PROCEEDINGS OF THE ARCTIC VEGETATION ARCHIVE & CLASSIFICATION WORKSHOP | ASSW 2023

18 February 2023 · Vienna, Austria

CAFF PROCEEDING SERIES REPORT

FEBRUARY 2024

B1 Cryptogam, herb barren
Ellef Ringnes Island, Nunavut, Canada
Inset: *Papaver radicatum*

D.A. WALKER (INSET: M.K. RAYNOLDS)

P2 Prostrate/hemiprostrate dwarf-shrub, lichen tundra
Zackenberg vicinity, East Greenland
Inset: *Cassiope tetragona*

H.H. CHRISTIANSEN (INSET: M.K. RAYNOLDS)

W2 Sedge, moss, dwarf-shrub wetland complex
Near Teshekpuk Lake, Arctic Coastal Plain, North Slope, Alaska, USA
Inset: *Carex aquatilis*

B.M. JONES (INSET: M.K. RAYNOLDS)

S2 Low-shrub, moss tundra
Vaskiny Dachi, Central Yamal Peninsula, Yamalo-Nenets Autonomous okrug, Russia
Inset: *Salix lanata*

D.A. WALKER (INSET: PEGANUM CC BY-SA 2.0)

G4 Tussock sedge, dwarf-shrub, moss tundra
Sagwon, Brooks Range foothills, North Slope, Alaska, USA
Inset: *Eriophorum vaginatum*

J. KNUDSON (INSET: M.K. RAYNOLDS)

W3 Sedge, moss, low-shrub wetland complex
Near Naryan-Mar, Pechora River, Western Siberia, Russia
Inset: *Rubus chamaemorus*

O.V. LAVRINENKO (INSET: O.V. LAVRINENKO)

ARCTIC COUNCIL

CAFF
Conservation of Arctic Flora and Fauna

Conservation of Arctic Flora and Fauna (CAFF): A Working Group of the Arctic Council

Suggested citation

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Cover photographs

Representative landscape and species photos from the raster version of the Circumpolar Arctic Vegetation Map (CAVM Team, 2024 in press). Circumpolar Arctic Vegetation Map, Ver. 2. Conservation of Arctic Flora and Fauna (CAFF) Secretariat. Akureyri, Iceland. Photo credits appear to the right of each photo.

Conservation of Arctic Flora and Fauna

ARCTIC VEGETATION ARCHIVE

IASC

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EXECUTIVE SUMMARY

The Arctic Vegetation Archive (AVA), Arctic Vegetation Classification (AVC), and Circumpolar Arctic Vegetation Map (CAVM) are long-term activities of IASC and CAFF with a goal to provide a map and plot-database framework to support Arctic-system climate-change studies that involve vegetation data.

The AVA/AVC workshop at Arctic Science Summit Week 2023 in Vienna had three main goals: (1) report of progress in each contributing circumpolar country since the last meeting at ASSW 2019 in Arkhangelsk, Russia; (2) discuss several data management issues; and (3) plan the next steps toward the Fourth International Conference on Arctic Research Planning (ICARP IV).

A 4.5-hour hybrid in-person/online meeting occurred during the afternoon of February 18, 2023. Twenty-three persons attended: 15 in Vienna and 8 joining via a Zoom link. Nine countries were represented (Austria 1, Canada 2, Czech Republic 1, Germany 2, The Netherlands 1; Russia 1, Switzerland 6, Slovak Republic 2, and United States 6). The meeting was divided into three sessions:

The first session was conducted over lunch, with four poster presentations by Early Career Scientists: Ksenia Ivanova, Anna Kučerová, Maria Šibíkova, and Vitalli Zemlianskii, followed by the workshop welcome (Gabriela Schaepman-Strub) and goals for the workshop (Skip Walker).

The second session included regional updates from Alaska (Amy Breen), Canada (Will MacKenzie), Greenland (Helga Bultmann), Russia (Vitalii Zemlianskii and Ksenia Ermokhina), Europe (Jozef Šibík), and the European Vegetation Archive (Stephan Hennekens).

The third session consisted of three group discussions devoted to (1) data management issues; (2) crosswalks among regional species lists; and (3) future activities. These discussions were cut short due to time constraints with most of the time devoted to planning for the next workshop toward ICARP IV. The participants agreed to continue these discussions during monthly Zoom meetings over the next year.

The main accomplishment of AVA/AVC initiative since ASSW 2019 included:

CAFF Proceedings and CAFF AVA website

- The proceedings of the AVA/AVC workshops at ASSW 2017 (Prague) and ASSW 2019 (Arkhangelsk) and a link to the Pan Arctic Species List were added to the CAFF Flora Group (CFG) webpage at: caff.is/work/projects/cfg-caffs-flora-group

Progress in Alaska

- The Alaska Arctic Geobotanical Atlas (arcticatlas.geobotany.org) was revised to include an open-source web-based CKAN Data Catalog for the plot archive and an ArcGIS-Online map archive.
- A new raster version of the CAVM was published in digital form (Raynolds et al. 2019). A color two-sided hard copy of the map at 1:7 million scale (CAVM Team 2024 in press) is available at the Alaska Geobotany Center website (www.geobotany.uaf.edu/cavm).
- Several new Alaska and Canada plot data sets have been obtained and are in the process of being added to the AVA-AK (e.g., Kasanke et al. 2023, 42 relevés; Watson-Cook 2022, 39 relevés; Walker et al. 2022, 2023, 35 relevés; Breen, DOE NGEE Arctic, 95 relevés; Breen, NSF Thaw Lakes, 87 relevés; Raynolds, Baffin PACEMAP, 287 relevés) (Breen et al. this volume).

Progress in Russia

- A new online Russian plot archive (AVA-RU, avarus.space) contains 4742 plots sampled using the Braun-Blanquet approach and includes observations of over 1730 vascular plant and cryptogam taxa. (Zemlianskii et al. 2023b). Approximately one-fifth of AVA-RU plots were entered in a TURBOVEG2 database several years ago, and approximately four-fifths have now been sent to Stephan Hennekens for entry into TURBOVEG3. The first two papers based on AVA-RU data paper have also been published (Zemlianski et al. 2023a, in press).
- A checklist of syntaxa for the Russian Arctic was published (Matveyeva and Lavrinenko 2021).
- A new Braun-Blanquet zonal tundra vegetation class was described (Matveyeva and Lavrinenko 2023).
- Several recent papers published in Russia described new Russian plant associations with circumpolar counterparts (e.g. Ermokhina et al. 2022; Koroleva and Kulyugina 2015; Lavrinenko and Lavrinenko 2015, Lavrinenko and Kochergina 2022, Lavrinenko et al. 2014, 2022; Telyatnikov et al. 2013, 2019, 2021a, 2021b, 2022).
- Trends in species composition, plant growth form, biomass, NDVI, and environmental variables of zonal vegetation were analyzed using AVA plot data from six bioclimate subzones along the 1700-km Eurasia Arctic Transect, Nadym to Franz Josef Land, Russia (Walker et al 2019, Epstein et al. 2020).

Progress in Canada

- Steady progress on the Canadian Arctic Vegetation Archive (AVA-CA) continued. The AVA-CA now houses 8827 plots. Future consolidation of project metadata will identify plot collection standards and quality.
- The Canadian archive currently uses an ACCESS data base with VPro data management software (Mackenzie and Klassen 2009) that is compatible with the U.S. EcoVeg principles (Faber-Langendoen et al. 2014, 2018, MacKenzie, this volume).
- Classification using the Canadian archive has been completed for the *Ecosystems of the Yukon Arctic Region: a guide to identification* (MacKenzie et al. 2022).
- Approximately 287 new plot samples were collected along latitudinal and elevation gradients on Baffin Island (Raynolds et al. 2023b).

Progress in Greenland and European Arctic

- The Greenland data are being assembled in one Turboveg database on one computer. Data from several student theses have been reviewed and need some work to repair lost species names in datasets stemming from the older Turboveg-version (DOS) and to screen the several versions of the same sets in the newer datasets.
- There are still datasets in old table formats (e.g. “TAB”). All those digital data have been assembled and are stored together. While the data are safe, some tedious work is needed to make the data ready for analysis together with the datasets in the main AVA. (Bültmann and Daniëls, this volume.)
- Fred Daniëls’ “Vegetation of Greenland” monograph is going to press soon.
- A review of data in the European Vegetation Archive (EVA) has found 12,264 relevés in total (12,241 geo-referenced) that could potentially enlarge data in AVA.

Progress regarding TURBOVEG3

- TURBOVEG3 is the data management tool for the European Vegetation Archive (EVA), which currently houses almost 2.4 million plot observations from more than 40 countries with over 800 plots each. Analysis of such large heterogeneous datasets has become feasible through TURBOVEG3 database management software that can harmonize the species names from multiple datasets by using a taxonomic backbone in which the various taxonomies are mapped to a common concept.
- TURBOVEG3 has an EXPERT tool to assign plot observations to vegetation types. Based on the assignment of vegetation plots to EUNIS habitat types, distribution maps of the habitat types can be created which can serve as input for habitat suitability modeling. Suitability maps show the potential area of a habitat, based on predictors (e.g., climate, soil, and topography parameters, as well as remote-sensing-enabled Essential Biodiversity Variables (EBVs).
- EVA Data Property and Governance Rules are followed for the dissemination of the data (euroveg.org/download/eva-rules.pdf). Data derived from the EVA database and other information related to flora and vegetation of Europe is available on FloraVeg.eu.
- The AVA-AK uses TURBOVEG3 to manage approximately 3,800 plots. TURBOVEG2 is used for the Greenland datasets, and there are also many Arctic plots currently in the EVA from the European (Hennekens, this volume).

References

References for the Executive Summary are included with the Walker abstract, p. 32.

AGENDA

Session 1: Poster session (1.5 hours)

12:30-14:00	Box lunches provided
14:00-14:10	Welcome, introductions, and goals for the workshop Gabriela Schaepman-Strub (in Vienna) and Skip Walker (remotely)

Session 2: AVA/AVC Regional Updates (3 hours; chaired by Jozef Šibík)

14:10—1430	Circumpolar Arctic Vegetation Skip Walker
14:30—14:45	Alaska AVA-AK update Amy Breen
14:45—15:00	Russia AVA-RU update Vitalii Zemilanskii, Ksenia Ermokhina, and Gabriela Schaepman-Strub
15:00—15:15	Canada AVA-CA update Will Mackenzie
15:15—15:30	Greenland AVA-GL update Helga Bültmann and Fred Daniëls
15:30-16:30	Coffee Break View Posters
16:30-16:50	Progress on the European Vegetation Archive (EVA) Stephan Hennekens
16:50-17:00	EVA contributions to the AVA (Greenland, Svalbard, Norway) Jozef Šibík

Session 3: Group Discussions (1 hour)

17:00-17:15	AVA/AVC Data sharing policy (Led by Jozef Šibík) To include data sharing with larger databases such as the Arctic Data Center and GBIF; data integration for Pan-Arctic analyses
17:15-17:30	Pan-Arctic Species List (PASL) update (Led by Amy Breen and Vitalii Zemilanskii) To include cross-walk among species lists
17:30-18:00	Planning for the future (Led by Skip Walker and Gabriela Schaepman-Strub) What is feasible for the next 1-5 years? Shared thoughts on the following topics: What is needed to complete regional archives and integrate them into a panarctic archive and classification? What activities should we plan to prepare for the Fifth International Polar Year (2032-33)?
18:00	Adjourn

WORKSHOP PARTICIPANTS

Figure 1. Participants at the AVA-AVC Workshop, ASSW 2023, Vienna, Austria.

Table 1. List of participants

Photo Nr.	First Name	Last Name	Institution	Country
NA	Jakob	Assmann	University of Zurich	Switzerland
14	Helena	Bergstedt	b.geos	Austria
5	Amy	Breen	University of Alaska Fairbanks	USA
21	Helga	Bültmann	University of Münster	Germany
11	Isaline	Businger	University of Zurich	Switzerland
NA	Howie	Epstein	University of Virginia	USA
6	Ksenia	Ermokhina	Moscow State University	Russia
8	Silvia	Giamberina	Institute of Geosciences and Earth Resources, CNR	Italy
19	Ramona	Heim	University of Zurich	Switzerland
1	Stephan	Hennekens	Wageningen Environmental Research	Netherlands
9	David	Hik	Polar Knowledge Canada and Simon Fraser University	Canada
7	Olivia	Hobgood	University of Alaska Fairbanks	USA
14	Kseniia	Ivanova	Max Planck Institute for Biogeochemisty	Germany
15	Anna	Kučerová	Department of Botany and Zoology Masaryk University	Czechia
2	Will	MacKenzie	British Columbia Ministry of Forests, Lands and Natural Resources	Canada
17	Rhonda	Müller	University of Zurich	Switzerland
4	Jana	Peirce	University of Alaska Fairbanks	USA
18	Gabriela	Schaepman-Strub	University of Zurich	Switzerland
20	Jozef	Šibík	Plant Science and Biodiversity Center SAS	Slovakia
16	Maria	Šibíkova	Plant Science and Biodiversity Center SAS	Slovakia
10	Craig	Tweedie	University of Texas El Paso	USA
3	Skip	Walker	University of Alaska Fairbanks	USA
12	Vitalii	Zemlianskii	University of Zurich	Switzerland

EXTENDED ABSTRACTS

Oral Presentations

The Alaska Arctic Vegetation Archive (AVA-AK): status and achievements

AMY BREEN[1,2]

Other contributors: Olivia Hobgood[2], Shawnee Kasanke[2], Jana Peirce[2], Martha K. Raynolds[2], Donald A. Walker[2], Emily Watson-Cook[2], Stephan Hennekans[3], Anna Kučerová[4], Jozef Šibík[5]

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The Arctic Vegetation Archive (AVA) is a repository of vegetation-plot data for the Arctic tundra biome. The geographic scope of the AVA spans seven countries across the circumpolar region and maritime boreal tundra areas. Work on the AVA is being accomplished within individual Arctic countries with the long-term goal to develop a Pan-Arctic Vegetation Classification. Herein, we provide an overview of the status and recent achievements for the Alaska AVA (AVA-AK) since our last workshop at Arctic Science Summit Week in Arkhangelsk, Russia in 2019. We share updates on: 1) our open-access data portal the Alaska Arctic Geobotanical Atlas, 2) recent projects and datasets, and 3) in progress and planned analyses including our recent relevant publications and theses.

The Alaska Arctic Vegetation Archive (AVA-AK)

The AVA-AK data repository is open access via the online Alaska Arctic Geobotanical Atlas, created by the Alaska Geobotany Center and the Geographic Information Network of Alaska. The AVA-AK contains ground-based vegetation plot data, associated environmental data, and related ancillary information such as photos and maps, from over 3,000 plots in Arctic and near-Arctic Alaska, as well as a few sites in the Canadian Arctic that were part of U.S. NSF-supported funding. In 2020, the data portal migrated to the open-source CKAN platform and navigation improvements were made, including an ArcGIS Online companion site for data discovery and map-based browsing (arcticatlas.geobotany.org).

Recent projects and datasets

Currently, the AVA-AK contains 32 legacy datasets that include 3404 plots in a Turboveg database (Table 1). Of these, 26 datasets with 2931 plots are from Alaska, and six datasets with 473 plots are from Canada. Additionally, four new datasets from Alaska (Walker et al. 2022; Watson-Cook 2022; Breen 2024 in prep., 2 datasets) and one dataset from Canada (Raynolds et al. 2024 in prep.) (587 plots total) were collected since our last update and will be added to the archive over time.

Three data sets (Elmendorf et al. 2012, Hanson 1951, Johnson et al. 1966) have a Catalog Record but were not included in the Turboveg database because the data did not satisfy protocols necessary for inclusion. Several other datasets (Jorgenson 2000; Jorgenson et al. 1997, 2003, 2009; Boggs and Boucher 2014; Boucher et al. 2016; Talbot 2014; Talbot and Talbot 1994, 2014; Talbot et al. 2005, 2010; Daniels et al. 2004) are awaiting receipt of data and pending evaluation for inclusion in the AVA-AK.

Recent analyses using AVA-AK data

Several vegetation analyses have been completed or are underway using data in the AVA-AK:

1. Master's thesis (Kasanke 2019) and published paper (Kasanke et al. 2023) describing the plant communities and plant succession on glacial moraines along an altitudinal/ age gradient that spans more than 125,000 years in the Brooks Range, near Toolik Lake, Alaska.
2. Analysis of fire succession on the Seward Peninsula using data from 64 plots at 15 locations on the Seward Peninsula (Hollingsworth et al. 2021).
3. Analysis of tundra canopy characteristics using UAV-sensor data (Yang et al. 2020, 2021)
4. Analysis of vegetation in thermokarst ponds at Prudhoe Bay, Alaska (Watson-Cook 2022).
5. Analysis of the cumulative impacts of a gravel road and climate change at Prudhoe Bay, Alaska (Walker et al. 2022).
6. Analysis of bryophyte functional type patterns in nonacidic coastal tundra at the Prudhoe Bay NIRPO site (Kučerová et al. 2023, this volume).
7. Analysis of vegetation on different aged thaw-lake basins, and an area unaffected by thaw-lake processes in the nonacidic tundra at Prudhoe Bay (Hobgood 2024 in prep.).
8. Vegetation classification and analysis of eight datasets collected at Prudhoe Bay Alaska during the past 40 years (Walker 1985, M.D. Walker 1990, Schickhoff 2002, Kade et al. 2005, Walker et al. 2015, 2016, 2022; Watson-Cook 2022) (Breen et al. 2024 in prep.).
9. Analysis of data from 13 datasets along the Dalton Highway transect from the Brooks Range to Prudhoe Bay, Alaska (Walker 1985; M. Walker 1990; Walker et al. 1987, 1997, 2015, 2016, 2022; Walker and Barry 1991; Schickhoff et al. 2002; Kade et al. 2005; Breen 2014; Kasanke 2019; Watson-Cook 2022) focused on nonacidic loess ecosystems of the Central Arctic Coastal Plain (Šibík et al. 2024 in prep.)
10. Vegetation succession associated with the thaw-lake cycle on the North Slope, Alaska (Breen et al. 2024 in prep.)
11. Analysis of the vegetation in 287 plots at 5 sites along latitudinal and elevation gradients on Baffin Island, Canada (Raynolds et al. 2024 in prep).

Figure 1. Recent and in prep. datasets for the AVA-AK (Clockwise from upper left: Plant *succession* on glacial moraines in the Arctic Brooks Range along a >125,000-year glacial chronosequence/topo-sequence (Kasanke, et al. 2023); Thermokarst-pond plant community characteristics and effects on ice-wedge degradation in Prudhoe Bay (Watson-Cook, 2022); Drained thaw-lake basins, Arctic Coastal Plain, Alaska (Breen 2024b, in prep.); Natural Ice-Rich Permafrost Observatory, Prudhoe Bay (Walker and Peirce, editors, 2023).

Table 1. Datasets included in the AVA-AK as of 15 February 2023

		Portion of AK-AVA record complete						
Acces -sion Nr.	**Dataset name** [locations if more than one] (key citation)	**Nr. of plots with species cover data**	**Turbo-veg**[1]	**Catalog Record**[2]	**Ancil-lary data**[3]	**GIVD**[4]	**DAAC**	**Veg-Bank**[5]
LEGACY DATASETS								
1	**Arrigetch Peaks** (Cooper 1986)	439	X	X	X	X	X	
2	**Frost Boils** [6 locations] (Kade et al. 2005)	117	X	X	X	X	X	
3	**Happy Valley** (Walker et al. 1997)	56	X	X	X	X	X	
4	**Imnavait Creek** (Walker et al. 1987)	84	X	X	X	X	X	
5	**Pingos** [41 pingos] (Walker 1990)	293	X	X	In prog.	X	X	X
6	**Poplars** [32 locations] (Breen 2014)*	32	X	X	X	X	X	
7	**Prudhoe Bay** (Walker 1985)	89	X	X	X	X	X	
8	**Toolik Lake** (Walker & Barry 1991)	81	X	X	X	X	X	X
9	**Willows** [31 locations] (Schickhoff et al. 2002)	85	X	X	X	X	X	
10	**ATLAS-1** [NSF flux towers, 4 locations] (Edwards et al. 2000)	15	X	X	X	X		
11	**ATLAS-2** [NSF flux towers, 2 locations] (Raynolds et al. 2002)*	52	X	X	X	X		
12	**Atqasuk** (Komarkova & Webber 1980; Villarreal 2013)**	31	X	X	X	X	X	
13	**Barrow – IBP Tundra Biome** (Webber 1978; Villarreal et al. 2012)**	43	X	X	X	X		
14	**Legacy** [DOD, Barter Island & Barrow] (Elias et al. 1996)	61	X	X	X	X		
15	**Barrow – DOE NGEE** (Sloan et al. 2014)	48	X	X	X	X		
16	**Oumalik** (Ebersole 1985)	87	X	X	X	X	X	
17	**Arctic Network** [5 NPS Arctic parks] (Jorgenson et al. 2009)*	763	X	X	X	X	X	
18	**North Slope ARCSS/LAII Flux Study** [NSF, 18 flux tower sites] (Walker 1996, unpublished)	29	X	X	X	X	X	
19	**Canadian Western Arctic** [Canoe Lake, Trout Lake] (Lambert 1968)*	154	X	X	X	X	X	
20	**Prudhoe Bay – ArcSEES Lake Colleen study** (Walker et al. 2015)	29	X	X	X	X		
21	**Unalaska** (Talbot et al. 2010)	70	X	X	X	X	X	
22	**Tundra Fires** [15 locations] (Breen et al. 2015)	64	X	X	X	X	X	
23	**Umiat** (Churchill 1955)	51	X	X	X	X	X	
24	**Nome** (Hanson 1953)	80	X	X	X	X	X	
25	**Flux Towers Zona** (Davidson et al. 2016)	140	X	X	X			
26	**Green Cabin, Banks Island, Canada** (Vonlanthen et al. 2008)	33	X	X	X			
27	**Isachsen, Ellef Ringnes I., Canada** (Vonlanthen et al. 2008)	52	X	X	X			
28	**Mould Bay, Prince Patrick I., Canada** (Vonlanthen et al. 2008)	39	X	X	X			
29	**Canadian Transect** (Gonzalez et al. 2000)	113	X	X	X			
30	**Baffin Island** (Webber, 1971)	82	X		X			

		Portion of AK-AVA record complete						
Acces -sion Nr.	**Dataset name** [locations if more than one] (key citation)	**Nr. of plots with species cover data**	**Turbo-veg[1]**	**Catalog Record[2]**	**Ancil-lary data[3]**	**GIVD[4]**	**DAAC**	**Veg-Bank[5]**
31	**Prudhoe Bay-ArcSEES Airport Study** (Walker et al. 2016)	50	X	X	X			
32	**Grizzly Glacier** (Kasanke 2019)	42	X		X			
	TOTAL LEGACY DATASETS	**3404**						
NEW DATASETS IN PREPARATION								
33	**NNA-IRPS NIRPO** (Walker 2022)	50						
34	**NNA-IRPS thaw ponds** [2 locations] (Watson-Cook 2022)	39						
35	**Baffin Island** (Raynolds in prep)	287						
36	**Seward Peninsula – DOE-NGEE** (Breen in prep)	95						
37	**Drained lake basins** [4 locations] (Breen in prep)	87						
CATALOG RECORD ONLY								
38	**ITEX Vegetation Plots** (Elmendorf et al. 2012)	NA		X				
39	**Kotzebue Vegetation Plots** (Hanson 1951)	21		X				
40	**Cape Thompson** (Johnson et al. 1966)	54		X				
PENDING EVALUATION FOR INCLUSION IN AVA-AK								
41	**Colville River Delta** (Jorgenson et al. 1997)	293						
42	**Fish Creek** (Lawson et al. 1978)	15						
43	**Fish Creek Delta NPR-A** (Jorgenson 2003)	285						
44	**Northern Alaska ANHP** (Boggs and Boucher 2014)	NA						
45	**NPR-A ANHP** (Boucher et al. 2015)	NA						
46	**Selawik National Wildlife Refuge** (Jorgenson et al. 2009)	275						
47	**Southwest Alaska Vegetation Plots** (Talbot et al. 2010, Talbot and Talbot 2008, Daniels et al. 2004, Talbot and Talbot 1994)	NA						
48	**Southwest Alaska Alders** (Talbot and Daniëls 2005)	NA						
49	**Yukon-Kuskokwim Delta Plots** (Jorgenson et al. 2000)	65						
TOTAL NEW, CATALOG ONLY, AND PENDING		**1566**						

*Plot totals include forested plots in the Poplar, ATLAS-2, Selawik and NPS Arctic Network datasets, and 154 plots in NW Canada.

**These datasets include repeat sampling: 1) Barrow (1972 – 43 plots, 1998, 2008, 2010 – 33 plots) and 2) Atqasuk (2000, 2010 – 31 plots).

[1]Species cover-abundance data and required header data entered into the AK-AVA Turboveg file and accessible through the Alaska Arctic Geoecological Atlas.

[2] Catalog record for the Alaska Arctic Geobotanical Atlas complete. Others are in progress or pending.

[3] Ancillary data files (if available) are included in the Catalog records. Others are in progress.

[4] Dataset included in the Global Inventory of Vegetation Datasets for the Alaska Arctic Vegetation Archive.

[5] Data included in VegBank. Will transfer data from Turboveg to VegBank when full database complete.

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The AVA Greenland update

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The arctic vegetation database has been pursued since 1992 (Walker et al. 1994) in workshops (e.g., Walker & Raynolds 2011, Walker et al. 2013) triggered by the ongoing need of a uniform panarctic vegetation approach and for modelling. As an outcome of an earlier workshop, a large part of the Greenland and other Arctic datasets have been used in a study of circumpolar species richness and genetic diversity in relation to past glaciations and current climate (Stewart et al. 2016)

The Greenland vegetation database has been slowly but successively reviewed since the workshops in Roskilde 2012 and 2013, Krakow 2013 (Bültmann & Daniëls 2013), Prague 2017 (Daniëls & Bültmann 2019), and this year's workshop in Vienna, with the focus on the digitized datasets.

Digitized data

Most of the data in Münster stem from theses from the working group of Fred Daniëls at the University of Münster. The relevés were intended mainly for the study of vegetation classification and ecology (e.g. Lünterbusch et al. 1995, Lünterbusch & Daniëls 2004, Lepping & Daniëls 2006, Drees & Daniëls 2009), of ecological indicators of altitude in the Arctic (Sieg & Daniëls 2005, Sieg et al. 2006, 2009, Jedrzejek et al. 2013) and diversity studies (Bültmann 2005, 2011, Bültmann & Daniëls 2001). One dataset monitors vegetation change by revisiting plots from the 1960s in 2007 (Daniëls & De Molenaar 2011, Daniëls et al. 2011).

Most of the relevés are homogeneous with plots sizes of a few square meters recorded according to the Braun-Blanquet method. Also a few small-scale transects over a ridge or a slope are included. Header data include vegetation parameters, estimated landscape and site factors (moisture, snow cover etc), measured site factors (e.g., altitude, slope), and often soil analyses (e.g., pH, humic content, texture, C/N, cations, anions). The more recent plots from SW Greenland are georeferenced by GPS; locations of earlier ones were not referenced with GPS, although estimated locations from maps, coordinates, elevation with slope exposition and inclination were noted. The cryptogams are well sampled.

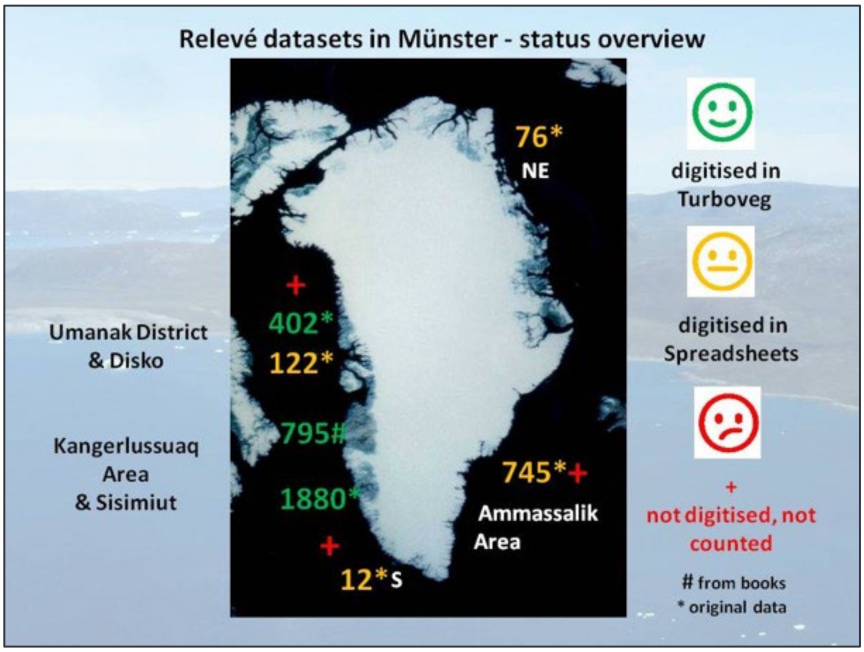

Figure 1. Distribution of digitized plots in the Greenland-AVA database in Münster

The main database is kept in Turboveg, a program written by Stephan Hennekens (Hennekens & Schaminée 2001), which is much used for datasets in Europe and also the Alaska-AVA. We use the nomenclature in the Panarctic Species List (PASL, Raynolds et al. 2013).

The database was started in Turboveg for DOS, then switched to TURBOVEG2. Stephan Hennekens brought the old and new databases together, which was major step since 2017.

At present we have 2282 original relevés from western Greenland in the Turboveg database (Figure 1, Table 1), which need polishing. This would require searching for corrections in theses and publications, which are not in the Turboveg database and hunt down suspected duplicates. In the database from the DOS Turboveg version (DOS), a few species names have no counterpart in the PASL and have to be corrected.

Furthermore, the Turboveg-database includes 795 relevés from three books describing West Greenland vegetation (Böcher 1954, 1959, 1963). These data are not included in Table 1.

Table 1: Digitized datasets saved and stored by the authors in Münster (abbrev.: col. 3: AZV: project Altitudinal zonation; NWG: project Northwest Greenland; FJAD: Fred J. A. Daniëls; CL: Christoph Lünterbusch; HB: Helga Bültmann; HF: Hezder Ferwerda; col. 4: OR: original data, © book)

Nr. of relevés	Region	Project/author	Type	Software	Georef.
1880	SW	AZV 2000-6	OR	Turboveg	yes
402	NW	NWG 1997-8	OR	Turboveg	no
386	SW	Böcher 1954	©	Turboveg	no
83	W	Böcher 1959	©	Turboveg	no
326	W	Böcher 1963	©	Turboveg	no
76	NE	FJAD 1995	OR	Excel	no
180	SE	CL 1995	OR	Word	no
152	SE	HB 1995	OR	Excel	no
153	SE	HF 1980	OR	Tab	no
242	SE	Back to the Future 2007 & older	OR	Excel	2007
18	SE	Back to the Future 2007 & older	OR	Word	2007
122	NW	NWG 1997-8	OR	Excel	no
13	S	HB 2009	OR	Excel	no
4033	**TOTAL**				

The largest of the Turboveg databases is the study of altitudinal vegetation zonation in SW Greenland (AZV in Table 1). It was carried out in the first decade of this century (about 2000–2010) in the continental Kangerlussuaq Area and the oceanic Sisimiut Area from sea level to over 1200 m altitude. The data were collected mainly for the PhD theses of Birgit Jedrzejek (née Sieg; Sieg 2006), Birgit Drees (2008) and Michael Girnth (2011), Diploma theses of Carsten Sult (2002), Ole Morgenstern (2003) and Jörg Hüls (2002), and by their supervisor Fred J. A. Daniëls. About half of the plots are georeferenced by GPS. The most relevant publication of the project's relevés is Sieg et al. (2006). A third (664 relevés) of this project has been included in EVA.

A dataset from the Umanak District in NW Greenland (NWG in Table 1) was assembled 1997–1998 by Fred Daniëls, Helga Bültmann, Ortrun Lepping, and Christoph Lünterbusch. Finalized in Turboveg are 402 relevés from vegetation types dominated by *Dryas integrifolia* and coastal vegetation. Further 122 relevés of snow beds, swamps, screes and steppe are digitized as Excel spreadsheet. The dataset includes detailed environmental data and the cryptogams. Localities, altitude, and exposition are noted, but the plots are not georeferenced by GPS. Core of the dataset is the PhD thesis of Christoph Lünterbusch (2002) with the publication Lünterbusch & Daniëls (2004) and another publication by Lepping & Daniëls 2006 (published 2007).

There are 485 relevés of scree, alluvial, fjellfield and terricolous lichen vegetation, digitized as spreadsheets, that were sampled in the Ammassalik Area, SE Greenland, by Hedzer Ferwerda (1980; TAB) and Helga Bültmann and Christoph Lünterbusch (Lünterbusch 1996, Bültmann 1999, Excel and Word) with corresponding publications by Lünterbusch et al. (1995; published 1997) and Bültmann (2005). Environmental data are detailed and cryptogams carefully studied. Again, the localities were not georeferenced by GPS.

Fred J. A. Daniëls and Hans De Molenaar revisited Ammassalik in 2007 and recorded 131 relevés corresponding to vegetation stands and types 40 years ago. The relevés from 2007 are digitized together with 130 corresponding relevés from 40 years ago (Daniëls & De Molenaar 2011, Daniëls et al. 2011). The 2007 relevés are georeferenced by GPS.

Fred J. A. Daniëls also collected a valuable set of 76 relevés from northern Greenland in 1995, which have been digitized as an Excel file without GPS data.

Another small dataset was collected in 2009 in S Greenland by Helga Bültmann and Fred J. A. Daniëls. The vascular plants and header data of 12 relevés are digitized, and for some relevés some of the cryptogams have to be identified.

Partly and undigitized data

On two expeditions to W Greenland in 1992 and 1993 the authors collected more than 200 relevés. For many of those relevés, the header data, the vascular plants and the macroscopic cryptogams are digitized as Excel files; however, smaller cryptogams are not yet identified, and the localities were not georeferenced by GPS. 14 relevés of the *Phyllodoco-Salicetum callicarpeae* are finalized and published in Daniëls (1994, digitized as pdf file). These data still need some work to get ready for the archiving.

Many relevés from 1966 to about 1980 by Fred Daniëls and Hans De Molenaar in the Ammassalik District are finalized and published but not digitized or as pdf-files (Daniëls 1975, 1980, 1982; De Molenaar 1974, 1976). Scans/pdfs can be prepared as tables. Further phytosociological tables have been published by Knapp (1964; constancy tables), Stumböck (1993), Böcher (1933), Fredskild (1998) and Dierßen & Dierßen (2005).

Vegetation types

The digitized data represent many different vegetation types in at least 20 classes (Table 2). The widespread dwarf shrub and graminoid vegetation of chionophytic and achionophytic types on acidic and calcareous substrate is well represented. However, because older research in eastern Greenland is less represented in the digitized data, the number of relevés is not representative for the distribution in Greenland.

Table 2. Vegetation types in the digitized datasets stored in Münster (classes follow Mucina et al. 2016; TV: Turboveg, DIG: digitized as spreadsheets; ANAL: analogous datasets, e.g. in published books; this list is incomplete.)

Vegetation types	TV	DIG	ANAL
Juncetea maritimi - Coastal salt marsh vegetation	X	X	X
Ammophiletea - Dry coastal beach and sand dune vegetation	X		
Cakiletea maritimae - Therophytic strandline vegetation	X		

Vegetation types	TV	DIG	ANAL
Potamogetonetea - Rooted floating or submerged macrophyte vegetation of mesoeutrophic waters		X	X
Phragmito-Magnocaricetea - Swamp vegetation of tall sedges, herbs and grasses		X	
Salicetea purpureae - Riparian willow shrub vegetation	X		
Isoeto-Littorelletea - Small rush vegetation on temporarily moist-wet soil		X	X
Scheuchzerio palustris-Caricetea fuscae - Sedge grass and dwarf shrub mire and fen vegetation	X	X	X
Asplenietea trichomanis - Fern and herb vegetation of rock fissures and ledges		X	
Thlaspietea rotundifolii - Talus slope, debris and alluvial vegetation	X	X	
Drabo corymbosae-Papaveretea dahliani - high Arctic polar desert vegetation of forbs, rushes, bryophytes and lichens		X	
Saxifrago cernuae-Cochlearietea groenlandicae - open grassy tundra disturbed by zoo-anthropogenic activities and cryoturbation in Svalbard and Greenland	X		
Salicetea herbaceae - Snowbed vegetation	X	X	
Loiseleurio procumbentis-Vaccinietea - Dwarf shrub heath and low shrub vegetation on acidic substrates	X	X	
Carici rupestris-Kobresietea bellardii - Achionophytic dwarf shrub and graminoid vegetation on non-acidic substrates	X	X	X
Saxifrago tricuspidatae-Calamagrostietea purpurascentis - Boreal and low Arctic steppe vegetation of the inland on dry, warm substrates	X		
Juncetea trifidi - Xerophytic graminoid vegetation on acidic sandy-gravelly substrates	X	X	X
Mulgedio-Aconitetea - Tall forb and shrub vegetation on mesic-moist soil			X
Vaccinio-Piceetea - Scrub and low forest of *Betula pubescens* ssp. *czerepanovii*		X	
Molinio-Arrhenatheretea - Anthropogenic pastures and meadows on fertile soil		X	
Rhizocarpetea geographici - lichen communities of siliceous rock surfaces exposed to rain			X
Ceratodonto-Polytrichetea - Bryophyte and lichen vegetation on acid to subneutral, silty-sandy and gravelly soils		X	

Outlook

Feedbacks provided during and after the workshop in Vienna showed the ongoing interest in the Greenland data and in cooperation. Thus, the workshop was a boost for the motivation to continue the work on the Greenland dataset.

A total of 4033 relevés are stored in digitized form; of those, 3238 are original relevés with 2282 in Turboveg, 605 in Excel-files, 198 in Word-files and 153 in Tab-files. Also, 795 relevés from the literature are digitized in Turboveg.

The Turboveg-files are in rather good shape. For one combined dataset, we have separate predecessors, which include more relevés than the combined version. At least two datasets do not fully correspond with the data in publications: the header data seem reliable, but identification of species was not always updated as in a corresponding publication (e.g. *Puccinellia* spec. instead of *Puccinellia vaginata*, *Bryum* spec. instead of *Bryum salinum*). This has to be corrected. For each dataset we already have a checklist, which includes basic information of the authors, number of relevés, the applied methods and scales and a quality evaluation of cryptogam inclusion.

The environmental data are similar between datasets, but not identical (e.g. slightly different ordinal scales for the same descriptor). A standard format is desirable for calculations; however, we have decided just to harmonise the names of the header data and remarks in English language and not change any data. A good description from the respective theses, regarding how the header data were obtained, already exists.

The same has to be done for the data in spreadsheet-table format. It seems feasible to finalize the Turboveg and spreadsheet data within this year. After that, the partly digitized data will be reviewed and completed if possible. Finalized parts can then also be imported in Turboveg.

Unfortunately, a larger part of the relevés is not georeferenced by GPS. However, good aerial pictures together with altitude and slope information might help to find the approximate spot for many of our plots. Work on this will be continued, starting with the datasets already in Turboveg.

Published older data, which are not digitized, are considered safe and can be added later. First goal is to rescue the already digitized data, especially the unpublished relevés. For the focus on syntaxonomy and maybe a Panarctic syntaxa-checklist, digitising relevés, which are nomenclatural types, and relevés of vegetation types not in the database could be prioritised.

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Progress on the European Vegetation Archive (EVA)

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The European Vegetation Archive (EVA) is an initiative of the European Vegetation Survey Working Group aimed at establishing and maintenance of a single data repository of vegetation-plot observations from Europe and adjacent areas. These data are for noncommercial purposes, mainly academic research and applications in nature conservation and ecological restoration. The archive currently comprises almost 2.4 million plot observations, resulting in in good coverage for most of Europe (Figure 1).

Analysis of these observations, however, was limited by the array of different species lists used by contributors that differed in nomenclature. We integrated a crosswalk among more than 40 different taxonomies, making analysis of large heterogeneous data sets feasible. For the dissemination of these data the EVA Data Property and Governance Rules are followed (euroveg.org/download/eva-rules.pdf).

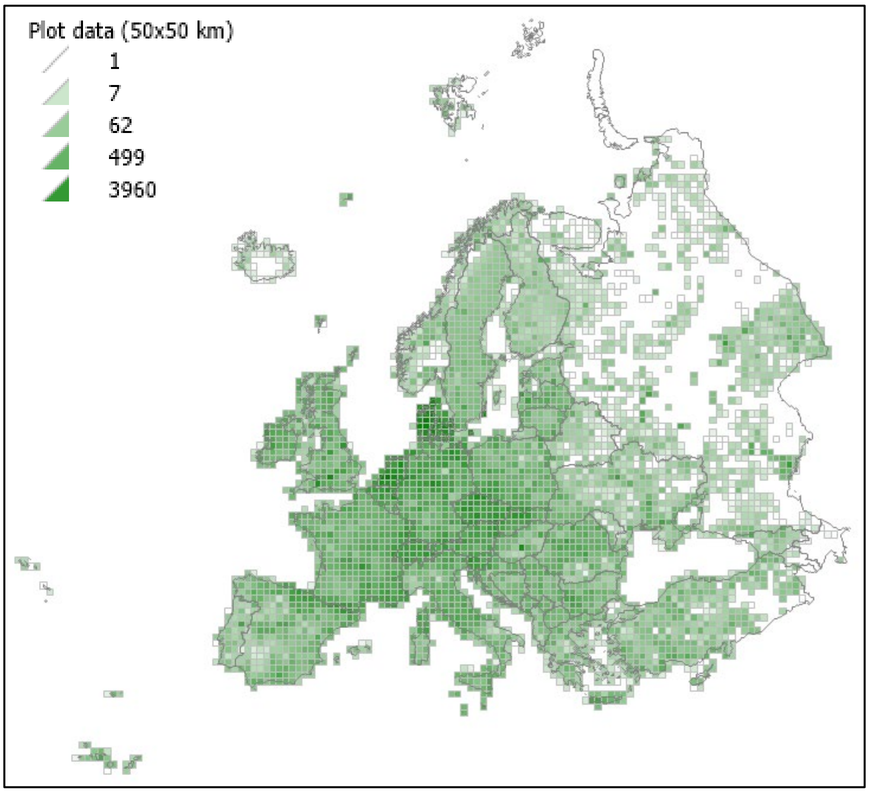

Figure 2. Density map of the plot observation in the European Vegetation Archive.

The EVA is managed with the plot database program TURBOVEG3 (www.synbiosys.alterra.nl/turboveg3) (Figure 2). This software tool harmonizes species names by using a backbone in which the various taxonomies are maintained and mapped to a single common concept. TURBOVEG3 also has EXPERT (onlinelibrary.wiley.com/doi/10.1111/avsc.12519) integrated, a tool to assign vegetation types to plot observations.

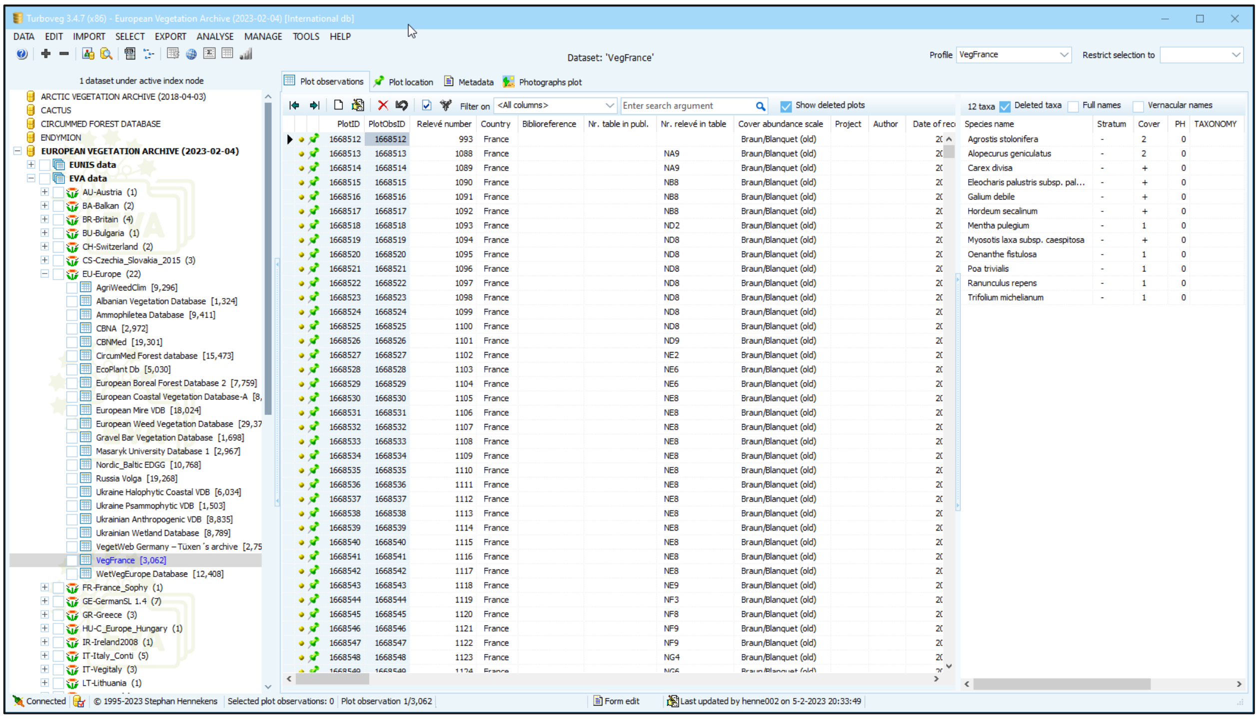

Figure 3. TURBOVEG3 program for managing the EVA data.

Regarding the EVA data identification rules for EUNIS (European Nature Information System), habitat types can be assigned to plot observations to create habitat type distribution maps that serve as an input for habitat suitability modelling (e.g., Figure 3). Suitability maps show the potential area of a habitat, based on various predictor parameters (e.g., climate, soils, and topography, as well as remote sensing-enabled Essential Biodiversity Variables).

For the modelling, the MAXENT (biodiversityinformatics.amnh.org/open_source/maxent) software has been used.

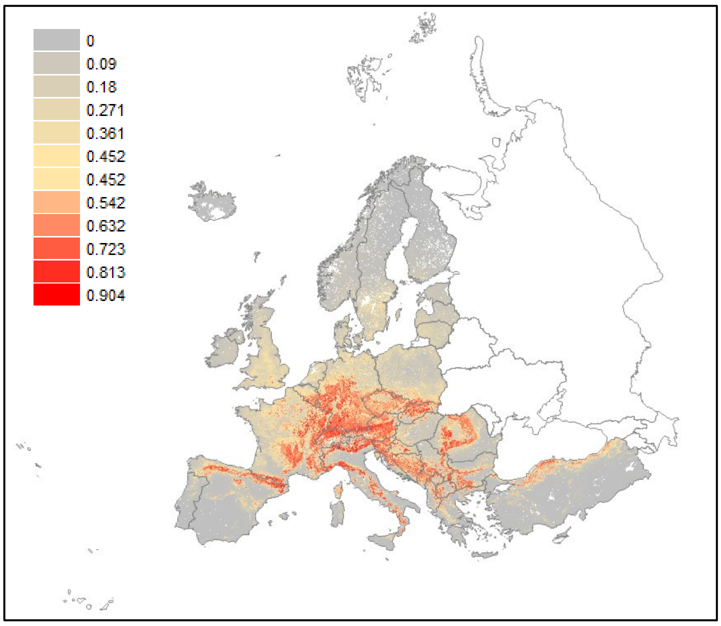

Figure 4. Suitability map of EUNIS habitat T17 (Fagus woodland on non-acid soils). The higher the suitability score the more likely the type can occur.

Progress on the Canadian Arctic Vegetation Archive, classification, and mapping

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The Canadian Arctic Vegetation Archive (AVA-CA) has expanded incrementally in the three years since the Archangelsk workshop. A planned field program of the Canadian High Arctic Research Station (CHARS) to sample extensively in the central Canadian Arctic was cancelled due to COVID-19 in 2020. A modest program to finalize sampling for subzones C and D of Victoria Island, NU in 2021 was hampered by poor weather, and a limited set of 40 relevés was acquired. A dataset of 150 plots from southern Baffin Island has been acquired from industry partners filling an important geographic void in the archive.

A set of scripts in the R programming languages has been produced to align taxonomic standards between different authorities and applied to the AVA-CA to harmonize with the larger North American dataset. The AVA-CA now houses 8735 plots and consolidation of project metadata will identify plot collection standards and quality (Table 1).

Table 1. Plot distribution in the AVA-CA by CAVM bioclimate subzone and floristic province

Subzone	Yukon	Central Canada	West Hudsonian	Baffin-Labrador	Ellesmere-N. Greenland	Total
A	N/A	104	N/A	N/A	0	**104**
B	N/A	97	3	N/A	69	**169**
C	100	1039	672	422	349	**2582**
D	915	1481	18	314	N/A	**2728**
E	1385	850	228	581	N/A	**3044**
TOTAL	**2400**	**3571**	**921**	**1317**	**418**	**8627**

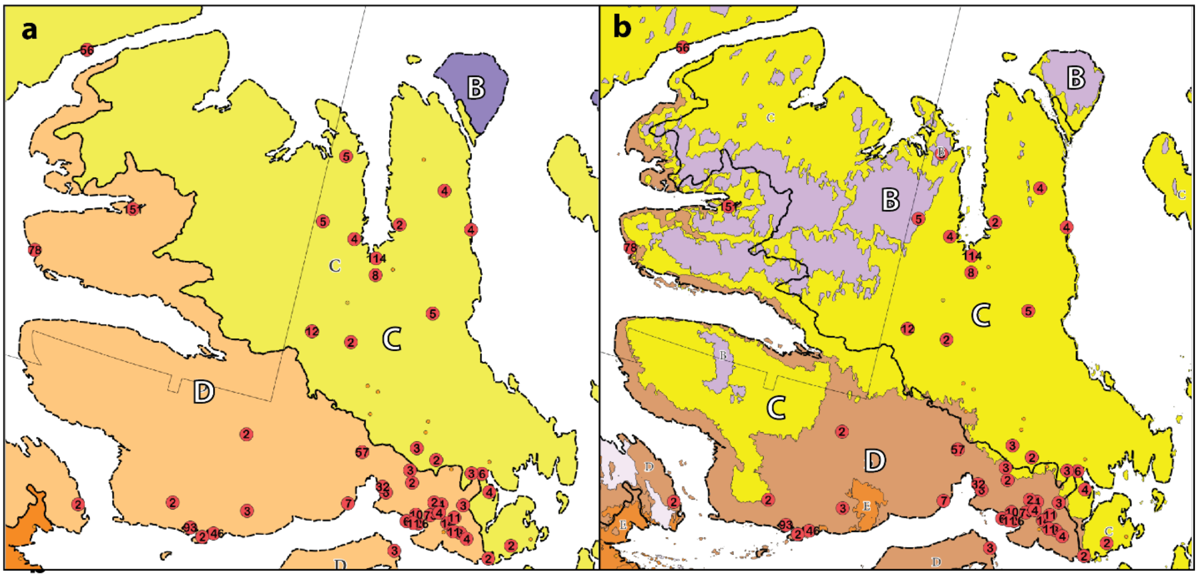

Figure 5. Subzones of Victoria Island in the central Canadian Arctic. **a** shows subzones as delineated by the CAVM; **b** shows the same area modelled with machine-learning and climate surface data. Modelling

differentiates elevational subzones and expands the range of subzones B above the C in northern areas, and subzone C above the D subzones in the southern areas.

The archive continues to be kept in VPRO, a programmed ACCESS database designed for management of vegetation and environmental relevés and classification hierarchies. Under new management, the CHARS is building expertise and infrastructure to be a long-term host of the archive. Classification work using the archive has been completed for the Yukon arctic in the western Canadian Arctic (MacKenzie et.al. 2022) following the methods of the Biogeoclimatic Ecosystem Classification system (McLennan et al. 2017).

Similar work is on-going in the CHARS experimental area to support ecosystem mapping. Modelled down-scaling of the Circumpolar Arctic Vegetation Map (CAVM) subzones to a scale of 1:50 000 has been undertaken for the Central Canadian arctic using the CAVA as training data (in part) for machine learning algorithms. Significant expansion of the C and B subzones into higher elevations of north Victoria Island, NU was confirmed by overflight and field visits in 2021 (Figure 1).

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The Raster Circumpolar Arctic Vegetation Map

Presented as an oral presentation at ASSW 2023, Session ID 10

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Land cover maps are the basic data layer required for understanding and modeling Arctic biodiversity, ecological patterns, and processes. The Circumpolar Arctic Vegetation Map (CAVM), produced in 2003 (CAVM Team 2003, Walker et al. 2005), has been widely used as a base map for studies in the Arctic tundra biome. However, the relatively coarse resolution and vector format of the original map were not compatible with many other data sets. We present a new version of the CAVM (Figure 1) (Raynolds et al. 2019, CAVM Team 2024), building on the strengths of the original map, while providing a finer spatial resolution, raster format, and improved mapping. The map uses the same extent, and projection of the original CAVM. It is based on automated unsupervised vegetation classifications of 17 geographic/floristic sub-sections of the Arctic using AVHRR and MODIS data (reflectance and NDVI) and elevation data. It is printed at 1:7 million scale compared to 1:7.5 million on the original map. The raster format and finer-scale resolution better reflect the heterogeneity of vegetation types. It includes more waterbodies and better portrayal of mountainous areas and coastal-inland gradients.

The back side of the map includes detailed information for each of the legend's 15 vegetation units (Figure 2), including a general description of the common habitats, the structure of the vegetation, where the unit is found, dominant species, representative syntaxa, and photographs of the typical landscape and a characteristic plant species.

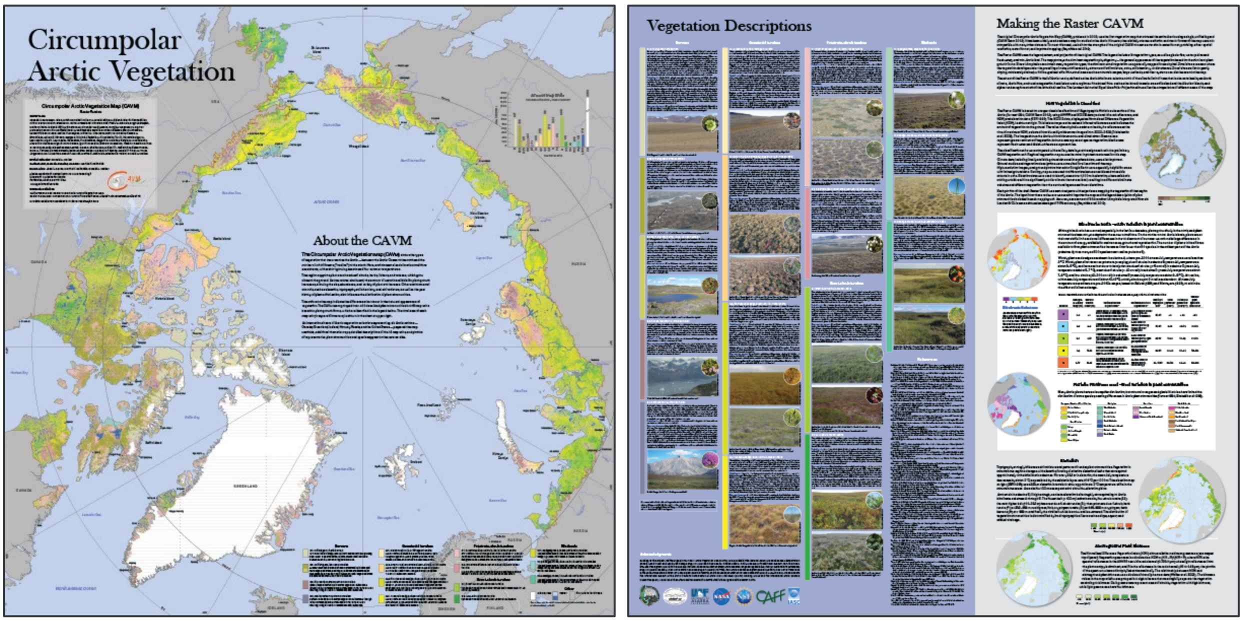
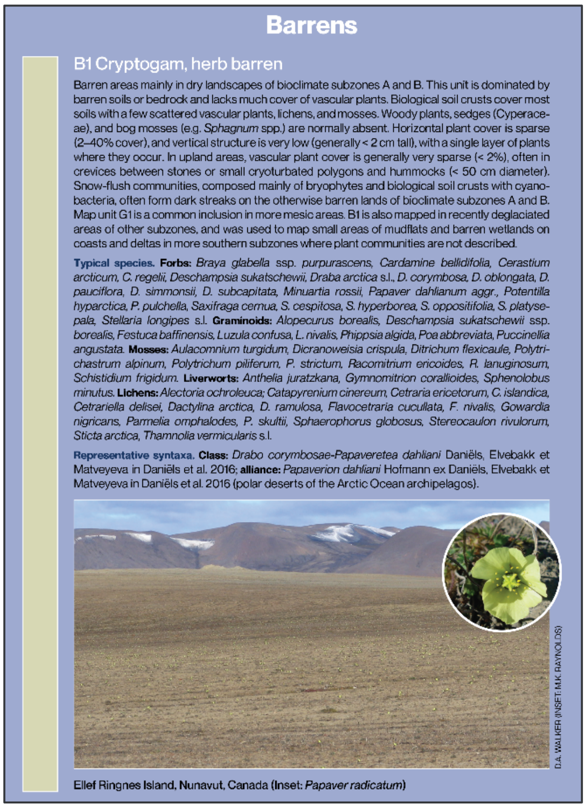


Figure 1. Front and back sides of the 36 x 36-in poster version of the Circumpolar Arctic Vegetation Map that will be printed at 1:7 million scale.



Barrens

B1 Cryptogam, herb barren

Barren areas mainly in dry landscapes of bioclimate subzones A and B. This unit is dominated by barren soils or bedrock and lacks much cover of vascular plants. Biological soil crusts cover most soils with a few scattered vascular plants, lichens, and mosses. Woody plants, sedges (Cyperaceae), and bog mosses (e.g. *Sphagnum* spp.) are normally absent. Horizontal plant cover is sparse (2–40% cover), and vertical structure is very low (generally < 2 cm tall), with a single layer of plants where they occur. In upland areas, vascular plant cover is generally very sparse (< 2%), often in crevices between stones or small cryoturbated polygons and hummocks (< 50 cm diameter). Snow-flush communities, composed mainly of bryophytes and biological soil crusts with cyanobacteria, often form dark streaks on the otherwise barren lands of bioclimate subzones A and B. Map unit G1 is a common inclusion in more mesic areas. B1 is also mapped in recently deglaciated areas of other subzones, and was used to map small areas of mudflats and barren wetlands on coasts and deltas in more southern subzones where plant communities are not described.

Typical species. Forbs: *Braya glabella* ssp. *purpurascens, Cardamine bellidifolia, Cerastium arcticum, C. regelii, Deschampsia sukatschewii, Draba arctica* s.l., *D. corymbosa, D. oblongata, D. pauciflora, D. simmonsii, D. subcapitata, Minuartia rossii, Papaver dahlianum aggr., Potentilla hyparctica, P. pulchella, Saxifraga cernua, S. cespitosa, S. hyperborea, S. oppositifolia, S. platysepala, Stellaria longipes* s.l. **Graminoids:** *Alopecurus borealis, Deschampsia sukatschewii* ssp. *borealis, Festuca baffinensis, Luzula confusa, L. nivalis, Phippsia algida, Poa abbreviata, Puccinellia angustata.* **Mosses:** *Aulacomnium turgidum, Dicranoweisia crispula, Ditrichum flexicaule, Polytrichastrum alpinum, Polytrichum piliferum, P. strictum, Racomitrium ericoides, R. lanuginosum, Schistidium frigidum.* **Liverworts:** *Anthelia juratzkana, Gymnomitrion corallioides, Sphenolobus minutus.* **Lichens:** *Alectoria ochroleuca; Catapyrenium cinereum, Cetraria ericetorum, C. islandica, Cetrariella delisei, Dactylina arctica, D. ramulosa, Flavocetraria cucullata, F. nivalis, Gowardia nigricans, Parmelia omphalodes, P. skultii, Sphaerophorus globosus, Stereocaulon rivulorum, Sticta arctica, Thamnolia vermicularis* s.l.

Representative syntaxa. Class: *Drabo corymbosae-Papaveretea dahliani* Daniëls, Elvebakk et Matveyeva in Daniëls et al. 2016; **alliance:** *Papaverion dahliani* Hofmann ex Daniëls, Elvebakk et Matveyeva in Daniëls et al. 2016 (polar deserts of the Arctic Ocean archipelagos).

D.A. WALKER (INSET: M.K. RAYNOLDS)

Ellef Ringnes Island, Nunavut, Canada (Inset: *Papaver radicatum*)

Figure 2. Description of CAVM map unit B1, Cryptogam, herb barren.

Accuracy assessment of random 1-km pixels interpreted from six Landsat scenes showed an average of 70% accuracy, up from 39% for the original CAVM. The distribution of shrub-dominated types changed the most, with more prostrate shrub tundra mapped in mountainous areas, and less low shrub tundra in lowland areas. This improved mapping is important for quantifying existing and potential changes to land cover, a key environmental indicator for modeling and monitoring ecosystems.

The data are available at Mendeley Data, doi:10.17632/c4xj5rv6kv.1. The double-sided 36 x 36-in print-version of the map is in press, and a PDF file with both sides of the printable map can be downloaded at www.geobotany.org/cavm.

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Russian Arctic Vegetation Archive update

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The Russian Arctic Vegetation Archive (AVA-RU) aims to bring together and harmonize plot data collected in the Russian Arctic by Russian geobotanists into a publicly accessible web-based archive.

The AVA-RU includes 4742 Braun-Blanquet plots, with 72% of the samples georeferenced. The data were collected between 1927 and 2020 and include observations of over 1730 vascular plant and cryptogam species and subspecies (Zemililanskii et al. 2023). The plots were sampled in Arctic Russia and Scandinavia (including Svalbard) (Figure 1).

Plots in Russia covered areas from the West to the East, including the European Russian Arctic (Kola Peninsula, the Bolshezemelskaya and Malozemelskya tundra, Kolguev island), Western Siberia (Northern Urals, Yamal, and Gydan peninsulas), Central Siberia (Taimyr peninsula, Severnaya Zemlya islands), Eastern Siberia (Indigirka basin), and the Far East (Sakha, Wrangel island) (Figure 2). The data are stored at avarus.space, and a backup at the University of Zurich is regularly updated with new plots (Ermokhina et al. 2022).

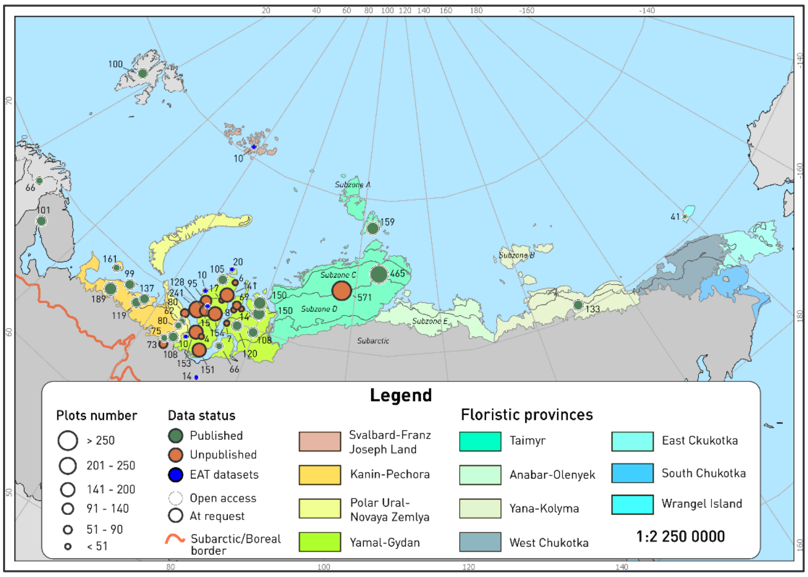

Figure 1. Overview of locations and number of geobotanical plots included in the Russian Arctic Vegetation Archive (Eurasian Arctic transect data included, status 3 March 2023).

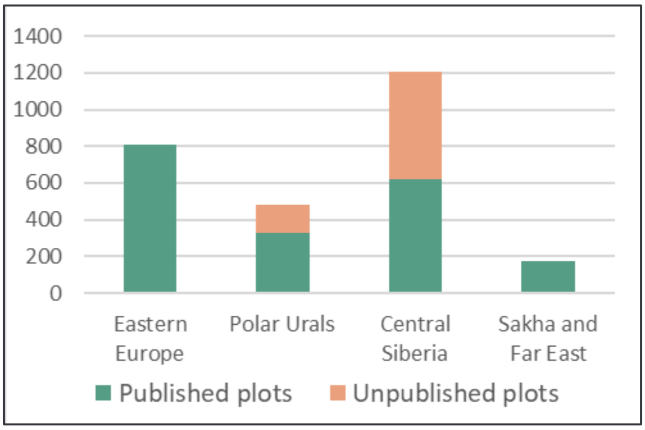

Figure 2. AVA-RU data by region (Western Siberia excluded)

The publication of the Russian part of the Arctic Vegetation Archive now provides full and open access to Russian Arctic vegetation data, filling the gap in the assessment and prediction of plant biodiversity and ecosystem functioning in the Russian Arctic.

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European Vegetation Archive (EVA) contributions to the AVA

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One of the most valuable tools utilized by vegetation scientists, ecologists, and nature conservationists worldwide is the hierarchical system of units representing plant communities that has been created based on floristic, ecological, and structural criteria. This approach, known as the Braun-Blanquet approach, was developed in Europe (cf. Mucina et al. 2016) in the beginning of 20st century. The language used in this classification system is advantageous due to its simplicity. Each name created follows specific guidelines (Theurillat et al. 2022), allowing for easy comparison of the content of each name with similar or different units in various regions respecting priority of created name/unit and specific content of each syntaxon.

The European Vegetation Archive (EVA) represents unique data repository of vegetation-plots records (phytosociological relevés) from Europe and adjacent area. The EVA serves to facilitate the use of these data for non-commercial purposes, mainly academic research and applications in nature conservation and ecological restoration. The initiative follows the EVA Data Property and Governance Rules (Chytrý et al. 2016, euroveg.org/eva-database). As management system for vegetation data, the TURBOVEG3 (Hennekens 2015) has been chosen as a descendant of TURBOVEG2 software (Hennekens & Schaminée 2001), the widely used software for management and storing of vegetation data in Europe.

As a compatible and significant source of data from the Arctic regions of Europe, we surveyed data in the EVA to see the distribution of potential data that can supplement recent Arctic Vegetation Archive. We found 12,264 relevés in total (12,241 geo-referenced relevés) that could potentially enlarge data in AVA. From these, 3783 relevés were from Finland; 441 from Greenland; 1 from Iceland; 3,612 relevés from Norway; 3,621 from European part of Russia, and 304 relevés from Svalbard and Jan Myaen Island (see also Table 1 and Figure 1).

The main intention of using robust dataset stored in a simple and available database is to create a logical expert system comparable and combinable with recently used units (e.g., the U.S. National Vegetation Classification) not only in the U.S., but also in other parts of the world and to apply obtained results to whole Arctic biome and identify the main variability patterns, gradients and consequently also threats affecting biodiversity.

Table 1. Basic information about relevés from EVA database north of the Arctic Circle

TV3 database name	GIVD code	GIVD database name	Custodian	# of plots
Czechia_nvd	EU-CZ-001	Czech National Phytosociological Database	Milan Chytrý	1
Euro-Asian tundra VDB	00-00-004	Vegetation Database of Eurasian Tundra	Risto Virtanen	1132
European Boreal Forest Database 1	EU-00-027	European Boreal Forest Vegetation Database	Anni Kanerva Jašková	580
European Boreal Forest Database 2	EU-00-027	European Boreal Forest Vegetation Database	Anni Kanerva Jašková	48
European Coastal Vegetation Database-A	EU-00-017	European Coastal Vegetation Database	John Janssen	337
European Mire VDB	EU-00-022	European Mire Vegetation Database	Tomáš Peterka	2698
European Weed Vegetation Database	EU-00-028	European Weed Vegetation Database	Filip Küzmič	2
Masaryk University Database 1	EU-00-031	Masaryk University's Gap-Filling Database of European Vegetation	Milan Chytrý	270
Nenets_Tundra	AS-RU-005	Nenets Tundra	Igor Lavrinenko	1108
Nordic Vegetation Database 1	EU-00-018	The Nordic Vegetation Database	Jonathan Lenoir	5163
Nordic Vegetation Database 2	EU-00-018	The Nordic Vegetation Database	Jonathan Lenoir	605
Russia Volga	EU-RU-002	Lower Volga Valley Phytosociological Database	Valentin Golub	313
VegetWeb Germany – Tüxen´s archive	EU-DE-013	VegetWeb Germany	Friedemann Goral	7

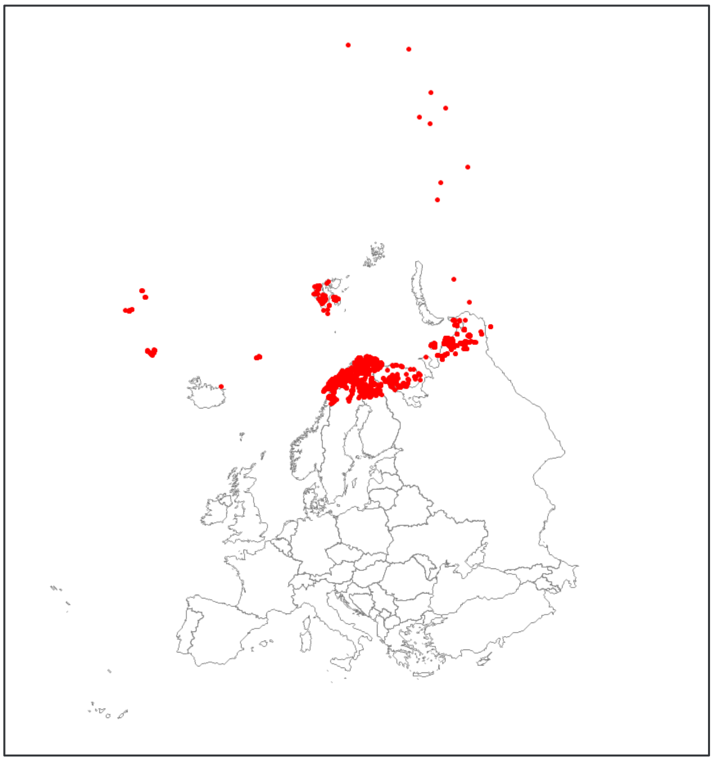

Figure 1. Occurrence of "Arctic (north of the Arctic Circle) relevés" from European Vegetation Archive (EVA) on February 2, 2023. EVA version 2023-01-27 (12264 total/12241 georeferenced relevés). Mapped boundaries are for countries within Europe including European Russia. Some relevés not within Europe are also shown.

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Review of Circumpolar Arctic Vegetation Initiatives and Future Directions

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Three main circumpolar Arctic vegetation initiatives were defined at the first International Workshop on Classification of Arctic Vegetation in Boulder, CO, 5-9 March 1992 (Walker, M.D. 1994): (1) an Arctic Vegetation Archive (AVA) of relevé (plot) data; (2) the Arctic Vegetation Classification (AVC), which includes a checklist and formal classification of Arctic plant communities; and (3) a circumpolar Arctic vegetation map (CAVM). These objectives have remained constant since the Boulder workshop. Here, I briefly review the history of these three initiatives plus three other initiatives that are essential parts of the story: the Pan Arctic Flora (PAF), the Pan Arctic Species List (PASL), and the Circum-Boreal Vegetation Map (CBVM).

The Pan-Arctic Flora (PAF) and Pan Arctic Species List (PASL)

A common taxonomical framework for all vascular plants, bryophytes, and lichens observed in Arctic plant communities is essential for comparing and analyzing vegetation plot samples. The idea for a Pan-Arctic Flora of vascular plants was suggested at the 1975 International Botanical Congress in St. Petersburg by John Packer, a Canadian botanist, but was not acted on until after the Arctic Flora of Russia was completed in 1987. The concept was revitalized in the 1990s under the leadership of Reidar Elven (Norway), David Murray (United States), and Boris Yurtsev (Russia) (Murray and Yurtsev 1999). Several workshops and meetings followed and laid the foundation for the final "Annotated checklist of the Pan-Arctic Flora: vascular plants" (Nordal and Razzhivin 1999, Elven et al. 2011). Once the PAF was completed, a Pan-Arctic Species List that included the bryophytes and lichens was developed specifically for the AVA (Raynolds et al. 2013). It combines the CAFF checklist for the vascular plants (Elven et al. 2011), an unpublished list of North America Arctic mosses (Belland 2012), the checklist of Russian liverworts (Konstantinova et al. 2009) and the CAFF checklist of lichens (Kristinsson et al. 2010).

The CAVM

The CAVM became the priority for a mapping subgroup of the CAFF Flora Group until the PAF was completed. The first step for making the Pan Arctic Flora, as well as a map of the vegetation, was to define biogeographic boundaries within the Circumpolar Arctic. At the time of the 1992 Boulder workshop, a variety of different mapping approaches were used in each of the Arctic countries. Russian phytogeographers already had mapped all of the Russian Arctic for a variety of purposes at different scales. Boris Yurtsev's keynote address at the 1992 Boulder workshop laid the floristic foundation for the PAF by subdividing the Arctic Tundra Zone into five north–south bioclimate subzones and six west-to-east floristic provinces (Yurtsev 1994). This framework was also used in many Russian maps that emphasized the zonal subdivisions.

Six workshops helped resolve differences in terminology and methods for drawing map boundaries: St. Petersburg, 1994 (Walker and Markon 1996); Arendal, 1996; Anchorage, 1997 (Walker and Lillie 1997); Anchorage, 1999 (Markon and Walker 1999); Moscow, 2001 (Raynolds and Markon 2002); and Tromsø: 2004. A 1:4-million scale base map was derived from a mosaic of midsummer (1994–1995) cloud-free false-color-infrared images obtained from Advanced Very-High-Resolution Radiometer (AVHRR) sensors aboard NOAA weather satellites. Separate maps using different mapping approaches were made by regional experts for Alaska, Canada, Greenland, Iceland, Svalbard, and four sections of Russia. In

Canada and Alaska, where most areas had not been previously mapped, an integrated terrain-unit-mapping (ITUM) approach was used to draw the map boundaries (Walker et al. 2002). In all regions, available maps, literature, and aerial photographs were used to help interpret the satellite images. In 1999, to see if bioclimate zonal concepts that were developed in Russia (Yurtsev 1994) and idealized variations of vegetation along toposequences in each bioclimate subzone (Elvebakk 1999) could also be applied to the Canadian Arctic, where relationships between vegetation and summer temperature were also well studied (Edlund and Alt 1989). Key CAVM team members from the Canada, Greenland, Norway, Russia, and U.S. sampled vegetation along toposequences in all five of the PAF bioclimate subzones in Arctic Canada (Gonzalez et al. 2000) and agreed that a common 5-subdivision bioclimate scheme used in Russia could also be applied in North America, but the group could not agree on the names of the units, so a compromise was reached labeling the subzones from north to south, A–E. The terminology for the dominant map units was based mainly on dominant plant growth-forms.

The final vector-based CAVM was the first vegetation map of an entire global biome at comparable resolution and was the basis for many circumpolar-scale analyses, including the Arctic Biodiversity Assessment (CAFF 2013) and changes to circumpolar vegetation in relationship to the shrinking extent of sea ice and warming air temperatures (Bhatt et al. 2010). The CAVM was published as CAFF Map No. 1 using a polar projection at 1:7.5 million scale (CAVM Team 2003). The methods, legends, area analyses, comparison with other maps of the Arctic, and relevance to global change research were described in a paper published in the *Journal of Vegetation Science* (Walker et al. 2005). A new raster-based CAVM (Raynolds et al. 2019) makes the map more useful for a wide variety of analyses and models that use pixel-based spatial information. A draft two-sided hard-copy color raster map at 1:7 million scale was presented at ASSW 2023 in Session ID 10 (Raynolds et al. 2023a) (see Raynolds et al., this volume.)

The CBVM

In 2007–2015, the focus of the CAVM Team shifted to a circum-boreal vegetation map to join to the CAVM at the Arctic tree line. Although numerous boreal-forest vegetation maps exist at a wide variety of scales using many legend approaches, there is not a map that covers the entire boreal forest biome with a scale or legend that is comparable to that of the CAVM. Such a map is needed for studies of the climate, hydrologic, and biotic interactions that occur across the Arctic tree line, as well as boreal-specific resource development, land-use planning, studies of boreal biota and biodiversity, education, and human interactions. The CBVM is a more ambitious idea than the CAVM. The boreal-forest biome covers approximately 20 million km^2, compared to approximately 5.5 million km^2 of Arctic tundra, with many more types of vegetation, governments, and administrative units.

Several CBVM workshops were conducted: Tórshavn in 2007 (Talbot 2008), Helsinki in 2008 (Talbot et al. 2010), Uppsala in 2009 (Talbot 2011), Akureyri in 2011 (Talbot 2012), Vladivostok in 2012 (Saucier 2013). A concept paper explained the CBVM plan (Talbot and Meades 2011), and a prototype map of the Alaska-Yukon boreal forest was made (Jorgenson and Meidinger 2015), but the project lost momentum through a series of retirements of key participants in the U.S., Canada, and Russia. There is still a need for a vegetation map that unites the Arctic and Boreal biomes with a common legend. Hopefully an international consortium of Arctic and boreal-forest scientists can revive the idea and develop a plan to gather the personnel and funds to finish the map.

Recent progress on the AVA and AVC

Momentum for an international arctic vegetation archive and classification was revived in 2011 with a CAFF Strategy Series Report that described the key conceptual elements of a digital plot database including: a unified Pan Arctic Species List and standardized species and environmental data (Walker and

Raynolds 2011). This was followed by four AVA/AVC workshops supported by IASC with the proceedings published by CAFF: Krakow, Spring 2013 (Walker et al. 2013); Boulder, Fall 2013 (Walker 2014); Prague, 2017, and Arkhangelsk, 2019 (Walker et al. 2019).

The first Arctic-specific plot archive was the Alaska archive (AVA-AK) (Walker et al. 2016), which is housed at the University of Alaska Fairbanks. The AVA-AK is modeled after the European vegetation archive (EVA) and uses the TURBOVEG3 vegetation data management system (Hennekens 2015). The archive of Alaska datasets is accessed through an open-source web-based CKAN data catalog, which includes the plot species-cover and environmental data and a wide variety of other related ancillary information (e.g., maps, photos, analyses, and derived products). An Arc-GIS-based approach is used to view plot locations on high-resolution satellite imagery. The AVA-AK currently contains 32 datasets and 3404 plots, and another 14 new and pending datasets with 1008 plots (Breen, this volume).

The plan is to eventually merge data from other regions of the Arctic into a single circumpolar TURBOVEG3 database for developing the Arctic Vegetation Classification. Approximately 31,000 Arctic plots have been identified for possible inclusion in the AVA (Walker et al. 2019).

The preferred approach for the classification in the AVC is presently the Braun-Blanquet method developed by Josias Braun Blanquet in the 1920's (Westhoff and van der Maarel 1978; Dengler et al. 2008). The main advantages for using the Br.-Bl. approach in the circumpolar Arctic are: (1) The system is well developed and presently widely used in many areas of the Arctic, including Europe, Greenland, Russia, Svalbard, and Alaska, and has had some application in most regions of the Arctic. (3) No other approach comes close in the number of existing plots that have used the Br.-Bl. approach. (4) There are many described, closely related well-accepted vegetation classes, and alliances that have a pan-Arctic distribution. (5) The floristic-based organization of higher-level units by habitat type (Mucina et al. 2016) is conceptually easy to understand and applicable at all scales of mapping.

The main disadvantages are: (1) The Br.-Bl. has been criticized in North America for the subjectivity used in establishing plot locations, bias involved in the subjective sampling, and the difficulty of applying some statistical methods to the ordinal cover values obtained in sampling (Podani 2006). (2) The Latinized names of units at all levels in the classification hierarchy require adherence to the International Code of Phytosociological Nomenclature, 4th edition (Theruillat et al. 2022), which is not widely used in the United States or Canada, two countries that combined have 57% of the total global area of Arctic tundra. The U.S. National Vegetation Classification (USNVC) uses the EcoVeg approach (Faber-Langendoen et al. 2014, 2018), an 8-level hierarchy of floristic, physiognomic, geographic, and ecological units. Vegetation scientists in the Canadian Arctic are using a Biogeoclimatic Ecosystem Classification (BEC) approach that leverages a modified Br.-Bl. vegetation classification approach to identify and delineate ecologically equivalent climatic regions and site condition (Mackenzie and Meidinger 2018).

A possible solution to the different dominant classification approaches used in North America and Eurasia is the development of crosswalks. The beginning of a harmonization of North America (EcoVeg) and European (Br.-Bl.) classification approaches tried a crosswalk comparison of *Dryas octopetala* communities described according to the EcoVeg and the Braun-Blanquet approach, but the non-parallel hierarchies of the two approaches made a crosswalk difficult above the plant-community level (Walker et al. 2019b). An Arctic checklist focused on typical Arctic habitat types similar that of Mucina et al. (2016) may be a more fruitful approach to developing crosswalks.

Despite the intervention of the COVID-19, the Ukraine War, and the lack of consistent sources of funding for the AVA and AVC during the past three years, international collaboration is still alive. Nadya

Matveyeva, via a recent email, reported the publication of a checklist of vegetation syntaxa for the Russian Arctic (Matveyeva and Lavrinenko 2021) and the formal description of a new Br.-Bl. class of zonal tundra vegetation “Carici arctisibiricae–Hylocomietea alaskani ” (Matveyeva and Lavrinenko 2023). Also, several recently published papers describe Russian plant associations with circumpolar counterparts (e.g. Koroleva and Kulyugina 2015, Lavrinenko and Lavrinenko 2015, 2021; Lavrinenko and Kochergina 2022, Lavrinenko et al. 2014, 2016, 2022; Telyatnikov et al. 2013, 2019, 2021a, 2021b, 2022). Progress of an online Russia Arctic Vegetation Archive (AVA-RU) has also been extensive in recent years funded in part by the European Union (Ermokhina et al. 2022; Zemlianskii et al. 2023; Zemlianskii et al., this volume).

Canada has also been making steady progress on the Canadian National Vegetation Classification (Baldwin et al. 2019) using VPro data management software (Mackenzie and Klassen 2009). (MacKenzie, this volume.) Also, 287 relevés, collected from a long latitudinal transect on Baffin Island, are in the process of being archived (Raynolds et al. 2020, 2023b).

In Greenland, progress has been made entering data into a common TURBOVEG archive (Bültmann, this volume). Some of the plot data from Greenland, Iceland, and Svalbard are already in the European Vegetation Archive (EVA) (Šibík, this volume). Considerable progress has also been made in Europe regarding applying TURBOVEG3 software to joining datasets with different species concepts (Hennekens, this volume). Also, Fred Daniëls sent a message that his book *Vegetation of Greenland* will be submitted for publication in April 2023!

The future

1. Begin right away to discuss an IASC proposal for a Circumpolar Arctic Vegetation workshop at ICARP IV 2025 and a science plan for the next decade (2026–2035) of Circumpolar Arctic Vegetation Science research.
2. The next step should probably be unification of two most similar archives, the AVA-RU and the AVA-AK, into a single archive. This will require considerable thought about how to unify the species lists and cross-reference aspects of each archive that are not common to both archives. Advances in TURBOVEG3 makes this a feasible step.
3. The map of potential plots published in 2019 needs to be updated with new datasets, including how many plots are appropriate for inclusion in the AVA, and how many are now in regional archives.
4. Regular updates to the Pan-Arctic Species List are needed as new species are found and the existing Latin names change to reflect new knowledge.
5. More steps are needed to standardize data in the national AVAs, including use of unique Turboveg relevé numbers [e.g., Alaska (10000-19999), Russia (20000-29999), Canada (30000-39999), etc.]; development of country archive coordinators; and development of species synonym lists for each country linked to the current Pan-Arctic Species List (PASL).
6. An “International Circumpolar Vegetation Group” could help coordinate the above activities. This could be a subgroup associated with the IASC and CAFF Terrestrial Working Groups. The focus would be development of the key circumpolar vegetation maps, plot archives, classification, and application of these to the core biodiversity- and circumpolar ecosystem-change questions. This could include an Arctic Vegetation Network to improve communication, share publications, data, and coordination regarding arctic vegetation data, regular monthly Zoom meetings to start, and possibly a more formal organization with dues, website, etc. if it seems useful and necessary.

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Customizing the classification of Arctic wetlands for an improved analysis of their carbon and energy cycles

Kseniia Ivanova[1]*

INTRODUCTION

Wetlands play an important role in the carbon balance of the Arctic and cover more than 60 % of the area. While most climate models **distinguish only one or two types of wetlands**, biogeographical approaches define **at least ten types of wetlands** in the Arctic.

The main aim of this study is **to improve the representation of wetland ecology** in carbon upscaling studies in the Arctic. This requires finding the balance between the diversity of wetlands in the Arctic and variability in responses to climate forcing. On the one hand, a larger number of classes allows a more precise description of the conditions and characteristics of the fluxes within each class. On the other hand, more classes also mean less information per class, and thus more gaps that need to be interpolated.

MAIN AIM

Optimized classification scheme

- Simple classification: aim at low number of wetland types
- Consider variability in main environmental parameters
- Focus on CO_2 and CH_4 fluxes (as well as variability)
- Reflect variability in vegetation structure and composition
- All classes identifiable with remote sensing data

DATA COLLECTION

Database:

78 articles

778 observations:
- CO_2 – 531
- CH_4 – 403

Data for 1988 – 2019

All seasons

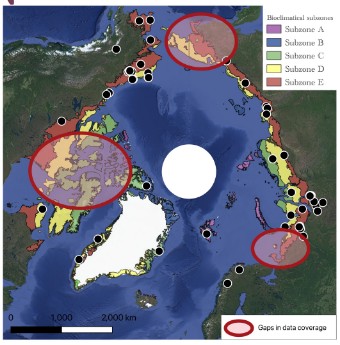


Fig. 1. Data coverage in the database on the satellite map (google.com). Colors indicate different tundra subzones by Walker et al., 2014.

CLUSTERING

The goal is to group similar objects into clusters based on input parameters, in order to identify classes of wetlands that can be distinguished based on their individual combination of environmental parameters, carbon fluxes, and vegetation.

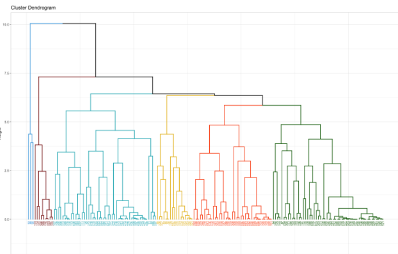


Fig. 2. Cluster dendrogram. The colors indicate different clusters.

PARAMETERS

Moisture type

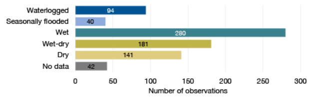


Fig. 3. Data distribution by different moisture types.

The five types of moisture were chosen as they reflect the diversity of moisture conditions in Arctic wetlands, can be determined based on available data for almost all studies, and can also be used in climate models in the future.

Water table level and its change during the vegetation season

Consideration of the water table level and its changes is crucial when accounting for CH_4 emissions from Arctic wetlands. An increase in water table level leads to an increase in anaerobic soil volume, resulting in a rise in methane emissions.

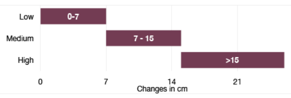


Fig. 4. Categories of change in the position of water level.

Preliminary types of wetlands

As a basis for further classification of Arctic wetlands and for initial data analysis (mean values, group dispersion), the wetland classification of the Arctic by Minayeva et al (2017) was used, with subsequent modifications based on the analysis of literature on GHG emissions. This classification was found to satisfy the majority of parameters (see "Main aim") but does not account for CO_2 or CH_4 emissions yet.

- Drained depression (Khasyrei)
- Fens with *Eriophorum*
- High- and low-centered polygonal tundra
- Near lake depression
- Palsa mires
- Peat plateaus
- Raised bogs, Sphagnum hollow
- Salt marshes
- Sedge meadows

pH

Active layer depth

Soil temperature

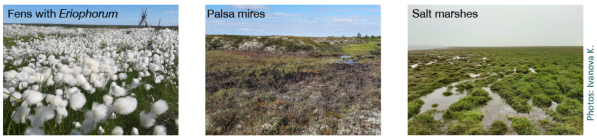
Vegetation (Presence of certain plant groups)

1. ***Sphagnum*** mosses (only hygrophytic). Wet or waterlogged environments with low nutrient availability and a low pH.
2. ***Eriophorum* spp.**. grow well in soils that are moist but not waterlogged, with a neutral to slightly acidic pH, and moderate to high soil fertility.
3. Group of ***Carex* spp.** that can be found in areas with a shallow water table or standing water.
   Species: *Carex aquatilis, C. rotundata, C. rostrata, C. chordorrhiza, C. wiluica, C. capitata, C. globularis, C. limosa., Arctophila fulva.*
4. **Cushion-forming lichens** indicate dry conditions.

Next steps:

- Exploring alternative methods for reflecting vegetation based on the limited descriptions provided by authors
- Figuring out if it is needed to use other groups or combinations of species in order to improve the accuracy of the vegetation classification.
- Search for the best combination of input parameters for statistical analysis.

Few examples of preliminary wetland types:



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Poster Presentations

Improving the classification of Arctic wetlands to better understand their role in the carbon and energy cycles

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Wetlands in the Arctic play a significant role in regulating carbon levels and have various physical characteristics, such as hydrological conditions and vegetation, that affect their interactions with climate and their exchange of greenhouse gases. While some models only recognize a few types of Arctic wetlands, there are at least ten different types based on biogeographic classification. In order to accurately represent the role of wetlands in the Arctic carbon cycle in modeling studies, it is necessary to find a balance between capturing the diversity of wetland types and the information that is typically available.

To do this, a database was created using data from published studies on Arctic wetland characteristics, including carbon pools and fluxes, for the period 1988-2019. The data, primarily collected using flux chamber techniques, includes site characteristics and methane and carbon dioxide fluxes. However, there is limited data available for some parameters, such as permafrost depth, pH, and water table level. To address this, remotely-sensed data was also included, though it is often less precise. Using statistical analysis, the data was divided into wetland categories based on their methane and carbon dioxide fluxes and their response to environmental factors. The results of this classification are presented for a range of total numbers of categories, allowing for the selection of the most appropriate scheme for a given modeling study. See poster on next page.

Bryophyte diversity in the Arctic wetland tundra along a site moisture gradient, Prudhoe Bay, Alaska

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INTRODUCTION

Thanks to specific adaptations, such as broad ability to recover from desiccation and freezing and low maximum photosynthetic rates, bryophytes thrive in northern wetland tundra ecosystems with ice-rich permafrost, where they often reach high diversity and abundance, and play an important role in many ecosystem processes. Unfortunately, species identification of mosses in the field is difficult, often requiring determination of microscopic characters. To exploit the potential of bryophytes present in tundra, we offer here a classification of bryophyte life-forms that can be easily recognised in the field. This approach enables to gain a better knowledge of ecological processes occurring in arctic tundra. Each aspect of bryophyte diversity (species richness, abundance, composition and distribution of life-forms) was studied in relation to site moisture gradient as water supply is a key variable which drives the diversity in bryophyte communities. This study is an exploratory examination of the use of bryophyte life-forms to help categorize the species-rich moss layer of nonacidic wetland tundra plant communities in the Prudhoe Bay region of Alaska.

STUDY AREA

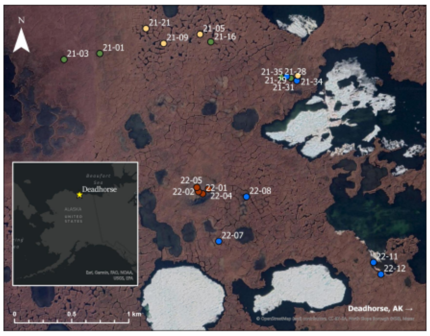


Fig. 1. Vegetation plots sampled at the NIRPO site within the Prudhoe Bay oilfield, Alaska.

SAMPLING METHODS

19 permanent vegetation plots

plot area: 1m^2

cover estimations according to nine-grade Braun-Blaquet cover-abundance scale

site moisture gradient represented by vegetation types:

dry tundra – types B1 and B2
moist tundra – types U3 and U4
wet tundra – types M2 and M4
aquatic tundra – M4/E1, E1 and E2

codes follow Walker (1985): Vegetation and environmental gradients of the Prudhoe Bay region, Alaska. – *CREEL* report 85-14, pp. 137–64

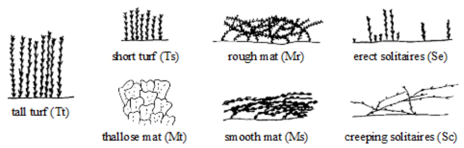
the selection of vegetation plots represents unique combinations of vegetation type and microrelief feature with at least one repetition for each vegetation type

DATA ANALYSIS

Mean values of species richness and mean cover values of bryophytes were calculated for each vegetation type (Fig. 2a,b). Detrended correspondence analysis (DCA) with square root transformation of percentage species covers was performed in R to examine trends in species composition along the site moisture gradient characterized by vegetation types (Fig. 3). To display the distribution of life-forms along the site moisture gradient covers of life-forms were plot with axes y log transformed (Fig. 4).

BRYOPHYTE LIFE-FORMS

7 distinct types occurring at the NIRPO research site;
illustrations are adapted from Grace (1995): A key to the growthforms of mosses and liverworts. – *Journal of Biological Education*, 29(4): 272–278



RESULTS

A total of 77 bryophytes were included in the analysis. **Species richness** (Fig. 2a) is highest in moist sites on raised microrelief features such as high-centered polygons and rims and decreases towards aquatic sites. In contrast, the **abundance of bryophytes** increases from dry towards aquatic sites (Fig. 2b). Both trends are commonly known from across the arctic tundra. The DCA shows a noticeable pattern in **species composition** along the first axes which corresponds to the moisture gradient (Fig. 3).

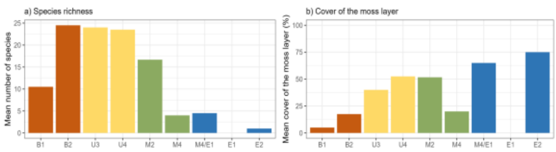


Fig. 2. Mean bryophyte species richness (a) and mean total bryophyte cover (b) per vegetation type.

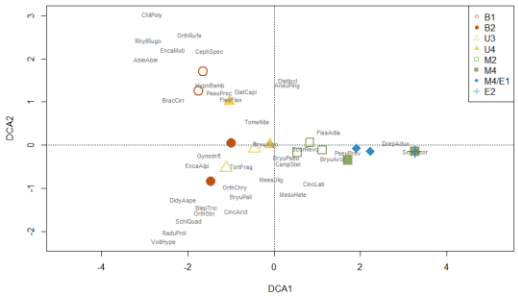


Fig. 3. DCA ordination diagram displaying both species and vegetation plots.

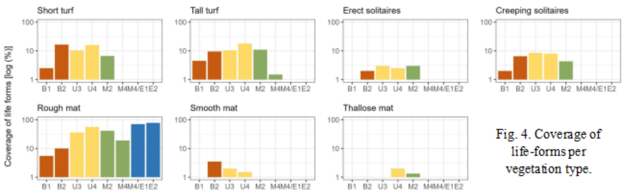
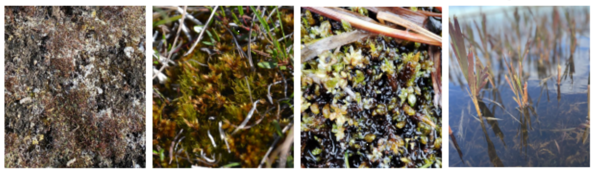


Fig. 4. Coverage of life-forms per vegetation type.

Mats occur at sites where the dessication stress is improbable. **Rough mats** dominate in wet and aquatic sites. Their prostrate appearance improves light capture in otherwise shaded or submerged conditions when light becomes a limiting factor rather than moisture. **Smooth mats** are common in more exposed dry sites where strong winds shape the shoots of the moss in one direction. **Turfs** are common in most types except the wettest sites as they represent a self-shading form favoured by species in harsh conditions in open landscape. **Short turfs** predominate **tall turfs**, which can be explain by impact of high light intensity on lenghtening of the main axes. **Solitaires** can be often found as a mixture of several species or can be present in otherwise monospecific colonies, **erect solitaires** in turfs, or **creeping solitaires** among mats or turfs.



Dry sites are preferred by species with affinity to open and disturbed habitats with lower amount of water supplies, which occupy left site of the ordination diagram. Moist tundra represents a transition between dry and wet sites with highest species richness in both prostrate and erect bryophytes, and leafy liverworts. Species present in this type tend to be related to higher site moisture while still performing full recovery after periods of lower water availability. Wet tundra is characterized by the presence of hygrophytic species that can withstand a considerable amount of standing water. Aquatic sites are typical with occurrence of prostrate species which form a prevailing and often monodominant vegetation cover. Such species possess morphological adaptations allowing them greater growth via prolonged photosynthetic activity and become dominant in wetlands.

DRY	MOIST	WET	AQUATIC
Abietinella abietina	*Tomentypnum nitens*	*Bryum pseudotriquetrum*	*Calliergon giganteum*
Encalypta mutica	*Flexitrichum flexicaule*	*Catascopium nigritum*	*Drepanocladus* sp.
Syntrichia ruralis	*Distichium capillaceum*	*Campylium stellatum*	*Pseudocalliergon brevifolium*
Rhytidium rugosum	*Orthothecium chryseum*	*Cinclidium* sp.	*Scorpidium scorpioides*
Pseudostereodon procerrimus	*Bryum pallescens*	*Meesia* sp.	
	Arnellia fennica	*Scorpidium revolvens*	
	Radula prolifera	*Cyrtomnium hymenophyllum*	
	Scapania simmonsii		

CONCLUSION

This study contributes to the ecological research at the NIRPO study site in the Prudhoe Bay region, where bryophytes are dominant component of most tundra plant communities. The analyses revealed distinct pattern in species richness, abundance, composition and distribution of life-forms along the site moisture gradient represented by vegetation types. Classification of life-forms may proved to be a useful concept that can serve a wide range of ecologists in an understanding and modeling the role of bryophytes in tundra ecosystem processes, such as controlling soil temperatures and the development of ice-rich-permafrost soils in these plant communities.

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Bryophyte diversity along a site moisture gradient

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Bryophytes are important part of arctic tundra ecosystems. They reach high diversity and abundance and play a key role in many ecological processes. Unfortunately, species identification of mosses in the field is difficult, often requiring determination of microscopic characters. This report examines distribution of bryophyte life forms that occur across a moisture gradient at a research site in the Prudhoe Bay Oilfield, Alaska. Several approaches for classifying bryophyte life forms were reviewed, but only a few focused on arctic flora.

Here we propose seven distinct life-forms that occur in the Prudhoe Bay study area. Species diversity, abundance and composition, and life-forms are studied in relation to nine vegetation types across a local site moisture gradient covering dry, moist, wet and aquatic tundra. Results show an obvious trend in all studied aspects of bryophyte diversity. Species richness is highest in moist sites on raised microrelief features and decreases towards aquatic sites. In contrast, abundance increases towards aquatic sites. Distribution of species and life-forms in an ordination diagram follows the studied gradient. Erect species, including those in turfs, are abundant in dry and moist sites, prostrate species, often occurring as mats, dominate to wet and aquatic sites. These results suggest that using life-forms in ecological studies can improve understanding of processes in arctic environments.

Mapping and monitoring of arctic vegetation using NaturaSat software

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Introduction

The NaturaSat software integrates knowledge of botany fieldwork scientists, nature protection managers, mathematicians and software developers focusing on habitats exploration. The software is already in use in Central Europe, allowing extraction of the habitat borders with pixel accuracy of the Sentinel-2 optical data, classification of plant communities in segmented areas by satellite image characteristics and monitoring their area and quality dynamic changes. The first application in Arctic region is presented with case study areas - Toolik Lake and Prudhoe Bay

Workflow

of the NaturaSat software development:

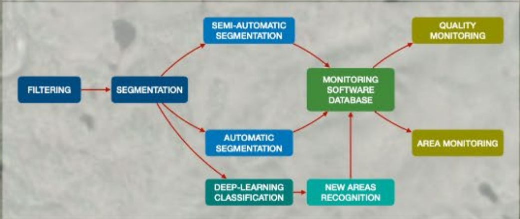


Fig. 1. The Toolik Lake area visualized by Senttinel-2 data

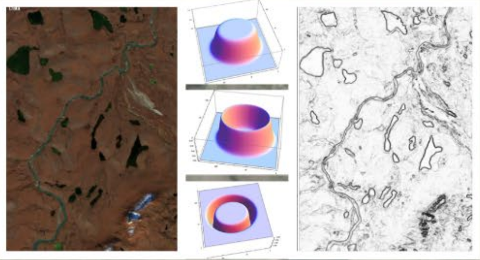


Fig. 3. Original data (a), image intensity function (b), norm of the gradient (c), edge detector (d) and its vizualization (e)

Semi-automatic segmentation

In the case of the semi-automatic segmentation, the user selects a straight line that is located along the desired habitat boundary edge, and the curve is automatically adjusted to the habitat boundary by the edge attracting term.

Vegetation data

Toolik Lake Area Vegetation map (Walker & Maier 2008, Fig. 2) was imported to NaturaSat. Original habitats borders were compared with recent segmented areas. Transects of vegetation plots in Prudhoe Bay Area was used for software calibration.

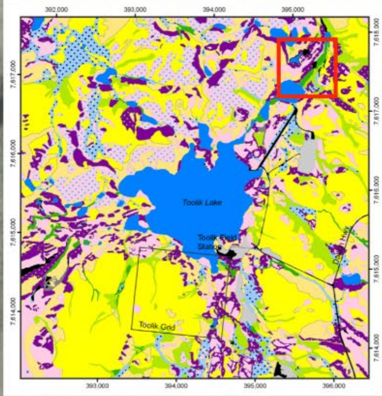
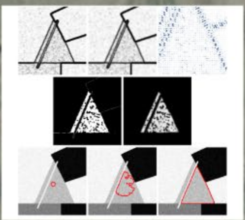


Fig. 2. The Toolik Lake Area Vegetation map (Walker & Maier 2008)



Automatic segmentation

The segmentation model is based on the evolving closed planar curve approach. In the fully-automatic segmentation the user selects a point inside the habitat or the habitat occurrence indicating point is chosen as the center of the circle which is then evolved by the curve evolution model.

Fig. 4. First row: the visualization of smoothed edge detector and the vector field, second row: the homogenity function, third row: the initial segmentation curve and its time evolution until the final segmentation

Fig. 5. Automatic segmentation of tall shrub tundra near Toolik lake

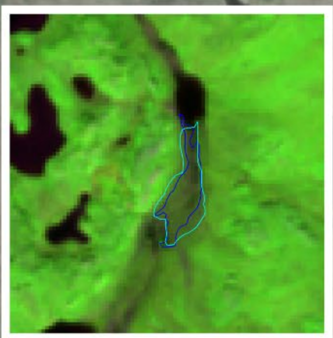


Fig. 7. Tall shrub tundra area (dark-blue) from 2008, and recent segmentation (light-blue)

Spatio-temporal monitoring

The quality monitoring of habitats is based on comparing optical band values inside the same segmented area on different dates. Area monitoring is based on comparison of Hausdorff distance of two curves. Presented areas (Fig. 7) are tall shrub tundra with area 1.7 ha in 2008, and same habitat with area 2.5 ha in 2022.

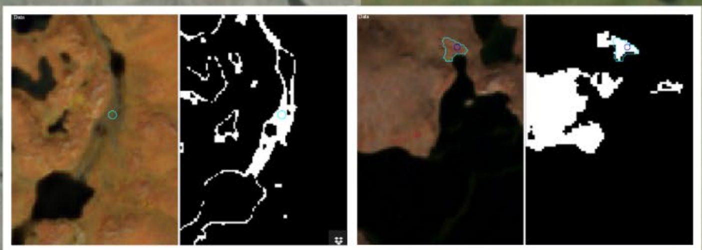


Fig. 6. Initial segmentation circle of tall shrub tundra and its homogenous area (left), and Initial segmentation circle of moist graminoid tundra and its homogenous area (right) near Toolik lake

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Mapping and monitoring of arctic vegetation using NaturaSat software

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Mapping and monitoring of Arctic vegetation with satellite-based remote sensing techniques can complement detailed ground-based approaches. The main advantages of satellite-based remote sensing approaches are their ability to image vast inaccessible regions repeatedly. Generally, the remote sensing methods can be repeated over long-time periods, with temporal consistency, and high cost-effectiveness to identify trends of changes to vegetation and other environmental factors.

Satellite-based interpretations are greatly enhanced if based on plant community and vegetation structure information obtained at the ground level. A previous remote-sensing-based study of change in the Toolik Lake region used a time series of normalized-difference-vegetation (NDVI) data derived from Landsat TM data (30-m pixel resolution) in combination with the Walker and Maier (2008) geobotanical maps to examine temporal changes in an 823-km^2 area of the Upper Kuparuk River region that included the Toolik Lake area (Raynolds et al. 2013). The study found 5% of pixels had significant linear increases in NDVI from 1985 to 2007, while 0.4% showed significant decreases. The NDVI trends varied by glacial history, elevation, and slope.

Here we explore the application NaturaSat software (Mikula et al. 2021a) to determine if it can be used to help extrapolate to larger regions the vegetation patterns that were originally mapped using the integrated terrain-unit approach near the Toolik Field Station, Alaska. The NaturaSat software (Mikula et al. 2021a) focuses on habitat-boundary exploration. The software has been successfully used in Central Europe, allowing extraction of the habitat borders with pixel accuracy of the Sentinel-2 optical data, classification of plant communities, segmented areas by satellite image characteristics, and monitoring of changes.

The vegetation in the vicinity of the Toolik Field Station was originally mapped at 1:5000 scale. The map consisted of 14 vegetation units distributed in more than 1400 map polygons. The legend of the map included details of typical plant communities found in each unit. For this analysis, a simplified version of the Toolik Lake Area Vegetation map included six higher-level map units: Barrens; Moist graminoid tundra; Wet graminoid tundra; Dry prostrate-shrub tundra (including snowbeds); Erect-shrub tundra (including riparian shrublands); and Water (Figure 2). Polygons larger than 2000 m^2 were included in the analyses.

Since the map was published in 2008, some vegetation unit borders have changed due to succession. To obtain “core area” of habitats, polygons were processed by an Adjust function in the NaturaSat software that allows automatic movement of habitat borders into natural borders identified in satellite data by an edge detector (Figure 3). For the final dataset, spectral characteristics of all bands were computed and compared by statistical methods to verify the possibilities of automatic recognition of arctic tundra habitats. Habitat borders were identified; however, in some cases there were shifts between original data, and recently detected borders. Therefore, segmentation functions were used for obtaining new polygons. In the case of the semi-automatic segmentation, we selected a straight line that is located along the desired habitat boundary edge, and the curve was automatically adjusted to the habitat boundary by the edge attracting term. The segmentation model is based on the evolving closed planar curve approach (Mikula et al. 2021b). In the fully-automatic segmentation, a point inside the habitat or the habitat occurrence indicating point was chosen as the center of the circle which was then evolved by the curve evolution model (Mikula et al. 2021c, Figure 4).

Analyses of spectral characteristics show differentiation in five habitat types (Figure 5). Barrens, Erect-shrub tundra, and Wet-graminoid tundra were clearly separated. Moist graminoid tundra with Prostrate-shrub tundra forms overlap that could be explained by the fuzzy distinction of the types. Prostrate dwarf-shrub, sedge, forb, fruticose-lichen (nonacidic) tundra, which occurs in moist conditions, was closely related to the Moist graminoid tundra habitat. The original habitats borders were compared with recent segmented areas, and the visible changes highlighted the need of continuous spatio-temporal monitoring of habitats under rapid change.

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The influence of climate and distance to infrastructure on plant species richness across the West Siberia tundra

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Western Siberia is one of the main significant areas of economic activity above the Arctic Circle. The tundra plant communities in the region are rapidly changing due to climate change, fossil fuel extraction, and reindeer herding.

We investigated the relative impact of environmental, topographic and anthropogenic factors on community-level plant species richness of the Western Siberian Arctic, using macroecological models. Our research is based on the Russian Arctic Vegetation Archive (Ermokhina et al. 2022; Zemlianskii et al. 2023b), which is a contribution to the international Arctic Vegetation Archive effort (Walker et al. 2013) (Figure 1, green shaded area). The Western Siberian part of the AVA consists of 1483 Braun Blanquet plots collected during 2005-2017 field campaigns (Figure 2). The number of species per plot was calculated and used as training data for the models.

We utilized General Linear Models (GLMs), General Additive Models (GAMs), Random Forest (RF), and Gradient Boosting Machines (GBMs) to estimate, model, and map the community-level species richness across the Western Siberian tundra (Table 2). We tested 48 environmental predictors, including climate and topographic factors. Climate variables were identified as the main explanatory factors. The final list of 10 selected predictors can be found in Table 1 and includes: Climate variables: growing degree days above 5˚C, mean air temperature of the driest 3 months of the year, potential evapotranspiration, cloud area fraction, evaporation (Penman equation, max and range), mean wind speed, mean ground temperature (2000–2016 PANGAEA); Terrain variables: distance to infrastructure, slope (Arctic DEM, log transformed). In addition to climate factors, we also estimated the role of anthropogenic factors by using the distance from infrastructure derived from Open Street Maps (www.openstreetmap.org, retrieved 30 June 2022) as a proxy for human influence.

We estimated the role of anthropogenic factors using the distance from infrastructure derived from Open Street Maps. We tested two options for anthropogenic influence: (1) using actual distance to infrastructure (Figure 3), and (2) a hypothetical zero human influence model ensemble (predictor 'distance to infrastructure' set to the maximum value (115.285 km) (Figure 4). Comparing the 'actual distance to infrastructure' with the 'zero human influence' ensemble of models shows that the 'zero human influence' models demonstrate much higher uncertainty (up to 40 species), especially in Southern and Western Gydan and Southern Yamal (Figures 5, 6).

Our results reveal a clear gradient from areas with low species richness in the southern lowlands and the Ob' delta to high species richness areas on the Gydan peninsula (Zemlianskii et al. 2023a, in press). Both high and low species richness areas occur in all three main bioclimatic subzones, but the arctic deserts of Bely Island generally exhibit low species richness. The decrease in species richness in

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URPP Global Change and Biodiversity

The influence of climate and distance to infrastructure on plant species richness across the West Siberia tundra

How is plant species richness distributed at community level in Western Siberian tundra?

- Western Siberian tundra communities are changing rapidly due to climate change, fossil fuels extraction and reindeer herding.
- We present macroecological models for species richness of Western Siberian tundra communities. We used General Linear Models, General Additive Models, Random Forest, and Gradient boosting machines to predict species richness as a response variable of environmental factors.
- The research is based on the Western Siberian part of Russian section of Arctic Vegetation Archive (http://avarus.space) ~ 1438 Braun-Blanquet plots (2005-2018 years) (Fig.2).
- We estimated the role of anthropogenic factors using distance from infrastructure derived from Open Street Maps as a proxy for human influence.
- We tested two mapping options: using actual distance to infrastructure raster (Fig.3) and a hypothetical zero human influence raster (distance to infrastructure was set to maximum value) (Fig.4).
- Comparing the 'actual distance to infrastructure' with the 'zero human influence' ensemble of models shows that the 'zero human influence' models demonstrate much higher uncertainty (up to 40 species), especially in Southern and Western Gydan and Southern Yamal (Fig. 5, 6).

Table 1: Predictors

Predictor	Original resolution, m	Explained deviance, %
Mean Ground Temperature (2000-2016) PANGAEA	1000	19
Potential evapotranspiration (min)	1000	17
Mean temperature of driest quarter	1000	14
Climate moisture index (max)	1000	13
Distance to infrastructure (OSM)	1000	11
Growing degree days above 5°C	1000	11
Climate moisture index (range)	1000	11
(log transformed) slope (ArcticDEM)	10	10
Cloud area fraction	1000	7
Mean wind speed	100	5

Table 2: Model performance

Model	Spearman correlation	Mean Absolute Error	Root Mean Square Error
GLM	0.53	8.4	10.8
Random Forest	0.59	8.1	10.3
GAM	0.59	8.0	10.2
GBM	0.60	7.9	10.1

Resulting map ensembles. Spatial resolution = 1000 m

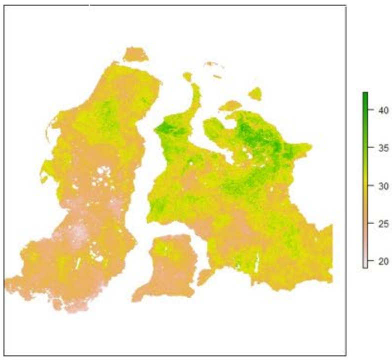

Fig 3: Actual distance to infrastructure used

Fig 4: Zero-human influence model ensemble

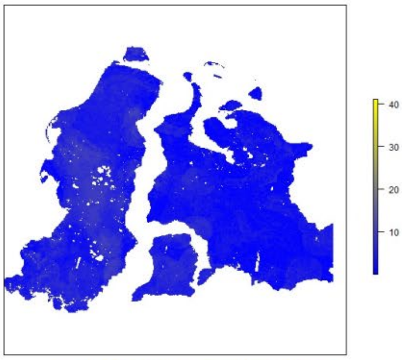

Fig 5: Models disagreement map ("actual distance to infrastructure")

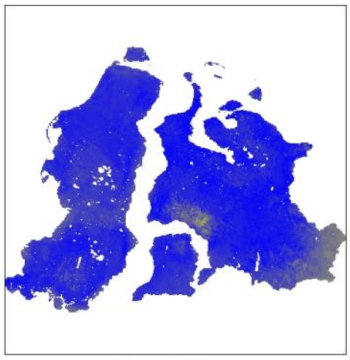

Fig 6: Models disagreement map ("zero human influence")

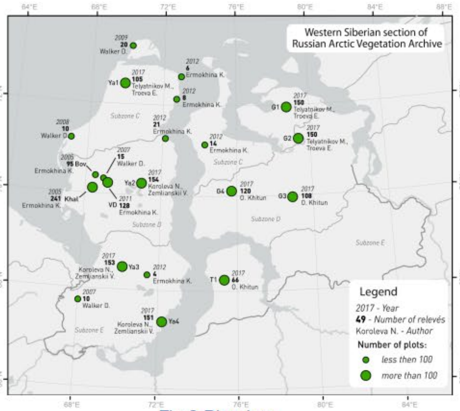

Fig.2:Plot data

Fig.1: Research area on Google Earth

Discussion

- Clear gradient in species richness from South-West to North-East.
- Climate factors such as ground temperature and precipitation play a key role in shaping community species richness while topographic relief plays a secondary role.
- The decrease in species richness in the southern part of the region might be a result of reindeer herding and gas extraction.
- Areas disturbed by human activity are characterized by relatively high model uncertainty.

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the southern part of the region might be a result of reindeer herding and the expansion of gas extractive infrastructure throughout the region, particularly in its southern and western parts. By overlaying the current nature protection areas with our species richness map, we found that areas with the highest species richness are poorly protected.

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