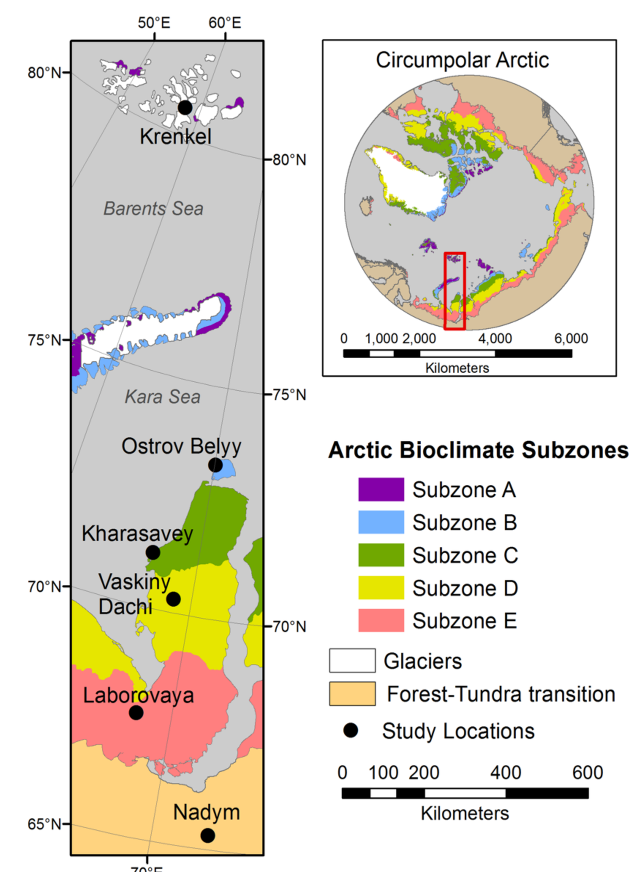
Vegetation along the 1700-km Yamal Peninsula–Franz Josef Land Eurasia Arctic Transect

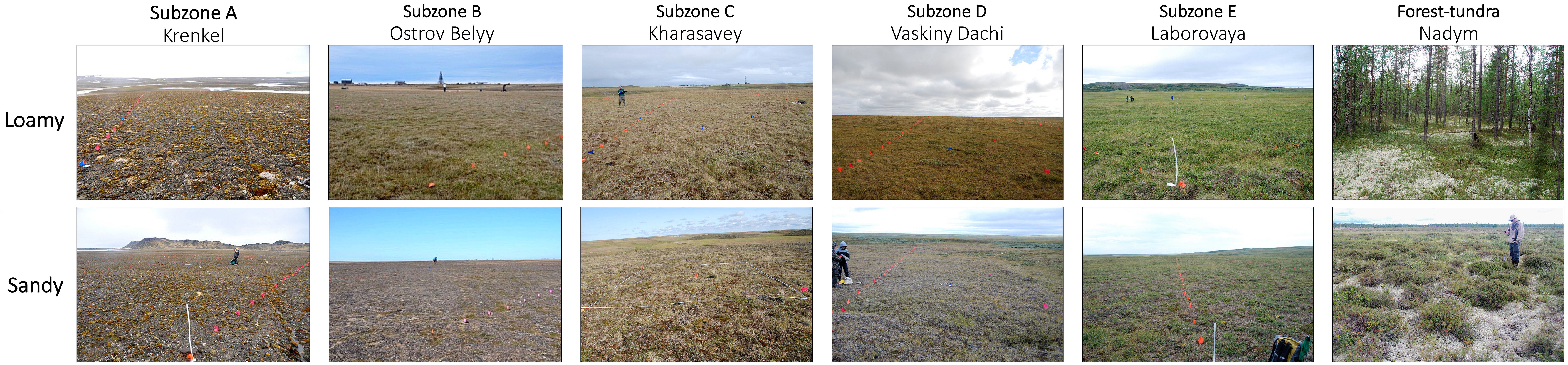
Donald A. Walker[1], Howard E. Epstein[2], Jozef Šibík[3], Uma Bhatt[4], Vladimir E. Romanovsky[5], Amy L. Breen[5], Silvia Chasnikova[3], Ronald Daanen[6], Lisa A. Druckenmiller[1], Ksenia Ermokhina[7], Bruce C. Forbes[8], Gerald V. Frost[9], Jozsef Geml[10], Elina Kaärlejarvi[11], Olga Khitun[12], Artem Khomutov[7,13], Timo Kumpula[14], Patrick Kuss[15], Marina Leibman[7], Georgy Matyshak[16], Natalya Moskalenko[7], Pavel Orekhov[7], Jana Peirce[1], Martha K. Raynolds[1], & Ina Timling[1]

[1]Institute of Arctic Biology and Department of Biology and Wildlife, University of Alaska, Fairbanks, Alaska, United States; [2]Department of Environmental Sciences, University of Virginia, Charlottesville, Virginia, United States; [3]Plant Science and Biodiversity Center, Slovak Academy of Sciences, Institute of Botany, Bratislava, Slovak Republic; [4]Geophysical Institute and Department of Atmospheric Science, University of Alaska, Fairbanks, Alaska, United States; [5]International Arctic Research Center, University of Alaska, Fairbanks, Alaska, United States; [6]Division of Geological and Geophysical Surveys, Alaska, United States; [7]Earth Cryosphere Institute, Tyumen Scientific Center, Russian Academy of Sciences, Siberian Branch, Tyumen, Russia; [8]Arctic Center, University of Lapland, Rovaniemi, Finland; [9]Alaska Biological Research, Inc., Fairbanks, Alaska, United States; [10]Naturalis Biodiversity Center, Leiden, The Netherlands; [11]Department of Ecology and Environmental Sciences, Umeå University, Umeå, Sweden; [12]Komarov Botanical Institute, Russian Academy of Sciences, St. Petersburg, Russia; [13]University of Tyumen, Tyumen, Russia ; [14]University of Eastern Finland, Joensuu, Finland; [15]Institute of Systematic and Evolutionary Botany, University of Zürich, Zürich, Switzerland; [16]Department of Soil Science, Lomonosov Moscow State University, Moscow, Russia

Abstract: Arctic tundra ecosystems occur in a broad circumpolar belt that extends from areas north of 80˚ N to forest-tundra areas south of 60˚ N, with mean July temperatures that vary from near 0˚ C to over 12˚ C. The 1700-km Eurasia Arctic Transect (EAT, Fig. 1) was conceived to characterize vegetation on zonal loamy and sandy soils along the complete maritime Arctic climate gradient in western Arctic Russia to aid in remote-sensing interpretations of land-cover and land-use change. We analyzed the variations in plant growth forms and species richness in each layer of the plant canopy with respect to summer temperature and soil texture, provided a preliminary numerical classification, and used indirect ordination methods to analyze the relationship of the plots and species to a suite of measured environmental factors.

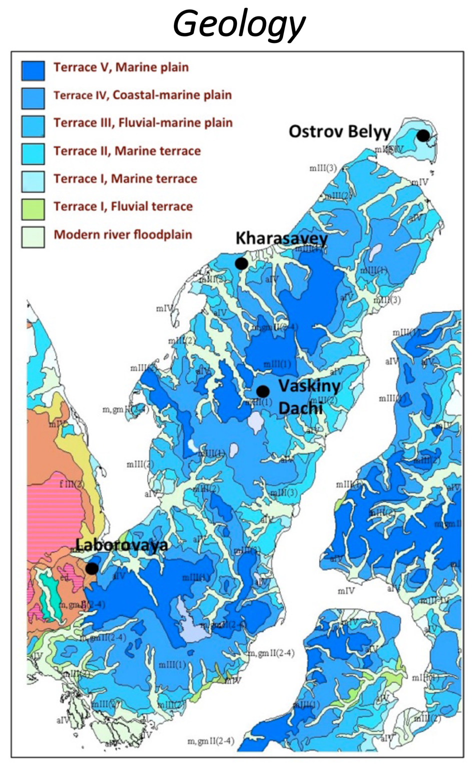
1. Eurasia Arctic Transect





2. Site selection and sampling

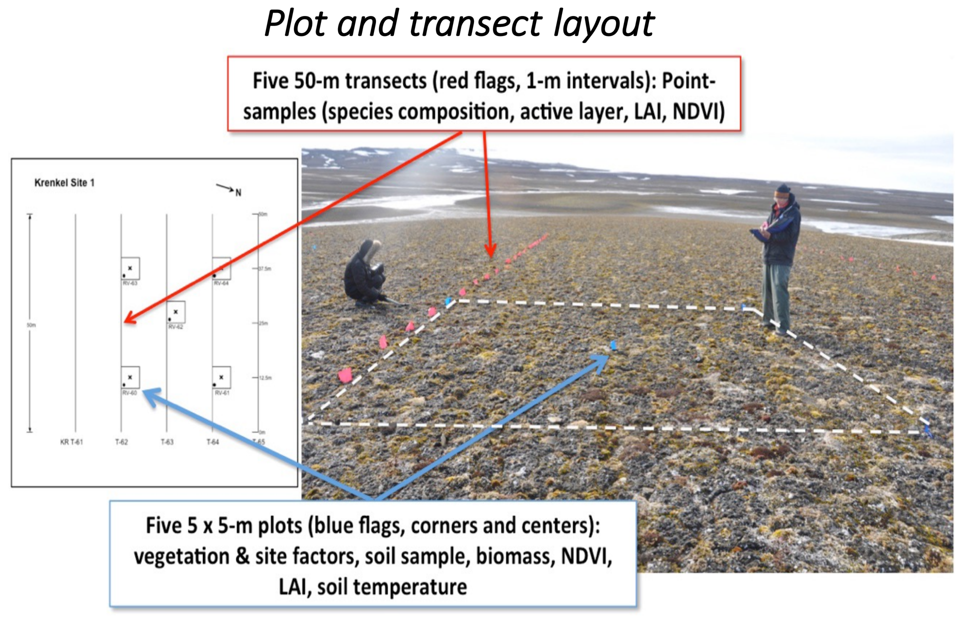
Geology



Climate

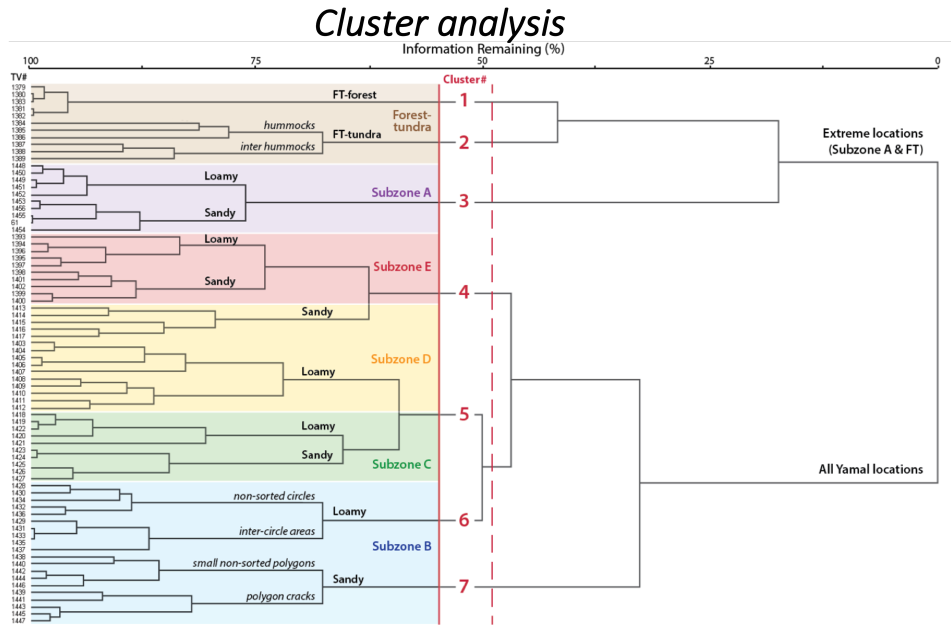
Bioclimate subzone	EAT study location	Mean July Temp. (1961-1990, ˚C)[1]	Mean annual precip-itation (1961-1990, mm)[1]	Mean SWI_a at local climate station (1961-1990, ˚C mo)[1]	Mean SWI_g for 12.5-km km pixel containin g the location (˚C mo)	Mean SWI_g for Circum-polar Arctic subzones (Mean ± s.d., ˚C mo)
A	Krenkel	1	282	1.1	2.0	8.2 ± 3.4
B	Ostrov Belyy	5.6	258	11	11.5	12.6 ± 5.8
C	Kharasavey	7.2*	310*	18.6*	18.5	19.8 ± 5.1
D	Vaskiny Dachi	ND	ND	ND	29.6	27.0 ± 4.9
E	Laborovaya	ND	ND	ND	36.6	33.2 ± 4.4
FT-transition	Nadym	15.8	479	43	41.3	ND

Plot and transect layout

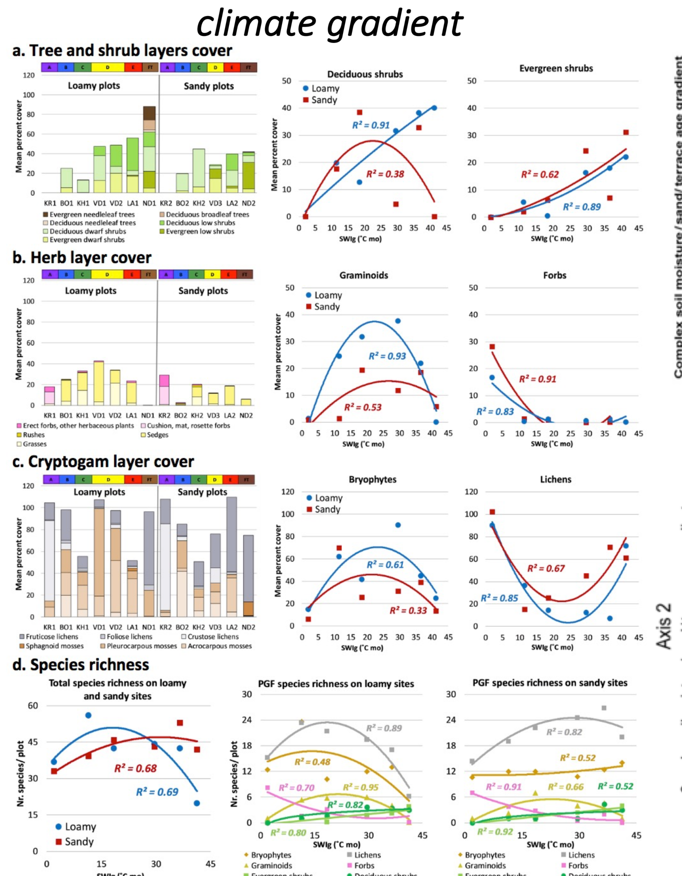


3. Vegetation description and analysis

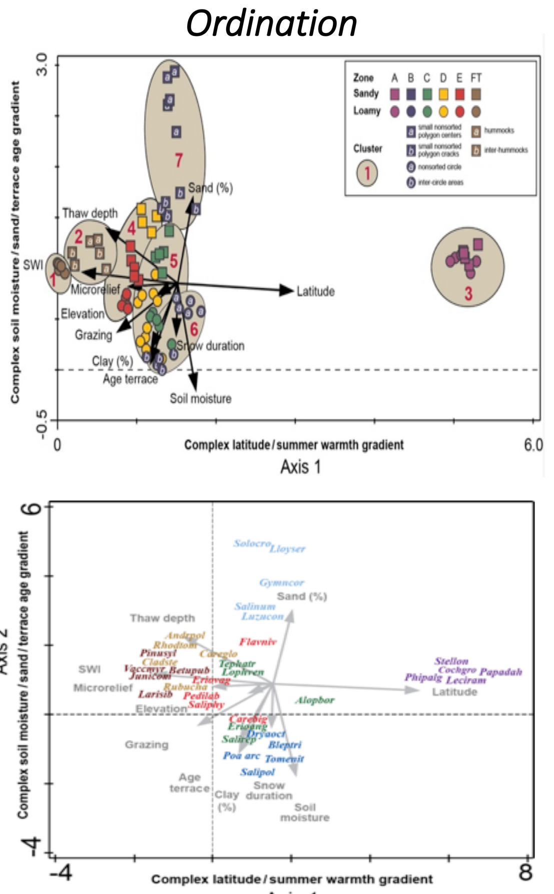
Cluster analysis



Canopy structure and diversity vs. climate gradient



Ordination



Synoptic table

Cluster nr.		1	2	4	5	6	7	3
Subzone(s) soil texture		FT lom	FT snd	E+ D snd	D lom +C	B lom	B snd	A
Number of plots		5	6	15	20	10	10	10
Diagnostic taxa for cluster 1	Growth form							
Pinus sylvestris	tne	100	.					
Betula pubescens	tbd	100	.					
Larix sibirica	tnd	100	.					
Vaccinium myrtillus	sdd	100	.					
Juniperus communis	sle	80	.					
Peltigera malacea	lfo	60	.					
Pleurozium schreberi	bmp	100	17	47	5	.	.	
Peltigera leucophlebia	lfo	100	.	13	50	20	.	
Cladonia stellaris	lfr	100	83	20	.	.	.	
Empetrum nigrum	sde	100	17	80	10	.	.	
Vaccinium uliginosum	sdd	100	33	67	15	.	.	
Diagnostic taxa for cluster 2								
Carex globularis	gs	.	100	.	.	.	.	.
Andromeda polifolia	sde	.	83	7	.	.	.	.
Rubus chamaemorus	sdd	.	83	7	.	.	.	.
Rhododendron tomentosum	sle	100	100	73	.	.	.	.
Diagnostic taxa for cluster 4								
Flavocetraria nivalis	lfr	.	.	93	25	.	.	.
Salix phylicifolia	sld	.	.	67	10	.	.	.
Eriophorum vaginatum	gs	.	17	87	25	.	.	.
Pedicularis labradorica	fe	.	.	53	.	.	.	.
Asahinea chrysantha	lfr	.	.	40	.	.	.	.
Pertusaria dactylina	lc	.	.	47	.	.	10	.
Cladonia grayi	lfr	.	.	40	5	.	.	.
Schljakovia kunzeana	bl	.	.	33	.	.	.	.
Luzula wahlenbergii	gr	.	.	33	.	.	.	.
Diagnostic taxon clusters 5&6								
Arctagrostis latifolia	gg	.	.	20	95	100	10	.
Diagnostic taxa for cluster 5								
Lophozia ventricosa	bl	.	.	40	80	.	.	.
Alopecurus borealis	gg	.	.	.	60	.	.	10
Salix reptans	sdd	.	.	13	55	.	.	.
Eriophorum angustifolium	gs	.	.	27	60	.	.	.
Tephroseris atropurpurea	fe	.	.	7	45	.	.	.
Peltigera canina	lfo	.	.	.	35	.	.	.
Peltigera aphthosa	lfo	.	.	.	40	10	.	.
Lichenomphalia hudsoniana	lfo	.	.	.	30	.	.	.
Diagnostic taxa for cluster 6								
Blepharostoma trichophyllum	bl	.	.	.	5	100	.	.
Salix polaris	sdd	.	.	.	50	100	.	.
Tomentypnum nitens	bmp	.	.	13	20	90	.	.
Dryas octopetala	sde	.	.	.	40	100	50	.
Poa arctica	gg	.	.	7	40	80	.	.
Juncus biglumis	gr	.	.	.	.	60	20	.
Bryum cyclophyllum	bma	.	.	.	.	40	.	.
Stellaria longipes	fe	.	.	.	25	60	.	.
Sphenolobus minutus	bl	.	.	73	80	100	20	.
Diagnostic taxa for cluster 7								
Pogonatum dentatum	bma	.	.	13	.	.	80	.
Oxyria digyna	fm	.	.	.	.	.	80	20
Gymnomitrion corallioides	bl	.	.	33	25	10	100	.
Luzula confusa	gr	.	.	.	60	10	100	.
Salix nummularia	sdd	.	.	27	50	.	100	.
Lloydia serotina	fe	.	.	.	.	.	50	.
Solorina crocea	lfo	.	.	.	.	.	50	.
Polytrichum piliferum	bma	.	.	7	.	10	50	.
Pohlia crudoides	bma	.	.	7	.	.	40	.
Gowardia nigricans	lfr	.	.	40	60	20	90	.
Diagnostic taxa for cluster 3								
Stellaria longipes taxon edwardsii	fe	.	.	.	.	.	.	100
Papaver dahlianum agg.	fm	.	.	.	.	.	.	100
Phippsia algida	gg	.	.	.	.	.	.	100
Cochlearia groenlandica	fm	.	.	.	.	.	.	100
Lecidea ramulosa	lc	.	.	.	.	.	.	100
Orthothecium chryseum	bmp	.	.	.	.	10	.	100
Cladonia pocillum	lfr	.	.	.	.	10	.	100
Cetrariella delisei	lfr	.	.	20	.	.	.	100
Cerastium nigrescens v. laxum	fm	.	.	.	.	.	.	80
Fulgensia bracteata	lc	.	.	.	.	.	.	80
Saxifraga cernua	fe	.	.	.	5	.	.	80
Draba subcapitata	fm	.	.	.	.	.	20	90
Cirriphyllum cirrosum	bmp	.	.	.	.	.	.	70
Cerastium regelii	fm	.	.	.	.	10	.	70
Encalypta alpina	bma	.	.	.	.	.	.	60
Solorina bispora	lfo	.	.	.	.	.	.	60
Bryum rutilans	bma	.	.	.	.	.	.	60
Saxifraga cespitosa	fm	.	.	.	.	.	.	60
Distichium capillaceum	bma	.	.	.	.	30	.	80
Cetraria aculeata	lfr	.	.	.	.	.	20	70
Pohlia cruda	bma	.	.	.	.	40	.	80
Gowardia arctica	lfr	.	.	.	.	.	.	50
Saxifraga oppositifolia	fm	.	.	.	.	.	.	50
Cladonia symphycarpia	lfr	.	.	.	.	.	.	50
Stereocaulon rivulorum	lfr	.	.	.	.	.	.	50
Polytrichastrum alpinum	bma	.	.	.	30	10	60	100
Bartramia ithyphylla	bma	.	.	.	.	.	10	50
Callialaria curvicaulis	bmp	.	.	.	.	.	.	40
Campylium stellatum v. arcticum	bmp	.	.	.	.	.	.	40
Ditrichum flexicaule	bma	.	.	.	5	40	.	70
Protopannaria pezizoides	lc	.	.	.	5	.	.	40

4. Conclusions

1. Subzone A (Krenkel) is unique. The low floristic similarity between the Krenkel plots and those of the rest of the transect reflects the geographic isolation of Franz Jozef Land. The unique properties of subzone A vegetation include the relatively high cover of forbs, lichens, and biological soil crusts; the lack of all woody plants, sedges, and *Sphagnum* mosses; and the preponderance of cushion growth forms across all plant groups. ***Subzone A should be considered an endangered bioclimate subzone because of its small geographic extent and the likely strong impact that even small increases in the amount of summer warmth will have on species diversity and structure of the vegetation.***

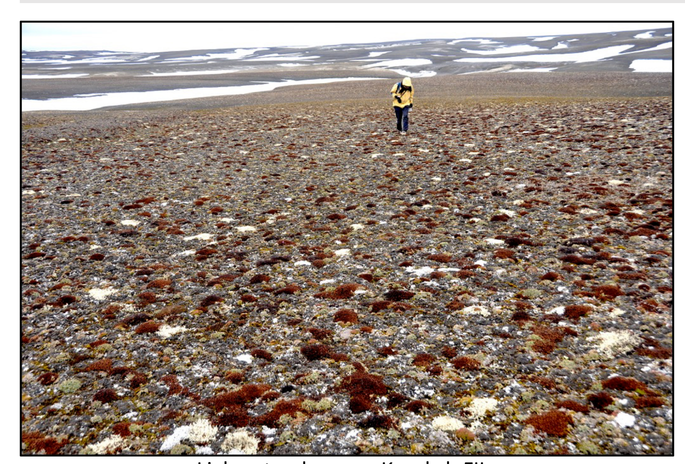
2. Vegetation response along the climate gradient varies according to plant growth forms. Cover and species richness of evergreen and deciduous shrubs increased with higher summer temperature. Graminoid and moss cover and diversity peaked in the middle part of the temperature gradient. Forbs and lichen cover peaked in subzone A.

3. Soil texture strongly effects a wide range of ecosystem properties. Within each subzone there is generally clear floristic separation of plots on loamy and sandy sites. The clearest trends of plant-growth-form cover and species richness with respect to summer warmth occurs on the loamy sites. The sandy sites were generally more heterogeneous and less stable.

4. Reindeer have a major effect on the vegetation. The only locations that were free of recent reindeer foraging were Nadym and Krenkel, and both these sites had high cover of lichens, indicating that reindeer at the other sites have greatly reduced the lichen cover. Comparison with results from a similar transect in North America indicate that the reindeer have had a long-term major impact to the shrub, graminoid and moss layers on the Yamal. Quantifying this effect is difficult because of lack of reindeer-exclusion areas.

5. There is a need for new high-level vegetation units in the middle part of the circumpolar Arctic. Vegetation units in the middle portion of the EAT bioclimate gradient display gradual floristic transitions between bioclimate subzones and are only weakly aligned with previously described Br.-Bl. classes. There is a need for new Br.-Bl. class corresponding to zonal acidic tundra in the middle part of Arctic bioclimate gradient. A formal association-level classification for the Yamal region should await a broader analysis that includes new data collected within the past few years.

6. The study has implications for Arctic climate change and ecosystem studies. The database of vegetation, soil, permafrost, and remote-sensing information from this study will aid remote-sensing interpretations and vegetation-change modeling along a full maritime Arctic climate gradient. The research sites are permanently marked and provide a baseline against which to measure future vegetation change. The data should prove useful for interpretations of change to a wide variety of ecosystem properties and functions, including shrub growth, permafrost changes, land-use changes and biodiversity. As arctic temperatures continue to increase, it will be important to continue ground-based measurements to document the consequences of changes seen in the remote-sensing data.


Lichen tundra near Krenkel, FJL


Reindeer and Nenets herders near Vaskiny Dachi


2010 expedition members at the Krenkel post office, Hayes Island, FJL

Presented at Arctic Science Summit Week in Arkhangelsk, Russia, 22-30 May 2019. Funding was mainly from the U.S. National Aeronautics and Space Administration, Land-Cover Land-Use Change Program (NASA LCLUC grants NNG6GE00A, NNX09AK56J, and NNX14AD90G) with additional support from the Russian Academy of Science, U.S. National Science Foundation Arctic Science Engineering and Education for Sustainability (NSF ArcSEES Award No. 1263854), Bureau of Ocean Energy Management (BOEM), and Slovak Academy of Science (VEGA award 2/0135/16). We especially thank Marina Leibman other members of the Earth Cryosphere Institute who organized the logistics for the EAT expeditions and made this research possible.

Walker, D. A., Epstein, H. E., Šibík, J., Bhatt, U., Romanovsky, V. E., Breen, A. L., et al. (2019). Vegetation on mesic loamy and sandy soils along a 1700-km maritime Eurasia Arctic Transect. *Applied Vegetation Science*, *22*(1), 150–167. doi: 10.1111/avsc.12401