08), Domin (09), Colin (10), Tansley (11), Didukh (12), Hult-Sernander-Du Rietz (Daniels) (13), Numbers (<65025) (98),Numbers (<24000) (99).** Generated in Turboveg.
Permanently marked (y/n)	MARKED	AVA	C	1	0	Are relevés permanently marked? **(Y or N).**
Repeat sampled (y/n)	REPEAT	AVA	C	1	0	Has the relevé been sampled more than once? **(Y or N).** Will change over time.
Collection*	COLLECT	AVA	C	1	0	Method used to collect vegetation-plot data. From pop-up list: **relevé (R), other (O).**
Collection method	COLL_METH	AVA	C	200	0	If data were not collected using the relevé method, specify collection method and source.
Syntaxon	SYNTAXON	TV	C	7	0	Syntaxon name according to the Braun-Blanquet School. From pop-up list. Will add to list as enter data.
System for plant community name	COMM_SYST	AVA	C	6	0	From pop-up list: **Braun-Blanquet syntaxon name (B-B), USNVC name (USNVC), CNVC name (CNVC), Russian nomenclature system (RU), field community name (FLD_NM).** Will add to list as enter data.
Plant community name	COMM_NAME	AVA	C	200	0	Original plant community name used by the author. Will specify the source of the name in the previous field.

Relevé Header data						
Header	**Field Name**	**Source**	**Type**	**Width**	**Decimals**	**Field Description**
Source of information						
Project name*	PROJECT	TV	C	3	0	Project title. From pop-up list. Will generate list as enter data.
Author name*	AUTHOR	TV	C	3	0	Relevé primary author(s). From pop-up list. Will generate list as enter data.
Reference for species data*	REF_SPE	AVA	C	6	0	Main publication or data report from which the species data were taken. From pop-up list in the field REFERENCES. Will generate list as enter data.
Table number for species data	TABLE_NR	TV	C	6	0	Table number in which species data occur in the reference for species data.
Relevé number in species table	NR_IN_TAB	TV	C	15	0	Relevé number in the species table in the reference for species data.
Reference for environmental data	REF_ENV	AVA	C	6	0	Reference from which the environmental data were taken. This field is necessary as raw environmental data is often not included in the main publication. From pop-up list in the field REFERENCES. Will generate list as enter data.
Table number for environmental data	TABLE_ENV	AVA	C	6	0	If environmental data are from a table, indicate table number from the reference for environmental data.
Locality						
Subzone*	SUBZONE	AVA	C	2	0	Arctic tundra bioclimate zone. From pop-up list: **Subzone A (A), Subzone B (B), Subzone C (C), Subzone D (D), Subzone E (E), Treeless Oceanic Boreal (O), Forest-Tundra Transition (FT)** (CAVM Team 2003)
Country*	COUNTRY	TV	C	2	0	Country code. From pop-up list. Will use list in Turboveg and their codes. For United States the code is US.
Dataset*	DATASET	AVA	C	6	0	Specific project dataset code. **From pop-up list: Prudhoe Bay Oilfield (PRU), Howe Island (HI), Deadhorse (DH), Franklin Bluffs (FB), Sagwon Uplands (SAG), Happy Valley (HV), Toolik Lake (TL), Imnavait Creek (IC), Pingos (PINGO), Dalton Highway Willows (WILLOW), Barrow (BRW), Atqasuk (ATQ), Fish Creek (FC), Colville River Delta (CRD), Oumalik (OUM), Umiat (UMI), Ivotuk (IVO), National Petroleum Reserve-Alaska (NPRA), Council (CNCL), Quartz Creek (QC), Kaktovik (KAK), Arctic National Wildlife Refuge (ANWR), Cape Thompson (CT), Arrigetch Peaks (ARR), Lake Peters (LP), Arctic Network of National Parks, Preserves and Monuments (NPS), Kobuk River Valley (KOB), Noatak River (NTK), Killik River (KR), Balsam poplar stands in the Arctic Foothills and western Alaska (POPLAR), Nome (NOM).** Will add to list as needed.

Relevé Header data						
Header	**Field Name**	**Source**	**Type**	**Width**	**Decimals**	**Field Description**
Locality						
Physiographic divison*	PHYS_DIV	AVA	C	5	0	Physiographic divisions. For Alaska pop-up list will include: **Arctic Coastal Plain (1); Arctic Coastal Plain Teshekpuk Section (1a); Arctic Coastal Plain White Hills Section (1b); Arctic Foothills (2); Arctic Foothills Northern Section (2a); Arctic Foothills Southern Section (2b); Delong Mountain (3); Noatak Mountains (4); Baird Mountains (5); Central and Eastern Brooks Range(6); Selawik Hills (23); Buckland River Lowland (24); Nushagak-Bristol Bay Lowland (32); Seward Peninsula (33); Yukon-Kuskokwim Lowland (34); Bering Platform (35); Saint Lawrence Island (35a); Pribelof Islands (35b); Saint Matthew Island (35c); Nunivak Island (35d); Ahklun Mountains (36); Aleutian Islands (37); Aleutian Range (38); Kodiak Mountains (53); N/A (0).** Will add to this list as needed. (Wahrhaftig 1965)
Physiographic region source*	REF_PHY	AVA	C	3	0	Source used for physiographic regions. From pop-up list in the field REFERENCES. Will add to list as needed.
Georeference* (y/n)	GEOREF	AVA	C	1	0	Are the relevés georeferenced? **(Y or N).** If yes, provide subsequent fields.
Georeference source	GEO_SOURC	AVA	C	5	0	From pop-up list: **GPS (GPS), Google Earth (GE), map (MAP), aerial photograph (PHOTO).**
Georeference accuracy (m)	ACCURACY	AVA	N	6	2	Accuracy of georeference as recorded by GPS (m).
Latitude (decimal degrees)	LATITUDE	TV	N	13	8	Latitude (decimal degrees). Positive latitudes are north of the equator, negative latitudes are south of the equator. Datum is WGS84.
Longitude (decimal degrees)	LONGITUDE	TV	N	13	8	Longitude (decimal degrees). Positive longitudes are east of Prime Meridian, negative longitudes are west of the Prime Meridian. Datum is WGS84.
Site description						
Elevation (m)	ALTITUDE	TV	N	4	0	Elevation of relevé (m).
Slope (degrees)	INCLINATION	TV	N	3	0	Slope of relevé (degrees).
Aspect (degrees)	EXPOSITION	TV	N	3	0	Aspect of relevé (degrees). Aspect is measured counterclockwise in degrees from 0 (due north) to 360 (again due north, coming full circle). As a convention, use 360 degrees for north. From pop-up list: **NNE (23), NE (45), EEN (68), E (90), EES (113), SE (135), SSE (158), S (180), SSW (203), SW (225), SWW (248), W (270), NWW (293), NW (315), NNW (338), N (360).**
Topographic position	POSITION	AVA	C	6	0	From pop-up list: **flat elevated plain (includes plateaus and elevated river terraces) (EL_PLN); hill crest (CREST); shoulder (SHLD); backslope (BACK); footslope (includes toeslopes) (FOOT); flat low plain (LW_PLN); riparian zone (includes active floodplains, drainage channels, water tracks) (RIPZN); lake or pond (LAKE).**
Surficial Geology	SURF_GEOL	AVA	C	5	0	Parent material. From pop-up list in supplementary table.
Habitat*	HAB_TYPE	AVA	C	4	0	Tentative Braun-Blanquet habitat as defined by classes. From pop-up list in supplementary table. Will change over time. (Walker 2014; modified from Bültmann & Daniëls 2013)

Relevé Header data						
Header	**Field Name**	**Source**	**Type**	**Width**	**Decimals**	**Field Description**
Site description						
Site moisture*	SITE_MOIST	AVA	C	3	0	Site moisture. From pop-up list: **dry (DRY), moist (MST), wet (WET), aquatic/emergent (AQU).**
Disturbance*	DISTURBAN	AVA	C	3	0	From pop-up list: **natural vegetation (NAT) or anthropogenically disturbed (DIST).**
Soils description						
Organic layer depth (cm)	ORG_DEPTH	AVA	N	5	2	Depth of organic layer (cm).
Soil texture of top mineral horizon	SOIL_TEXT	AVA	C	3	0	Field estimate of texture at the top of the mineral horizon. From pop-up list: **gravel (GRV), sand (SND), silt (SLT), clay (CLY), loam (LOM), organic (if no mineral soil within the active layer) (ORG).**
Soil pH	SOIL_PH	AVA	N	3	1	The pH reported by author. Methods for quantifying pH vary. Refer to reference to determine methods used.
Vegetation description						
Quality of species information						
Mosses* (y/n)	MOSS_IDENT	TV	C	1	0	Mosses identified? **(Y or N).**
Liverworts* (y/n)	LIV_IDENT	AVA	C	1	0	Liverworts identified? **(Y or N).**
Lichens* (y/n)	LICH_IDENT	TV	C	1	0	Lichens identified? **(Y or N).**
Vascular plant taxonomic quality*	FLOR_QUAL	AVA	C	2	0	Subjective assessment of floristic quality by the party that submitted the plot. From pop-up list: **highest (1), high (2), high but incomplete (3), moderate (4), moderate and incomplete (5), low (6).**
Cryptogam taxonomic quality*	CRYP_QUAL	AVA	C	2	0	Subjective assessment of taxonomic quality of the cryptogam data by the party that submitted the plot. From pop-up list: **highest (1), high (2), high but incomplete (3), moderate (4), moderate and incomplete (5), low (6).**
Horizontal structure of vegetation						
Cover trees (%)	COV_TREES	TV	N	3	0	Tree cover (%).
Cover total shrubs (%)	COV_SHRUBS	TV	N	3	0	Total shrub cover (%).
Cover tall shrubs (%)	COV_TSHRUB	AVA	N	3	0	Tall shrub cover (%).
Cover low shrubs (%)	COV_LSHRUB	AVA	N	3	0	Low shrub cover (%).
Cover erect dwarf-shrubs (%)	COV_DSHRUB	AVA	N	3	0	Erect dwarf-shrub cover (%).
Cover prostrate dwarf-shrubs (%)	COV_PSHRUB	AVA	N	3	0	Prostrate dwarf-shrub cover (%).
Cover graminoids (%)	COV_GRAM	AVA	N	3	0	Graminoid cover (%).
Cover tussock graminoids (%)	COV_TGRAM	AVA	N	3	0	Tussock graminoid cover (%).

Relevé Header data						
Header	**Field Name**	**Source**	**Type**	**Width**	**Decimals**	**Field Description**
Vegetation Description						
Horizontal structure of vegetation						
Cover forbs (%)	COV_FORB	AVA	N	3	0	Forb cover (%).
Cover seedless vascular plants (%)	COV_SLVAS	AVA	N	3	0	Seedless vascular plant (ferns, horsetails, club mosses) cover (%).
Cover mosses & liverworts (%)	COV_MOSS	AVA	N	3	0	Bryophyte cover (%).
Cover fruticose & foliose lichens (%)	COV_LICHEN	TV	N	3	0	Lichen cover (%).
Cover of crustose lichens & biological soil crusts (%)	COV_CRUST	AVA	N	3	0	Crustose lichen and biological soil crust cover (%).
Cover algae (%)	COV_ALGAE	TV	N	3	0	Algae cover (%).
Cover bare soil (%)	COV_SOIL	AVA	N	3	0	Bare soil, or unvegetated (%).
Cover rock (%)	COV_ROCK	TV	N	3	0	Rock cover (%).
Cover water (%)	COV_WATER	TV	N	3	0	Water cover (%).
Cover litter (%)	COV_LITTER	TV	N	3	0	Litter cover (%).
Cover total (%)	COV_TOTAL	TV	N	3	0	Total (live + dead) vegetation cover (%).
Vertical structure of vegetation						
Mean canopy height (cm)	MEAN_HT	AVA	N	4	0	Mean height of the canopy within the stand (cm).
Mean tree layer height (m)	TREE_HT	AVA	N	3	1	Mean height of the tree layer (m).
Mean shrub layer height (cm)	SHRUB_HT	AVA	N	4	0	Mean height of upper shrub layer including tall and low shrubs (cm).
Mean herb layer height (cm)	HERB_HT	AVA	N	4	0	Mean height of herb layer including graminoids, forbs and dwarf shrubs (cm).
Mean moss layer height (cm)	MOSS_HT	AVA	N	3	0	Mean thickness of the moss layer including live and dead moss (cm).
Other						
Remarks	REMARKS	TV	N/C	2000	0	Comments, if needed. These could include: 1) Taxonomic notes regarding specific species in the dataset; 2) Field name for community, habitat description and location that defines the site. For example: Dryas integrifolia-Saxifraga oppositifolia-Lecanora epibryon (Type B2); high-centered polygons, margin of drained lake basin; near Spine Road-Oxbow Road intersection at Pruhoe Bay.; 3) Other field observers; 4) Who entered the data into Turboveg and the date.

Table 3. *Surficial Geology codes and pop-up list included in the AAVA data dictionary*

Parent Material Code	Parent material
1	**Unconsolidated marine deposits**
1.1	Marine sands and gravels
1.2	Marine silts and clays
2	Unconsolidated eolian deposits (deposited by wind)
2.1	Eolian sands
2.2	Eolian silts (loess)
3	Eluvial deposits (deposited by in situ weathering, plus gravity movement)
3.1	Frost shattered bedrock
4	Colluvial deposits (slope deposits, derived from a combination of gravity and alluvial processes)
4.1	Hillslope colluvium
4.2	Talus
4.3	Solifluction deposits
5	Lacustrine deposits (lake deposits)
5.1	Organic lacustrine deposits
5.2	Mineral lacustrine deposits
6	Alluvial deposits (deposited by rivers and streams)
6.1	Alluvial sands and gravels
6.2	Alluvial silts
7	Glacial deposits
7.1	Glacial till
7.2	Glacio-marine sediments
7.3	Glacio-fluvial fluvial sediments
8	Bedrock
8.1	Sedimentary rocks and metamorphosed sedimentary rocks
8.1.2	Sedimentary and metamorphic rocks derived from course grained sediments of mixed minerology: conglomerates and breccias
8.1.3	Sedimentary and metamorphic rocks derived from quartz-rich sediments: sandstones, quartzites, cherts
8.1.4	Sedimentary and metamorphic rocks derived from fine grained silts and clays: siltstones, claystones, mudstones, shales, slates, phyllites, schists
8.1.5	Sedimentary and metamorphic rocks derived from carbonate sediments: limestone, dolomite, marlstone, marble
8.2	Igneous and metamorphosed igneous rocks
8.2.1	Felsic igneous rocks (rich in Si, Al): obsidian pumice, rhyolite, granite, pegmatite, gneiss
8.2.2	Mafic igneous rocks (rich in Fe, Mg): basaltic glass, scoria, basalt, diabase, gabbro,
8.2.3	Ultramafic igneous rocks (extremely rich in Fe, Mg and often other metaliferous minerals Co, Ni, Ch), peridotite, dunite, serpentine, olivine, hornblende, pyroxene

Table 4. Habitat type codes and pop-up list included in the AAVA data dictionary.

Habitat Code	Habitat Description and groups of associated plant communities	Anticipated Br.-Bl. Class	Author & Year
1	**Coastal salt marsh vegetation**	**Juncetea maritimi**	**Br.-Bl. 1931**
1.1	Puccinellia phryganodes, Carex subsapathecea coastal salt marsh communities		
2	**Dry coastal beach and sand dune vegetation**	**Ammophiletea**	**Br.Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946**
2.1	Elymus arenarius and other active dune communities		
2.2	Coastal communities influenced by saline soils (Puccinellia andersonii, Mertensia maritimia, Honkenya peploides, Salix ovalifolia, Braya purpurascens, Cochlearia communities)		
3	**Rooted floating or submerged macrophyte vegetation of meso-eutrophic water**	**Potametea**	**Klika in Klika & Novák 1941**
3.1	Aquatic forb marshes (Hippuris, Sparganium, Menyanthes, Utricularia, Ranunculus communities)		
4	**Riparian willow shrub and poplar stands of warm habitats**	**Salicetea purpureae**	**Moor 1958**
4.1	Willow shrub vegetation of riparian areas and warm habitats (south-facing slopes)		
4.2	Poplar vegetation of warm Arctic habitats		
5	**Sedge grass and dwarf shrub mire and fen vegetation**	**Scheuchzerio palustris-Caricetea fuscae**	**Tüxen 1937**
5.1	Aquatic grass marshes (Arctophila fulva)		
5.2	Moist to wet coastal grasslands (Dupontia)		
5.3	Wet nonacidic tundra (Carex spp.-, Eriophorum spp.-Amblystegiaceae communities)		
5.4	Coastal moist tundra (Carex stans, Carex atrofusca communities)		
6	**Bog vegetation, acidic mires, including tussock tundra**	**Oxycocco-Sphagnetea**	**Br.-Bl. et Tüxen ex Westhoff et al. 1946**
6.1	Wet acidic Sphagnum-rich mires (bogs)		
6.2	Moist to wet acidic tussock and nontussock (Eriophorum vaginatum-, Carex bigelowii-Sphagnum, -Hylocomium) tundra		
6.3	Moist to wet acidic low-shrub heaths (wet to moist Betula nana-Sphagnum heaths)		
7	**Talus slope, debris and alluvial vegetation**	**Thlaspietea rotundifolii**	**Br.-Bl. 1948**
7.1	Ruderal riparian vegetation (Epilobium latifolium, Artemisia arctica, Trisetum spicatum, etc.)		
8	**Deep snowbed vegetation**	**Salicetea herbaceae**	**Br.-Bl. 1947**
8.1	Moderately drained deep snowbeds (Salix rotundifolia, S. polaris, S. herbacea snowbeds)		
8.2	Poorly drained deep snowbeds (Phippsia algida, Saxifraga rivularis, Ranunculus pygmaeus, etc.)		
9	**Dwarf-shrub heath and low-shrub vegetation on acidic poor substrate**	**Loiseleurio-Vaccinietea**	**Eggler 1952**
9.1	Dry acidic prostrate-shrub heaths (Arctous alpina, Salix phlebophylla, Empetrum heaths)		

Habitat Code	Habitat Description and groups of associated plant communities	Anticipated Br.-Bl. Class	Author & Year
9.2	Shallow acidic snowbeds (Cassiope-Carex microchaeta-Hylocomium communities)		
9.3	Moist and dry acidic dwarf-shrub heaths (Vaccinium uliginosum, Emetrum nigrum, Ledum decumbens, some Betula nana-lichen heaths)		
9.4	Frost boil vegetation in acidic tundra (Anthelia, Juncus communities)		
10	**Achionophytic dwarf-shrub and graminoid vegetation on non-acidic substrate**	**Carici-Kobresietea**	**Ohba 1974**
10.1	Dry nonacidic tundra (Dryas integrifolia, including Dryas river terraces)		
10.2	Dry nonacidic alpine tundra (Dryas octopetala)		
10.3	Shallow nonacidic snowbeds (Cassiope-Dryas-Tomentypnun, and Cassiope-Dryas-lichen communities)		
10.4	Moist nonacidic tundra (Sedge-Dryas-Tomentypnum communities)		
10.5	Frost boil vegetation in nonacidic tundra (Juncus biglumis, Saxifraga oppositifolia)		
11	**Boreal and low Arctic steppe inland vegetation on dry, warm substrate**	**Saxifrago-Calamagrostietea purpurascentis**	**Drees & Daniëls 2009**
11.1	Steppe tundra communities on south facing slopes of pingos		
11.2	Artemisia communities along streams and in dunes		
12	**Tall forb and shrub vegetation on mesic-moist soil**	**Mulgedio-Aconitetea**	**Hadač in Klika et Hadač 1944**
12.1	Alder communities		
13	**Lichen communities on silicate rocks**	**Rhizocarpetea geographici**	**Wirth 1980**
14	**Lichen communities on calcareous rocks**	**Verrucarietea nigrescentis**	**Wirth 1980**
0	**Habitats of yet to be described classes**		
0.1	Zoogenic communities associated with animal dens and bird mounds (arctic ground-squirrels, arctic foxes) (Poa glauca, Festuca rubra, Ranunculus pedatifidus, etc.)		

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Balsam poplar communities on the Arctic Slope of Alaska

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Introduction

Trees are generally absent on Alaska's North Slope except for isolated stands of balsam poplar (*Populus balsamifera L.*, Salicaceae) that are disjunct by over 100 km from the boreal forest south of the Brooks Range. Balsam poplar occurs preferentially on floodplains of braided rivers in areas with a sharp change in relief from the Brooks Range to the Arctic Foothills (Bockheim et al. 2003), at warm springs (Viereck 1979), and at sheltered sites or near perennial springs where groundwater is abundant throughout the year (Murray 1980, 1992).

Since balsam poplar is anomalous in the Arctic, their plant communities had not been thoroughly characterized compared with more typical arctic plant assemblages (Daniëls et al. 2005, Walker et al. 1994). Herein, I summarize results from a study that described and classified balsam poplar plant communities on the Arctic Slope and interior Alaska and Yukon (Breen In Press). The aim of the study was to analyze floristic variation within and among arctic and boreal balsam poplar communities, classify vegetation types, and identify the ecological gradients underlying community differentiation.

Methods

This study was conducted in the Arctic Foothills of Alaska and the interior boreal forests of Alaska and Yukon (Fig. 1). The Arctic study area (19 relevés) is bounded by the Noatak River (162°W) to the west and the Kongakut River (142°W) to the east. Broad sloping valleys with elevations up to 350 m characterize the foothills of the Arctic Slope. The boreal forest study area (13 relevés) is bounded to the east by the Kobuk River (159°W) and to the west by the headwaters of the Yukon River (137°W). The boreal forest landscape consists of rolling hills, lowlands and nearly-flat bottomlands along major rivers.

Sampling localities were selected subjectively in areas of homogeneous vegetation dominated by balsam poplar. The minimum sampling area was approximately 100 m2. I scored the occurrence of vascular plant, bryophyte and lichen species using the Braun-Blanquét cover-abundance scale (r, +, 1-5; Braun-Blanquét 1964, Mueller-Dombois & Ellenberg 1974), recorded the height and absolute cover of trees, shrubs, and herbs and estimated the percent cover of standing dead and woody debris, and litter. At each relevé, I quantified several aspects of the stand, site and soils. The physical characteristics of each site were described by the following variables: elevation, slope, aspect, stability, exposure, parent material and geomorphology. Site and soil moisture and snow duration were categorized on scales of 1 to 10 (Komárková 1983). I followed the point centre quarter method to estimate stand density (trees/ha), basal area and canopy height (Mueller-Dombois & Ellenberg 1974). Vegetation was classified using the Braun-Blanquét sorted table method, and ecological gradients underlying community differentiation were identified using Nonmetric Multidimensional Scaling (NMDS).

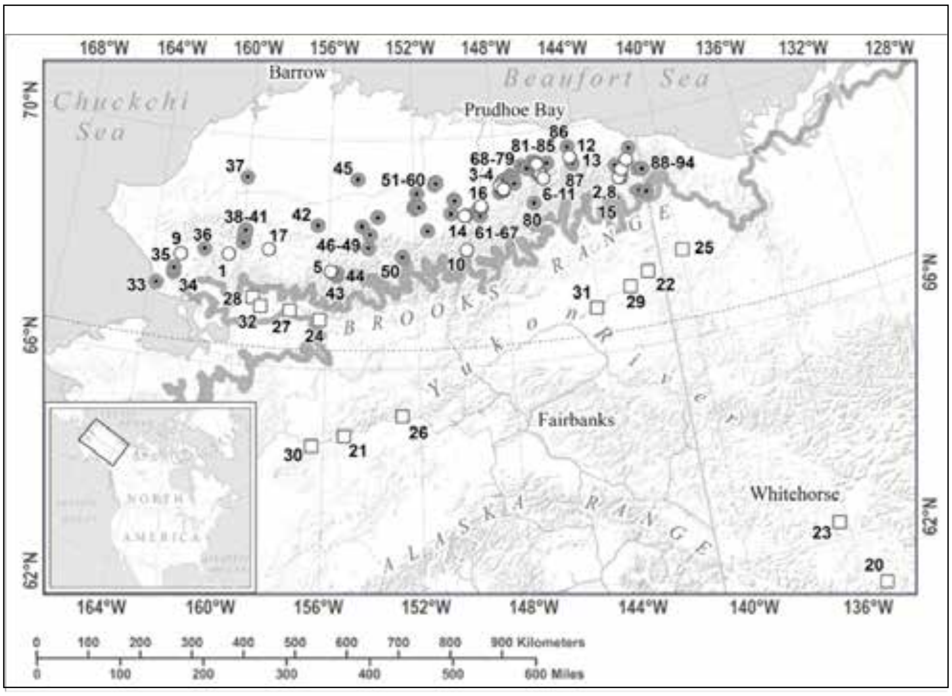

Figure 1. *Location of study sites in Alaska and Yukon (1-32, open symbols) and known balsam poplar occurences north of treeline on the Arctic Slope in Alaska (33-94, gray circles). The study sites in the Arctic are denoted with circles and those in the boreal forest are denoted with squares. The gray line depicts Arctic treeline (CAVM Team 2003).*

To examine the influence of climate on the presence of balsam poplar on the Arctic Slope, I constructed a map of all known balsam poplar stands in northern Alaska. The area of interest is restricted to the region north of treeline, or the northern limits of *Picea glauca* (white spruce), that is characterized by an arctic climate, arctic flora and tundra vegetation. Occurrence data were compiled from the literature, the Herbarium of the University of Alaska Museum of the North (ALA) and observations of the author and her colleagues. Summer warmth index (SWI = thawing degree months, sum of monthly mean temperature > 0 ˚C). The balsam poplar occurrence data are presented overlain on a map of northern Alaska showing SWI at a resolution of 12.5 km pixels (Raynolds et al. 2008).

Results and Conclusion

The ordination revealed a clear differentiation between arctic and boreal communities. Ecological gradients, reflected by ordination axes, correspond to a complex productivity gradient and a complex gradient in slope angle and aspect (Fig. 2). A new order and alliance were described, *Populetalia balsamiferae* and *Eurybio-Populion balsamiferae*, respectively (Table 1). Within the alliance, two new associations are described: (1) *Salix alaxensis-Populetum balsamiferae* (arctic communities, Fig. 3) with three variants (typical variant in riparian areas, var. *Androsace chamaejasme* on south-facing slopes and var. *Cystopteris montanum* associated with perennial springs), and (2) *Roso acicularis-Populetum balsamiferae* (boreal communities). In all communities, species richness is driven by herbaceous and woody species, which make up 85% of the total species (Fig. 4). Species richness of lichens and mosses is low throughout the communities, most likely because of annual flooding in riparian sites and shading by the balsam poplar overstory.

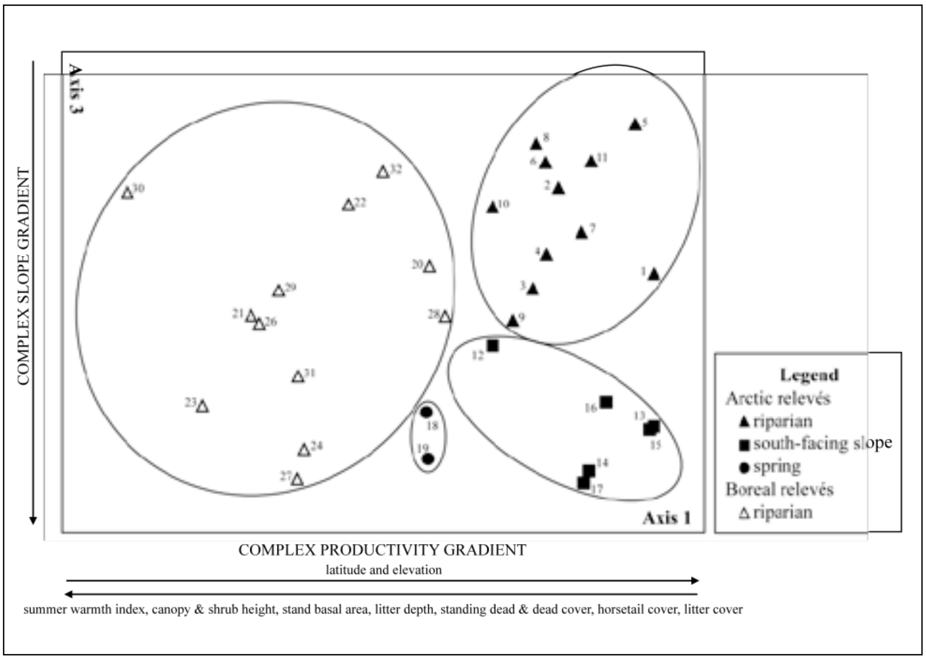

Figure 2. *Nonmetric multidimensional scaling ordination of all relevés. The sample plots are grouped according to plant communities. Arrows along each axis indicate the direction of principal environmental gradients. The relevés are numbered as in Figure 1*

Figure 3. *Landscape (a) and stand (b) view of* Salix alaxensis-Populetum balsamiferae.

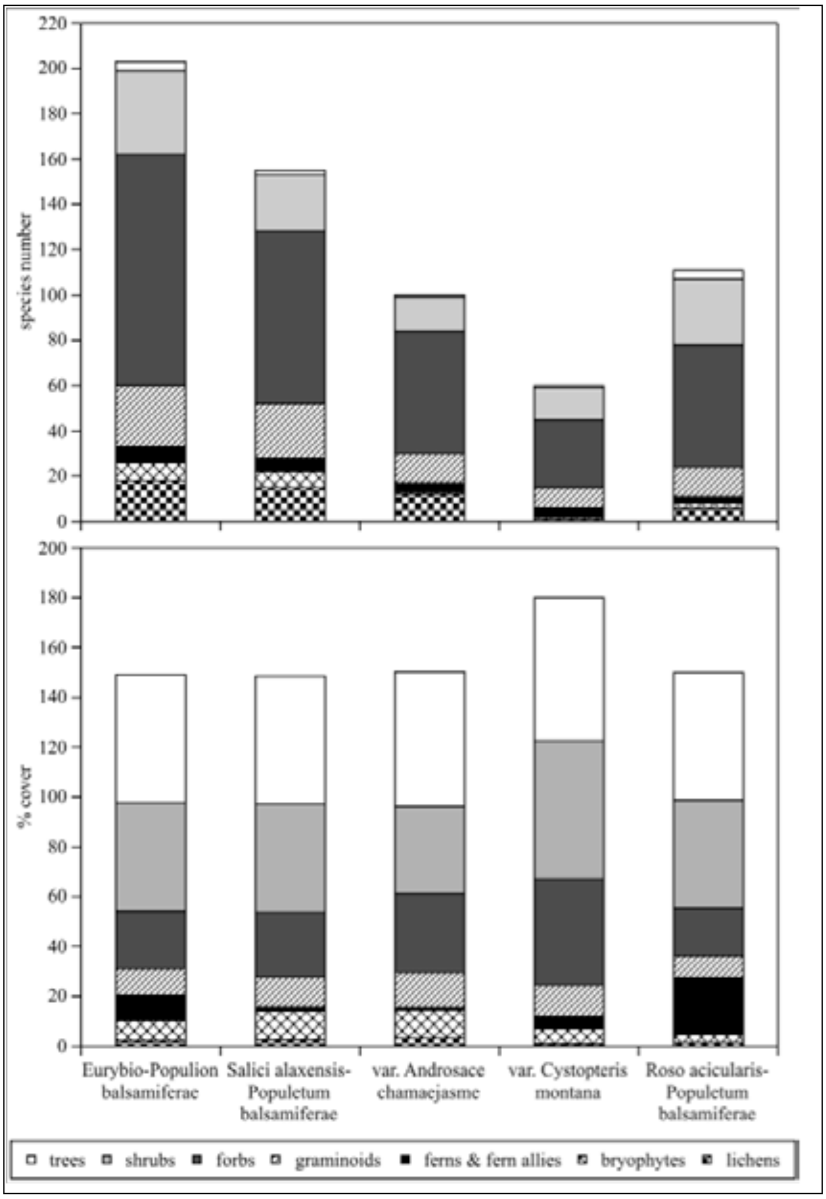

Figure 4: *Analysis of species richness and functional types in the* P. balsamifera *communities. Plant functional types are show as total species numbers and percent cover values.*

Table 1. *Class, order, alliance, association and variant names and habitats of the balsam poplar communities in Alaska and Yukon.*

Class *Salicetea purpureae* Moor 1958

Order *Populetalia balsamiferae* ord. nov.

Alliance *Eurybio-Populion* balsamiferae all. nov.

Association *Salici alaxensis-Populetum balsamiferae* ass. nov. (Arctic communities)

Typical variant (riparian communities)

Variant *Androsace chamaejasme* (south-facing slope communities)

Variant *Cystopteris* montana (spring communities)

Association *Roso acicularis-Populetum balsamiferae* ass. nov. (boreal communities)

A comprehensive baseline map documenting the current distribution of extralimital stands of balsam poplar significantly expands upon our previous knowledge of this species' northern distribution (Fig. 1). A strong link between summer warmth index (SWI) and the presence of balsam poplar is observed for the Arctic Slope (Fig. 5, SWI > 25 for ~80% of the stands). This finding supports the hypothesis of the importance of climate for persistence of balsam poplar on the Arctic Slope. Over the past 30 years, the Arctic has warmed ~2^{o} C per decade and this trend is predicted to continue over the coming years. Climatic change is expected to have major effects on vegetation patterns, including shifts in plant distributions, community composition and northward migration of treeline (Serreze et al. 2000). Moreover, the rapid retreat of summer ice cover in the Arctic Ocean threatens the region with climatic conditions without recent analogues (Bhatt et al. 2010). An alteration of temperature regime caused by climate change will likely result in an increase in the abundance and distribution of balsam poplar on the Arctic Slope of Alaska.

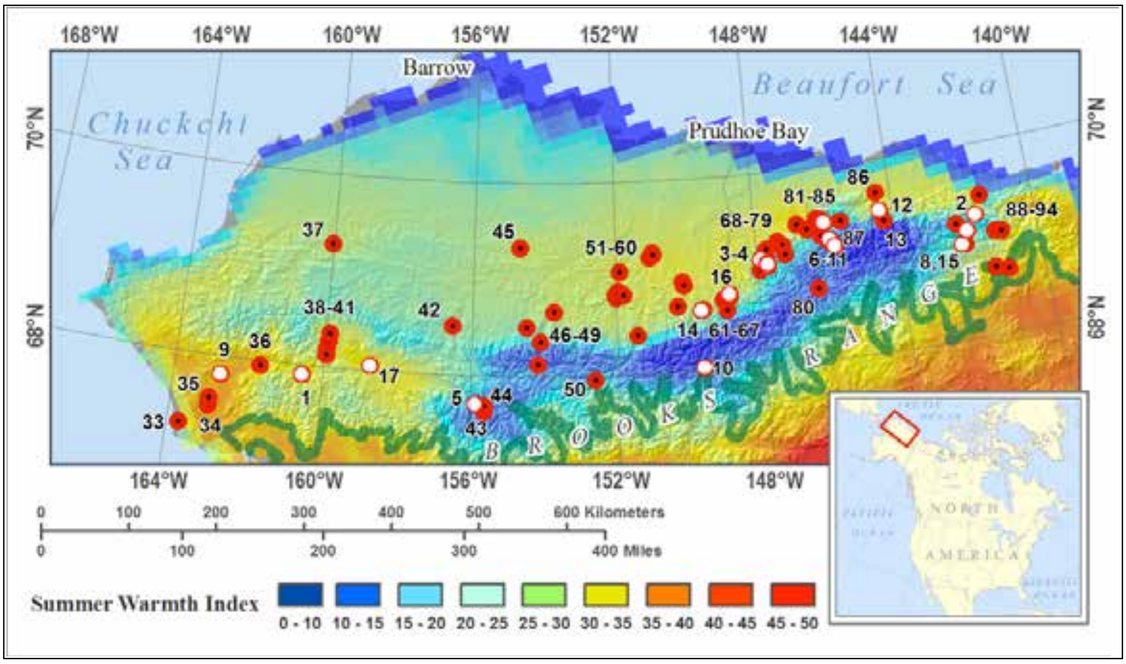

Figure 5. *Map showing summer warmth index and the location of study sites in Alaska (open symbols) and known balsam poplar occurences north of treeline on the Arctic Slope in Alaska (red circles). Summer warmth index is the sum of mean monthly temperatures > 0° C from May to September and was used to characterize the amount of summer warmth available for plant growth at each site (Raynolds et al. 2008). The green line depicts arctic treeline (CAVM Team 2003). The relevés are numbered as in Figure 1.*

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Applying the Braun-Blanquet method in mountainous Arctic Alaska: the Central Brooks Range

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Applying the Braun-Blanquet approach to vegetation sampling and classification outside of Europe has been challenging for researchers. Without a baseline data set and a classification framework to fit new relevés and associations into, the establishment of new associations, alliances, orders and classes has lagged far behind most regions of the world. Higher-level syntax are established and widely used in Eurasia, however most character species for European classes are absent in North America. For example character species of the class *Thlaspeetea rotundifolia* Br.-Bl. 1926 are European in distribution, and most are endemic to the Alps (Willard 1979). The European and Asian syntaxa however provide a robust framework for identifying the types of habitats to be expected in temperate, boreal and arctic regions outside of Europe (Ellenberg 1988, Dierssen 1996). This could facilitate the placement of new relevés, even in regions without previous sampling or classifications into a habitat framework that can be related to other circumpolar vegetation classifications. Associations from a previously unsampled region can be placed into alliances, and perhaps a provisional order, but the establishment of classes requires the synthesis of many studies and a larger number of relevés than most local and regional studies produce.

My work, which began in 1978, had at its goal the collection of new data for the analysis of arctic-alpine tundra vegetation of the central Brooks Range, and a vegetation classification that could be used to compare the vegetation of this region with other high mountain regions of the world (Cooper 1986). Several previous studies of high mountain vegetation that had been published in Norway (Dahl 1964), Scotland (McVean and Ratcliffe 1962), and the US (Komarkova 1979, Willard 1979), and initial work in northern Alaska by Sptezman (1959) and Cantlon (1960) paved the way for my work in the Brooks Range. Wanting to do expedition style research in a pristine area I choose an area with access only by floatplane, or long, overland foot travel, and spectacular mountains … the Arrigetch Peaks region.

The Arrigetch Peaks were sculpted by Pleistocene glaciers from a granitic pluton that had intruded through Skajit limestone and Hunts Fork Shale. It created a relatively small region (50 km^2) with three bedrock types exposed on similar slopes above the tree line (650 m elevation) producing soils with a full range of alkaline to acid condition. The study area also had more than 1250 m of vegetated relief above the tree line. There was considerable topographic, hydrologic and geomorphic complexity producing the full range of mountain habitats to analyze.

Learning the field and analytical methods of the Braun-Blanquet method is challenging, as they are not taught in university courses in the US. Choosing homogenous stands is critical and must be learned from an experienced phytosociologist. A complete knowledge of the local or concrete flora (sensu Khitun et al. 2013) is imperative and can take years of work. In mountain regions lichens and bryophytes are key elements of the flora and must be recognized and identified, greatly increasing the floristic demands on the phytosociologist.

I analyzed 372 relevés to develop a classification with 49 associations, 7 alliances and 3 provisional orders (Cooper 1986). Only when a number of closely related associations were described could alliances and orders be constructed. Table methods are essential for the final ordering of relevés, although cluster analysis and ordination programs help sort large numbers of relevés into groups. The arctic-alpine flora of the Arrigetch Peaks study area contained 569 taxa, including 235 vascular plants, 199 lichens and 135 bryophytes. The flora contained circumpolar taxa such as *Kobresia myosuroides*, but also Beringian taxa such as *Dryas alaskensis* (*Dryas octopetala* L. ssp. *alaskensis* (A.E. Porsild) Hulten) (Hulten 1968). The data provide good structure for the vegetation composition in the full range of habitats that occur in mountainous Alaskan arctic, including marshes, fens, meadows, fell fields, snow beds, springs, willow and alder woodlands, and steppes.

The next steps in developing a classification for mountain regions of arctic Alaska include integrating relevés from other study areas and building on the habitat based classification of snow beds, meadows, fens, and other habitat, and describe as many associations as possible from the available data, and use these associations to establish higher level floristic alliances, orders and classes. It is critical that all relevés added to the database be collected in homogenous sites, and that they have identified all species, including bryophytes and lichens. The classification could be built from the bottom up, with relevés used to create associations and higher syntaxa formed from the associations.

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Natural and anthropogenically disturbed vegetation at the Oumalik Oil Well, Arctic Coastal Plain, Alaska

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Introduction

During the U.S. Naval exploration for oil in what is now the National Petroleum Reserve-Alaska, the exploratory Oumalik Test Well No. 1 (69°50´N, 155°59´W) was drilled in 1949-1950 to search for petroleum and subsequently abandoned. About thirty years later, in 1979-1981, I investigated the unassisted recovery of vegetation damaged by these exploration activities and studied the undisturbed surrounding vegetation in order to place the recovering vegetation into context (Ebersole 1985). Studies on the role of the seed bank in providing colonizers for the disturbance and on short-term recovery in response to the 1980 removal of debris are reported elsewhere (Ebersole 1987, Ebersole 1989).

Oumalik lies about 160 km south of Barrow, Alaska, at the southern boundary of the Arctic Coastal Plain (Wahrhaftig 1965). The surface of the entire area is aeolian silts (Lawson 1983). The thaw lake cycle has reworked most of the vicinity, and these reworked areas are flat, wet, and covered with a variety of marsh vegetation. Some uplands, about 15 m higher than the lower flat areas, remain and are covered with the *Eriophorum vaginatum* tussock tundra typical of the northern foothills of the Brooks Range. Broad drainage channels on these uplands are dominated by *B. nana, Salix planifolia*, and *Carex aquatilis*. The sides of many of these uplands have complex microtopography caused by small-scale solifluction.

The Oumalik well was drilled in a flat, wet area. Bulldozing, presumably to remove saturated soils that impeded vehicle movement in the summer, created wet areas due to subsequent thermokarst as well as mounds of bulldozed material. The camp area, on an adjacent knoll, apparently experienced a great deal of pedestrian trampling and vehicle traffic, which eliminated much of the original vegetation and led to thermokarst. Vehicle tracks, especially between and around the well and camp areas and also from these areas to the lake to the north, partially disturbed vegetation in many other areas. Most of these areas retain many pre-disturbance plant taxa and have additional species that respond positively to disturbance.

Methods

Vegetation was sampled with the relevé method of Westhoff and Maarel (1978) with sites subjectively chosen to represent the full range of natural vegetation. Unless the size of communities did not permit, I used sample areas of 10 to 25 m^2. Most plots were marked on aerial photos and staked. Cover of vascular plants and cryptogams was estimated visually and later converted to an ordinal scale. Multiple environmental factors were estimated on ordinal scales (Komárková 1979, Walker et al. 1979) and, for a subset of plots, soil analyses were done. For the undisturbed vegetation I used 87 relevés with all plants and complete soils data and 61 additional relevés with only vascular plant data to define communities, and for the anthropogenically disturbed vegetation I used 34 relevés with all plants and complete soils data and 19 additional relevés with only vascular plant data.

I used the Braun-Blanquet table method to define communities but did not place communities into the Braun-Blanquet syntaxonomy. I named communities with a combination of dominant and characteristic taxa. Detrended correspondence analysis (DECORANA) was used to ordinate the data set.

For disturbed vegetation the enormous number of combinations of disturbance types in a wide variety of communities prevented sampling all possibilities, but I estimate that the communities described cover more than 95% of the disturbed area.

Results and Interpretations

Classification defined 23 natural and 13 disturbed communities (Tables 1 and 2). The communities reflect the position of Oumalik near the boundary between the Arctic Coastal Plain (numerous marsh communities) and the Northern Foothills (tussock tundra).

Table 1.
Natural vegetation communities at Oumalik

Number	Community	Comments
1	*Arctophila fulva - hippuris vulgaris*	In water 30-100 cm deep
2	*Arctophila fulva - Eriophorum scheuchzeri*	Early successional community in drained lake basins; *Eriophorum angustifolium* also common
3	*Carex aquatilis - Eriophorum angustifolium*	Species-poor community occurring in areas that recently became wet, e.g., recent thermokarsts
4	*E. russeolum – Hierochloë pauciflora*	In shallow standing water; *C. aquatilis* and *E. angustifolium* also common
5	*C. chordorrhiza - C. rotundata*	In sites with standing water early in the season and at least saturated soils later in the season; the most species-rich Oumalik march community; *C. aquatilis, C. saxatilis, E. angustifolium, E. russeolum*, and *Scorpidium scorpioides* also common
6	*C. chordorrhiza - Salix planifolia*	Similar to community 5 but with a shrub layer of *Salix planifolia*
7	*Salix planifolia - Carex aquatilis*	On low-centered polygon rims and in drainages coming off the uplands; *Betula nana, Hylocomnium splendens, Tomenthypnum nitens*, and *Sphagnum* spp. also common
8	*Salix lanta - S. planifolia*	In drained lake basins with saturated soils for most of the growing season; *C. aquatilis, E. angustifolium, Betula nana, Hylocomnium splendens, Tomenthypnum nitens* also common
9	*S. lanata - Equistum arvense*	Unusual at Oumalik, only in small creeks; *C. aquatilis, E. angustifolium*, and *Calliergon giganteum* also common
10	*E. vaginatum - Salix planifolia*	The tussock tundra that dominated the northern foothills of the Brooks Rang
11	*Salix rotundifolia*	Snowbed community; snowbed communities are rare at Oumalik because there are few long-lasting snowbanks and where they do occur, other factors, especially instability of surfaces predominate and prevent snowbed communities from developing
12	*Dryas integrifolia - E. vaginatum*	Physiognomically similar to community 10 but floristically most like community 13; *Rhacomitrium lanuginosum* distinguishes this community
13	*Dryas integrifolia - S. glauca*	Species-rich community on slopes with substantial solifluction; *S. reticulata, C. bigelowii*, and *Arctous rubra* also common
14	*Ledum palustre - Cassiope tetragona*	On mounds that are occasionally present at intersection of rims of low-centered polygons and are used by perching birds; *Vaccinium vitis-idaea, Betula nana*, and *Carex bigelowii* also common
15	*Eriophorum angustifolium - Ochrolechia upsaliensis*	On frost boils with continually wet subsurface soils; *Dryas integrifolia, Equisetum scirpoides, E. variegatum*, and *Saxifraga oppositifolia* also common
16	*Dryas integrifolia - Ochrolechia upsaliensis*	On frost boils in more mesic sites than community 15, especially within communities 10 and 13; *Carex bigelowii* also common
17	*Dryas integrifolia - Carex spp.*	Infrequent on moist, flat surfaces within drained lake basins; *Salix reticulata, Carex bigelowii, C. scirpoides*, and *C. vaginatum* also common
18	*Betula nana - Ledum palustre*	On moist palsas and centers of high-centered polygons; *Salix planifolia, Vaccinium vitis-idaea, Aulocomnium turgidum*, and *Hylocomnium splendens* also common
19	*Hierochloë alpina - Arctagrostis latifolia*	On ground squirrel mounds; *Poa arctica* also common
20	*Salix glauca - Poa arctica*	On stabilized lake bluffs; *A. latifolia* also common
21	*S.alexensis - S. arbusculoides*	Unusual at Oumalik, on stabilized lake bluffs and one eroded pingo
22	*A. latifolia*	On very recently stabilized lake bluffs
23	*Puccinellia borealis - A latifolia*	Unusual at Oumalik, early successional community on dry mounds isolated by erosion of lake bluffs

Table 2:
Vegetation communities on the anthropogenically disturbed areas at Oumalik.

Number	Community	Comments
24	*Arctophila fulva*	In areas where bulldozing and/or thermokarst created standing water > 40 cm
25	*Carex aquatilis – Eriophorum angustifolium (disturbed)*	In areas of bulldozing and multiple-pass vehicle trails where disturbance and/or thermokarst created shallow water; indistinguishable from community 3
26	*E. vaginatum - Salix planifolia (disturbed)*	Created by partial disturbance of community 10; with original species and additional *Arctagrostis latifolia* and *Salix* spp.
27	*E. vaginatum - C. aquatilis*	Created by partial disturbance of community 10; thermokarst has lowered the area so *C. aquatilis* has become a part of the community
28	*Saxifraga cernua - Marchantia polymorpha*	Unusual community in relatively dark areas among stacked oil drums; destroyed by the 1980 removal of debris from Oumalik
29	*Betula nana - C. aquatilis*	On bottoms of bulldozed trails that are wet but without standing water
30	*Salix planifolia - Carex aquatilis (disturbed*	Created by multiple passes of vehicles through community 8
31	*Salix spp. - Arctagrostic latifolia - Eriophorum angustifolium*	On mounds of bulldozed material that are mesic trending toward wet; *S. planifolia, S. glauca, S. alaxensis, C. aquatilis,* and *Equisetum arvense* are also common
32	*Salix spp. - Arctagrostic latifolia*	On mesic mounds of bulldozed material; similar to community 31 but without *E. angustifoium* and *C. aquatilis*
33	*A. latifolia (disturbed)*	On mesic mounds of bulldozed material but without as much organic matter as communitis 31 and 32; nearly monospecific
34	*Dryas integrifolia - Equisetum arvense*	In multiple-pass vehicle trails through communities 13 or 17 where moisture regime is not much changed; in addition to original species, *A. latifolia* and *Poa arctica* are commo
35	*Betula nana - A. latifolia*	From partial disturbance of community 18

Ordinations showed that moisture and a pH / organic matter gradient correlated most strongly with the variation in undisturbed vegetation (Figure 1). Axis 1 separates the wettest communities on the high end from mesic communities on the low end (there are no dry natural communities at Oumalik). Axis 2 shows the pH / organic matter gradient. Areas with little organic matter and subsequent pH of about 8 of the underlying silts lie at the high end of this axis, and mesic communities controlled mainly by the accumulation of organic matter with pH of 5 to 6 lie at the low end.

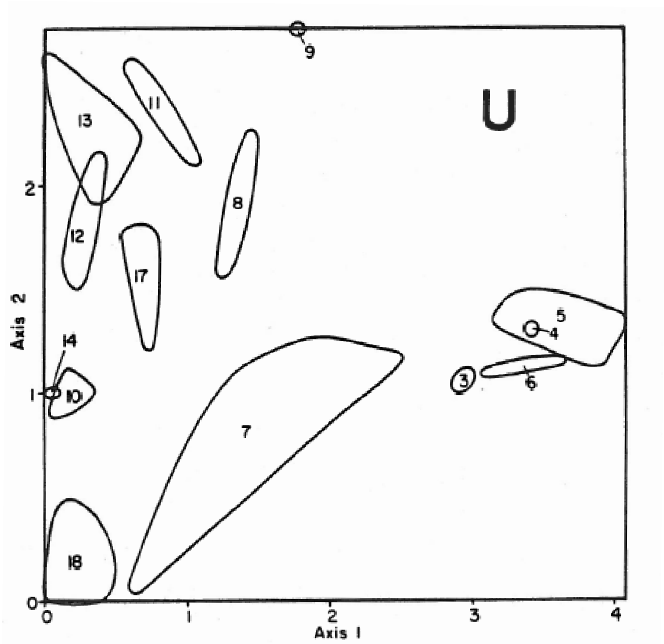

Figure 1: *Detrended correspondence analysis ordination of undisturbed vegetation at Oumalik. For this paper, relevés of natural disturbances, such as eroding lake bluffs, were omitted. Numbers refer to communities from Table 1.*

Disturbed communities comprise several groups. Areas partially disturbed, e.g., by multiple passes of vehicles, retained many of the original taxa and were colonized by many taxa that respond positively to disturbance, e.g., *Arctagrostis latifolia* and *Salix* spp. Disturbed areas that are now wet have several species-poor communities, e.g., *Arctophila fulva*, and *Carex aquatilis – Eriophorum angustifolium* (disturbed) (Table 2), that are nearly or completely indistinguishable from their undisturbed equivalents. Apparently the primary controlling factor of moisture / water depth allows the same taxa to fairly quickly (within 30 yr) colonize disturbed areas.

Mounds of bulldozed soil created the most visually striking communities on disturbed areas (communities 31, 32, 33). Vigorous willows (*Salix alaxensis, S. lanata, S. planifolia,* and *S. glauca*) were much taller, had much greater annual twig elongation, and higher reproduction than the same species in undisturbed areas. Higher soil temperatures and good drainage allow much more rapid decomposition rates in these soils than in undisturbed areas (Ebersole 1985, Ebersole and Webber 1983). One species, *S. alaxensis*, survives above the snow in winter on the open tundra on these mounds, apparently because the extremely favorable growth conditions created by the disturbance allows some twigs to grow above the zone of greatest snow abrasion in the 30 to 40 cm above the snow (Ebersole 1985). The *Arctagrostis* community (community 33) occurs on mounds of bulldozed material with little organic matter (ca. 5%) compared to the willow communities (ca. 30%) (Ebersole 1985).

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Overview of the International Tundra Experiment (ITEX) data sets and discussion of point data

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Overview

The International Tundra Experiment (ITEX) is a grass-roots, international scientific collaboration to study the effects of climate change on tundra plant communities worldwide. The core experiment consists of a passive summer warming experiment using open-topped chambers, and specification of sampling protocols to document plant responses including measurements of growth, phenology, and community composition. ITEX sites are maintained by individual PIs, who implement a subset of protocols specified in the ITEX manual (Molau and Molgaard 1996), as time and funding permits. ITEX data have resulted in numerous publications from individual sites, as well as several highly cited meta-analyses and syntheses (e.g. Walker et al. 2006, Elmendorf et al. 2012a, 2012b, Oberbauer et al. 2013). As a result, the ITEX study is regarded as an early model for ecological coordinated distributed experiments (Fraser et al. 2012).

ITEX and the AVA

Community composition data from the ITEX experiment are complementary to the AVA's goals of collating vegetation datasets for panarctic vegetation classification, climate change, and biodiversity studies. Indeed, the original ITEX data have already been combined with repeat survey data from tundra monitoring sites worldwide to study vegetation change in response to ambient summer warming (Elmendorf et al. 2012b). However, this extensive set of repeat survey data differ from the target data sets for the AVA in several ways. The AVA centers on releve data from homogeneous plant communities and requires cover-abundance scores for all species, including cryptogams, whereas the repeat survey data used in Elmendorf et al. (2012b) included a diversity of methods, including point-frame data based on top only, top and bottom only, or all hits through the canopy, ocular cover estimates, stemcounts, biomass harvests, and subplot frequency count measurements. Complete species lists are not reliably generated from these methods, which may miss rare species. In addition, species that are difficult to identify reliable (predominantly cryptogams), were combined into easily recognized morphospecies for surveys. These differences, combined with the fact that the entire dataset has already been archived (Elmendorf 2012c), led us to conclude that direct incorporation of the ITEX data into the AVA would not be appropriate. However, they remain a valuable resource for combined studies.

Lessons learned from ITEX syntheses

Extensive work with the ITEX data suggests several recommendations for the AVA and similar initiatives going forward. First, standardizing methodology across monitoring protocols such that data are recorded in comparable units greatly enhances the utility of the resulting data. While meta-analytic techniques can be employed to harmonize disparate datasets, inference is limited to the direction and statistical significance of changes, rather than magnitude in biologically relevant units. Second, generating comparable data across space or time based on human observers is inherently difficult. Detailed protocols, formal training, field-based assessment of protocol implementation can help reduce observer bias. Quality-control procedures applied to the ITEX data revealed that nonvascular species and rare species were the most difficult to reliably identify. As a result, analyses which rely on complete and accurate identification of locally uncommon species are the least robust metrics of vegetation change. Examples of such analyses include using local species richness as a response variable and ordination or other multivariate procedures that do not downweight rare species.

From an informatics perspective, design of the AVA metadata and database structure should ensure that the data are primed for use in future studies beyond the initial vegetation classification goals. This includes attention to data discovery, archiving in commonly used, open access formats, and detailed metadata. EML and Darwin Core provide a good basic framework for metadata, but lack some of the detailed specification and controlled vocabulary necessary to fully capture important details of releve or other checklist data including (1) characteristics of species targeted in search; (2) detailed methodology including plot size and sampling protocol; (3) expertise of botanist conducting surveys, all of which heavily influence the comparability of the resulting datasets. Such information can be readily incorporated into hierarchical models for comparisons over space and time by explicitly modeling the observation process in order to integrate large datasets that are based on similar but not identical sampling regimes

An open data access policy is strongly recommended in order to facilitate future use of the data. Optional embargo periods could be included for those contributors who are actively working on site-specific analyses. Without timely archiving, even published datasets are lost at a rate of 7%/year (Vines et al. n.d.). Information on tundra vegetation is expensive to obtain, due to the remote nature of most sites and expense of access. Given the current and anticipated future rates of tundra vegetation change, the AVA is a timely mission to rescue, harmonize, and preserve these valuable datasets for future studies.

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NDVI, LAI, and biomass data from the Western Alaska Arctic Transect and the North American Arctic Transect

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Data on the Normalized Difference Vegetation Index (NDVI), Leaf Area Index (LAI) and aboveground plant biomass have been collected throughout northern Alaska and northern Canada as part of two National Science Foundation (NSF) projects dating back to 1999. Collectively, the sites sampled during these projects form the Western Alaska Arctic Transect (WAAT), and the North American Arctic Transect (NAAT). The Western Alaska Arctic Transect includes the sites (from south to north) at Council and Quartz Creek (Seward Peninsula), Ivotuk, Oumalik, Atqasuk, and Barrow. Sites along the NAAT include Toolik Lake, Happy Valley, Sagwon Hills, Franklin Bluffs, Deadhorse, West Dock, Howe Island, as well as Green Cabin (Banks Island, Canada), Mould Bay (Prince Patrick Island, Canada), and Cape Isachsen (Ellef Ringnes Island, Canada) (Figures 1 &2; Walker et al. 2003a, 2003b, 2009, 2011).

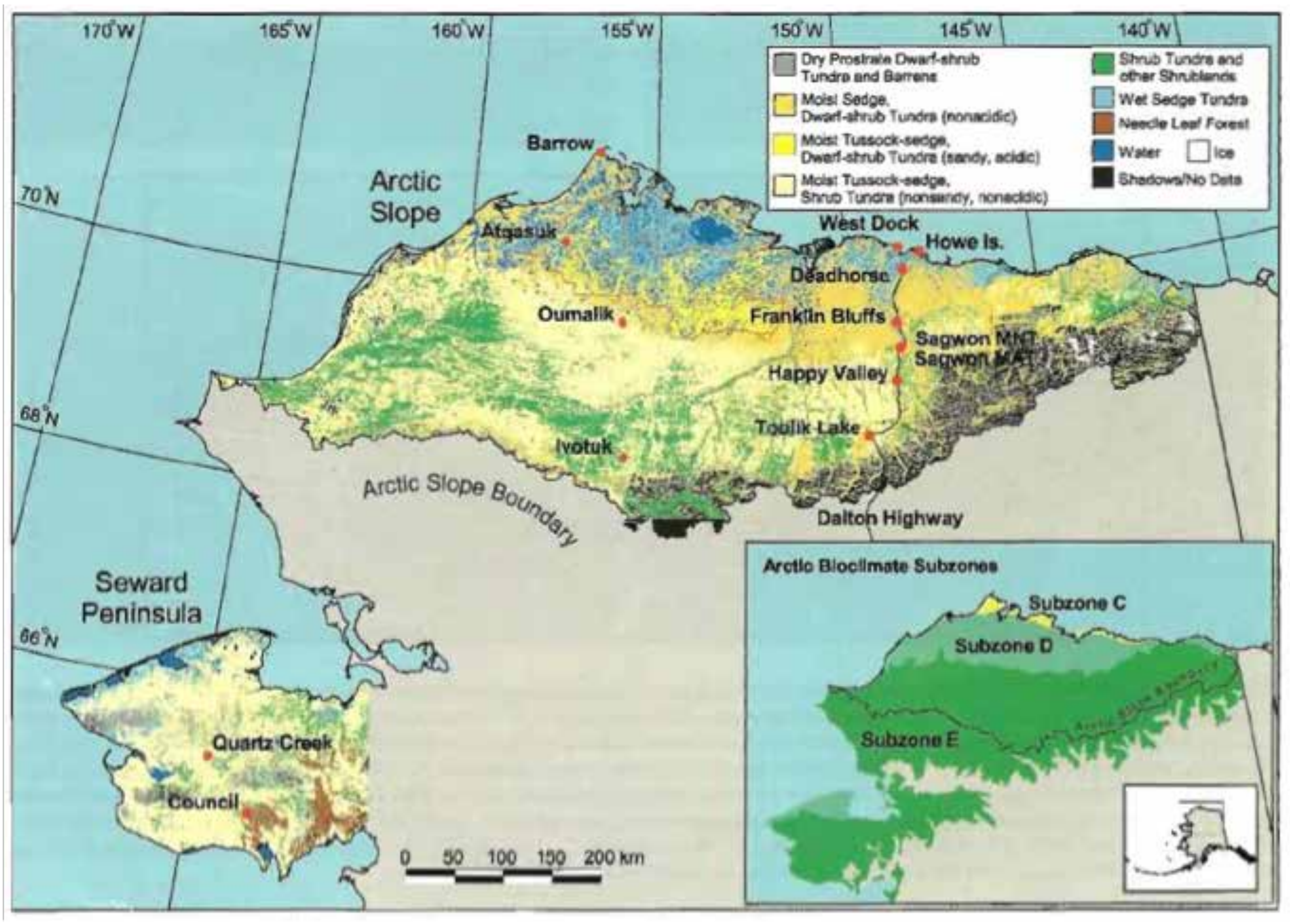

Figure 1. *Sites along the Western Alaska Arctic Transect and the Alaskan portion of the North American Arctic Transect.*

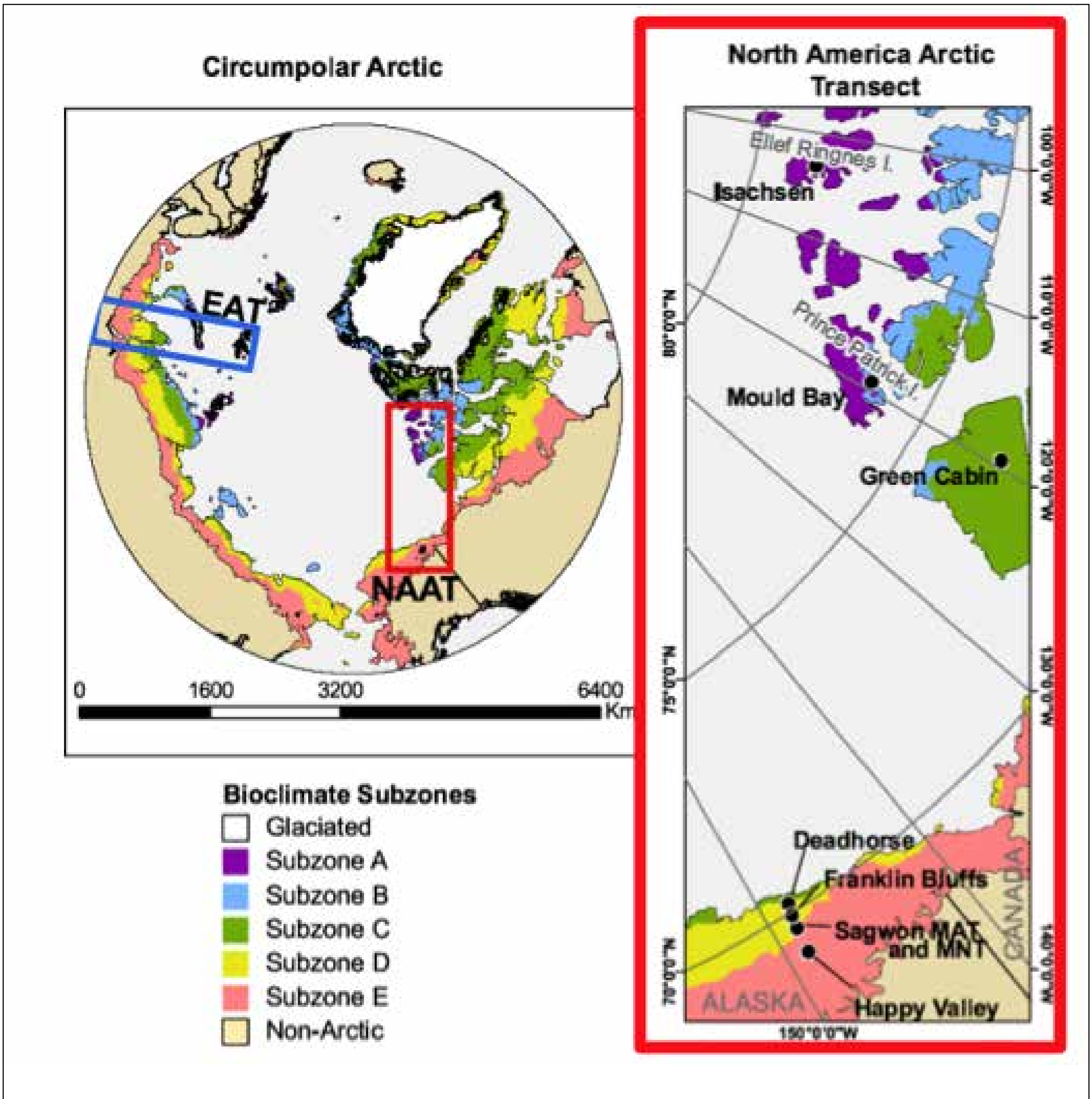

Figure 2. *The full North American Arctic Transect (Walker et al. 2012).*

During the summer of 1999, as part of the Arctic-Transitions in the Land-Atmosphere System (ATLAS) project, we collected a suite of vegetation data from four tundra plant community types at Ivotuk, Alaska over the course of the growing season from June through August. Four 100m x 100m grids were established in moist acidic tundra (MAT), moist non-acidic tundra (MNT), shrub tundra (ST) and moss-dominated tundra (MT) (Figure 3). Twenty random grid points were sampled for leaf area index (LAI – using a LI-COR 2000 Plant Canopy Analyzer) and the normalized difference vegetation index (NDVI – using an Analytical Spectral Devices FieldSpec), and ten of these random grid points were harvested for aboveground plant biomass (20 x 50 cm quadrats). These same grid points were sampled consistently approximately every two weeks, for a total of 6-7 sampling dates; all twenty points were sampled for biomass at the peak of the growing season. There were clear distinctions in the magnitude, spatial variability, and seasonality of these vegetation variables across the plant community types (Figure 4), and these results are described in Riedel et al. (2005a, 2005b).

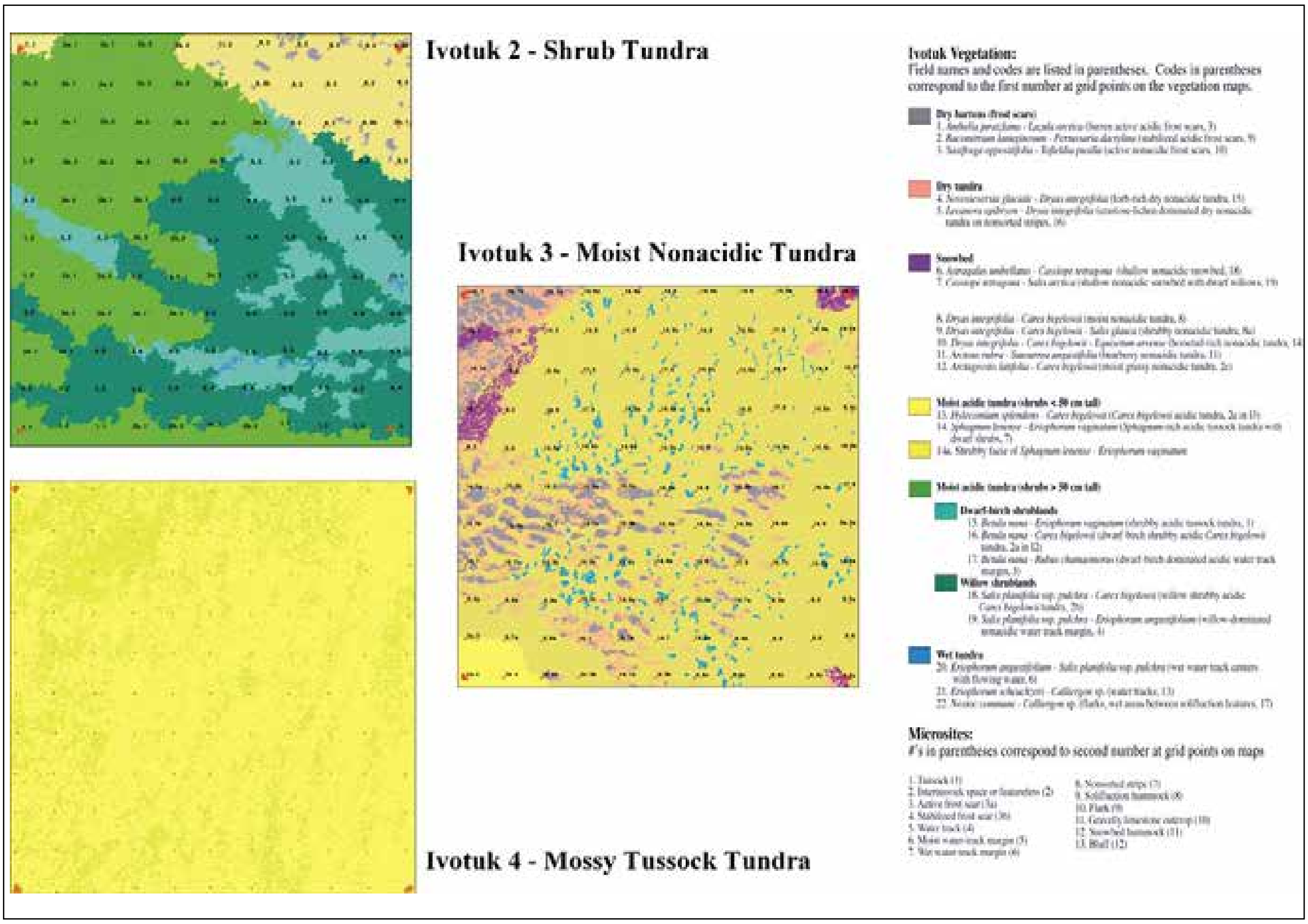

Figure 3. *Vegetation maps of three of the four 100 m grids at Ivotuk. (Reidel et al. 2005).*

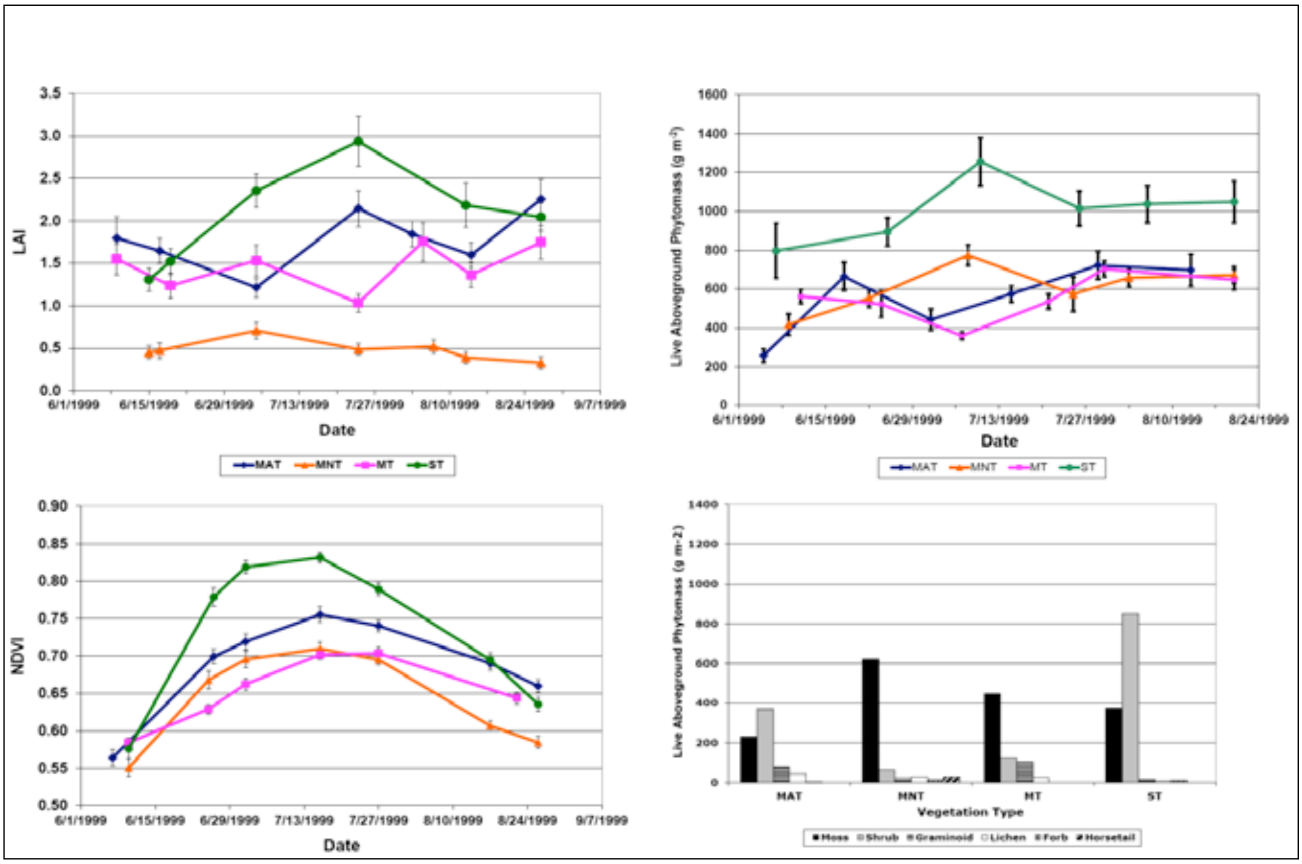

Figure 4. *LAI, NDVI, and live aboveground biomass for the four Ivotuk grids.*

In 2000, the field sampling for the ATLAS project moved to the Council and Quartz Creek sites on the Seward Peninsula. Vegetation was sampled at five 100 x 100 m grids at Council and three grids at Quartz Creek. LAI was measured at 33 random grid points at the peak season for the Quartz Creek grids and a Barren grid at Council, and was also collected at uniform points for four Quartz Creek relevés. LAI was additionally measured every 10 meters (121 grid points) for the other Council grids (Thompson et al. 2004). Aboveground biomass was estimated from 20 x 50 cm quadrants (1 x 1 m for the Shrub grid) at several random grid points in each of the Quartz Creek grids. Aboveground biomass was also collected at 10 random grid points (1 x 1 m) for the Council grids (Thompson et al. 2004).

Other ATLAS sites along both the Western and Eastern Alaska Transects were sampled between 1999 and 2001. For the other Western Transect sites (Oumailk MAT/MNT, Atqasuk, Barrow), LAI was measured at 33 random points in each grid, and biomass was estimated at 10 random grid points (20 x 50 cm). For the Eastern Transect (Happy Valley, Sagwon MAT/MNT, Franklin Bluffs, Deadhorse, West Dock, Howe Island), LAI was measured at 2-m intervals along two 50-m transects at each grid, and biomass was estimated at three points 5m, 25m, and 45m (20 x 50 cm) along each of the transects. NDVI data were collected at each meter along the transects. Both Happy Valley and Franklin Bluffs locations had three grids along toposequences (dry, moist, wet). Additionally there are biomass data from permanent plot harvests at Toolik Lake from 1993 (three replicates from five MNT sites and four MAT sites) (Figure 5).

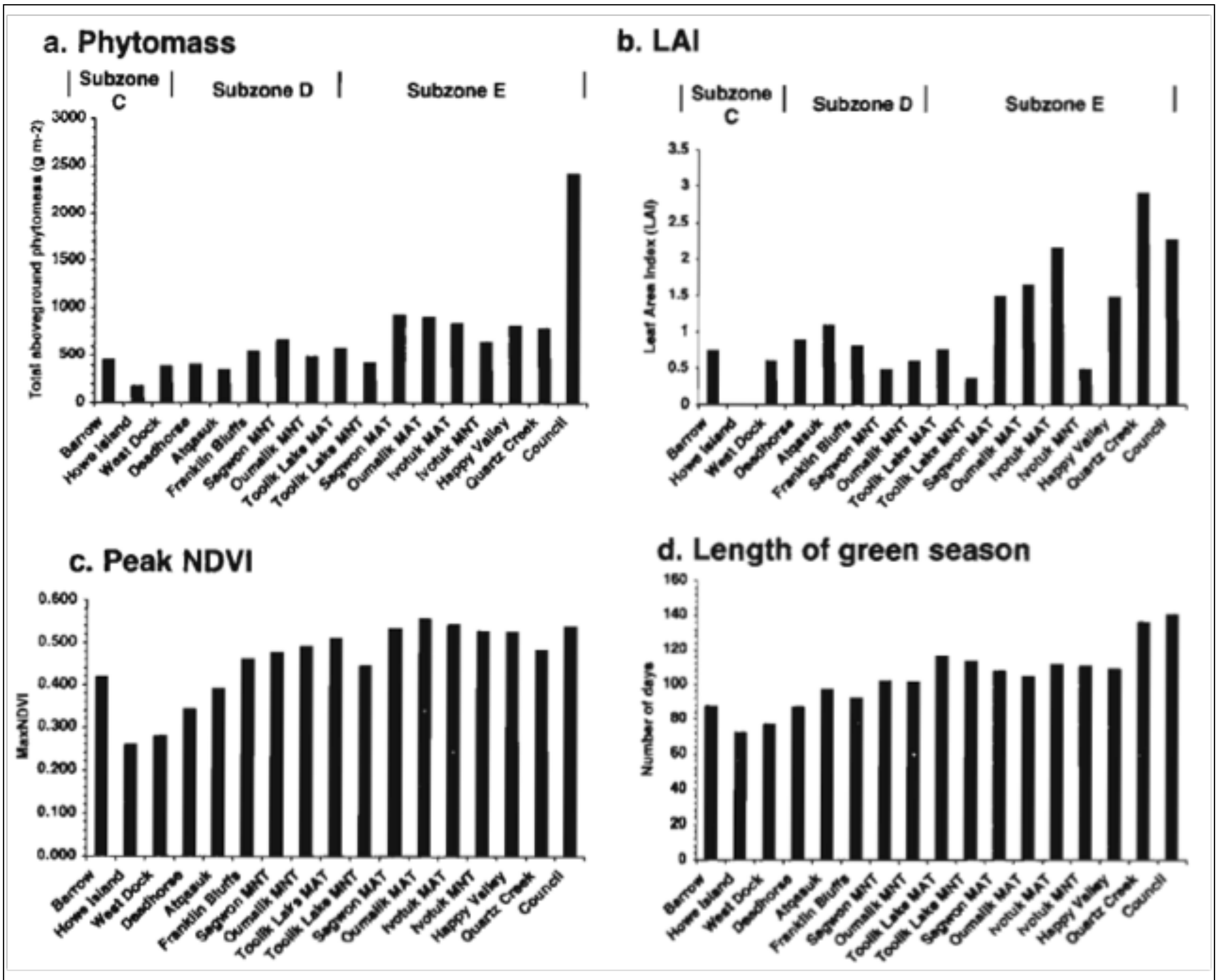

Figure 5. *Aboveground biomass, LAI, and NDVI for the ATLAS sites (Walker et al. 2003b).*

In 2002, the Biocomplexity of Patterned Ground Ecosystem project (NSF-funded) began on the North Slope along the Dalton Highway. LAI, NDVI, and biomass had already been collected during the ATLAS project, but additional LAI, NDVI, and biomass data (20 x 50 cm) were collected from three replicate non-sorted circles and inter-circle areas for Happy Valley, Sagwon MNT/MAT, and Franklin Bluffs (Kelley et al. 2004, Kelley and Epstein 2009, Kelley et al. 2012).

For the three Canada sites along the NAAT (Green Cabin 2003, Mould Bay 2004, Isachsen 2005), 10 x 10 m grids were established in dry, mesic, and wet topographic positions (plus a riparian grid at Isachsen). LAI and NDVI were collected every meter along two 50-m transects adjacent to each grid. Aboveground biomass (20 x 50 cm) was collected at 5m, 25m, and 45m points along each transect, and was additionally collected for each relevé at the three sites. NDVI was collected for 11 relevés at Isachsen. In 2006, the North Slope sites along the NAAT were revisited, and aboveground biomass (20 x 50 cm) and NDVI were collected for each relevé (Walker et al. 2004, Walker et al. 2008, Epstein et al. 2008 - Figure 6).

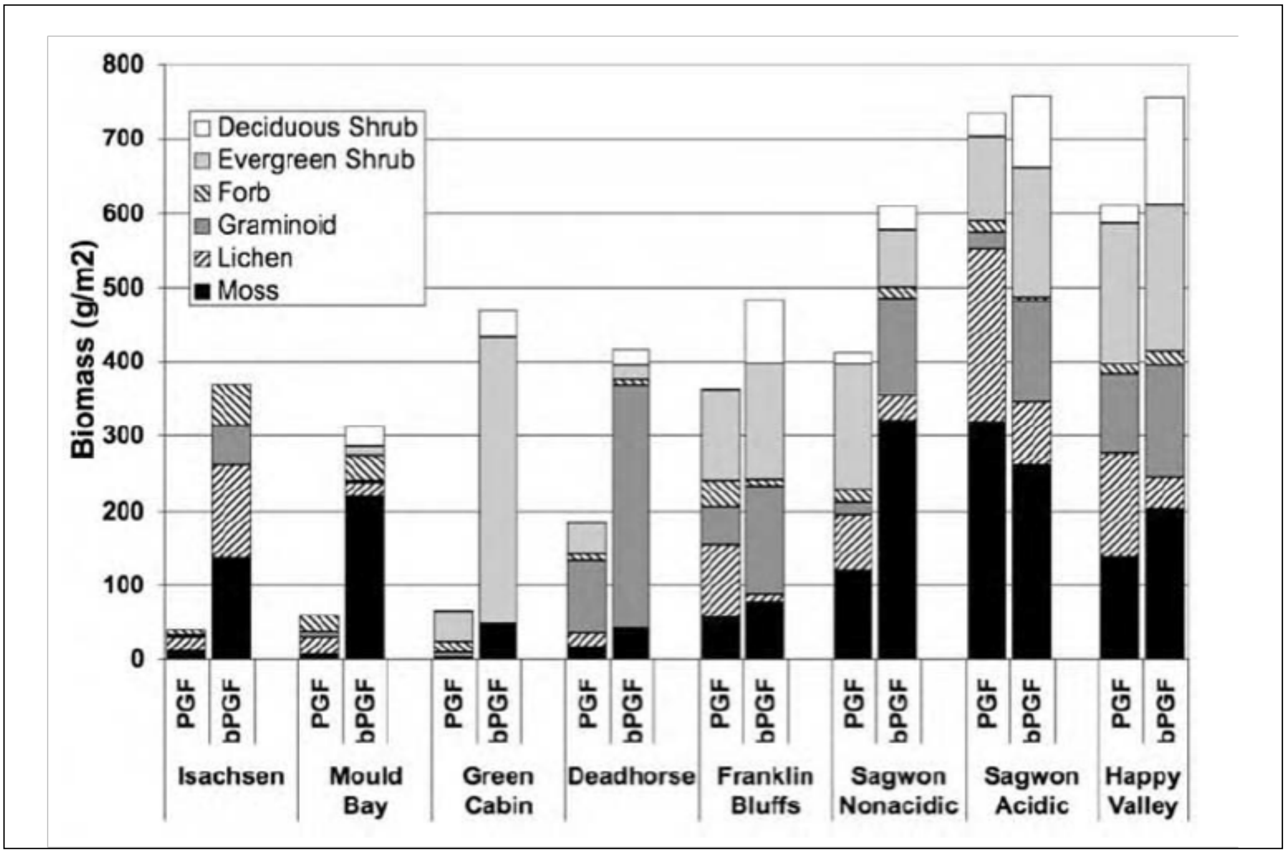

Figure 6. *Aboveground biomass by plant functional type on and between patterned-ground features along the NAAT. Increasing summer temperature gradient is from left to right.*

All of the NDVI data collected across the Western Alaska Transect and the NAAT were calculated from hyperspectral information recorded by hand-held spectroradiometers, the extent of which was never fully utilized. In a 2011 field campaign, Buchhorn et al. (2013) collected hyperspectral information for the Deadhorse, Franklin Bluffs (dry, zonal, wet), Sagwon MNT/MAT, and Happy Valley (dry, zonal, wet) sites. These data combined with the extensive hyperspectral data collected during the ATLAS and Biocomplexity projects (Figure 7) could form the basis for a future direction in tundra remote sensing analyses.

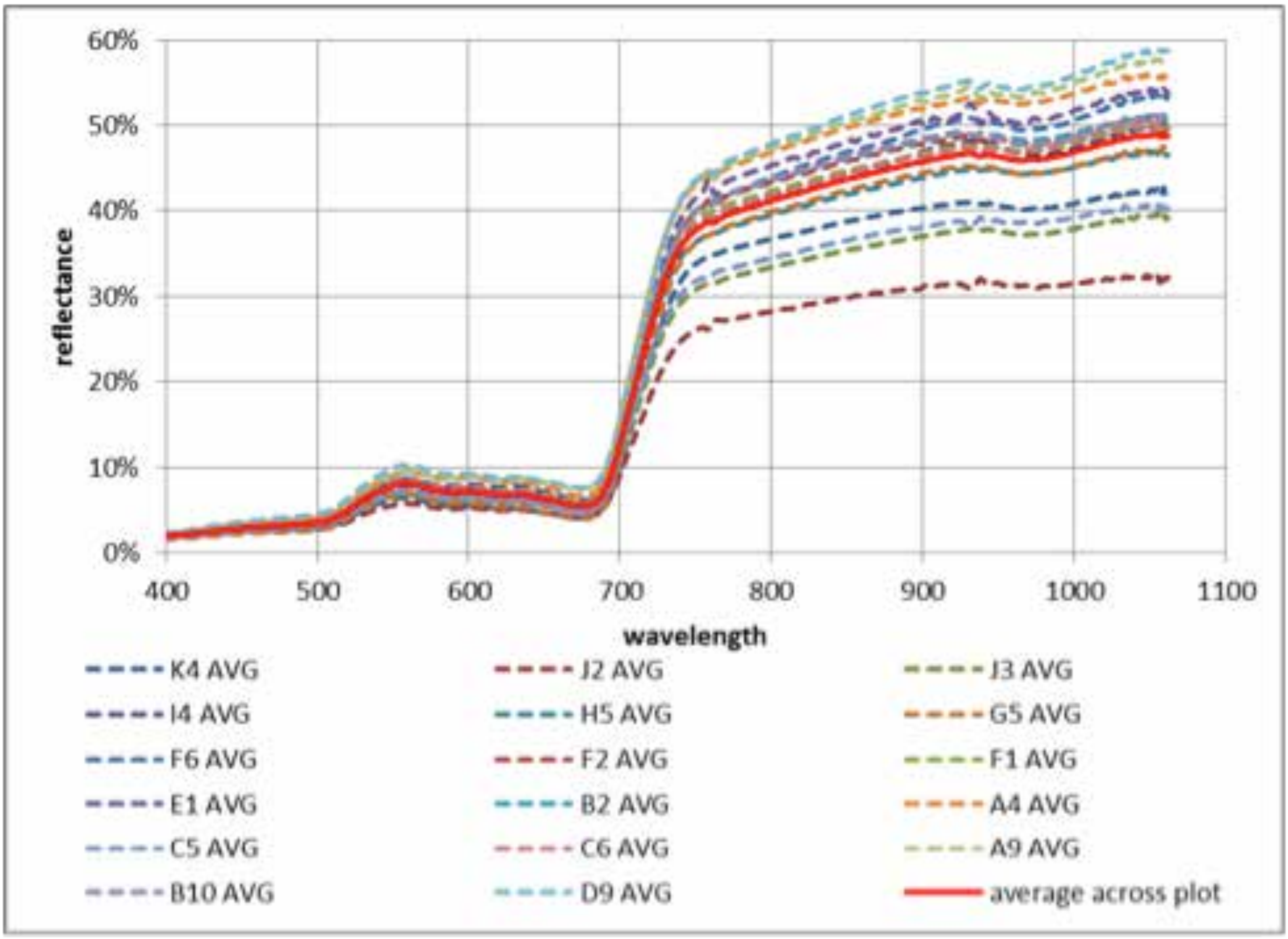

Figure 7. *Sample reflectance spectra for multiple grid points at one of the four Ivotuk grids.*

In summary, the LAI, NDVI, and biomass data in their entirety for Alaska and Canada are not completely consistent, given multiple projects, several personnel, and evolving sampling protocols; however several subsets of the data are in very good shape. Ivotuk represents an excellent dataset, as does the Dalton Highway relevé biomass and NDVI data. The data for the Canadian sites along the NAAT are also essentially complete. Our ultimate goal for the pre-ABoVE project is to fully develop the LAI, NDVI, and biomass dataset (in addition to the hyperspectral information) as a link within the Alaska Vegetation Archive.

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Plant community composition data: Bathurst Inlet and the Canadian Transect

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Background

Two datasets relevant to the Arctic Vegetation Archive include a study of plant community composition, landscape and remotely-sensed spectral diversity from the central Canadian Arctic, Bathurst Inlet area (Gould 1998) and a series of relevés conducted along a climatic gradient in the Canadian Arctic as a component of the Circumpolar Arctic Vegetation Map (CAVM Team 2003). The datasets include plant community composition and associated site environmental characteristics from 12 locations (Fig. 1, Table 1). The objectives of the sampling in the Bathurst Inlet area were to test hypotheses related to species richness patterns and environmental controls along gradients of climate, pH, and landscape heterogeneity (Gould and Walker 1997, Gould and Walker 1999, Gould 2000). The objectives of the Canadian Transect were to bring Arctic vegetation experts to sites along the complete climatic gradient in the Canadian Arctic in order to better understand vegetation patterns, develop a table of major vegetation types along a topographic sequence within climatic subzones, and ultimately develop consensus on bioclimatic zonation for the Canadian Arctic and the Circumpolar region (CAVM team 2003, Gould et al 2003, Walker et. al 2005).

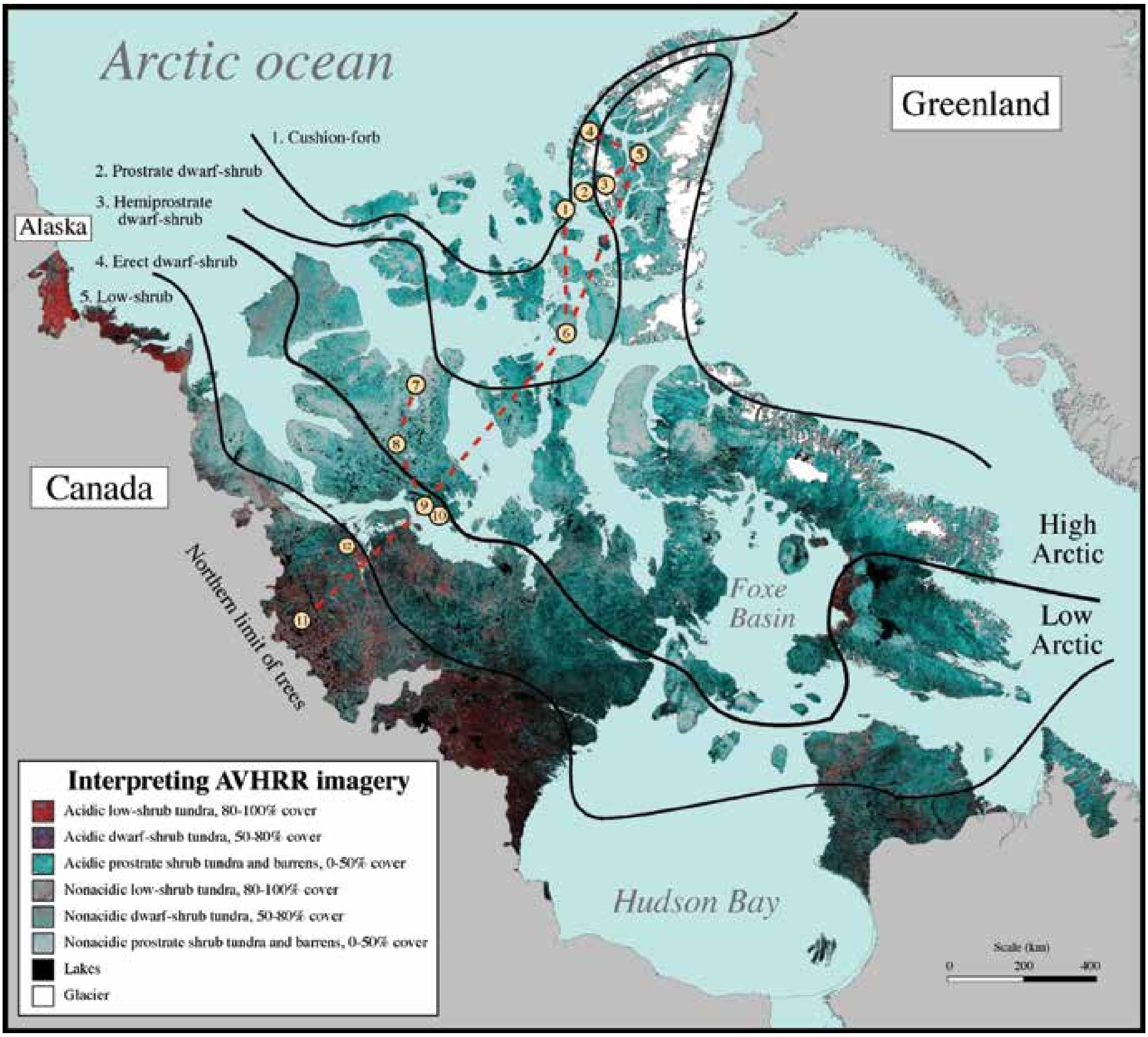

Figure 1. *Location of relevé sampling sites in the Canadian Arctic (modified from Gould et al 2003).*

Table 1. *Relevé sampling sites in the Bathurst Inlet and Canadian transect studies*

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			Elevation (m)	Dominant Subzone	Vegetation	Mean July Temp. (°C)	Annual Precip. (mm)
Amund Ringnes Island							
Northweast coast	8/2/99	78 41 N, 96 45 W	2	1	cushion-forb		
1 Stratigrapher river	8/2/99	78 38 N, 96 50 W	40 - 50	1	cushion-forb		
Axel Hieberg Island							
2 Cape Levvel	8/2/99	78 58 N, 94 15 W	10	2	prostrate dwarf-shrub		
3 Bunde Fiord	8/1/99	80 30 N, 94 35 W	30-40	2	prostrate dwarf-shrub		
4 Expedition Fiord	8/2/99	79 25 N, 90 45 W	150	3	prostrate dwarf-shrub		
Ellesmere Island							
5 Eureka	7/29/99 - 8/4/99	80 00 N, 84 55 W	20-30	3	prostrate dwarf-shrub	5.4	68.0
Black top Ridge	7/30/99	80 04 N, 85 29 W	200	1	cushion-forb		
Hare Ridge	7/30/99	80 05 N, 86 15 W	200	1	cushion-forb		
East Wind Lake	7/31/99	80 06 N, 85 34 W	135-150	3	hemiprostrate dwarf-shrub		
Cornwallis Island (Resolute area)							
North of Signal Hill	8/6/99	74 44 N, 94 52 W	125	2	prostrate dwarf-shrub		
6 Resolute Bay	8/6/99	74 41 N, 94 55 W	75	2	prostrate dwarf-shrub	4.0	139.6
Victoria Island							
7 Hadley bay	8/8/99	72 31 N, 109 19 W	135	2	prostrate dwarf-shrub		
8 Tuktu River	8/8/99	70 46 N, 109 09 W	150	3	hemiprostrate dwarf-shrub		
9 Thanhieser site	7/28/99	69 08 N, 105 09 W	30	4	erect dwarf-shrub	8.0	141.0
10 Mount Pelly	7/19-28/99, 8/9/99	69 11 N, 104 45 W	60	4	erect dwarf-shrub	8.0	141.0
Mainland							
11 Daring Lake	8/9/99 - 8/11/99	64 51 N, 111 31 W	70	5	low-shrub	9.5	219.5
12 Bathurst Lake	1994 -1997	67 26 N, 108 53 W	0-300	5	low-shrub	12.0	230.0

Methodology

Sampling in both studies involved selecting sites of homogeneous vegetation and locating relevés using the centralized replicate technique (Mueller-Dombois & Ellenberg 1974). Relevés were ranged from 4-50 m^2 and include a list of all vascular plants, bryophytes, and lichens and an estimation of percent cover for each species. Additionally, we recorded vegetation characteristics such as percent cover of growth forms and shrub heights. Plot environmental characteristics recorded typically included associated landforms, surficial geology and geomorphology, site and soil moisture estimates, topographic position, estimated snow duration, stability, exposure, slope, aspect, animal disturbance, and thaw depth. In the Bathurst Inlet study 287 relevés were conducted in a set of 17 sites along the riparian corridor of the Hood River, Nunavut. In the Canadian Transect 115 relevés were conducted at 11 sites, with representative relevés from five positions along a toposequence: Dry exposed ridges, mesic zonal sites, wet meadows, snowbeds, and streamside sites.

Results

In the Bathurst Inlet study we described 24 community types which encompass the range of vegetation found along the Hood River corridor (Gould and Walker 1999). These communities occur within seven Braun-Blanquet phytosociological classes: *Rhizocarpetea geographici, Cetrario-Loiseleurietea, Carici rupestris-Kobresietea bellardii, Scheuchzerio-Cariceteafuscae, Betulo-Adenostyletea, Oxycocco-Sphagnetea*, and *Salicetea herbaceae*. In terms of variation and controls on biodiversity patterns, we found that an increase in site species richness correlated with an increase in the number of communities rather than an increase in the alpha-diversity of individual communities. Moisture and pH controlled most of the differences in composition between communities. Measures of species richness and correlations with moisture and pH within communities differed among vascular, bryophyte, and lichen species. Bryophyte and lichen richness were positively and negatively correlated (respectively) with moisture. Vascular plant richness along a soil acidity gradient peaked at pH 6.5. We concluded that site variation in vascular richness in this region is controlled by landscape heterogeneity, and structured as variation in the number and distinctiveness of recognizable plant communities.

Data from the Canadian transect is compiled in an extensive data report, which includes information on soils, environmental factors, species occurrence and abundance, and site photographs (Gonzalez et al. 2000). The transect contributed to a successful collaboration among an international group of Arctic vegetation experts (Fig. 2), consensus on zonation terminology (Fig. 3) and progress in the development of the Circumpolar Arctic Vegetation Map (CAVM team 2003). The report documents the occurrence of 156 vascular, 200 bryophyte, and 140 lichen taxa among the set of relevés (Gonzaléz et al. 2000).

Figure 2. *Canadian Transect participants at the Daring Lake research camp. Standing from left to right: Christine Hill, Howard Hill, Boris Yurtsev, Fred Daniëls, Sylvia Edlund, Arve Elvebakk, April Desjarlais, Dianna Alsup.*
Seating from left to right: Skip Walker, Nadya Matveyeva, Bill Gould, and Chris Schadt (Gonzaléz et al 2000).

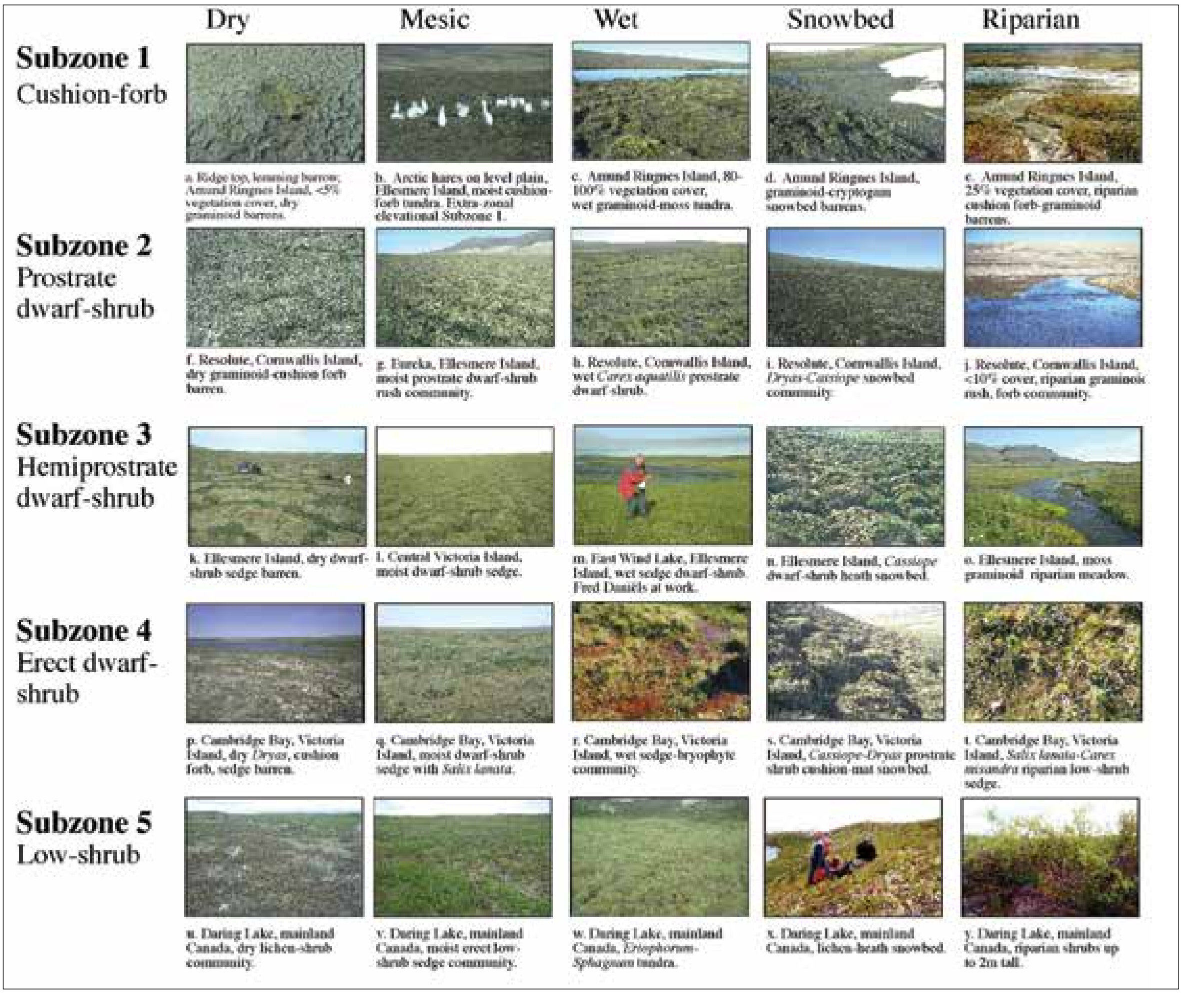

Figure 3. *Characteristic vegetation communities along a mesotopgraphic sequence in each of five subzones of the Canadian Arctic (Gould et al. 2003).*

Conclusion

The 403 relevés from the Canadian Arctic included in these datasets can represent a significant contribution to a North American Arctic Vegetation Archive and companion dataset to the Alaskan Vegetation Archive.

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Data management for the Braun-Blanquet project and the European Vegetation Archive

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Introduction

The Braun-Blanquet project and the European Vegetation Archive are among the first initiatives for analyzing comprehensive datasets of vegetation plots in Europe (Jiménez-Alfaro et al. 2013). Both initiatives are based on the compilation of vegetation data from different collaborators, including national and regional databases and additional data from individual researchers or research groups or the literature. The management of this information is complex since it derives from heterogeneous sources and many different research contexts.

Here we report the conceptual management plan developed for merging European databases and for creating taxonomically consistent outputs to be used for vegetation analyses. The main aim is to develop an archive of data sets which can be regularly updated, allowing to create comprehensive matrices of species x plots, and ensuring that the databases are compatible in terms of species taxonomy and header data.

Storing data

The data sets are managed separately in Turboveg 2, a software program widely used for storing vegetation data in Europe (Hennekens & Schaminée 2001). Our general procedure is to preserve the original structure of the databases in order to facilitate regular updates from data providers.

Databases provided by partners of the Braun-Blanquet project or the European Vegetation Archive are in most cases linked to one of the species lists available for Turboveg 2, although in some cases they are linked to adhoc lists created by one or more authors for specific projects. As a general rule, we suggest data providers to use one of approximately 30 most commonly used European national or regional checklists. Accordingly, new digitized data are linked to these lists or to the general European checklist for Turboveg which is based on *Flora Europaea* (Tutin et al. 1993).

Header data are also very heterogeneous, and only a few fields (e.g. plot size, total cover and altitude) are regularly assigned to the plots in the databases. For the specific purposes of the Braun-Blanquet project (i.e. the characterization of phytosociological alliances), we prioritized the standardization of only three fields: plot size, geographical coordinates and vegetation or habitat type. However, a more ambitious system of header data harmonization will be created for the European Vegetation Archive, which is expected to provide data for many different purposes.

Combining data

We are using a prototype of Turboveg 3 (Figure 1) to combine species and header data from the original databases that are regularly managed in Turboveg 2. A copy of each of these databases is imported into Turboveg 3 from a single repository that is shared in GoogleDrive by the data managers. The general settings of Turboveg 3 are then fixed to link any version of the original databases. Thus further update of a given database with the same structure will be automatically integrated into the system.

Figure 1. General view of the main panel of Turboveg 3 prototype (version January 2014).

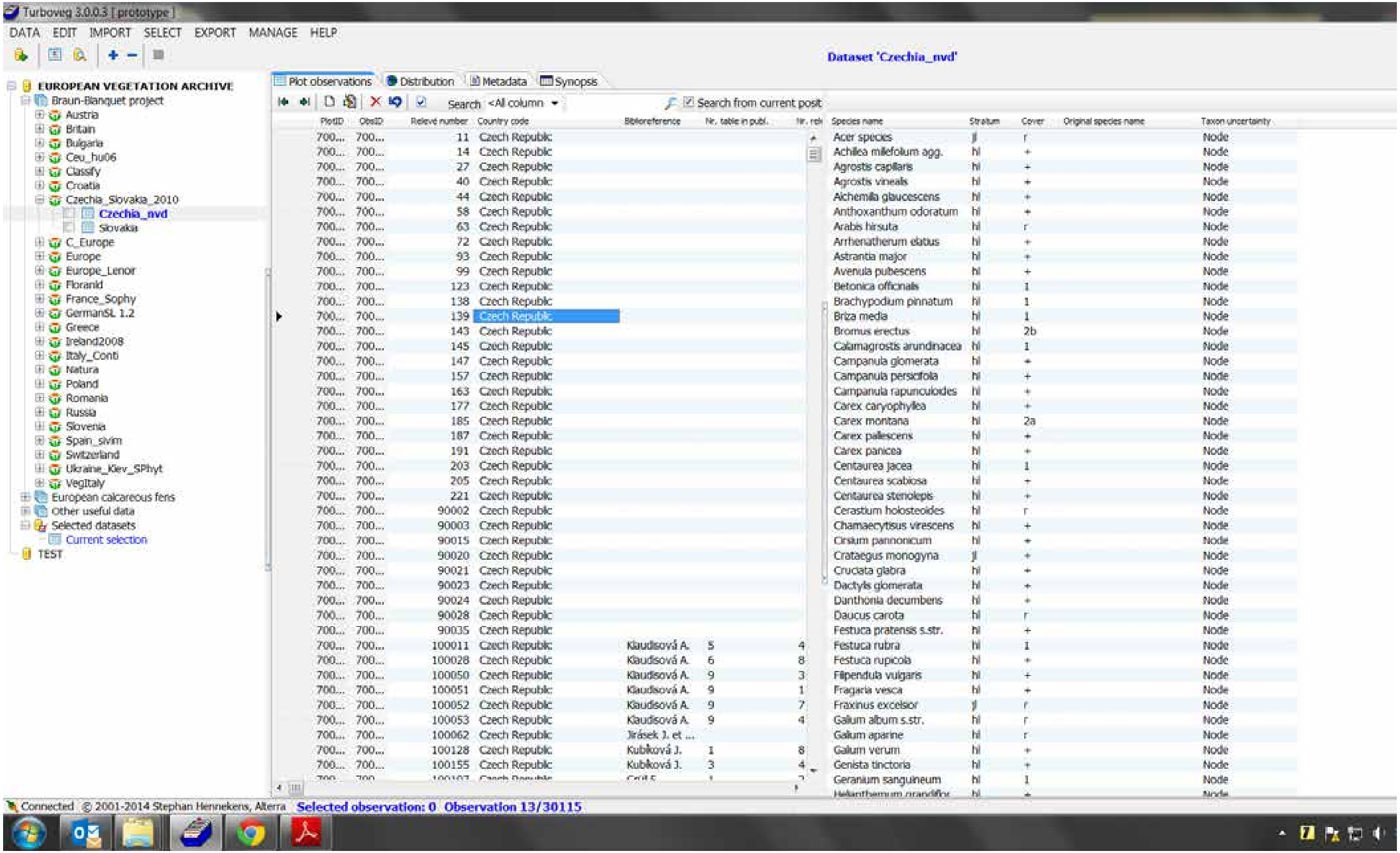
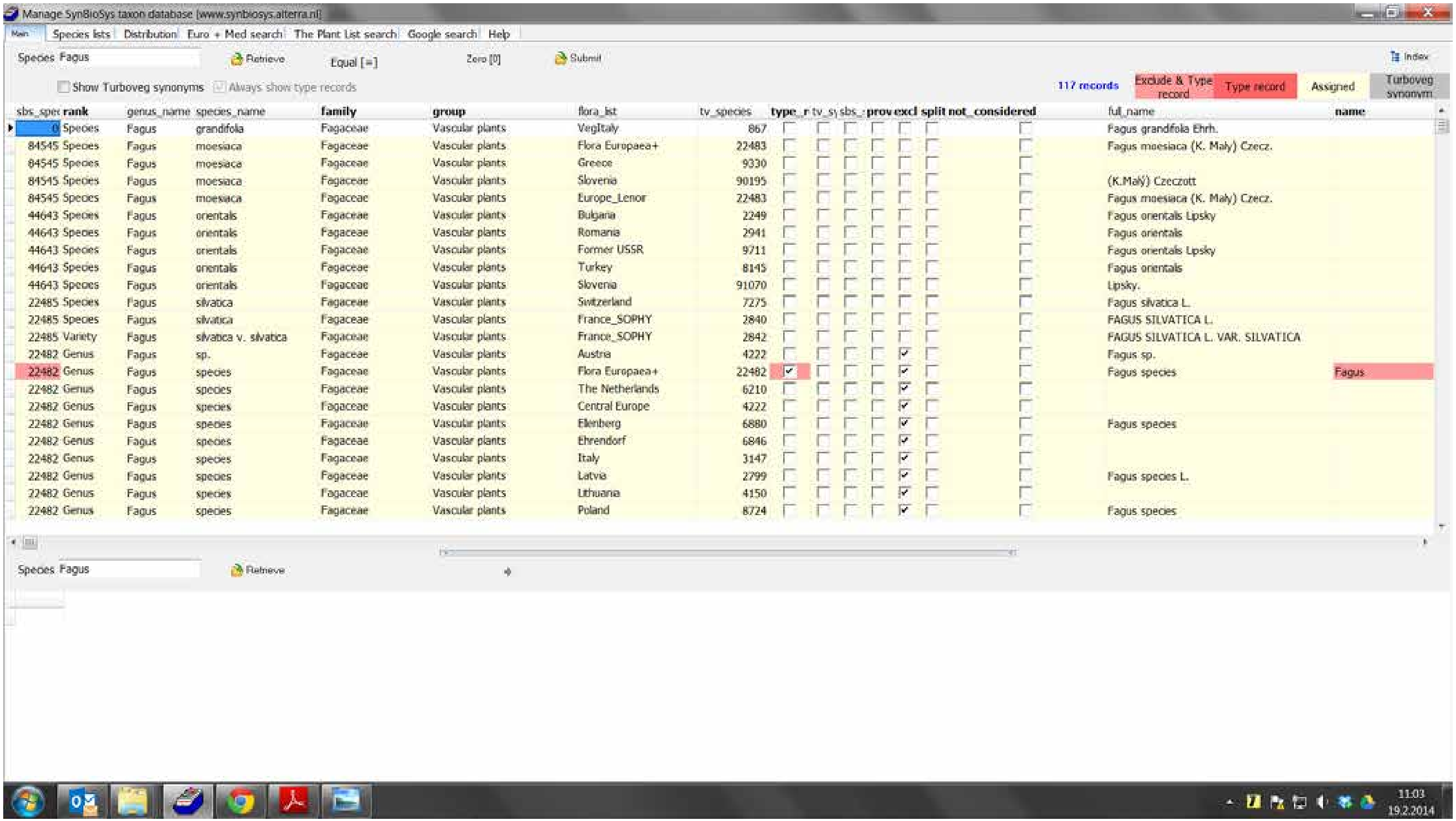


Figure 2. *Cross-link species system of SynBioSys integrated in Turboveg 3 prototype (version January 2014).*



The most important issue for combining the databases is to crosslink the various species checklists. We followed the general procedure developed for SynBioSys Europe (Schaminée et al. 2007) to create a crosslink between taxon concepts of different species checklists (Figure 2). On the one hand, species names from different checklists that fit at 100% are linked automatically and identified by the same alphanumeric code. On the other hand, species that are not matched must be linked manually to harmonize taxon concepts. This process is dynamic and can be continuously reviewed by data contributors under the supervision of a number of taxonomical authorities selected among regional experts. At the moment, more than 80% of the species included in 30 European checklists have been taxonomically harmonized, although more effort is still necessary to create formal guidelines for the harmonization of taxon concepts in SynBioSys Europe and Turboveg 3.

Under this system, we are able to perform queries in Turboveg 3 based on the presence or cover of a given species that is systematically checked in more than 40 individual databases. This allows us to create outputs in form of species x plot matrices including the associated header data for each plot (when existing). These outputs can be then used for performing analyses based on species composition (e.g. ordination or classification) or the properties of vegetation (e.g. distribution patterns of plots assigned to the same community type).

Further steps

Under the proposed data management plan, new functionalities of Turboveg 3 are being developed, and a more detailed procedure for managing European databases will be developed in the year 2014. Among the main priorities for the integration of vegetation databases into the Braun-Blanquet project, the European Vegetation Archive or any other initiative, we highlight the following:

- Quality control of the original datasets
- Feedback with data providers for improvement of header data
- Involvement of new databases from underrepresented regions
- Continuous updating of species crosswalks in SynBioSys Europe
- New functionalities for exporting output matrices and associated data in Turboveg 3
- Project-specific analyses at continental scale

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Arctic Vegetation datasets for Northern and Western Alaska

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Abstract

There are six datasets of vegetation and environmental data for northern and western Alaska that have been collected by ABR, Inc. and Alaska Ecoscience since the early 1990s that potentially could be incorporated into the Arctic Vegetation Archive (Figure 1). Data have been collected at ~293 plots on the Colville Delta (Jorgenson et al. 1997) and ~285 plots in the eastern NPRA as part of baseline environmental studies by ARCO and ConocoPhillips (Jorgenson et al. 2003). Ongoing studies of ice-wedge degradation at the Jago River, Prudhoe, and Barrow has collected data at ~50 plots. Ecological land surveys for the Arctic Network of Alaskan parklands collected data at ~763 plots (Jorgenson et al. 2009a), while a similar survey in the Selawik National Wildlife Refuge collected data at ~275 plots (Jorgenson et al. 2009b). Monitoring of coastal changes near Hazen Bay on the Yukon-Kuskokwim Delta has collected data at ~65 plots since 1994 (Jorgenson 2000). The vegetation data were used for ecological classification and developing vegetation-ecosystem maps for each study area.

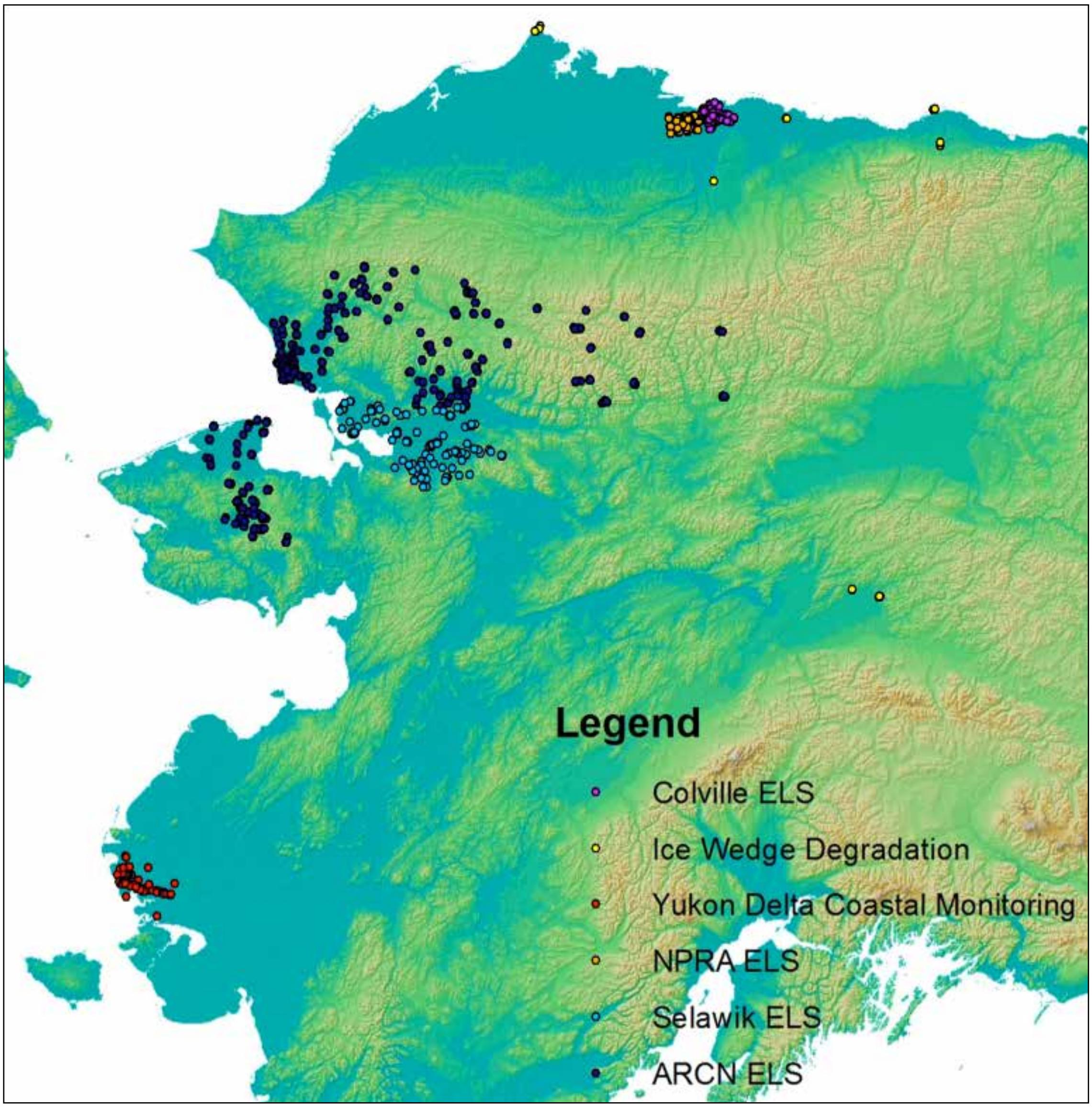

Figure 1. *Locations of vegetation plots sampled by six projects in northern and western Alaska.*

Sampling typically was done in plots established within homogeneous vegetation patches along toposequences that covered the entire range of environmental gradients within a study area. Plot dimensions varied by purpose and patch size; temporary plots typically had 5 or 10 m radii, while size of permanent plots for ice-wedge degradation and coastal monitoring varied from 1 x 5 m in ice-wedge troughs to 5 x 10 m in larger homogeneous patches. For temporary plots, percent cover of each species was visually estimated for all vascular plants (30–45 minute search time), while for nonvascular plants cover was estimated for common, reliably identifiable cryptogram and lichen species (~30). In permanent plots, plant cover was measured by point sampling with trace values (0.1%) assigned to additional species not hit by point sampling. Voucher specimens were collected for uncertain vascular plants, and frequently collections were made for abundant unknown nonvascular species. Plant nomenclature mostly follows Hultén (1968) and Viereck and Little (1972) for vascular plants to take advantage of static floras, and USDA Plants for nonvascular plants. Environmental data were collected at most plots, including data on geomorphic characteristics, hydrology, soil stratigraphy, and simple chemistry (pH and EC), as well as oblique and vertical ground photos of the plots.

Data are stored in Access relational databases for more recent projects, with tables for site (environment), vegetation cover, vegetation structure, and soil stratigraphy, and numerous reference tables for coding information. Older data are in Excel spreadsheets. Vegetation data are serially listed to allow better flexibility for combining datasets. Most data are open access, while industry-supported data will require permission for use.

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Biocomplexity of patterned ground along a climate gradient in the Low Arctic, Alaska

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Introduction

The vegetation and soils in many arctic tundra regions are influenced by the distribution of patterned-ground features such as nonsorted polygons, nonsorted circles (also known as frost boils), and earth hummocks. Cryogenic disturbances such as differential frost heaving and seasonal frost cracking play an integral role in the formation and maintenance of these features (Washburn 1980). We formally described and analyzed vegetation associated with patterned-ground features in Arctic Alaska in order to better understand the linkages among disturbance, vegetation and soils. We recorded data at 117 relevé plots and recognized nine plant-community types, including three new associations. In addition, we studied the floristic and structural aspects of the vegetation along a latitudinal climate gradient to better predict arctic ecosystem responses to climate change.

Methods

We chose seven study sites in northern Alaska that were situated along a latitudinal gradient and encompassed the Coastal Plain and Arctic Foothills physiographic provinces (Wahrhaftig 1965) and bioclimate subzones C–E (Walker et al. 2005) (Fig. 1). We established a total of 117 study plots that measure 1m by 1m and have one corner permanently marked. We recorded a complete species list of all vascular and nonvascular species at each relevé and noted the Bran-Blanquet cover classes of each species along with the cover of plant functional types. In addition, we recorded site and soil variables at each plot. The vegetation and site data, GPS locations and photo documentation for all 117 relevé plots are housed within the Alaska Geobotany Center at the University of Alaska Fairbanks. We classified the plant communities according to the Braun-Blanquet sorted table method (Mueller-Dombois and Ellenberg 1974) and studied the relationships between vegetation and the environment with the help of detrended correspondence analysis (DCA) ordinations (Peet et al. 1988).

Floristic associations

At the northern end of the study gradient in bioclimate subzone C, we described the *Braya purpurascens-Puccinellia angustata* community on dry nonacidic nonsorted circles, the *Dryas integrifolia-Salix arctica* community on dry nonacidic adjacent stable tundra, and the *Salici rotundifoliae-Caricetum aquatilis* association (Kade et al. 2005) on moist coastal tundra. Farther inland in bioclimate subzone D, the Junco biglumis-Dryadetum integrifoliae association (Kade et al. 2005) occurred on moist nonacidic nonsorted circles, the *Dryado integrifoliae-Caricetum bigelowii* association (Walker et al. 1994) on moist nonacidic adjacent stable tundra, and the *Scorpidium scorpioides-Carex aquatilis* community on wet nonacidic tundra. To the south in the Arctic Foothills of bioclimate subzone E, we found the *Cladino-Vaccinietum* idaeae association (Kade et al. 2005) on moist acidic hummocks, the *Sphagno-Eriophoretum* vaginati assocation (Walker et al. 1994) on moist acidic adjacent stable tundra, and the *Anthelia juratzkana-Juncus biglumis* community on wet acidic nonsorted circles.

Vegetation characteristics

The morphology of patterned-ground features changes along the climate gradient. Large, almost barren nonsorted circles with a high degree of contraction cracking and small, barren nonsorted polygons dominate the landscape at the northern end of the study gradient, while less active nonsorted circles and earth hummocks to the south have thick vegetation mats and resemble the adjacent tundra areas in species composition (Fig. 2). The nonsorted circles are generally dominated by lichens, while the adjacent stable tundra is characterized by dwarf shrubs, sedges and thick moss carpets. Along the climate gradient, the cover of erect dwarf shrubs, graminoids and mosses increases from north to south, while the cover of prostrate dwarf shrubs and lichens decreases. With regards to floristic characteristics, the nonsorted circles support more species with distribution limits farther north and might thus serve as safe islands for the northern hardier but less competitive species in a southern environment. The DCA ordination revealed that the plant-community types are grouped according to several environmental gradients, including soil pH, air temperature, site moisture and cryogenic disturbance (Fig. 3). The first axis of the DCA ordination corresponds to a complex bioclimate/pH gradient, where the percentage of bare soil and pH increase, while air temperature, elevation and shrub cover decrease. The second axis corresponds to a complex disturbance/soil moisture gradient.

Conclusion

We focused on patterned-ground features as separate plant communities in arctic Alaska and recognized nine community types, including three new associations. The plant-species cover data and site information for the 117 relevé plots are stored with the Alaska Geobotany Center at the University of Alaska Fairbanks. Part of this data set has been used to analyze vegetation data of patterned-ground features across a larger, latitudinal North America transect, ranging from bioclimate subzone A in arctic Canada to bioclimate subzone E in the Arctic Foothills of Alaska (Walker et al. 2011). Based on the morphological and floristic changes in plant communities we detected along the latitudinal study gradient, warmer summer temperatures and thawing of permafrost due to climate change could potentially lead to a shift in plant-community composition and vegetation zones along with a decline in patterned-ground features towards the southern end of the gradient. The potential loss of these features and associated plant communities would especially impact areas with great floristic differences between patterned-ground features and adjacent tundra and result in the loss of landscape heterogeneity.

Acknowledgements

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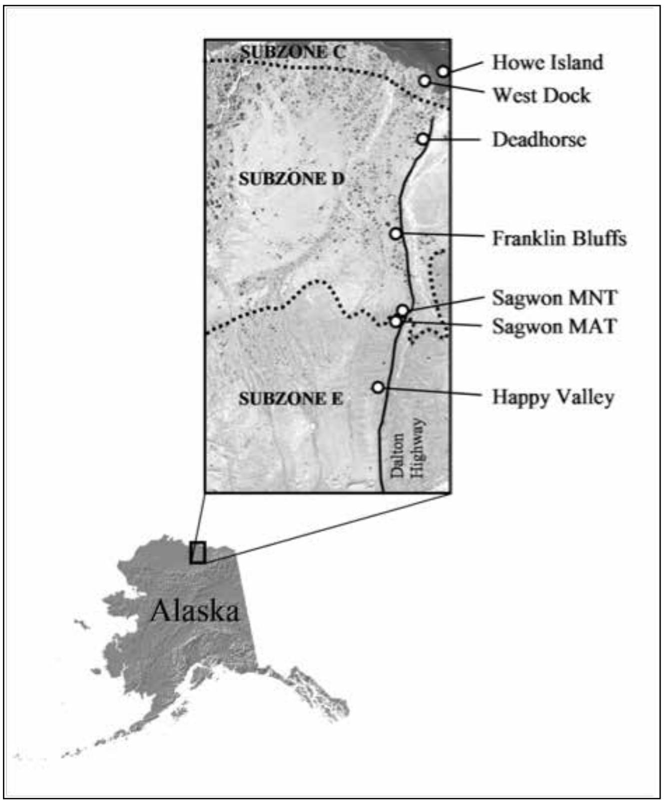

Figure. 1. *Location of the seven study sites and bioclimate subzones in northern Alaska. Subzones C and D are part of the Coastal Plain and Subzone E is in the Arctic Foothills physiographic province. References*

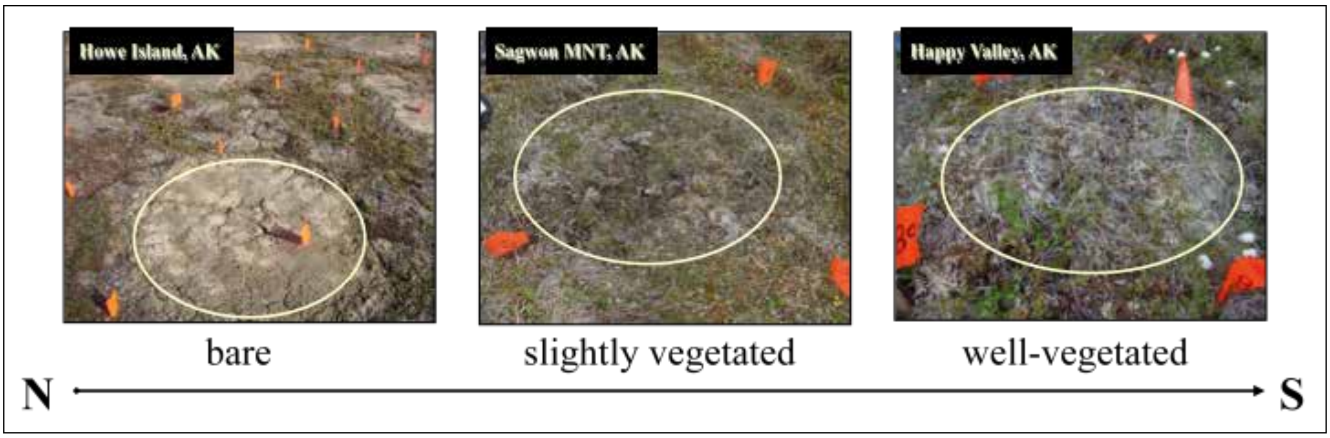

Figure. 2. *Morphological changes of patterned-ground features along the study gradient. Large, barren nonsorted circles with a high degree of contraction cracking dominate in bioclimate subzone C; smaller, more vegetated nonsorted circles are found in bioclimate subzone D; and earth hummocks with thick vegetation mats similar to the surrounding tundra are part of bioclimate subzone E.*

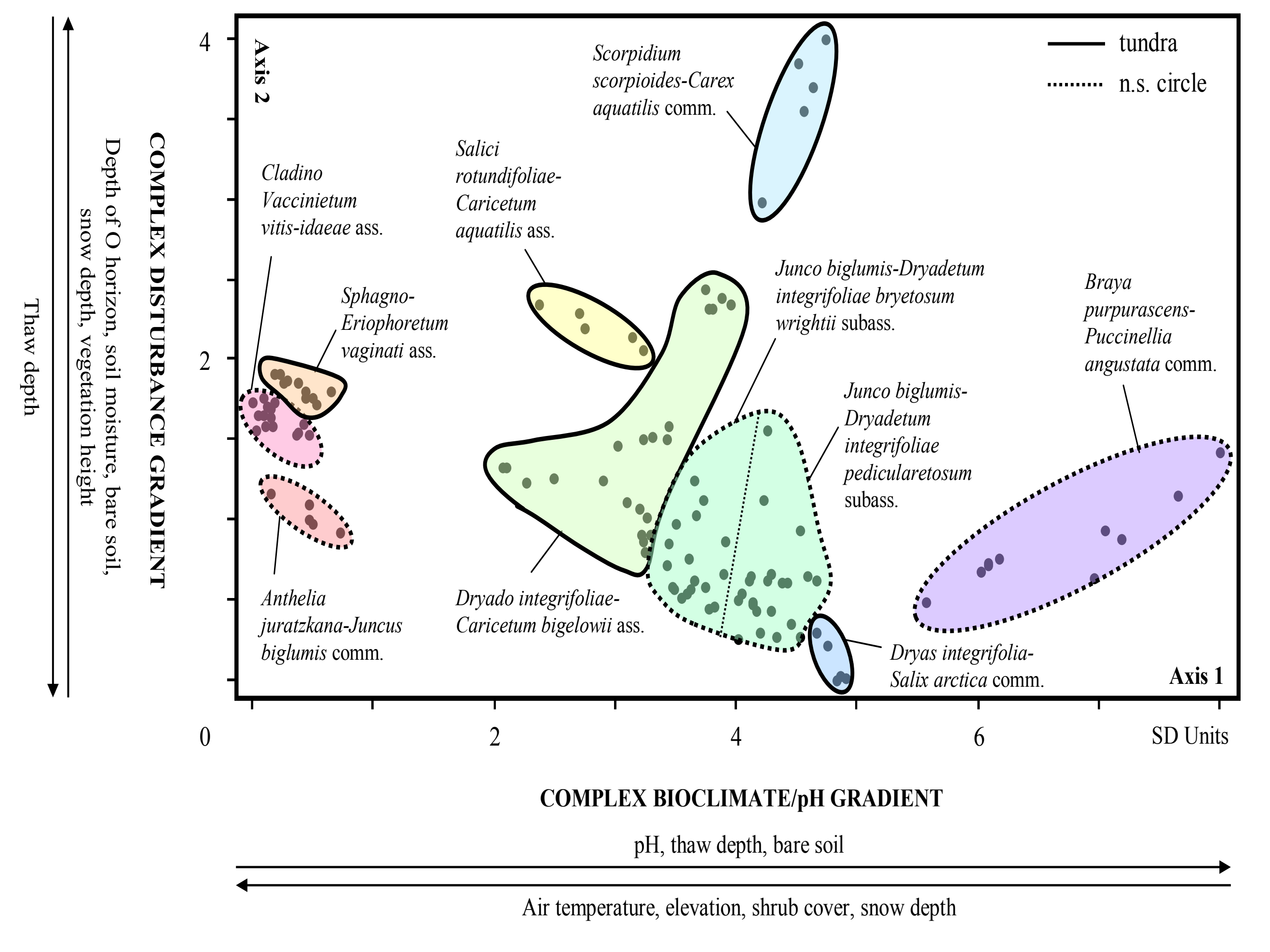

Figure. 3. *Detrended Correspondence Analysis ordination of all relevés. The sample plots are grouped according to vegetation type. Arrows along each axis indicate the direction of the principal environmental gradients.*

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Classification of vegetation in Arctic regions: An extension of the Canadian National Vegetation Classification (CNVC)

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Vegetation data have been collected throughout the Canadian arctic for decades. However, these data are widely dispersed and largely inaccessible. The goal of this project was to identify and acquire arctic vegetation data stored in archives and institutions; build a centralized database of arctic vegetation and ecological data; and classify and describe arctic vegetation associations, consistent with the Canadian National Vegetation Classification (CNVC). This project initiated linkages between Canada and other circumpolar jurisdictions to develop a common international nomenclature for arctic vegetation.

The development of an arctic vegetation database and classification will be invaluable in providing an ecological framework for all biological and environmental studies in the region. A standardized arctic vegetation classification constitutes a fundamental tool for communication of ecological information between jurisdictions. Applications include: monitoring permafrost, biodiversity, wildlife habitat, species at risk; land use planning, protected areas management; conservation strategies; and monitoring climate change, as reflected by vegetation cover.

Project deliverables include: a harmonized database of vegetation and associated ecological data collected in arctic Canada and adjacent Alaska; classification and description of arctic vegetation associations, as an expansion of the CNVC; posting of detailed arctic vegetation association descriptions on the CNVC and Government of Yukon websites and a georeferenced GIS database of site locations for all data sources.

Background

As International Polar Year approached, the international community planned collaborative and individual research projects throughout the circumpolar world.

In 2006, the Canada federal office for International Polar Year announced opportunities for research funding for the natural and social sciences in Canada's North. The Government of Canada Program for IPY defined Canada's North as the land and ocean based territory that lies north of the southern limit of discontinuous permafrost from northern British Columbia to northern Labrador.

Environment Yukon in partnership with Natural Resources Canada, Canadian Forest Service, submitted a proposal for the classification of vegetation in arctic regions, as an extension to the existing Canadian National Vegetation Classification (CNVC). In 2007, the project proposal was awarded multi-year funding under the CiCAT (Climate Impacts on Canadian Arctic Tundra) core project.

The mandate of IPY strongly encouraged the participation of residents of northern Canada, the career development of new northern scientists and the support of students in northern science. This project achieved these goals, through the combined efforts of the public and private sectors.

Funding and personnel

Principal investigator and project lead was Catherine Kennedy, Vegetation Ecologist, Yukon Government; project partner was Ken Baldwin, Ecologist and CNVC Chair, Natural Resources Canada, Canadian Forest Service. The total funding awarded this project was $205,000. Most of this funding supported the salary of approximately 14 northern scientists and students working in the private sector. Key project personnel included a project data manager, a computer software specialist and a vegetation classification analyst. Other personnel included data researchers, data entry technicians, a terrain scientist and vegetation ecologists.

Strategy

The project was divided into three phases, each comprising numerous tasks. Service contracts for each project phase were tendered through the Yukon government contract services process:

Phase 1 - *Identify and acquire arctic vegetation data and references*

Identifying and acquiring arctic vegetation data and references was a difficult and lengthy process. An extensive search was made through literature, internet and personal contacts for all pertinent references, including journals, theses, monographs, articles and government reports, published and unpublished. These documents were acquired electronically, by inter-library loan, and in some cases, by acquisition of field data cards from individual researchers. The project data manager reviewed each document and compiled a metadata table for tracking numerous variables (date, authors, geographic location, data included etc.). In particular, submissions were assessed as to their vegetation plot data content and or ecological vegetation description. There were 468 submissions reviewed in total and entered into a reference tracking table. The majority of references were identified and acquired in Phase 1, but this activity continued throughout the project.

Phase 2 – *Build a harmonized database of arctic vegetation and ecological plot data, consistent with national standards of the CNVC*

Once vegetation data of possible interest were identified, they were assessed to ensure they met the data standards of the CNVC. Approximately 75 publications contained plot data of acceptable quality. The collection methodology and plot size could vary, but the data had to meet the minimum standards of the CNVC, i.e: a complete listing of vascular plant species, frequency of occurrence and percent cover; bryophyte and lichen species were acceptable if only identified to species or genera.

If data were not in published journals or otherwise in the public domain, a data sharing agreement was obtained from individuals, agencies or institutions as required. As well, contributors were informed of the data sharing policy of IPY.

A large proportion of the vegetation plot data had to be entered manually into the database from hardcopy reports, publications and original field forms.

One of the most challenging parts of the project was building a single, harmonized database from disparate source data. In total, 12,360 plots were harmonized into a single VPro database. Approximately half of these plots included ecological site attributes such as slope, aspect, elevation, soil moisture and soil texture. The plots were all GIS referenced.

Phase 3 – *Classify and describe arctic vegetation associations, consistent with national standards of the CNVC*

Using the multivariate analysis methods and classification software Vpro, vegetation plots were analyzed and classified into 58 vegetation associations, consistent with the methodology of the Canadian National Vegetation Classification (CNVC). Summary fact sheets were prepared for each of these vegetation associations, summarizing the ecological concepts of each association, and listing numerous qualitative and quantitative attributes. These fact sheets will be posted on the CNVC and Government of Yukon websites following peer review.

Project deliverables

- Classification and description of arctic vegetation associations, as an expansion of the CNVC
- Posting of detailed arctic vegetation association descriptions on the CNVC website
- A harmonized database of vegetation and associated ecological data collected in arctic Canada, and adjacent Alaska, derived from archived and recent data sources
- A spatial display (GIS) of vegetation data in the database

Applications

The development of an arctic vegetation classification will be invaluable in providing an ecological framework for all biological and environmental studies in the region.

A standardized arctic vegetation classification constitutes a fundamental tool for communication of ecological information between jurisdictions.

This project will initiate linkages between Canada and other circumpolar jurisdictions to develop a common international nomenclature for arctic vegetation.

Applications include:

- Monitoring permafrost, biodiversity, wildlife habitat, species at risk
- Land use planning, protected areas management; conservation strategies
- Monitoring climate change, as reflected by vegetation cover

Acknowledgments

Support for this project came from the Government of Canada, Federal Office of IPY (International Polar Year) Greg Henry, Project Leader, CiCAT (*Climate Impacts on Canadian Arctic Tundra Ecosystems*); the Government of Yukon, Department of Environment; Government of Canada Natural Resources Canada (NRCan), Canadian Forestry Service (Ken Baldwin – Project Partner. Assistance for the project was accomplished by the Bulkley Valley Research Centre, Smithers, B.C.: Adrian de Groot, Project Data Manager; Will Mackenzie, Ecologist and Classification Analyst; and Russell Klassen, Software Specialist.

The Canadian Arctic Vegetation Archive (CAVA) and a preliminary classification of Canadian arctic vegetation

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Abstract

Funds acquired by the Yukon Territorial government through the International Polar Year (IPY) initiative were used to compile existing vegetation plot data from the Canadian Arctic and Subarctic in 2009-2010. This initial subarctic/arctic data compilation include approximately 12, 360 relevés acquired from historical and contemporary published and unpublished sources. 4800 relevés of this dataset are located within the Circum-Arctic Vegetation Map (CAVM) region and are included in the Canadian Arctic Vegetation Archive (CAVA). All plots are compiled in VPro, an ecosystem plot and classification management database. A preliminary classification of Canadian arctic vegetation was created from this data and used to describe 58 prospective Associations for the Canadian National Vegetation Classification.

Introduction

The Classification of Vegetation in Arctic Regions project funded by the IPY has compiled available arctic and sub-arctic data for Canada. Kennedy (this publication) outlines the background, phases, and project deliverables and possible applications of products from this project. This extended abstract provides additional details for the data compilation and preliminary classification phases, which were the main deliverables from the IPY project.

Phase 1: Data acquisition
The CAVA data compilation is generally inclusive in its acceptance of plots for archiving. It contains plots from any project that used an area-based sampling method (line transects were excluded), a species abundance measure (percent cover or cover classes), and the sampling was aimed at characterizing relatively homogeneous vegetation at a scale of approximately 10 – 1000m^2.

De Groot and others (2010) acquired, in total, 468 theses, reports, and private or government databases that were assessed for relevant plot data or other descriptions of vegetation. Approximately 75 of these projects contained plot data of acceptable quality for the archive. Of the 12,360 arctic and subarctic plots identified, 4800 of the relevés from 31 projects fall within the bounds of the CAVM mapped arctic region and 3769 within the Canadian Arctic (several Alaskan datasets were incorporated into the CAVA for comparative purposes).

The quality of datasets is variable with most having high quality vascular species list and lower quality non-vascular species list and abundance values for vegetation. Environmental attributes included in field collection and reporting were variable but all had some georeferencing information and typically aspect and elevation.

A full list of the publications and data sources that populate the CAVA is presented at the end of this abstract.

Phase 2: Database compilation
The CAVA harmonized the data sets through documented conversions including:

- Combining multiple microplots into a single plot for the CAVA for studies that used this field method to sample homogenous ecosystems.
- All abundance values are converted to mid-point percent cover.
- Vegetation stratification was included where it was collected and placed within broad height categories.
- Georeferencing was included for all plots but for many historical projects an approximate central location for the project area was all that was available.
- Coding species with 8-character codes consisting of the first 4 genera letter, first 3 species letters and number for subspecies or variety. The full taxonomic name is contained in a linked species library. Initially, species were entered as originally attributed by the authors but were later harmonized to a single modern taxon.
- Environmental data was included where possible but for many data sets this plot information was lacking or was summarized by a project's classification unit rather than by plot. Environmental attributes where available were coded following standards outlined in British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment (2010).

All data was entered into the ecosystem plot and classification management database, Vpro (MacKenzie and Klassen 2013). VPro is a freeware database program designed for managing large bodies of ecological plot data as well as create and retain hierarchical classification structures constructed from the plot data. It operates within the commercial software package Microsoft Access. VPro facilitates data manipulations and summaries frequently used in the classification of vegetation communities, including the export of data for analysis and generation of summary and diagnostic table reports. While designed specifically for data collected using the standard methodologies outlined in "Field Manual for Describing Terrestrial Ecosystems" (British Columbia Ministry of Forests and Range and British Columbia Ministry of Environment. 2010.), VPro is also suitable for managing other types of plant community data sets and is used by the Canadian National Vegetation Classification (CNVC 2013).

An "Export to TurboVeg" function exists within VPro which produces a data format that can be imported by several programs including TurboVeg and JUICE. Meshing the CAVA data with the rest of the AVA is likely to be unproblematic.

Metadata summarizing project collection methods used, project area, and number of relevés is summarized in a linked metadata table within Vpro but more complete metadata is contained in a project tracking spreadsheet created for the IPY project. This spreadsheet also contains the projects that were reviewed for inclusion but not subsequently included in the data compilation along with the rationale for their exclusion (de Groot et al., 2010)

Phase 3: Classification and Description of Arctic Vegetation Associations
3000 of the 3769 compiled arctic relevés were used to generate a classification for the Canadian arctic (de Groot et al., 2011) broadly following Braun-Blanquet table analysis methods with the assistance of mulitivariate techniques. The prospective classification describes 58 Associations and an additional 50 Sub-associations divided into seven broad groups:

1. Tundra ecosystems of relatively high pH substrates are represented by 13 *Dryas integrifolia* Associations in the CNVC (600 plots).
2. Tundra of acidic parent materials and characterized by ericaceous dwarf shrubs (e.g. *Empetrum nigrum*, *Vaccinium* spp., and *Ledum* spp.) have the most plots in the CAVA (630 plots) and represent 11 Associations.
3. Graminoid-dominated (e.g. *Alopecurus magellanicus* and *Arctagrostis latifolia*) tundra common in slightly moister climates and possibly also heavily grazed ecosystems are represented by 7 associations (240 plots).
4. *Cassiope tetragona* dominated snow bed ecosystems are described by 3 Associations (120 plots).
5. Marine shore zone ecosystems characterized by salt tolerant species (e.g. *Carex subspathacea*, *Honkenya peploides*, *Leymus mollis*) are currently described by only 5 Associations and have relatively few relevés in the CAVA. Additional types are known though compiled data is insufficient.
6. Wetland ecosystems and wet tundra characterized by hydrophytic graminoids such as *Carex aquatilis*, *Eriophorum angustifolium*, and *Arctophila fulva* are well sampled (470 plots) and represented by 13 Associations.
7. "Barrens" ecosystem with very low vegetation cover representing the harshest arctic climates are characterized by 6 prospective associations (270 plots).

Many of the shrub ecosystems that occur in the subzone E of the Arctic region, but are more common in the subarctic, have not yet been analyzed and described.

Future work for the CAVA

There are at least two additional substantive high quality data sets yet to be acquired for the CAVA. A historical data set comprised of 2500 high quality relevés is available from Dietbert Thannheiser for the western arctic. And, an extensive contemporary dataset for northern Quebec and the Ungava peninsula, which is currently unrepresented in the CAVA, is being created by Benoît Tremblay. Additional data sets from environmental impacts studies and territorial government habitat classifications appear to have some useful plot data but were not provided by the proponents for this work. Many of the plots included in the current CAVA were compiled from published sources and are missing detailed site and environmental information originally collected. Acquiring copies of the original data cards and addition of these plot attributes to the database should be part of future updates to the CAVA. The Canadian High Arctic Research Station (CHARS) has been proposed as the agency for long-term maintenance and development of the CAVA (D. McLennan, pers. Comm.)

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Riparian vegetation and environmental gradients on the North Slope of Alaska

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Introduction

Willow shrublands along river margins and streamsides form a prominent feature of the tundra landscape on the North Slope of Alaska and must be considered an extremely important component of arctic landscape ecosystems in general. Riparian shrublands are the most productive arctic vegetation types, they provide stream bank stability, and may reach, together with floodplains, a considerable spatial extent (up to 20 % of the total landscape cover). Moreover, riparian corridors play a vital role as reservoirs of species diversity in a relatively species-poor environment (Walker, M.D. 1995; Gould & Walker 1997). Additionally, riparian shrublands provide organic matter for the aquatic food chain, and they are of primary importance as winter forage resource, cover, nesting and denning habitat for abundant wildlife in the open tundra, including moose, caribou, muskox and barren ground grizzly bear. Riparian vegetation of the North Slope predominantly consists of *Salix*-shrublands. Almost all riparian habitats - cutbanks, river bars, floodplains and lower terraces along major rivers, upper terraces with further developed alluvial soils, margins of smaller upland streams and creeks, and sites along fast-flowing, gravelly creeks in the mountains - are occupied by different *Salix*-communities. Only on some microsites, e.g. locally along stream channels, along pools of beaded streams or in flooded areas, minor riparian vegetation types like *Carex aquatilis*- or *Carex rotundata*-communities occur (Walker, M.D. et al. 1994). This paper concentrates on *Salix*-communities, and summarizes available knowledge of floristic-sociological differentiation and synecological characteristics based on a classification and ordination analysis of riparian shrub communities on the North Slope of Alaska (Schickhoff et al. 2002).

Study area

The study was conducted along a S-N-transect from the southern slope of the Brooks Range (Endicott Mountains/ Philip Smith Mountains) to the arctic coast in the vicinity of Prudhoe Bay/Deadhorse. The transect follows the northern segment of Dalton Highway, the only permanent road in the area. This gravel access road ("haul road"), completed in 1974 after the discovery of oil at Prudhoe Bay, parallels the Trans-Alaska Pipeline System (TAPS). It crosses the major ecoregions of northern Alaska (Brooks Range, Arctic Foothills, Arctic Coastal Plain) and makes accessible a relatively undisturbed series of ecosystems along a latitudinal-elevational gradient. It provides the only opportunity for studying a ground-accessible transect of arctic and alpine tundras of northern Alaska.

The major portion of the transect lies within the drainage system of Sagavanirktok River, the second-largest river (267 km length), after the Colville, on the North Slope of Alaska. The drainage system has its headwaters in the northern Brooks Range, including Atigun River as the major tributary along the transect. Numerous smaller mountain and tundra streams and creeks flow into the system on its way to the Arctic Ocean. Additionally, the transect traverses headwaters of the Kuparuk River basin in the Arctic Foothills as well as headwaters of the Chandalar and Dietrich Rivers on the southern slope of the Brooks Range.

Much of arctic Alaska still consists of relatively pristine tundra and riparian ecosystems, only slightly modified by anthropogenic disturbances. As far as riparian systems are concerned, Alaska can still be termed a "warehouse of pristine running water systems" (Oswood 1997). All rivers are free-flowing, unregulated rivers; most river corridors are undisturbed over the whole of the river continuum, from headwaters to mouth. However, *Salix*-shrublands in the Atigun and Sagavanirktok river valleys were destroyed to some extent during construction of the TAPS, mostly through shallow mining of vegetated river bars for gravel. Subsequent restoration of these habitats was only partially successful.

Material and methods

In order to cover the full variety of riparian shrubland habitats between the Brooks Range and the coastal plain, study sites were selected along rivers and streams of different orders; in total 85 relevés were completed according to the Braun-Blanquet approach (Braun-Blanquet 1964, Kent 2012). The southernmost relevé was sampled at Dietrich Creek (68°02'N, 149°39'W), just north of the arctic treeline on the southern slope of the Brooks Range, the northernmost study site was at the Sagavanirktok River (braided section of delta plain) in the vicinity of Deadhorse (70°11'N, 148°26'W).

Phytosociological and environmental data collection was conducted on carefully selected sample plots along the transect in order to fulfill the requirements of homogeneity and minimal area. Sample plots were of square or rectangular shape. Representative samples of *Salix*-communities required minimal areas between 50 m2 (low shrublands) and 100 m2 (tall shrublands). After establishing a sample plot, height and actual cover of the separate vegetation layers (shrub, field, moss, and lichen layer) were measured or estimated. A detailed inventory of taxa followed, including all vascular, bryophyte, and lichen species. Species cover was estimated according to the traditional Braun-Blanquet cover-abundance scale (7 classes). A voucher specimen of each species was collected on the relevé sites for final identification in the herbaria of the University of Alaska at Fairbanks/AK and of the University of Colorado at Boulder/CO.

Vegetation sampling was complemented by a detailed characterization of habitat conditions. Soil samples (three 100 cm3 cylinder samples on each plot) were collected from 10 cm depth, fresh field samples were oven-dried at 105 °C for 72 h in camp (Toolik Field Station) to determine percentage weight loss and soil moisture. Laboratory soil analyses (carried out in the Soil, Water and Plant Testing Laboratory, Colorado State University, Fort Collins/CO) comprised soil pH (saturated paste method), EC, lime estimate, % organic matter, NO3-N, plant available P, K, Zn, Fe, Mn, Cu, and % gravel, sand, silt, and clay.

Vegetation was classified according to the Braun-Blanquet sorted table method, i.e. the relevés were arranged in phytosociological tables to differentiate and characterize associations and subassociations. Differentiations of vegetation units are based on diagnostic species (character species, differential species, and constant companions). Determinations of differential species as well as assessments of degrees of fidelity of character species followed the criteria proposed in Dierschke (1994). In order to analyze relationships between variation in vegetation and environmental variation, Detrended Correspondence Analysis (DCA) ordinations were carried out using PC-ORD program (McCune & Mefford 2011). Performing DCA, all species and environmental data were used. Rare species were downweighted; axes were rescaled based on program defaults. Classification and ordination were perceived as interactive, complementary procedures. For example, preliminary assignments of particular relevés to subassociations during table work could be later revised and corrected according to positions of samples in the ordination space.

Results and discussion

Classification of *Salix*-shrublands resulted in three associations and four subassociations, marked by characteristic species combinations and distinct habitat conditions. Salix alaxensis pioneer communities on gravel bars, floodplains and lower terraces indicate sites with frequent disturbances and initial alluvial soils. They may persist on river banks as long as predominantly allogenic processes are operative in successional cycles. Higher terraces show the paradox of better developed soils, but decreasing productivity of the shrub layer. Decreasing active layer depth and higher soil moisture are key factors for the successional replacement with low willows (Salix richardsonii). Salix pulchra communities form the terminal riparian vegetation type on older, long-deglaciated land surfaces with paludified, loamy, acid soils, obviously connected to long-established hydrologic patterns and associated riparian ecosystem evolution along headwaters in upland tundra.

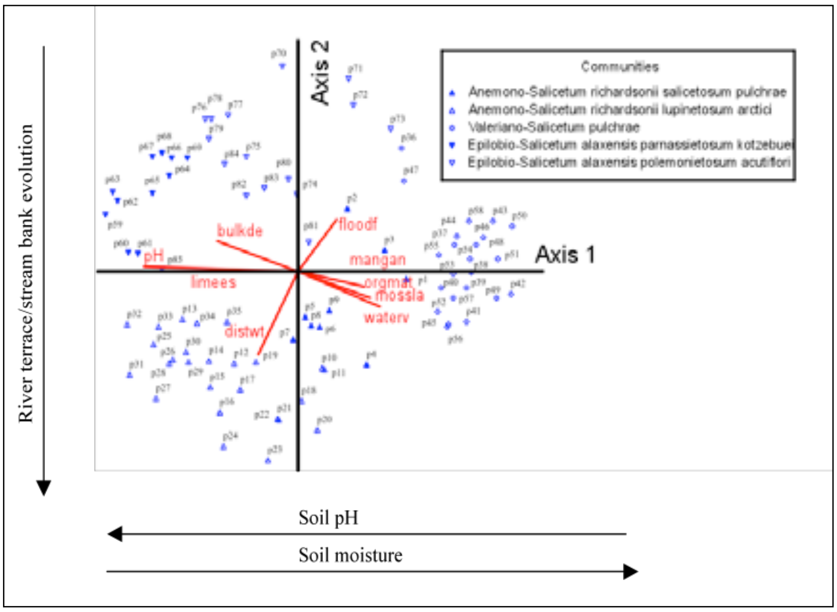

Figure. 1 *DCA ordination of Salix associations and subassociations in the study area.*

The floristic differentiation of the community types is clearly reflected in the ordination diagram of all relevés, even on sub-association level (Fig. 1). Actually, this ordination diagram can be considered a graphic representation of the similarity structure of a combined phytosociological table of all relevés. Each of the community types occupies a distinct range within the ordination space. Thus, the ordination results corroborate the results of the classification.
A relatively narrow range is occupied by the Valeriano - Salicetum pulchrae, indicating a floristically very homogeneous vegetation type with a comparatively narrow ecological amplitude. In contrast, the Anemono - Salicetum richardsonii and the Epilobio - Salicetum alaxensis show a more heterogeneous species composition and occur over a broader range of environmental conditions. As a consequence, both associations can be further differentiated into two subasso ciations.

The diagram represents not only the floristic similarity structure, but also indicates relationships of relevés and communities to the most important environmental gradients. Axis 1 corresponds to a complex edaphic gradient primarily representing soil pH and soil moisture. Relevés of moist acidic stream banks are concentrated in the right corner of the diagram, whereas those of edaphically drier, nonacidic sites increase in abundance towards the left side. Vertical distance to the water table and frequency of flooding show highest correlation with Axis 2, which has to be interpreted as a complex gradient of river terrace/stream bank evolution or successional gradient with relevés of young, gravelly mountain streamsides or floodplain sites of rivers in the upper half of the diagram and relevés of higher river terraces with better developed alluvial soils in the lower half. However, this interpretation is only valid for the *Epilobio - Salicetum alaxensis* and *Anemono - Salicetum richardsonii* on river alluvium. Relevés of headwater stream banks on old land surfaces in upland tundra, mainly belonging to the *Valeriano - Salicetum pulchrae*, do not fit into this successional scheme since they have developed in different temporal scales. The influence of landscape history (deglaciation ages) on riparian vegetation differentiation is obvious. Relevé positions of the *Valeriano - Salicetum* pulchrae along the vertical axis mainly reflects the intermediate position in terms of height above river/stream water level and associated flooding frequency.

The results reveal distinct relationships of riparian *Salix* associations and subassociations with major landscape-level environmental variables. A combination of edaphic conditions (soil pH, soil moisture) and factors pertaining to topography, disturbance regime and landscape evolution (river terrace/stream bank development) controls spatial patterns and floristic compositions of these riparian vegetation units. Landscape age, topography, substrate and disturbance effects like annual flooding, erosion and sedimentation are crucial underlying parameters for the present-day differentiation of the riparian vegetation mosaic. Environmental gradients affecting the vegetation in this study correspond to those well-known to control plant distribution across the Arctic (esp. soil moisture, soil pH, landscape age; cf. Webber et al. 1980; Walker, D.A. 1985; Walker, M.D. et al. 1994; Gould 1998). Specific riparian replacement successions can be derived from floristic-sociological traits, synecological characteristics, and spatial patterns of *Salix*-communities. The *Epilobio – Salicetum alaxensis* is a true pioneer community along mountain creeks and on gravel bars, floodplains and lower terraces of rivers, where it is favoured by frequent disturbances, coarser-textured soils with a deep active layer and relatively high soil temperatures. Corresponding to the permanent habitat disturbances, this self-perpetuating pioneer association may persist on river banks as long as erosion and deposition of new increments of alluvium occurs, i.e. as long as predominantly allogenic processes are operative in succession cycles (cf. Bliss & Cantlon 1957, Peterson & Billings 1978). It is replaced by the *Anemono - Salicetum richardsonii* (subass. *lupinetosum arctici*) on higher terraces with better developed soils (however, with a shallower active layer due to insulation by a thick moss cover and lower soil temperatures). This association characterizes later stages of succession on river alluvium with predominantly autogenic processes resulting inter alia in an uniquely arctic soil thermal regime.

In the riparian successional series within the gently rolling terrain of upland tundra, the *Anemono - Salicetum richardsonii* (subass. *salicetosum pulchrae*) is replaced on streamsides with more progressive soil development by the *Valeriano - Salicetum pulchrae*. The latter association is found on older land surfaces with paludified, loamy, acid soils with massive ground ice and thick moss layers, resulting in cold soils, decreased depth of thaw, and increased soil moisture. However, since the overall Arctic Foothills vegetation pattern is not a simple successional sequence due to the diverse glacial history (cf. Walker, M.D. 1995), riparian vegetation likewise has to be seen in the light of a landscape mosaic of contrasting deglaciation ages. Terminal riparian vegetation types like the *Salix pulchra*-communities seem to be connected to long-established hydrologic patterns and associated riparian ecosystem evolution along headwaters in upland tundra (up to mid-Pleistocene), and have, thus, developed in other time scales compared to riparian communities in younger landscapes. The present-day pattern of riparian plant communities reflects a mosaic of developmental states governed by landscape age heterogeneity. Both spatial and temporal environmental heterogeneity influence this pattern.

Conclusions

Combining phytosociological and gradient analyses, i.e. using classification and ordination of arctic riparian plant communities as complementary procedures, a wealth of information on floristic-sociological structure and environmental relationships of floristically defined vegetation types can be inferred. A major implication of our results is the possibility to use *Salix*-communities as indicators for riparian habitat characteristics and landscape evolution. Conducted on the only easily accessible gradient from the Brooks Range to the Arctic Ocean, it would be of high scientific interest to extend the scope of this study to other regions north of the Brooks Range and to subject the above findings to supraregional comparisons within the scope of the International Arctic Vegetation Database (Walker, D.A. & Raynolds 2011). Considering the need for arctic ecosystem studies in view of rapid environmental changes (e.g. climate warming, pollution from various sources, etc.), the completion of a circumpolar phytosociological/ecological synthesis of arctic vegetation should continue be a top priority on the arctic research agenda.

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Why Turboveg?

The advantages of time-tested and widely used software package for managing vegetation databases

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Abstract

This talk introduces the Turboveg program for managing large vegetation data sets. Turboveg, a Windows based software package for the input, storage and handling of vegetation and floristic data was developed by Stephan Hennekens in 1995 (Hennekens & Schaminée 2001). It also facilitates the processing of phytosociological data. It is used in more than 50 countries and has been accepted as an international standard management system for vegetation data. Turboveg is used for storing vegetation-plot data in Europe, most widely in the Netherlands, Belgium, Czech Republic and Slovakia (Schaminée et al. 2009). Turboveg is the official tool for storing vegetation data for the European Vegetation Archive (EVA), the largest project to deal with large vegetation dataset with intent to compare data from a wide region, analyze spatial-temporal changes, continental level assessment of plant community species richness, patterns of alien species invasions etc. (Chytrý et al. 2012). For the Slovak Vegetation Database (Šibík 2012) the possibilities of TurboVeg are not only in phytosociology, but also in ecology, taxonomy and in nature conservation research. Historically, vegetation description and analysis has had close ties to the Braun-Blanquet approach throughout most of the Arctic. It is necessary to compare data from the entire circumpolar arctic including Europe, Greenland and Russia, where Turboveg already has been used. In addition a significant amount of vegetation data has been obtained using the Zürich-Montpellier School (Braun-Blanquet 1964) in the U.S. and Canada. Together these data sets make Turboveg software the best option to use as the official package for storing data for Arctic Vegetation Archive.

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Vegetation studies from the hemiarctic, northern and middle boreal zones of the National Wildlife Refuges of Western Alaska

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Introduction

This paper presents an overview of baseline vegetation descriptive data recorded from several National Wildlife Refuges of western Alaska within the hemiarctic zone and adjacent northern and middle boreal zones to the south. The data were collected according to a standardized protocol and are currently maintained in the electronic database, Turboveg (Hennekens and Schaminée 2001). These data were recorded by the author and team associates and do not include data collected by others. In general, previous descriptions of the vegetation within the western Alaska region are infrequent, usually qualitative, and lack complete species lists, particularly of bryophyte and lichen species composition.

The proximal objectives of the vegetation studies referenced herein for western Alaska were: (1) describe major plant communities along environmental gradients; (2) identify the main vegetation types using multivariate methods; (3) interpret the community types in relation to selected site factors; and (4) compare the communities identified with other regional Alaska vegetation. Ultimately the data are intended for use in developing a global arcto-boreal vegetation classification, and to portray vegetation zonation relationships from the middle boreal to hemiarctic zones of Alaska. The data may also serve as a resource for climate change and biodiversity research (Walker 2013).

Background

Over a 20+ year period relevé data were collected on the structure and composition of the boreal and Arctic vegetation within the National Wildlife Refuges (NWR) of western Alaska according to Braun-Blanquet methods (Westhoff and van der Maarel 1973). During this period team members sometimes included Fred J. A. Daniels, Wilfred B. Schofield, Ayzik Solomeschch, and Sandra L. Talbot; their knowledge and insight enriched these studies.

The location of our boreal phytosociological sites primarily occur within the northern boreal zone of the Aleutian Islands (Alaska Maritime NWR), Alaska Peninsula (Alaska Peninsula/Becharof and Izembek NWR) and neighboring islands, and the middle boreal zone of Kodiak NWR (Tuhkanen (1984). All these sites are generally within "maritime non-arctic tundra" (Yurtsev 1994); their locations are indicated in Fig. 1.

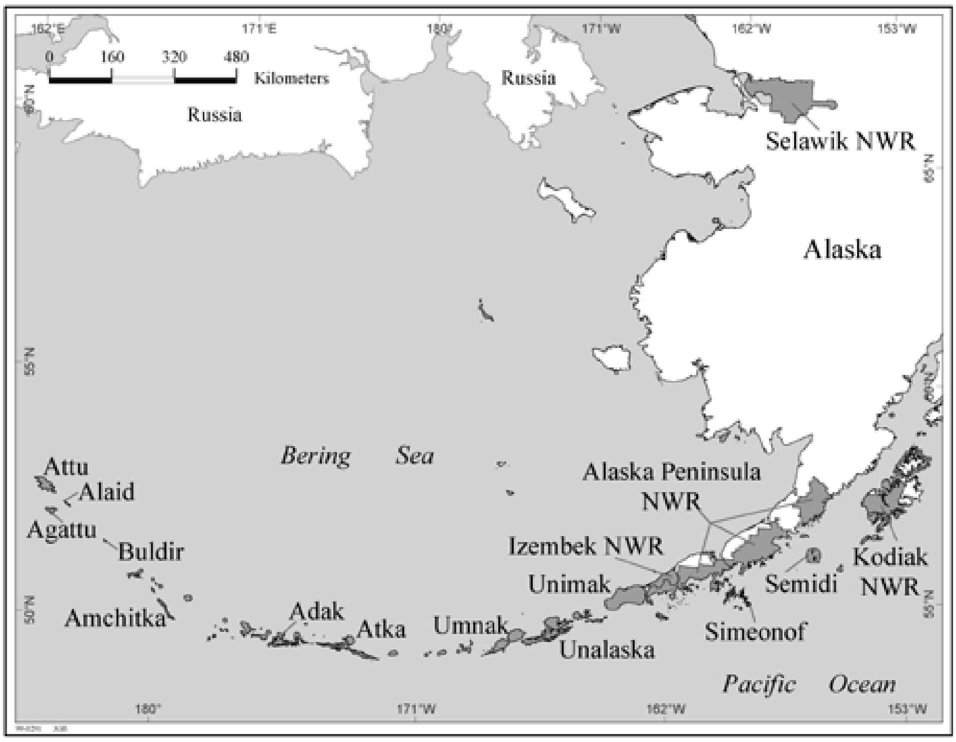

Figure 1. *Location of the major vegetation study sites sampled in western Alaska.*

In the hemiarctic zone (Tuhkanen 1984) of northwestern Alaska, the vegetation of the Selawik NWR was described (Fig. 1); this area corresponds to the "mixed continental and maritime Arctic tundra" (Yurtsev 1994). The vegetation of all these boreal and Arctic sites is essentially treeless and comprises 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.

Data Collection

Plots were laid out in units of homogeneous vegetation to represent conspicuous variation in plant communities usually over a topographic gradient. Relevé size, 25 m^2 for heaths, meadows, and mires; 100 m^2 for thickets; and 400 m^2 for forests equaled the minimal area 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 (vascular plants, bryophytes, and macrolichens), reviewed by taxonomic specialists, and archived in major herbaria. Taxonomic nomenclature generally follows the USDA Plants Database.

In addition to the floristic information of the plant communities, the vegetation structure within each relevé was 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.

For all sites latitude and longitude by GPS we recorded 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, NO3-N, NH4-N, P, SO4-S, B, Zn, Mn, Cu, Fe, K, Ca, Mg, Na, total bases, and texture (sand, silt, and clay).

Status of the Vegetation Data

Some of the data are published, including those from the Aleutian Islands (Attu Island, Talbot and Talbot 1994; Kasatochi Island, Talbot et al. 2010; and Unalaska Island, Talbot et al. 2010); Alaska Peninsula (Talbot et al. 2005); Tuxedni Wilderness Area (Talbot and Talbot, 2008); and Simeonof Island (Daniëls et al. 1998, 2004); other locales are actively being analyzed for publication.

In the summary given below the number of relevés for each region and site is shown in parentheses. Studies with detailed environmental data are indicated with an asterisk:

Aleutian Islands, Eastern Aleutian Islands (213 total): 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, published in Botany 88: 366-388; + 5), Unalga (4), *Unimak (70), Vsevidof (6); Islands of the Four Mountains — Chagulak (3), Kagamil (4), Uliaga (4).

Aleutian Islands, Central Aleutian Islands (368 total): Andreanof 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 (170 total): Near Islands — Agattu (8), Alaid (3), *Attu (65 + 76, published 76 relevés in J. Veg. Science 5: 867-876), Nizki (10), Shemya (8).

***Alaska Peninsula/Becharof National Wildlife Refuge (NWR) (363 total)** — Mountain transects from sea level to alpine (357 + 6 – 16 environmental variables).

Neighboring Islands of the Alaska Peninsula (117 total) — *Deer (15), *Simeonof (30, published in Phytocoenologia 34: 465-489), *Semidi (48), *Wosnesenski (24).

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

Kodiak Archipelago (281 total)— Kodiak NWR, mountain transects from sea level to alpine, Spiridon Peninsula (263 + 4 environmental variables); Chirikof Island (18).

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

GLORIA (Global Observation Research Initiative in Alpine Environments) is an initiative towards an international research network to assess climate change impacts on mountain environments. In July 2007 we established the first Alaska Arctic GLORIA study area in in Selawik NWR (Fig. 1) in the the Hockley Hills of the eastern Waring Mountains. This "target area" comprises a four summit sites, representing the regional elevational gradient. The sites were monitored in 2010. All these data are stored at the University of Austria.

Timeline

A five year timeframe is anticipated for the analysis, synthesis, and publication.

Acknowledgements

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Vegetation datasets from Northern Alaska, Baffin Island, Canada, and Beringia

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Introduction

The data reviewed in this paper were collected in order to describe arctic plant communities and, in most cases, how these plant communities have changed over the last few decades. Several high spatial resolution map layers are also described herein. Datasets include (Table 1): i) Plant community data collected at marked 1x10 sites near Barrow and Atqasuk, northern Alaska and near the Barnes Ice Cap, Baffin Island Nunavut. These sites were established by Webber in the 1960-70's and have been resampled during the recent International Polar Year - Back to the Future project (IPY-BTF) project; ii) plant community and other physical data (elevation, thaw depth, soil moisture, etc.) for a 1 x 34m gridded site (IBP Microtopographic Grid) near Barrow Alaska that was established in 1972 and resampled in 2000, 2008, and 2010. iii) Plant community data associated with an herbivore exclusion experiment that has been in place since the mid 1950's and sampled in 2002 and 2010; and iv) high spatial resolution land-cover maps derived for seven sites in Beringia (Chukotka, Russia and the Seward Peninsula and North Slope, Alaska.

***Table 1**. Summary of datasets. i) IPY-BTF Webber, ii) microtopographic grid, iii) herbivory exclusures, iv) Beringia Land cover.*

Title and Publication	Location	Site Establishment; Dates Resampled	Relevé Size (m2)	Species Data			Environmental Data	Format
				Vascular Plants	Bryophytes	Lichens		
i) BTF Webber (1978); Villarreal, et al. (2012)	Barrow, AK	1971; 1999, 2008, 2010	1 and .25	yes	no	yes	yes	MS Access Database
i) BTF Komárková, V. & P. J. Webber (1980); Villarreal et al. (In Prep b.)	Atqasuk, AK	1975; 2000, 2009	1 and .25	yes	yes	yes	yes	MS Access Database
i) BTF Webber (1971); Villarreal et al. (In Prep a.)	Baffin Island, Canada	1964; 2009	1 and .25	yes	yes	yes	yes	MS Access Database
ii) Microtopography grid Webber et al. 1980; Lara et al. (In Prep)	Barrow, AK	1973; 2000, 2008, 2010	0.25	yes	no	yes	yes	MS Access Database
iii) Herbivory exclosures Johnson et al. (2012)	Barrow, AK	1959; 2010	1	yes	yes	yes	yes	MS Access Database
iv) Beringia Land Cover Change Lin et al. (2012)	Beringia	n/a	0.25	no	no	no	yes	GIS

Back to the Future (BTF): Webber Datasets

The most extensive datasets have been compiled for sites established in the 1960-1970's near Barrow and Atqasuk in northern Alaska, and near the Barnes Ice Cap, Baffin Island Nunavut by Patrick J. Webber and (see Table 2 and Webber, pp. 86-90, this volume). Sites near Atqasuk and Barrow were resampled by both Webber's research group at Michigan State University in the early 2000's and Craig Tweedie's research group at the University of Texas at El Paso (UTEP) between 2008-2013. Tweedie's lab also resampled the Baffin Island sites in 2009. The most recent resampling effort undertaken by Tweedie's research group was a contribution to the IPY-BTF project. Except for a few sites near Barrow, each site consisted of a 1 x 10-m area composed of ten contiguous 1 m^2 plots. Percent cover was visually estimated for all vascular, bryophyte, and lichen species within a 10 cm x 100 cm strip along one edge of each 1 m^2 plot (Webber 1971). Species that occurred outside the strip but within a plot were recorded as present. Plots were sampled close to peak growing season between mid-July and early August during each sampling period. As well as collecting numerous repeat photographs at each sampling location, resampling efforts also collected a range of ecosystem functional data in close proximity to the historical study sites (e.g. Lara et al. 2012). Ecosystem functional data included soil moisture, active layer depth, hyperspectral reflectance, albedo, Leaf Area Index, peak-season component of the land-atmosphere carbon flux (CO_2 and CH_4), and above ground biomass (at most sites). All sites have been relocated with survey-grade differential or hand-held GPS and have been photographed extensively. Analysis of plant community and ecosystem change at these sites is described in Villarreal (2013), Villarreal et al (2012), Lara (2012), and Lara et al. (2012). Data have also been included in several synthesis efforts (Elmendorf et al. 2012, Callaghan et al. 2011). All data are managed in Microsoft Access databases and archived at the National Snow and Ice Data Center (NSIDC).

Table 2. *Description of physical parameters, vegetation map classification, and BTF summary of the four study locations.*

Physical Parameters	Baffin Island, CAN	Barrow, AK	Atqasuk, AK
Location	70°25'N, 74°40'W	71o18'N 156o40'W	70°29' N, -157°27' W
Elevation (m ASL)	600	3	30
Mean Annual Temperature °C	-12.8	-12.6	-11.9
Mean July Temperature °C	2.9	3	7.2
Average maximum Thaw Depth (cm)	n/a	35-39	36-71
Soil pH	Circumneutral/Acidic	Acidic	Acidic
Substrate	Sand, gravel, silt	Sand, gravel, silt	Aeolian sand and Sand, silt
Succession Pattern	Deglaciation	Thaw-Lake Cycle	Thaw-Lake Cycle
Circumarctic Vegetation Map Classification			
Bioclimate Subzone	C	C	D
Vegetation	B2: Cryptogam barren complex	W1: Sedge/grass, moss wetland	W2: Sedge, moss, dwarf-shrub wetland
Sampling History			
Historic study	Webber Dissertation	IBP	RATE
Historic publication	Webber 1971	Webber 1978	Komárková and Webber 1980
Year of Site Establishment	1964	1972	1975
Resampling Dates	2009	1999, 2008, 2010	2000, 2009
Number of Original Sites	82	43	60
Number of Resampled Sites	79	33	31
Number of Species	117	81	213
Type sampled	Vascular and non-vascular	Vascular and lichens only	Vascular and non-vascular

IBP Microtopographic Grid

The IBP microtopographic grid was established near Barrow, Alaska in 1973 and measures 1 m x 34 m (Figure 1). The site is subdivided into a grid of 50 x 50 cm^2 plots that are marked by wooden stakes and the site was established to describe how vegetation and other biophysical parameters vary in association with subtle differences in microtopography typically associated with polygonized tundra (Webber et al. 1980). Vascular species and lichen species percent cover was visually estimated for each plot and the cover of bryophytes were lumped into a single cover estimate for this plant functional type. The grid was resampled in 2000, 2008, and 2010 for vegetation cover and a range of other data including: CO_2 flux, kite aerial photography, photographs of each subplot, survey grade horizontal and vertical position of each wooden marker (with Differential Global Positioning System -DGPS), LiDAR (2013), hyperspectral reflectance, albedo, soil moisture, active layer depth, and above ground biomass (adjacent to the grid).

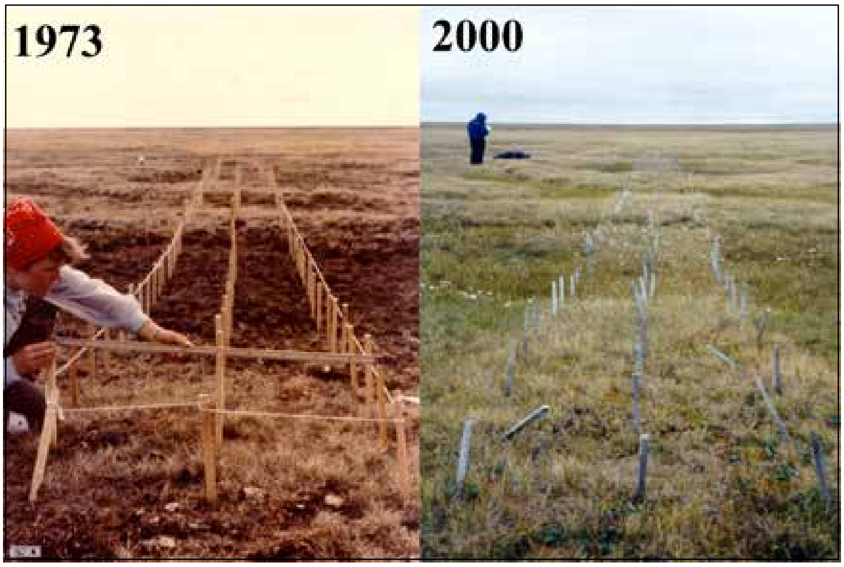

Figure 1. *Repeat photography of the microtopography grid near Barrow, Alaska.*

Historic Herbivore Exclosures near Barrow, Alaska

Approximately 70 herbivore exclosures were established near Barrow in the 1950s in dry, moist, and wet land-cover types. Exclosures measured 2 m × 2 m and were enclosed by a 1.27 cm^2 wire mesh that was buried 10–15 cm into the active layer and extended to approximately 75 cm above ground level. A control plot measuring 2 m × 2 m was established within 5 m of each exclosure and marked by wooden pegs at the four corners. Approximately 20 exclosures were found to be intact in 2010, evidenced by the absence of lemming and caribou fecal material inside the exclosure. Historical data for these exclosures appears to have been lost but vegetation inside the exclosures and in control plots have been sampled for vascular, lichen, and bryophyte species percent cover and biomass in 2002 and 2010 (Johnson et al. 2012). Other data, including soil moisture, active layer depth, hyperspectral reflectance, albedo, Leaf Area Index, and peak season land-atmosphere component carbon flux (CO_2 and CH_4), were also collected in 2010.

Figure 2. *Herbivore exclosure (left) and control plot (right) near Barrow, Alaska.*

4. Beringia Land Cover Change Datasets

Historic and recent aerial and satellite imagery has been used to create multi-temporal high spatial resolution (<2m^2 rasterized data layer) land cover maps for seven locations in the Beringian Arctic (Barrow, Atqasuk, Midway, Ivotuk, and Kougarok, Alaska and Penkigney Bay and Yanrakinot, Chukotka, Figure 3). These time series land cover maps span 6 to 20 km^2 and have been used to assess patterns of decadal time scale land cover change (Lin 2012, Lin et al. 2012) and to assess how landscape scale Greenhouse Forcing Potential associated with land-atmosphere CO_2 and CH_4 exchange has also changed. Spectral and environmental data includes hyperspectral reflectance, albedo, soil moisture, active layer depth, Leaf Area Index (LAI), peak season land-atmosphere component carbon flux (CO_2 and CH_4), and biomass harvest. Species cover data were not collected at these sites but the cover of plant functional types was collected for plots replicated in 3-5 land-cover types at each sampling location.

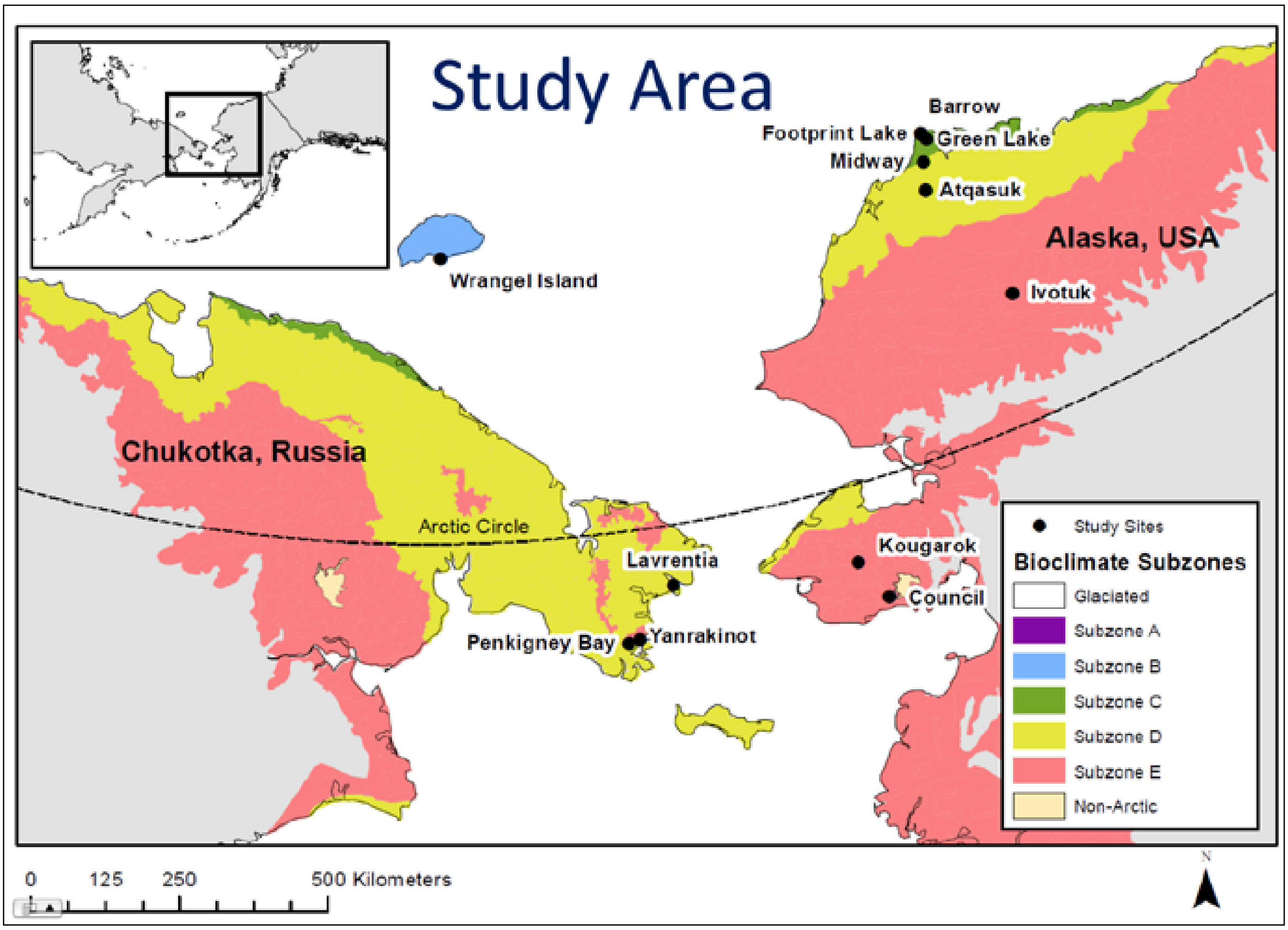

Figure 3. *Location and bioclimate subzones of the seven Beringian landscapes for which time series high spatial resolution land cover maps have been derived (Lin et al. 2012).*

Summary and Conclusions

All nomenclature for vascular Alaskan species follows Hultén (1968), and vascular species from Baffin Island, Canada follows Aiken et al. (2007). Nomenclature for all bryophyte and lichen species follows Anderson et al. (1990) and Esslinger and Egan. (1995), respectively. The United States Department of Agriculture (USDA) Natural Resources Conservation Center (NRCS) PLANTS (2013) database was used to update nomenclature for all species.

These data, especially IPY-BTF datasets from Barrow, Atqasuk, and Baffin Island, are useful datasets to add to the Arctic Vegetation Archive because, with the exception of the Barrow BTF and microtopography grid datasets, both vascular and non-vascular plant groups have been sampled. Additionally, most datasets span several decades due to resampling efforts, have undergone change analysis (Villarreal 2013, Lin et al. 2012), have been used in several synthetic studies (Elmendorf et al. 2012, Callaghan et al. 2011) and are complemented by an assortment of other environmental data (Lara 2012, Lin 2012). All datasets are stored and managed in Microsoft Access relational databases, which should facilitate data archiving efficiencies with TurboVeg. Challenges that are expected to be encountered as these data are included in AVA include (1) standardization of metadata, (2) standardization of species nomenclature, and (3) cross-walking sampling approaches used to derive the datasets described above with the Braun-Blanquet approach to ensure a high degree of inter-comparability .

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The Prudhoe Bay, Imnavait Creek, Toolik Lake, and Happy Valley vegetation datasets

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Introduction

A considerable amount of vegetation data that are appropriate for classification and analysis using the Braun-Blanquet approach has been collected from northern Alaska (Breen et al. 2014). Many of these data have been collected in areas that are accessible from the Dalton Highway between Prudhoe Bay to the north and Toolik Lake to the south (Figure 1, and Table 1). Seven main vegetation-plot datasets containing 796 relevés have been collected from this region using Braun-Blanquet protocols. This abstract describes four data sets containing 301 relevés from Prudhoe Bay, Imnavait Creek, Toolik Lake, and Happy Valley. These are data sets that I have collected and am most familiar with. I describe them below in the order they were studied. The other three are described in other abstracts from this meeting.

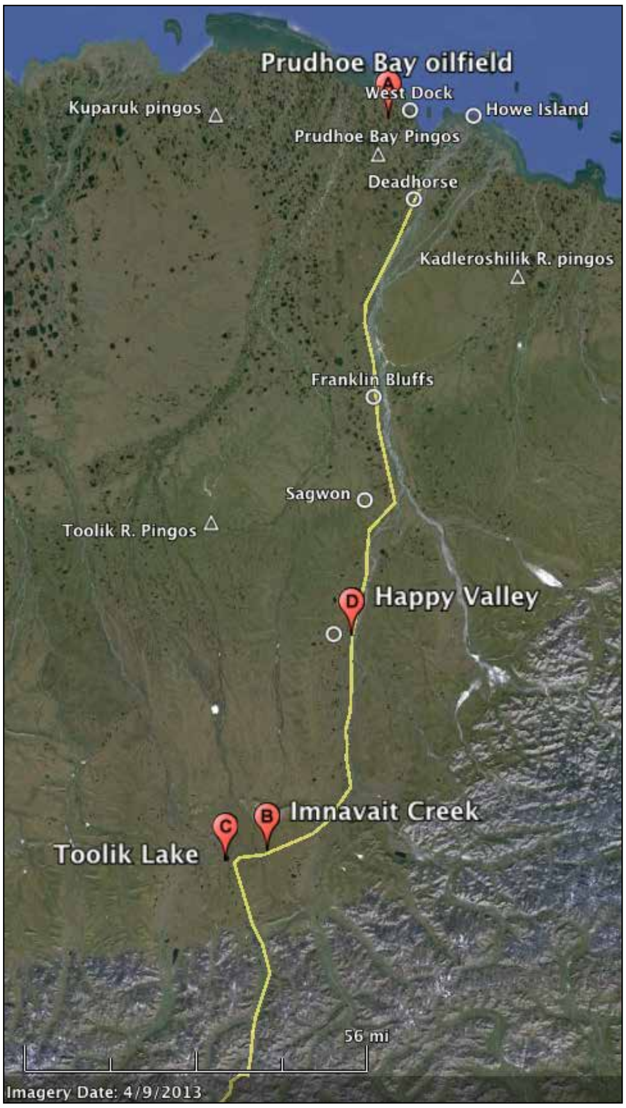

Figure 1. *Locations of phytosociological studies along the Dalton Highway in northern Alaska. The Beaufort Sea is to the north, and mountains are part of the Brooks Range. The four lettered locations (red balloons) are the locations of data sets discussed in this abstract: A) Prudhoe Bay Oilfield, B) Imnavait Creek, C) Toolik Lake, and D) Happy Valley. Other study locations shown here are: (triangles) the four pingo areascontaining the 41 pingos studied by M.D. Walker (1990); (circles) the six areas of cryoturbated-tundra studies by Kade et al. (2005); and (yellow line) the Dalton Highway, where Schickhoff et al. (2002) examined riparian plant communities at 29 locations. Google Earth Image.*

The data provide baseline vegetation information for the common vegetation types occurring at Prudhoe Bay and along the Dalton Highway in Bioclimate Subzones C, D, and E of the Circumpolar Arctic Vegetation Map (CAVM Team 2003) and are representative of vegetation found in the wet nonacidic tundra on the Arctic Coastal Plain in the vicinity of the Sagavanirktok River, the acidic tussock tundra landscapes of the northern Arctic Foothills, and varied tundra landscapes common in the more recently deglaciated landscapes of the southern Arctic Foothills. Cover estimates were made for vascular plants, bryophytes, and lichens. Soil and environmental data were also collected at all the sites. Most of these data (excluding those from Happy Valley have been formally published (Table 1) and all are contained in hard-copy data reports (cited in Table 1, and now in digital format). The sampling was done in homogeneous areas of vegetation that were representative of the main habitat types).

Table 1. *Vegetation studies along from Toolik Lake to Prudhoe Bay along the Dalton Highway. Datasets in italics where were conducted by the author and field assistants.*

Location	Number of plant communities described. Number of habitats sampled: habitat types (number of plots in each habitat type)	No. of plots	Key publication or data report	Other publications and ancillary data sets
Prudhoe Bay	*43 plant communities (stand types). 4 broad habitat categories:* ***Dry tundra*** *(including gravelly pingos, high-centered polygons, frost scars, dry river sands and gravels, sand dunes, river bluffs, coastal beaches, and early-melting snowbeds) (24 plots);* ***moist tundra*** *(including moist nonacidic tundra, acidic coastal tundra, snowbeds, moist stream banks, bird mounds & animal dens, and moist sandy tundra (33),* ***wet tundra*** *(including wet nonacidic tundra, wet acidic tundra, and wet saline coastal tundra) (25),* ***aquatic tundra*** *(including shallow and deep water habitats) (10). Most plant communities correspond to specific habitat types*	*92*	(Walker 1985)	***Geobotanical descriptions and maps:*** (Walker et al. 1980), ***Soils and vegetation:*** (Everett and Parkinson 1977, Walker and Everett 1991). ***Permafrost***: (Kanevskiy et al. 2013) ***CALM active layer and climate***: http://www.udel.edu/Geography/calm/about/permafrost.html. ***General ecology:*** (Brown 1975). ***Change analysis:*** (Raynolds et al. 2013b)
Innavait Creek	*14 plant communities. 19 habitats: Dry sandstone outcrops (6 plots), glacial boulder fields (2), dry rocky till (5), hill slope nonsorted stripes (5), frost scars on stripes (5), areas between nonsorted stripes (3), hill slopes with solifluction (5), snowbeds (10), water tracks (7), margins of water tracks (2), hill slopes between water tracks (zonal tussock tundra) (11), wet frost scars (3), hummocks and strangs in wet meadows of colluvial basins, (3), wet tundra between strangs (poor fens) in colluvial basins (6), palsas (2), stream margins (4), stream channels (2), beaded-stream ponds (3).*	*73*	(Walker et al. 1987)	***Terrain and vegetation including maps:*** (Walker et al. 1989, Walker and Walker 1996). ***Vegetation classification:*** (Walker et al. 1987b). ***General ecology:*** (Oechel 1989, Reynolds and Tenhunen 1996). ***CALM active layer and climate:*** http://www.udel.edu/Geography/calm/about/permafrost.html.
Central Arctic Coastal Plain pingos (41 pingos)	25 plant communities (including stand types and facies of stand types). 3 broad habitat categories: **North facing slopes and ENE facing wind-exposed sites** (77 plots), **snowbeds** (131), **south slopes and summits** (85). Data are from 7 microsites on pingos: ENE wind-exposed sites, summits (animal dens), dry leeward sides above snowbed, middle of snowbeds on leeward side (well drained), bottom of snowbed on leeward side (poorly drained), south slopes (including shrublands and rich forb meadows), north slopes.	293	(Walker (1990)	**Description of P.B. pingos:** (Walker et al. 1985). **Steppe vegetation on pingos:** (Walker et al. 1991). **Pingo soils:** (Walker et al. 1996).
Toolik Lake	*26 plant communities. 4 broad habitat types:* ***Dry tundra*** *(including gravelly south-facing slopes, till and outwash deposits, ground squirrel mounds, stone stripes, and nonsorted circles) (19 plots),* ***snowbeds*** *(7),* ***moist tundra*** *(including tussock tundra, moist nonacidic tundra, moist shrublands) (27), and* ***wet tundra*** *(including fens, and aquatic tundra) (15). Most plant communities correspond to more specific habitats as at Imnavait Creek.*	*81*	(Walker and Barry 1991)	***Vegetation classification:*** (Walker 1990). ***Vegetation maps:*** (Walker and Maier 2008). **Biomass, LAI, and NDVI:** (Shippert et al. 1995, Walker et al. 1995). **Change analysis:** (Raynolds et al. 2013a). ***General ecology:*** (Raynolds et al. 2013a, Hobbie and Kling 2014). ***CALM active layer and climate:*** http://www.udel.edu/Geography/calm/about/permafrost.html.

Location	Number of plant communities described. Number of habitats sampled: habitat types (number of plots in each habitat type)	No. of plots	Key publication or data report	Other publications and ancillary data sets
Happy Valley	*17 plant communities. 5 broad habitat types:* ***Dry tundra*** *(including river terraces and frost scars) (10 plots),* ***snowbeds*** *(2), moist tundra (including acidic and nonacidic) (10),* ***shrub-lands*** *(including riparian alders, riparian willow communities, and dwarf-birch shrub tundra (16),* ***wet tundra*** *(including fens, poor fens, and aquatic marshes) (14).*	*55*	(Walker et al. 1997)	***ARCSS Flux Study:*** (Kane and Reeburgh 1998). ***ATLAS synthesis:*** (McGuire et al. 2003). ***CALM active layer and climate:*** http://www.udel.edu/Geography/calm/about/permafrost.html. ***Vegetation map:*** (Walker et al. 2013). ***NDVI and hyperspectral data***: (Buchhorn et al. 2013).
Dalton Highway riparian willow commun-ities (29 sites)	5 plant communities (3 associations, and 4 subassociations). Riparian habitats including: a) gravel bars and lower terraces of the Sagavanirktok River and fast flowing mountain streams (dominated by *Salix alaxensis*), b) upper terraces of streams and river (dominated by *Salix richardsonii*), and c) water tracks and smaller acidic stream banks (dominated by *Salix pulchra*).	85	(Schick-hoff et al. 2002)	**Willow height and growth rings along climate gradient:** (Walker 1987). **Dalton Highway baseline ecology:** (Brown and Berg 1980)
Dalton Highway patterned-ground vegeta-tion (7 sites)	9 plant communities (5 formal associations and 4 other communities). 9 habitat types: 4 habitats on nonsorted circles and small nonsorted polygons in bioclimate subzones C, D, and E and 5 habitats of areas between circles and polygons in bioclimate subzones C, D, and E.	117	(Kade et al. 2005)	**Biocomplexity studies along the North America Arctic Transect:** (Walker et al. 2008). **Vegetation maps:** (Raynolds et al. 2008). ***Biomass:*** (Epstein et al. 2008). **Soils:** (Michaelson et al. 2008, Ping et al. 2008). **N-factor of vegetation:** (Kade et al. 2006). **Other biocomplexity data:** (Barreda et al. 2006).
N. Slope balsam poplar commun-ities (8 sites)	3 plant communities (1 association, 3 vari-ants that differ in habitat type including: a) typical variant in **riparian areas**, b) **south-facing slopes** and c) **perennial springs**). Plots range from Noatak River east to the Kongakut River with 3 plots along the Dalton Highway corridor.	19	Breen 2014, In press)	***Biogeography:*** (Breen et al. 2012). ***Rare bryophytes:*** (Afonina & Breen 2009). ***Nucleotide diversity:*** (Breen et al. 2009)

Prudhoe Bay: Coastal tundra

The Prudhoe Bay Oilfield (70˚ 23'N, 148˚ 25'W) is located on an extraordinarily flat portion of the Alaskan Arctic Coastal Plain on ancient floodplains of the Sagavanirktok River to the east, the Kuparuk River to the west, and Putuligayuk River in the middle portion of the region (Figure 2). The Sagavanirktok River flows out of glaciated limestone-rich portions of the Central Brooks Range and provides the major source of calcareous alluvial gravels and loess that blanket most of the region and contributes to the rich flora (Murray 1978).

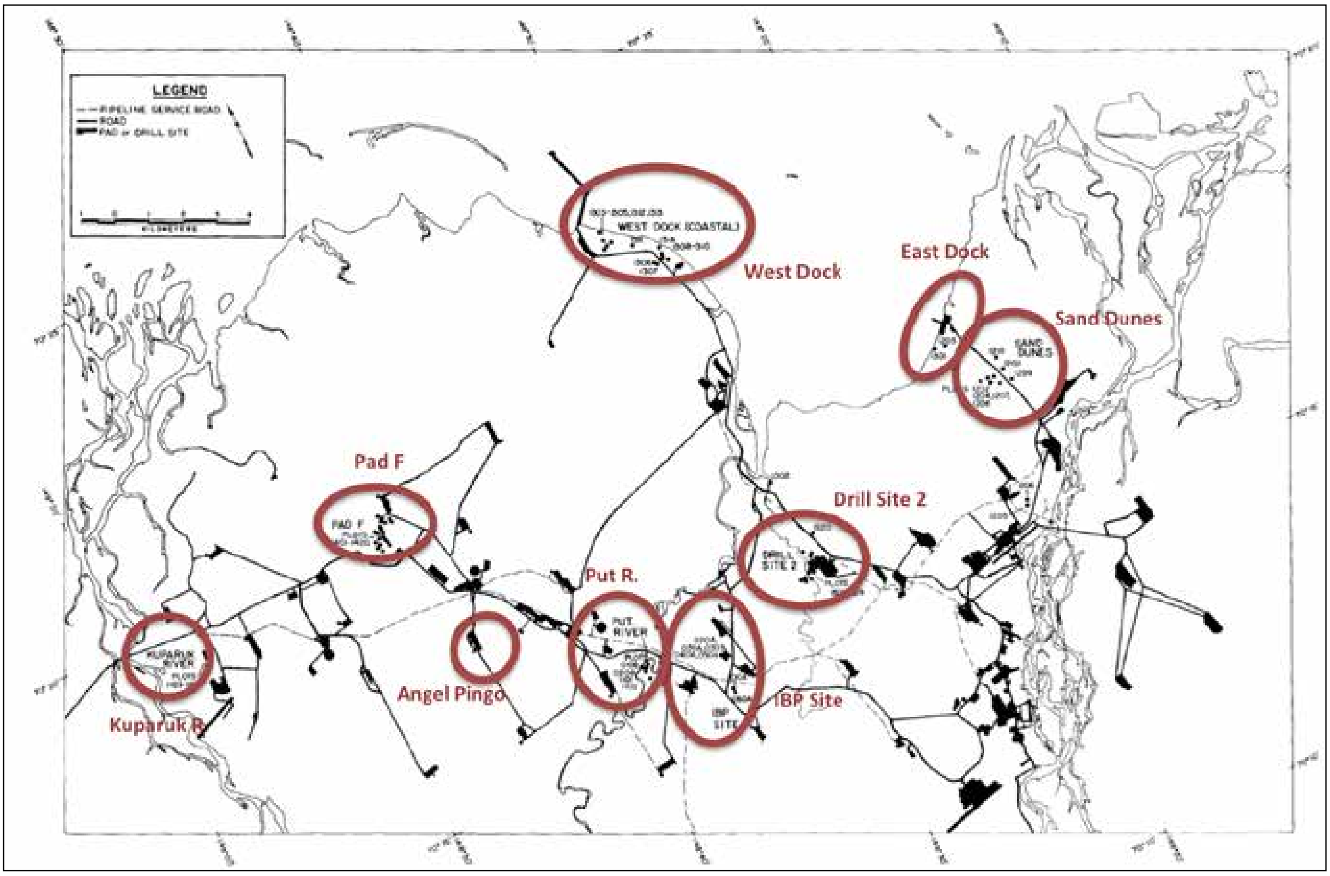

Figure 2. *Location of main vegetation study areas within the Prudhoe Bay region. The oilfield road network (shown as of 1977) provided access to the study locations.*

The climate, snow cover, soils, landforms, vegetation, and animals of the region were studied as part of research conducted by the International Biological Programme (IBP) Tundra Biome research at Prudhoe Bay (Brown 1975, Walker et al. 1980). The vegetation was described and analyzed during geoecological mapping efforts (Webber and Walker 1975, Walker and Webber 1980, Walker 1985). Ninety-two vegetation plots are located within nine main study locations that are accessible from the extensive Prudhoe Bay road network (Fig. 2). Fifty-two plots were sampled using the 1 x 10-m nested sampling design of P.J. Webber (Webber 2013). Another 40 plots, mainly in smaller microhabitats used 1 x 1-m plots. The plots were subjectively grouped into 44 stand types representative of typical dry, moist, wet, and aquatic tundra habitats along the coastal climate and soil pH gradients, and also include habitats found in saline coastal environments, braided rivers, tundra streams, pingos, and sand dunes (Table 1). The plots were permanently marked and are now located on a Google Earth image permitting future revisits to examine change.

Environmental data from each plot included location, vegetation type, topographic feature, plot size, thaw depth, water depth, distance to coast, distance to the Sagavanirktok River (source of loess), hummock height, site moisture class, snow regime, cryoturbation regime, temperature regime, five plant growth-form categories, nine animal-sign variables, eleven soil physical factors, and eight soil chemical factors. The environmental data were used to examine the trends of species occurrence along major environmental gradients at the microscale (e.g., soil moisture, snow depth, animal disturbance), mesoscale (the regional pH gradient associated with loess from the Sagavanirktok River), and macroscale (summer temperature gradient associated with the distance from the Arctic coast) (Walker 1985, Walker and Everett 1991).

Foothill locations

Data from Toolik Lake, Imnavait Creek, and Happy Valley were collected using similar protocols to each other, and are contained in data reports with similar format (Walker et al. 1987a, Walker and Barry 1991, Walker et al. 1997). These three data sets provide a good sampling of vegetation from foothill landscapes that were covered by glaciers flowing out of the Brooks Range during three different glacial intervals (Hamilton 2003). The Toolik Lake region was deglaciated at the end of the Late-Pleistocene subepoch (about 11,500 years ago); the Imnavait Creek watershed was glaciated in the late phases of the Middle-Pleistocene subepoch (about 126,000 years ago); and the Happy Valley area is thought to have been deglaciated at the end of the Early-Pleistocene Subepoch (about 780,000 years ago). These are described below in the order that they were sampled (not their chronological age).

Imnavait Creek (68˚ 36'N, 149˚ 17'W) is a small headwater creek of the Kuparuk River, located in the southern Arctic Foothills of the Brooks Range. The rolling tussock-tundra-covered landscape is typical of portions of the southern parts of the Arctic Foothills that were deglaciated at the end of Sagavanirktok glacial interval (Middle-Pleistocene subepoch, about 126,000 years ago) (Hamilton 2003). Well-drained areas are restricted to a few sandstone outcrops, and mineral soils exposed on hillcrests and sorted stone stripes. Most areas, including the broad mossy hill slopes covered by moist acidic tussock tundra, are poorly drained. Typical landforms include "horsetail drainages" consisting of many parallel, shallow, peaty, drainage channels (water tracks) that resemble horse tails on aerial photographs, wet colluvial basins and beaded streams in the valley bottoms (see Table 1).

The vegetation of the Imnavait Creek research area was described and mapped during the U.S. Department of Energy's R4D (Response, Resistance, Resilience, and Recovery from Disturbance of Arctic ecosystems) program (Oechel 1989, Reynolds and Tenhunen 1996). Seventy-three vegetation plots were subjectively located in representative habitat types (Table 1). The plots were 10-m-diameter (78.5 m2) circular plots wherever possible, except where constrained by the boundaries of the habitats (e.g., frost boils, sorted stripes, long linear hummock features or water tracks). GPS coordinates were obtained for most plots in recent years. A small 1-m2 plot within the plot was also permanently marked with pin flags and photographed as a photo reference plot for future change analysis. A complete list of vascular plants, mosses and lichens was obtained for each plot. Plant cover was estimated according to the 7 point Braun-Blanquet cover-abundance scale. A soil pit was dug to permafrost or slightly deeper according to U.S. Soil Conservation Service protocols (Soil Survey Staff 1975). Soil samples were collected and analyzed for physical and chemical characteristics from each soil horizons in most of the plots.

The raw vegetation, environmental, and soil data, soil descriptions, and photos of all the plots and soils are in a data report (Walker et al. 1987a). Another data report contains descriptions of the terrain, surface forms, and vegetation units with photographs and maps of the geoecological units, a sorted table analysis of the data, and a cross-walk of the vegetation types to other classification systems used in northern Alaska (Walker et al. 1987b). This information was used in a paper and a book chapter that describe the Imnavait Creek research area (Walker et al. 1989, Walker and Walker 1996).

Toolik Lake (68˚ 37'N, 149˚ 33'W) is about 11 km west of Imnavait Creek. The landscape was deglaciated during two phases of the late Pleistocene subepoch, about 60,000 and 11,500 years ago) (Hamilton 2003). The landscape is topographically much more diverse than the Imnavait Creek watershed with many relatively recent glacial lakes, and small streams. Numerous well-drained moraines, kames, and outwash deposits have a rich diversity of plant habitats (Walker et al. 2014).

The vegetation of the Toolik Lake area was described and mapped during the DOE R4D studies using nearly the same protocols as at Imnavait Creek (Walker and Barry 1991, Walker and Maier 2008). Eighty-one plots were subjectively located in representative habitat types (Table 1). The centers of the plots were permanently marked. GPS coordinates were obtained for most plots in recent years. The size of each sample area was estimated after a complete species list was obtained. The raw vegetation and environmental data are in a data report (Walker and Barry 1991).

The vegetation data from Imnavait Creek and Toolik Lake region were combined and classified using the Braun-Blanquet approach (Walker et al. 1994). Five new associations and 15 community types were tentatively placed within eight Braun-Blanquet classes.

An important aspect of the Imnavait Creek and Toolik Lake vegetation studies is the hierarchy of geoecological maps that have been constructed for both locations (Walker and Maier 2008). At both sites a 1-km grid with 100-m grid-point spacing was surveyed, and the topography, landforms, surficial geomorphology, percentage water cover, and vegetation were mapped at 1:500 scale. These grids became essential elements of the sampling protocols for the Circumpolar Active Layer Monitoring (CALM) project (Nelson et al. 2004).

Happy Valley is about 60 km north of Imnavait Creek and is typical of older glaciated terrain in the northern part of the Arctic foothills with broad gently sloping hills, well-developed colluvial basins, and water tracks. Glacial moraines are subdued; only a few remnant glacial ponds remain, and there are very few erratics that stick above the tundra surface. The site is adjacent to the Sagavanirktok River and includes terraces and river bluffs along the river.

The Happy Valley area was studied primarily as site for CO2 flux measurement during the NSF-Sponsored Land-Air-Ice Interactions (LAII) Flux Study (Oechel 1989, Kane and Reeburgh 1998) and the Arctic Transitions in the Land-Atmosphere System (ATLAS) studies (McGuire et al. 2003). As with the Imnavait Creek and Toolik Lake sites, a 1-km grid with 100-m grid-point spacing was surveyed, and the topography, landforms, surficial geomorphology, percentage water cover, and vegetation were mapped at 1:500 scale (Walker et al. 2013).

Fifty-five vegetation plots were subjectively located in representative habitat types in the same manner as at Toolik Lake (Table 1). The centers of the plots were permanently marked with 1.3-m striped PVC pipes and located on an aerial photograph of the region. The vegetation plot boundaries were not permanently marked, but the size of each area sampled was estimated after a complete species list was obtained. More recently, GPS coordinates were obtained for all plots that could be relocated.

A complete list of vascular plants, mosses and lichens were obtained for each plot, and cover estimated according to the Braun-Blanquet cover-abundance scale. A soil pit was dug adjacent to the vegetation plot to permafrost or slightly deeper and described according to U.S. Soil Conservation Service protocols (Soil Survey Staff 1975). Soil samples were collected from each soil horizon and analyzed for at least one representative example of all vegetation types. All the soil chemical and physical data were summarized in tables. The raw vegetation and environmental data are in a data report (Walker et al. 1997).

Future application of the Dalton Highway data for a regional Braun-Blanquet synthesis

The data sets from the Dalton Highway and Prudhoe Bay represent a north-south cross section of vegetation of the Coastal Plain and Foothills in the central part of Alaska's Arctic Slope. Three previous vegetation analyses from this region have used the Braun-Blanquet approach (Walker et al. 1994, Schichkoff 2002, Kade 2005). Twelve associations and 19 plant-community types from these studies provide new perspectives on variations of vegetation in nine Br.-Bl. classes described from northern Europe (Dierssen 1996), including *Potametea* Klika in Klika & Novák 1941, *Salicetea purpureae* Moor 1958, *Scheuchzerio-Caricetea nigrae* (Nordhagen 1936) R. Tx. 1937, *Oxycocco-Sphagnetea* Br.-Bl. & R. Tx. 1943, *Salicetea herbaceae* Br.-Bl. 1947, *Loiseleurio-Vaccinietea* Eggler 1952, *Carici rupestris-Kobresietea bellardii* Ohba 1974, *Mulgedio-Aconitetea* Hadač in Klika et Hadač 1944, and *Rhizocarpetea geographici* Mattik em. Wirth 1980.

Our intent is now to broaden this core set of Br.-Bl. information to include Prudhoe Bay (Walker 1985), Happy Valley (Walker et al. 1987), the pingo studies of Marilyn Walker (1990), and the poplar communities recently described by Amy Breen (Breen 2014 in press). This will expand the Br.-Bl.-classification perspective of this region to encompass communities of Bioclimate Subzone C, saline coastal areas, sand dunes, additional snowbed types, steppe-tundra, zoogenic sites, poplar groves, and some of the non-willow riparian communities along the major rivers (Table 2). The Br.-Bl. classification of the vegetation in the Arrigetch Peaks (Cooper 1986) will add many alpine communities from the Brooks Range. The set of other vegetation plot datasets described at the Boulder AVA workshop should help provide a broader Br.-Bl. synthesis of Alaska Arctic vegetation.

Table 2. *Habitat-types and preliminary Br.-Bl. classes expected within the datasets along Dalton Highway transect.*

Habitat description	Anticipated Br.-Bl. Class
1. Coastal salt marsh vegetation 1a. *Puccinellia phryganodes, Carex subsapathecea* coastal salt marsh communities	*Juncetea maritimi* Br.-Bl. 1931
2. Dry coastal beach and sand dune vegetation 2a. Elymus arenarius and other dune communities 2b. Coastal communities influenced by saline soils (*Puccinellia andersonii, Mertensia maritimia, Honkenya peploides, Salix ovalifolia, Braya purpurascens, Cochlearia* communities)	*Ammophiletea* Br.Bl. & Tüxen ex Westhoff, Dijk & Passchier 1946
3. Rooted floating or submerged macrophyte vegetation of meso-eutrophic water 3a. Aquatic forb marshes *(Hippuris, Sparganium, Menyanthes, Utricularia, Ranunculus communities)*	*Potametea* Klika in Klika & Novák 1941
4. Riparian willow shrub and poplar stands of warm habitats 4a. Willow shrub vegetation of riparian areas and warm habitats (south-facing slopes) 4b. Poplar vegetation of warm Arctic habitats	*Salicetea purpureae* Moor 1958
5. Sedge grass and dwarf shrub mire and fen vegetation 5a. Aquatic grass marshes (*Arctophila fulva*) 5b. Moist to wet coastal grasslands (*Dupontia*) 5c. Wet nonacidic tundra (*Carex spp.-, Eriophorum spp.-Amblystegiaceae* communities) 5d. Coastal moist tundra (*Carex stans, Carex atrofusca* communities)	*Scheuchzerio palustris-Caricetea fuscae* Tüxen 1937

Habitat description	Anticipated Br.-Bl. Class
6. Bog vegetation, acidic mires, including tussock tundra 6a. Wet acidic *Sphagnum*-rich mires (bogs) 6b. Moist to wet acidic tussock and nontussock (*Eriophorum vaginatum-, Carex bigelowii-Sphagnum, -Hylocomium*) tundra 6c. Moist to wet acidic low-shrub heaths (wet to moist *Betula nana-Sphagnum heaths*)	*Oxycocco-Sphagnetea* Br.-Bl. et Tüxen ex Westhoff et al. 1946
7. Talus slope, debris and alluvial vegetation 7a. Ruderal riparian vegetation (*Epilobium latifolium, Artemisia arctica, Trisetum spicatum*, etc.)	*Thlaspietea rotundifolii* Br.-Bl. 1948
8. Deep snowbed vegetation 8a. Moderately drained deep snowbeds (*Salix rotundifolia, S. polaris, S. herbacea* snowbeds) 8b. Poorly drained deep snowbeds (P*hippsia algida, Saxifraga rivularis, Ranunculus pygmaeus*, etc.)	*Salicetea herbaceae* Br.-Bl. 1947
9. Dwarf-shrub heath and low-shrub vegetation on acidic poor substrate 9a. Dry acidic prostrate-shrub heaths (*Arctous alpina, Salix phlebophylla, Empetrum* heaths) 9b. Shallow acidic snowbeds (C*assiope-Carex microchaeta-Hylocomium* communities) 9c. Moist and dry acidic dwarf-shrub heaths (*Vaccinium uliginosum, Emetrum nigrum, Ledum decumbens*, some *Betula nana-lichen* heaths) 9d. Frost boil vegetation in acidic tundra (*Anthelia, Juncus* communities)	*Loiseleurio-Vaccinietea Eggler* 1952
10. Achionophytic dwarf shrub and graminoid vegetation on non-acidic substrate 10a. Dry nonacidic tundra (*Dryas integrifolia*, including *Dryas* river terraces) 10b. Dry nonacidic alpine tundra (*Dryas octopetala*) 10c. Shallow nonacidic snowbeds (C*assiope-Dryas-Tomentypnun*, and *Cassiope-Dryas-lichen* communities) 10d. Moist nonacidic tundra (*Sedge-Dryas-Tomentypnum* communities) 10e. Frost boil vegetation in nonacidic tundra (*Juncus biglumis, Saxifraga oppositifolia*)	*Carici-Kobresietea Ohba* 1974
11. Boreal and low Arctic steppe inland vegetation on dry, warm substrate 11a. Steppe tundra communities on south facing slopes of pingos 11b. Artemisia communities along streams and in dune	*Saxifrago-Calamagrostietea purpurascentis Drees & Daniels* 2008
12. Tall forb and shrub vegetation on mesic-moist soil 12a. Alder communities	*Mulgedio-Aconitetea Hadač* in Klika et Hadač 1944
13. Lichen communities on silicate rocks	*Rhizocarpetea geographici Wirth* 1980
14. Lichen communities on calcareous rocks	*Verrucarietea nigrescentis Wirth* 1980
0. Habitats of yet to be described classes 0a. Zoogenic communities associated with animal dens and bird mounds (arctic ground-squirrels, arctic foxes) (*Poa glauca, Festuca rubra, Ranunculus pedatifidus, etc.*)	

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Vegetation data from pingos, Central Arctic Coastal Plain, Alaska

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Introduction

A total of 293 plot samples of vegetation were taken from 41 pingos (ice-cored mounds) in the area surrounding Prudhoe Bay, Alaska during the summers of 1983 and 1984 (Walker 1987). The study purpose was to determine if there were unique elements to the pingo vegetation, and if so, what was their origin. This was the first (and perhaps only) comprehensive study of pingo flora and vegetation.

The central arctic coastal plain region in and around Prudhoe Bay (70°N, 148°W) has some of the world's largest concentrations of pingos. The gravel-rich surficial deposits and an active thaw-lake cycle combine to create an environment that supports pingo development (D.A. Walker et al. 1985). The pingos have never been dated, but morphology and soil studies suggest that there have been two active and distinct periods of pingo formation, one in the last 10,000 years and an earlier period about 40,000 years ago (Walker et al. 1996). There is evidence of ongoing pingo formation in the area, as I observed incipient pingos in recently drained lakes.

Pingos are extraordinarily unique landforms on Alaska's North Slope – the only significant relief on the flat coastal plain. They have strong microclimatic gradients within very small physical areas, with common surficial geology, so they offer an opportunity to examine the effect of microclimate on both vegetation and soil development. This in sharp contrast to the surrounding coastal plain, which has large areas of similar vegetation, with small changes in topography explaining most of the diversity. Pingos and riparian areas account for the majority of the floristic diversity in the region.

Methods

The sampling approach was to visit all pingos in the region that were at least 5 m high and that could be accessed by road and foot, or in some cases air transport was arranged into areas with high pingo concentrations. The sampled region extended approximately 50 km east and west of Prudhoe Bay and about 70 km inland. The area has steep climatic gradients from the coast inland and differing terrain ages based on glaciofluvial outwash stages (D.A. Walker 1985). The sampling areas were classified into four subareas on the basis of climate and surficial geology:

	Coastal	**Inland**
Flat Thaw-lake Plain	Prudhoe Bay (11 pingos, 77 plots)	Toolik River (10 pingos, 68 plots)
Gently Rolling Thaw-lake Plain	Kuparuk (15 pingos, 103 plots)	Kadleroshilik (5 pingos, 45 plots)

Figure 1. *The four study areas based on terrain type and distance from coast. There is a strong warming climate gradient from the coast inland.*

The sharp microclimate gradients on the pingos are defined by their interaction with regional wind and snow patterns. Winds are strongly predominantly from the ENE, so there is a consistent drift on the leeward (WSW side). The same 7 microsites were sampled on all pingos, to the extent possible (Figure 2).

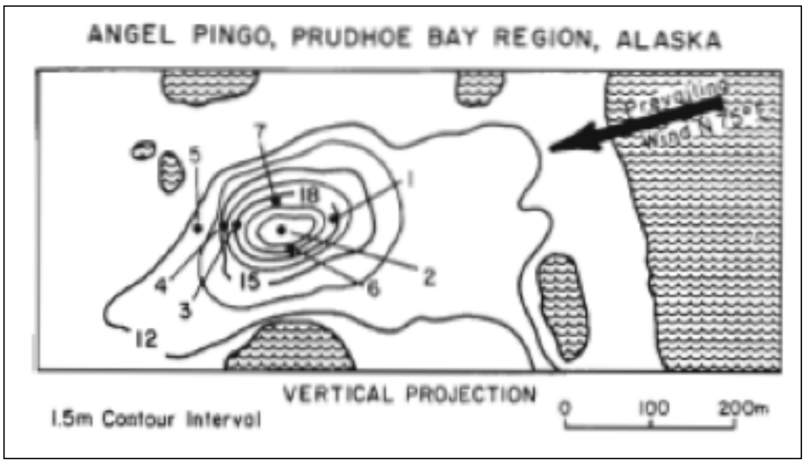

Figure 2. *The same 7 microsites were sampled on all pingos, to the extent possible, shown here on Pingo #6, Angel: (1) windward side, (2) summit, (3) upper snowbank, (4) middle snowbank, (5) lower snowbank, (6) south-facing slope, (7) north-facing slope.*

In a few cases, there was no distinct vegetation for each microsite, or a recent animal disturbance had made it impossible to take a complete sample. In one case, Kadleroshilik Mound, an additional 5 samples were taken in order to capture the diversity of that large and significant landscape feature.

I collected an extensive list of morphological data for each pingo, and detailed environmental and soil data for each vegetation sample (Walker 1990). Vegetation was described in 12.5-m^2 areas, defined by a circle of 2-m diameter. A stake was placed in the center of an area deemed to be the center point of a visually homogeneous stand. The size was increased to 2.8-m diameter where erect shrubs were present. The goal was to get a large enough area to collect and estimate all species. After a complete species list was made, including all cryptogams, I visually estimated percentage cover of all species.

I used a modified Braun-Blanquet approach to sort the 293 samples and species, with the goal of identifying meaningful associations of vegetation and their differentiating species. I used reciprocal averaging as the first step in developing the sorted tables, which should result in maximal correlation between the species and samples (Hill and Gauch 1980). I had no formal training in the Braun-Blanquet approach and no preconceived notions of what patterns I might find, other than the likelihood that my consistent sampling scheme should relate to the results.

I used an informal syntaxonomic system that I loosely linked to Braun-Blanquet units: Groups, which may be comparable to Alliances, Stand Types, which should be comparable to Associations, and Facies, which are subtypes or possibly subassociations. I deliberately avoided formal placement into the Braun-Blanquet system in order to avoid the possibility of producing new units that were not adequately described. My hope at the time was that eventually a regional vegetation synthesis would be completed. Thus the inclusion of the pingo data set in this regional analysis is most welcome and needed.

Results

I collected a total of 232 vascular taxa in 218 species, 104 species of lichens, and 59 species of bryophytes. An annotated species list (Walker 1990) links each species to its voucher collections and discusses any issues that I had with recognition or possible confusion between species. This annotated list should be useful during a regional analysis.

I recognized three major divisions of the pingo vegetation (my "Groups," which may be equivalent to Alliances in some cases), defined by my sampling microsites: (1) south-facing slopes and summits, (2) ENE and north-facing slopes, and (3) snowbeds. The possible relationship to previously described arctic or alpine vegetation units has never been adequately analyzed.

The pingo vegetation was characterized by the presence of *Dryas integrifolia* throughout. My initial classification is in Table 1.

Table 1. *The preliminary pingo vegetation classification.*

- **GROUP** *Dryas integrifolia – Lecanora epibryon* (North-facing slopes and windward sides)
  - **STAND TYPE** *Saxifraga bronchialis – Sphaerophorus globosus*
    - FACIES *Rhacomitrium lanuginosum – Polytrichum piliferum*
  - **STAND TYPE** *Cerastium beeringianum – Minuartia rubella*
  - **STAND TYPE** *Dryas integrifolia – Oxytropis nigrescens*
    - FACIES *Carex nardina – Calamagrostis purpurascens*
  - **STAND TYPE** *Dryas integrifolia – Astragalus umbellatus*
    - FACIES *Kobresia myosuroides – Pedicularis capitata*
    - FACIES *Carex bigelowii – Cassiope tetragona*
- **GROUP** *Dryas integrifolia – Tortula ruralis* (South-facing slopes and summits)
  - **STAND TYPE** *Cerastium beeringianum – Ranunculus pedatifidus*
    - FACIES *Festuca baffinensis – Luzula confuse*
    - FACIES *Trisetum spicatum – Potentilla uniflora*
  - **STAND TYPE** *Poa glauca – Bromus pumpellianus*
    - FACIES *Potentilla hookeriana – Polemonium acutiflorum*
    - FACIES *Artemisia glomerata*
    - FACIES *Carex obtusata – Sasifraga tricuspidata*
    - FACIES *Kobresia myosuroides – Salix glauca*

STAND TYPE *Carex rupestris – Saxifraga oppositifolia*

FACIES *Carex petricosa – Carex nardina*

FACIES *Carex franklinii – Salix brachycarpa ssp. Niphoclada*

FACIES *Carex rupestris – Saxifraga oppositifolia*

GROUP *Dryas integrifolia – Saxifraga rivularis*

STAND TYPE *Salix rotundifolia - Dryas integrifolia*

FACIES *Salix rotundifolia – Oxyria digyna*

FACIES *Salix rotundifolia –Eriophorum triste*

STAND TYPE *Cassiope tetragona – Dryas integrifolia*

SUBTYPE *Vaccinium uliginosum – Salix glauca*

FACIES *Ledum decumbens – Betula nana*

FACIES *Arctous rubra – Rhododendron lapponicum*

FACIES *Cassiope tetragona – Dryas integrifolia*

STAND TYPE D*ryas integrifolia – Astragalus umbellatus – Carex rupestris*

FACIES *Dryas integrifolia – Astragalus umbellatus – Kobresia myosuroides*

FACIES *Carex rupestris – Oxytropis nigrescens*

NO GROUP: Singular snowbed case

STAND TYPE: *Phippsia algida – Saxifraga rivularis*

Conclusion

The pingo vegetation data set is an extraordinarily rich and unusual set of data for this otherwise strongly uniform area. It has potential linkages to Brooks Range and Greenland vegetation. The vegetation data set has been published only in part (Walker et al. 1991), and should be a critical part of a phytosociological analysis of the Alaska North Slope and the Arctic as a unit.

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The nature and appropriateness, to the Arctic Vegetation Archive (AVA), of data sets gathered using the Webber plant community sampling method

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Abstract

An historical account is given of a plot method for sampling vegetation that was the basis of several data sets that are available to the AVA. The method was developed in 1963 by the author with the purpose of testing R.H. Whittaker's Association Unit and Individualistic hypotheses in an Arctic setting. It consisted of recording the composition of vegetation in plots each of which was a linear, contiguous arrangement of ten 1 x 1m quadrats placed in a visually homogeneous patch. For each plot, relative cover and frequency of bryophyte, lichen and phanerophyte species were recorded. The plot design meets minimal area and homogeneity criteria. Initial sampling was done during the 1960s and 1970s and most plot sets were re-sampled in recent years at decade plus intervals. The plots tend to record fewer species than would be sampled using the relevé method, however, a cluster of similar plots provides an extensive list with useful mean values of cover and frequency for each encountered plant taxon. Some clusters are almost exactly equivalent to the Braun Blanquet Association while others might correspond to a grouping of related syntaxa. All reports using this method generate vegetation classifications and ordinations showing various levels of homogeneity within units and continuity within and between plant assemblages. How these plot data are used and grouped will require careful consideration of purpose and examination of special site history considerations.

Introduction

Data sets being contributed to AVA were gathered in a variety of ways and for a variety of purposes. As they are retrofitted for yet other purposes, appropriateness and legitimacy to the new purpose must be considered. Here a plot sampling method that has been used at several North American sites is described. Villareal et. al. (pp. 68-72, this volume) presented three data sets based on this sampling scheme.

The method was developed in 1963 by the author (Webber 1971) with the purpose of examining R.H. Whittaker's Association Unit and Individualistic hypotheses (Whittaker 1962, 1967) in a High Arctic setting. At issue was a contentious debate in the early 1960s about the nature of the arctic vegetation Association. For example, Müller (1954) and Savile (1960) *inter alia*, expressed doubts about its reality in the Arctic. Some of the debate can be read in Daubenmire (1966) who was a stalwart supporter of the Association and who even pointedly criticized some efforts near to home (Beschel & Webber 1962).

The setting for the first application of the method was the northwestern margins of the Barnes Ice Cap, Baffin Island.

The Method

The sampling method was influenced by the author's training in the British Tansleyan tradition and by his mentor Roland Beschel and the latter's mentor Helmut Gams. These two Austrian botanists were concerned more with ecological sequences ("ökologische Reihe") than classification and were not especially enthusiastic about the Zürich-Montpellier floristic approach to vegetation study (Gams, 1961). The method consists of recording the composition of vegetation in plots each of which is a linear, contiguous arrangement of ten 1 x 1m quadrats placed in a visually homogeneous patch (Figure 1).

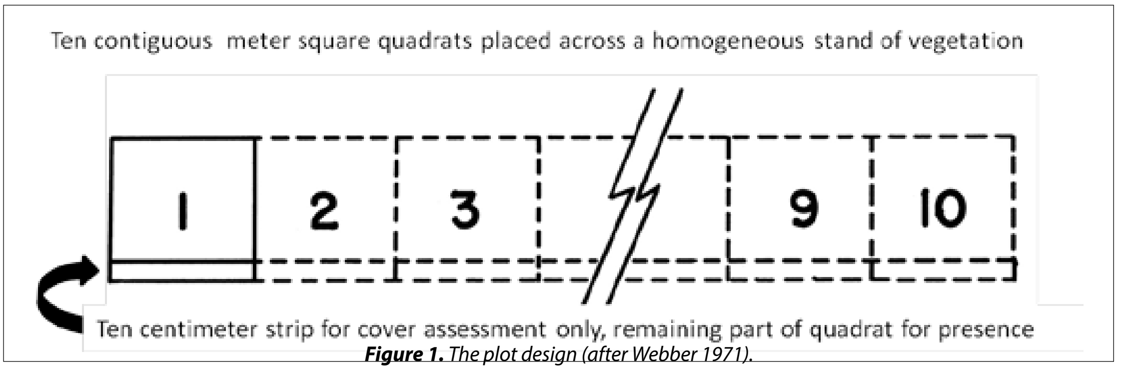

Figure 1. *The plot design (after Webber 1971).*

The method has been applied also to the North Slope of Alaska and alpine settings of central Alaska and the Colorado Rocky Mountains (USA). Results of decadal resampling may be seen in Villarreal et al. (2011), Callaghan et al. (2012) and Johnson et al. (2012). The number of plots at a site range from 30 to 90. The plots were selected to represent the variety of plant assemblages across a landscape. Pioneer, rudimentary or disturbed assemblages were seldom included. Relative cover and frequency of bryophyte, lichen and phanerophyte species were recorded and in most instances good vouchers were collected and deposited in major herbaria. During methods testing, sets of ten quadrats were shown to adequately represent minimal area and high across-plot homogeneity. As part of the method, the plots were photographed and soil characteristics and moisture and snow regimes were assessed. Plots were pin-pointed on maps and usually permanently staked. In recent years, when being re-sampled, they have been accurately geo-referenced. A site encompassing a set of plots ranged in size between 10 and 50 square kilometers and had, at some time, a climate station. Initial sampling was done during the 1960s and 1970s and all plot sets were resampled in recent years.

Data analysis consists of plot classification by average linkage methods (Figure 2) and ordination. Plot clusters are called noda (*sensu* Poore, 1955) so as not to be confused with the hierarchical units of formal community classifications. The noda are readily matched with the CAVM community types (CAVM Team, 2003) (Table 1). The ordination space provides correlation of species distributions and noda with environmental and temporal gradients and is used as a framework for showing the distribution of plant productivity, standing crop, growth form, and diversity and, even, herbivore use (for example Webber 1977). Whenever this method was used by the author and his colleagues the data and results are archived and intended as a framework for large-team ecosystem process, experiment and long-term studies.

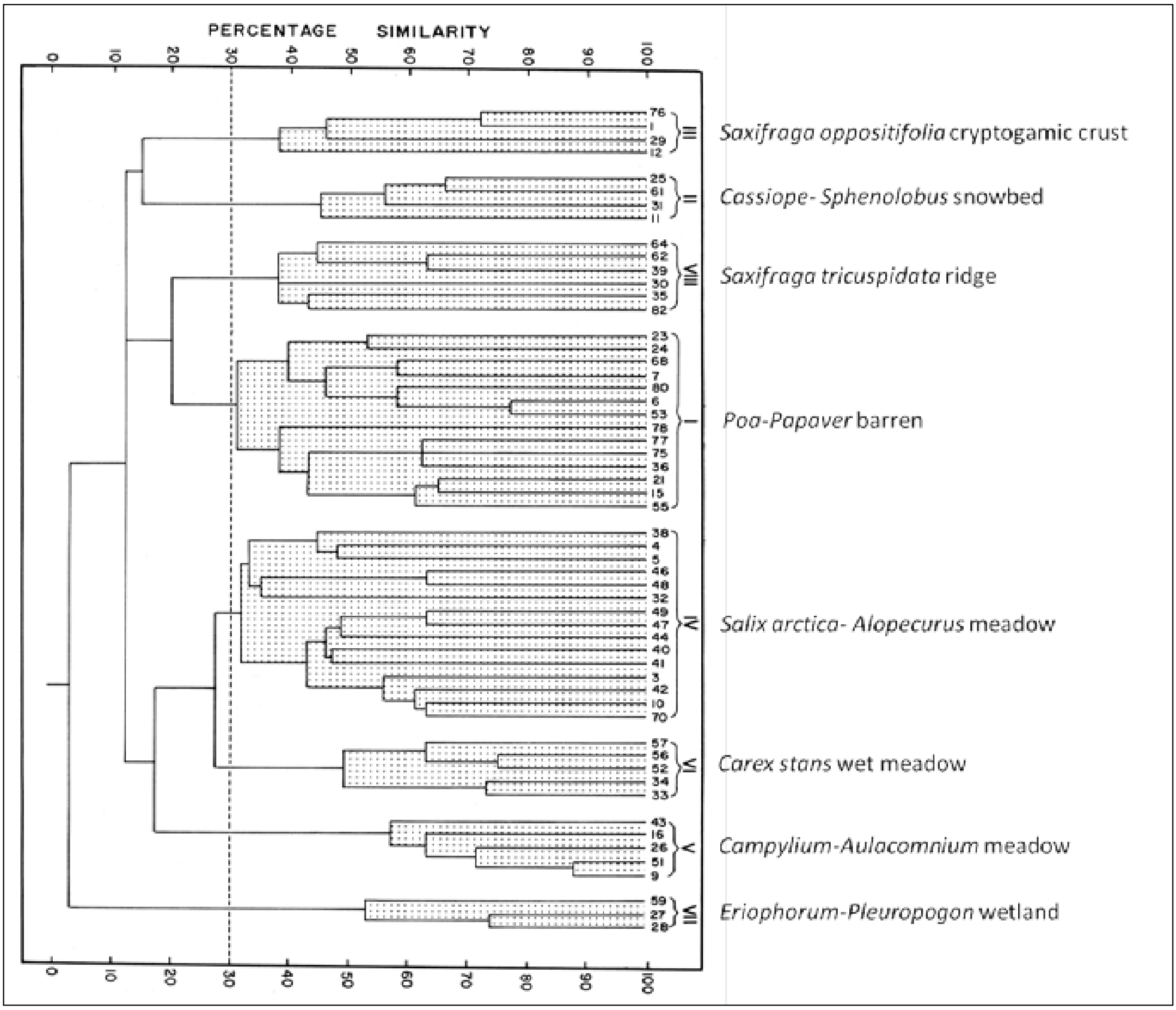

Figure 2. *Average linkage dendrogram of 56 plots sampled at the northwestern margins of the Barnes Ice Cap, Nunuvut, Canada. The line, drawn at the 30% percentage similarity value, was used as the basis of identifying 8 noda (after Webber 1971).*

Table 1. *Equivalency between the noda derived from Figure 1 and their colloquial names and the CAVM community types.*

Nodum	Plant Community Name	CAVM Map Units
I	*Poa-Papaver* barren	B1. Cryptogam Herb Barren
II	*Cassiope- Sphenolobus* snowbed	P2. Prostrate -Hemi-prostrate dwarf-shrub tundra
III	*Saxifraga oppositifolia* cryptogamic crust	B1. Cryptogam Herb Barren
IV	*Salix arctica- Alopecurus* meadow	G2. Graminoid, prostrate -shrub, forb tundra
V	*Campylium-Aulacomnium* meadow	G1. Rush/grass, forb, cryptogam tundra
VI	*Carex stans* wet meadow	W1. Sedge/grass, moss wetland
VII	*Eriophorum-Pleuropogon* wetland	W1. Sedge/grass, moss wetland
VIII	*Saxifraga tricuspidata* ridge	P2. Prostrate -Hemi-prostrate dwarf-shrub tundra

Results and Discussion

What transpired from the early application of the sampling method was that the vegetation around the Barnes Ice Cap could be classified and treated as a continuum. Thus purpose should drive the choice of analysis. For example, classification would help with goals such as mapping or comparison with units from other areas and that gradient analysis would give good information on environmental controls. Because of the youthfulness of the vegetation around the glacier and ice cap margins the noda (see Figure 2) had broad membership due most likely to the youth of the communities in such recently deglaciated terrain. The bottom line from the study was that a powerful understanding of vegetation structure comes from using classification and gradient analysis *in tandem*. Today, this sentiment may seem mundane but not so long ago it was radical.

The 1x10m plot method tends to record fewer species than would be sampled using the relevé method, however, a nodal group provides an extensive list with useful mean values of cover and frequency for each encountered plant taxon. Vera Komarkova and the author made a comparison of noda (*sensu* Webber 1971) with Braun Blanquet syntaxa (Komarkova and Webber 1980). We found that some noda were almost exactly equivalent to an Association while others might correspond to a grouping of related Associations (Table 2).

Table 2. *Correlation between the noda and syntaxa of mapping units recognized in the Saddle area of Niwot Ridge, Colorado, USA (from Komarkova and Webber, 1978.*

Nodum		Mapping unit Number and Syntaxa
I.	Moderately dry sedge meadow with yearly snowfree period between 150 and 200 days, dominated by Kobresia myosuroides, Selaginella densa, and Acomastylis rossi	6. Association Selaginello- Kobresietum mysosuroidis
II.	Exposed dry fellfield with more than 200 snow-free days, dominated by Trifolium dasyphyllum, Silene acaulis, and Carex rupestris	3. Association Trifolietum dasyphyllum 4. Association Sileno- paronychietum
III A	Moist shrub tundra, with a snow free period of 100 to 150 days, dominated by Salix planifolia	20. Alliance Salicion planifolio- villosae
III B.	Moist meadow with snowfree period of 100 to 150 days, dominated by Acomastylis rossii and Deschampsia caespitosa	8. Alliance Descampsio- Trifolion parryi 9. Association Acomastylidetum rossii 11. Association Stellario- Deschampsietum caespitosae
IV.	Snowbank community with a snowfree period of less than 75 days, dominated by Sibbaldia procumbens and Carex pyrenaica	14. Order Sibbaldio- Carietalia pyrenaicae 15. Association Toninio- Sibbaldietum 16. Association Caricetum pyrenaicae
V.	Wet meadow with snowfree period of approximately 100 days, dominated by Caltha leptosepala and Carex scopulorum	18. Order Pediculari-caricetalia scopulorum 19. Association Caricetum scopulorum

The three data sets are being presented at this time to the AVA: Baffin Island, Nunuvut, and Barrow and Atqasuk, Alaska. These are from sites with special characteristics which must be taken into account when considering their representativeness, say of a biozone. For example, the Baffin plots were deglaciated between 100 and 700 years BP (Andrews and Webber 1964); some plots of the Barrow site were momentarily inundated with sea water during a storm surge in 1963 AD (Lynch et al. 2008) and all Barrow plots are within the Littoral Tundra zone of Cantlon (1961) with cool summer temperatures (Haugen and Brown 1980); and the Atqasuk site is situated on an extensive sand plain, with active sand dunes, and many young landforms and soils (Everett 1979).

The pre-AVA "Krakow conference" (Walker et al. 2013) does a good job identifying key plot data and metadata issues (see especially Breen et al. 2013). In the same conference report the VegBank paper (Lee and Peet 2013) shows a catholic approach with flexibility to include varied plot and relevé data and anticipates issues relating to data sharing, taxonomic ambiguity (taxa and syntaxa) and metadata. I commend these authors.

My challenge to the developers and contributors to AVA, while perhaps beyond the scope of the present meeting, is to anticipate various applications of the AVA to scientific questions and issues of conservation and environment.

Acknowledgments

I thank Marilyn Walker for generously presenting this paper at the Workshop. I thank also my former students and now colleagues who adapted the sampling method and endeavored to resample and maintain the data sets over the years. In particular, I am grateful to the late Vera Komárková, Skip Walker, Marilyn Walker, Bob Hollister, Diane Ebert May, Jim Ebersole, and Craig Tweedie and his colleagues David Johnson and Sandra Villarreal for keeping the faith that permanent quadrats have value.

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Alaska geospatial data resources

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Abstract

The University of Alaska's Geographic Information Network of Alaska (GINA) is a leading geospatial data service provider in Alaska, freely serving large volumes of data. Since 1993, GINA has operated a satellite ground receiving station on the University of Alaska Fairbanks (UAF) campus, processing in near-real-time. Currently, data is received from the MODIS, AVHRR, and Suomi NPP satellites. Data products are made immediately available for monitoring of wildfire hotspots (Figure 1), low cloud and fog distribution, and volcanic ash cloud tracking through the puffin feeder website; http://feeder.gina.alaska.edu/.

GINA and the National Park Service has worked together to develop a MODIS-derived Normalized Difference Vegetation Index (NDVI) metrics algorithm. The data products from this project are available as a Web Coverage Service (WCS) with MODIS-derived yearly NDVI metrics; http://ndvi.gina.alaska.edu/metrics. The data coverage includes the entire state of Alaska for the years between 2000 and 2012. The NDVI metrics algorithm uses eMODIS data provided by the U.S. Geological Survey (USGS) Earth Resources Observation and Science (EROS) Center. The algorithm takes 7-day composite eMODIS NDVI data, performs data stacking, interpolating, smoothing, and then calculates 12 NDVI metrics (Figure 2).

***FIgure 1.** MODIS image with 250 meter spatial resolution from June 2004 showing multiple wildfires burning in and around Fairbanks, Alaska.*

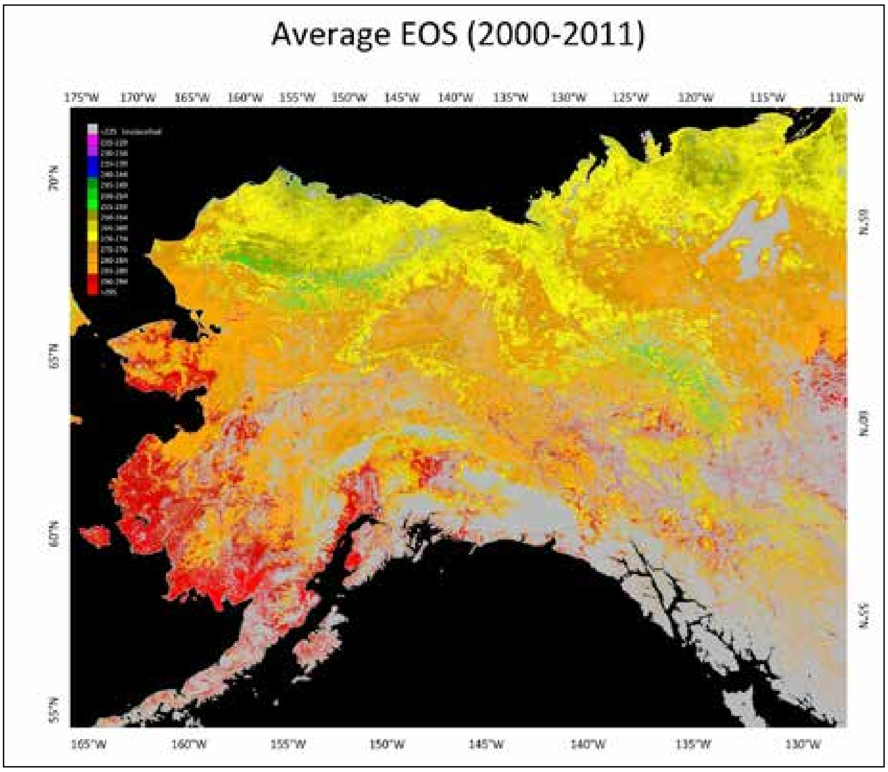

Figure 2. *Map showing the average End of Greenness / End of day season (EOS) metric from 2000-2011 that is produced using the NDVI algorithm.*

GINA is the project manager for Alaska's Statewide Digital Mapping Initiative (SDMI) ortho-mosaic program, providing high-resolution (2.5 meters) satellite imagery and elevation data used to provide a consistent imagery base layer for the state of Alaska. In addition to the SDMI program, we are working towards providing historical imagery base layers as a tool for remote sensing change detection analysis. To provide a common platform for change detection and historical comparison UAF GINA and the UAF Alaska Satellite Facility are providing orthorectified historical imagery of three vintages: 1950s era USGS aerial photography, 1980s Alaska High Altitude Photography (AHAP) color infrared imagery, and 2010s Alaska SPOT5 Statewide Ortho-mosaic satellite imagery (Figure 3). This effort began with the EPSCoR Alaska Adapting to Changing Environments (ACE) project, which conducts biological, physical and social research into the adaptive capacity of Alaskan communities. Change detection is a key component of the EPSCoR-ACE research at three Test Case sites, in the North near Nuiqsut, Southcentral on the Kenai Peninsula, and in Southeast near Juneau.

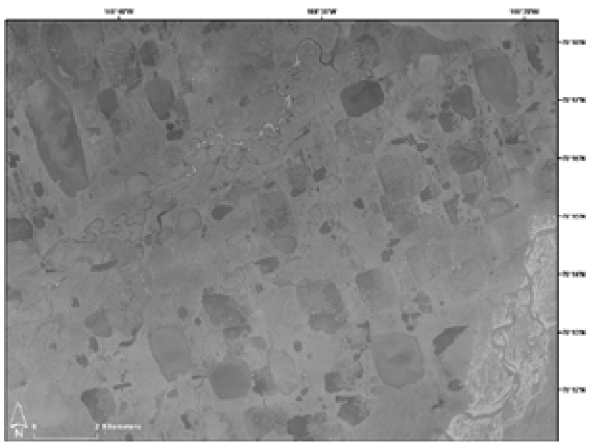

Figure 3 *A*

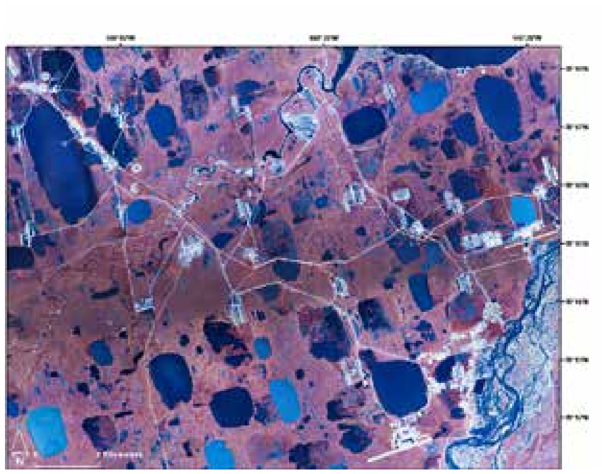

Figure 3 *B*

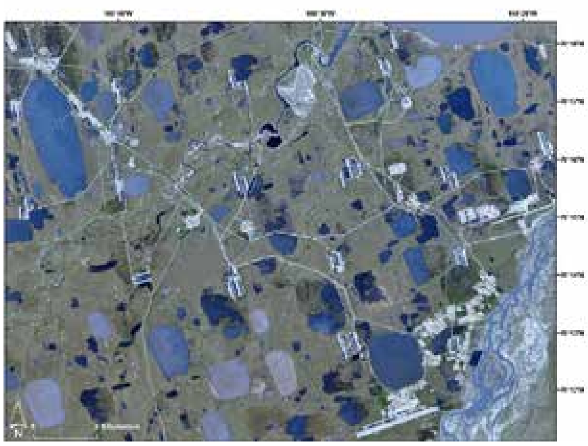

Figure 3 *C*

Figure 3. *Images showing land-use change through time at Prudhoe Bay, Alaska, (A) in 1950s with a 3 meter spatial resolution,* ***(B) in*** *1980s with a 2 meter resolution, and (C) 2010s with a 2.5 meter resolution.*

GINA has developed a web interface that is innovative and the first of its' kind in Alaska, called gLynx. This system was first developed for the North Slope Science Initiative (NSSI), further refined for the EPSCoR Alaska ACE project, and has now been adopted for use in NASA's Pre-Above data curation effort. The NASA Pre-ABoVE web portal, which is called the Arctic Alaska Geoecological Atlas is located at: http://geobotanical.portal.gina.alaska.edu/ (Figure 4). This system allows for search and discovery of datasets for a particular project and allows for sharing of data between distinct projects that may be relevant either by study region or subject matter. For example, the Geoecological Atlas designed for the Pre-Above project is focused on North Slope vegetation datasets (Figure 5). These datasets are relevant to the NSSI and Alaska ACE Northern Test Case because they are all focused in the North Slope region of Alaska. Data records for all three distinct projects can be shared through each of the project portals, making the data more widely discoverable.

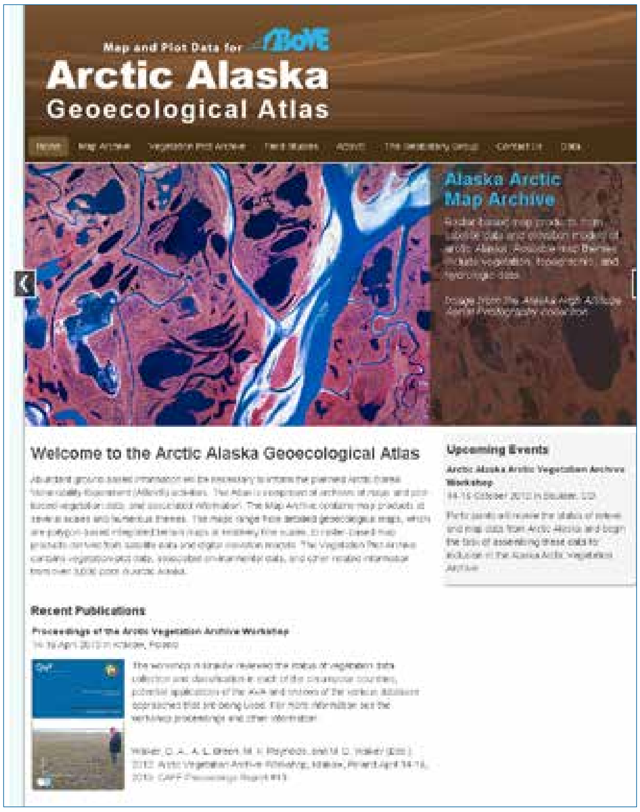

Figure 4. *The NASA Pre-ABoVE Geoecological Atlas web portal landing page. The Geoecological Atlas is divided into three main sections: Map Archive, Vegetation Plot Archive, and Field Studies.*

Figure 5. *A data record in the Geoecological Atlas for the Beechey Point land cover classification, giving a description of the data and showing all files that can be downloaded. Also, if there is a GIS file associated with a data record, it can be viewed prior to data download and all files for the data record can be downloaded at one time.*

Meeting agenda

Monday, Oct 14: Welcome, overview, and presentation of key data sets (20 min talks, 10 minutes for discussion)

Meeting: Aspen Room, Boulder Inn.

Morning:
09:00 Welcome and origins of the AVA, and the pingo data set: Marilyn Walker.
09:30 Welcoming notes: Pat Webber via Marilyn Walker.
09:45 Keynote address: Pioneering the use of the Braun-Blanquet approach in Arctic Alaska: The Arrigetch Mountains: David Cooper.
10:30 Overview of the AVA, early progress: Skip Walker.

11:00 Coffee

11:30 Progress on the Alaska Arctic Vegetation Archive, PASL, and Arctic poplar groves: Amy Breen.
12:00 Barrow, Atqasuk, and Baffin Island: Sandra Villareall and Craig Tweedie
12:30 Oumalik: Jim Ebersole

1:00 Lunch

2:00 Prudhoe Bay, Imnavait Creek, Happy Valley data sets: Skip Walker
2:30 Biocomplexity of Pattern Ground project: Anja Kade via Skype or other (?)
3:00 NDVI, LAI and biomass data from Ivotuk, the Western Alaska Arctic Transect and the North America Arctic Transect: Howie Epstein

3:30 Coffee
4:00 Arctic Alaska Riparian Willow communities: Udo Schikhoff via Marilyn Walker
4:30 Colville River, Arctic Parks, etc.: Torre Jorgenson via Skype or other (?)
4:30 Discussion: where we are at?
5:00 Adjourn for day

Dinner on own at local restaurants.

Tuesday, Oct 15: Data issues, metadata, other types of data, Arctic Alaska Geoecological Atlas, data rights

Morning: (note late start)
10:00 Overview of day's activities and dinner plans: Skip Walker
10:15 Update on the Braun-Blanquet project and the European Vegetation Archive: Borja Jíménez-Alfaro via Skip Walker
10:45 Status of the Canadian Arctic Vegetation Archive (CAVA) in 2013: Will MacKenzie and Catherine Kennedy
11:15 VPro as a possible data entry method for the AVA: Will Mackenzie
11:45 VegBank discussion with Mike Lee and Bob Peet via Skype

12:15 Lunch

1:15 Overview of the ITEX data sets and discussion of point data: Sarah Elmendorf
1:45 Bathhurst Inlet Canada, and student expeditions in Canada and Alaska: Bill Gould
2:15 Arctic Alaska Geoecologial Atlas: Lisa Wirth
2:45 Metadata for projects, Header data for data sets, Format for Turboveg files, misc. data rights issues, distribution of data, etc: Amy Breen

3:15 Coffee

3:45-5:30 Continue metadata discussion and working session: AAVA data entry.

6:00 Group dinner at favorite restaurant in Boulder.

Wednesday, Oct 16:

Morning:
9:00 Why Turboveg?: Jozef Sibik
9:30 Continuation of database discussion.

10:30 Coffee

11:00 Continue work on metadata, data formats, data entry
12:30 Discussion of where to go from here, proceedings volume, next workshop, wrap up.

1:30 Adjourn.

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