THE 2011 EXPEDITION TO KHARP, SOUTHERN YAMAL PENINSULA REGION, RUSSIA

DATA REPORT

G.V. Frost, H.E. Epstein, D.A. Walker, G. Matyshak, and K. Ermokhina

Alaska Geobotany Center, University of Alaska
P.O. Box 757000, Fairbanks, AK USA 99775

Department of Environmental Sciences, University of Virginia
P.O. Box 400123, Charlottesville, VA USA 22904

May 2012

Funded by NASA Grant Nos. NNG6GE00A and NNX09AK56G

Citation: Frost, G.V., Epstein, H.E., Walker, D.A., Matyshak, G., & Ermokhina, K. 2012. The 2011 expedition to Kharp, southern Yamal region, Russia. Data report of the Alaska Geobotany Center, University of Alaska, Fairbanks, AK. 83 pp.

Members of the 2011 Kharp expedition. *Clockwise from upper left: Gerald "J.J." Frost, UVa; Howie Epstein, UVa; Ksusha Ermokhina, ECI; Roman Ivanov, ECI; and Gosha Matyshak, Lomonosov Moscow State University.*

ACKNOWLEDGEMENTS

We are greatly indebted to Marina Leibman at the Earth Cryosphere Institute (ECI) in Moscow for her tireless efforts in coordinating logistics for the Kharp expedition. We also thank Roman "Roma" Ivanov, ECI, who maintained a wonderful field camp and cheerfully supported our work. This research was funded by the NASA Land-Cover Land-Use Change (LCLUC) Initiative, Grant Nos. NNG6GE00A and NNX09AK56G.

Cover photo: Young alders growing on mineral-rich microsites at the centers of sorted-circles, Kharp study site.

ABSTRACT

This report summarizes the methods and results of field studies conducted 18 July-2 August, 2011 at the Kharp study site in the southern Yamal region, northwest Siberia, Russia. Kharp is located in a forest-tundra ecotone at the southern margin of the Arctic tundra biome, in the eastern foothills of the northern Ural Mountains (66.83ºN, 65.98ºE). Comparisons of high-resolution satellite imagery from 1968 and 2010 indicate widespread increases in alder (*Alnus fruticosa* ssp. *sibirica*) cover at the site. This finding is corroborated by pixel-based regression analysis of the Normalized Difference Vegetation Index (NDVI), derived from a Landsat imagery time-series spanning 1985-2011, that indicates strong, widespread increases in plant productivity ("greening") in alder shrublands. A brief field reconnaissance to Kharp in 2009 revealed that most of the alder expansion occurred in areas of patterned ground with abundant sorted-circles, and that shrub recruitment was closely linked to mineral-dominated microsites at the circle centers. The primary goals of field studies in 2011 were to (1) identify important environmental state-factors associated with recent shrub expansion and greening; (2) determine whether alder expansion at Kharp is facilitated by cryogenic disturbance processes in patterned ground; (3) determine whether the distribution of older shrubs can be explained by shrub recruitment on sorted-circle microsites; (4) characterize changes to permafrost thermal regime that occur during shrubland development; and (5) characterize the changes in plant community composition that occur during shrubland development.

Field methods used in 2011 differ from previous expeditions along the Eurasian Arctic Transect, which had different objectives (Walker et al. 2008, 2009a, 2009b, 2011). Studies at Kharp primarily occurred along transects established in alder-free tundra and in alder shrublands belonging to one of three categories of shrubland stand-age: recent colonization zones, mature shrublands (shrubs evident in 1968 imagery, and most shrubs ≥ 2 m height), and paludified shrublands (very old shrubs growing on organic-dominated soils). Data collected at each transect include (1) measurements of soil surface organic depth and mineral horizon thickness taken at uniform intervals along the transects, and at alders; (2) physical attributes of shrubs including age-class and canopy height; (3) soil descriptions at circle and inter-circle microsites; and (4) relevé data including plant species cover-abundance. At a subset of the transects, we also (1) mapped the locations of alders and patterned ground microsites; (2) measured Leaf Area Index (LAI); and (3) recorded daily time-series of near-surface soil temperature at different patterned ground microsites (with and without alder) using iButton dataloggers.

Appendices to this report include: Appendix A – Names and addresses of the participants in the expedition; Appendix B – Soil descriptions for the transects; Appendix C – Relevé data; and Appendix D – Bird species list.

This research is funded by NASA's Land-Cover Land-Use Change (LCLUC) Initiative (Grant nos. NNG6GE00A and NNX09AK56G). It contributes to NASA's global-change observations regarding the consequences of declining Arctic sea ice and the greening of terrestrial vegetation that is occurring in northern latitudes. The work is also part of the Northern Eurasia Earth Science Partnership Initiative (NEESPI), and addresses questions regarding the local and hemispheric effects of anthropogenic changes to land-use and climate in northern Eurasia.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

INTRODUCTION

The 2011 expedition to Kharp was the fifth and final expedition of the project entitled "Land-Cover and Land-Use Changes on the Yamal Peninsula, Russia", funded by the NASA Land-Cover and Land-Use Change (LCLUC) initiative. One of the primary goals of the Yamal LCLUC project is to examine trends in vegetation, soils, permafrost characteristics, and surface spectral properties along the Eurasian Arctic Transect (EAT), which spans the entire Arctic bioclimate gradient in northwest Russia. The Kharp site is located in an ecotonal area at the southern margin of the Arctic tundra biome (Figure 1). Data reports from the previous Yamal expeditions (Walker et al. 2008, 2009a, 2009b, 2011) are available on-line at: http://www.geobotany.uaf.edu/yamal/reports.

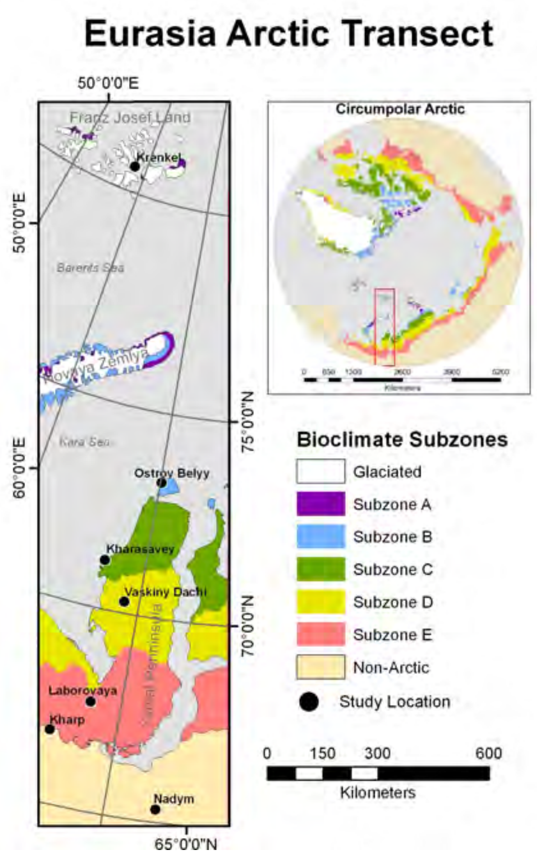


Figure 1. Map of the Yamal Peninsula region showing location of Kharp (lower left) and other study sites along the Eurasia Arctic Transect (EAT). Bioclimate subzones are according to CAVM Team (2003).

Kharp is the primary study site of G. V. Frost's dissertation research at the University of Virginia. While evaluating 1960s-era Corona satellite imagery for use in studies of boreal tree and shrub expansion in Low Arctic tundra, it so happened that the first imagery reviewed was the Kharp study area. Comparison with contemporary imagery indicated that alder shrubland extent has increased markedly at the site in recent decades (Figure 2). This finding is corroborated by pixel-based linear regression of the Normalized Difference Vegetation Index (NDVI), derived from Landsat time-series spanning 1985-2010, that indicate strong increases in plant productivity ("greening"), especially in association with alder shrublands (Figure 3).

During the 2009 expedition to Ostrov Belyy, we learned that the Kharp study site is within easy hiking-distance of the road linking the towns of Kharp and Labytnangi. Several members of the 2009 expedition were able to make a brief field reconnaissance of the site after completion of studies at Ostrov Belyy (see Walker et al. 2009b). During this ~5-hour reconnaissance, it became clear that most alder expansion occurred in areas of patterned-ground, with most young shrubs growing on mineral-rich microsites on the centers of sorted-circles (see front cover). Additionally, the widespread presence of larch snags and buried charcoal in the soil indicated that most of the expansion had taken place within an old burn (≥ 150 years ago). The linkage between alder expansion and two disturbance agents—cryogenic disturbance in patterned-ground at the meter-scale, and wildfire at the landscape-scale—was compelling and it was clear that the site merited further investigation. An expedition

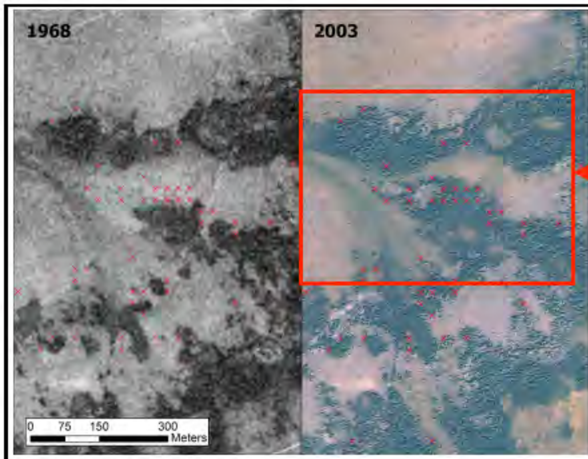


Figure 2. Comparison of 1968 Corona (left) and 2003 QuickBird (right) satellite imagery showing alder shrubland expansion in vicinity of transects K-T04 and K-T05. Red markers denote points with new shrub cover.

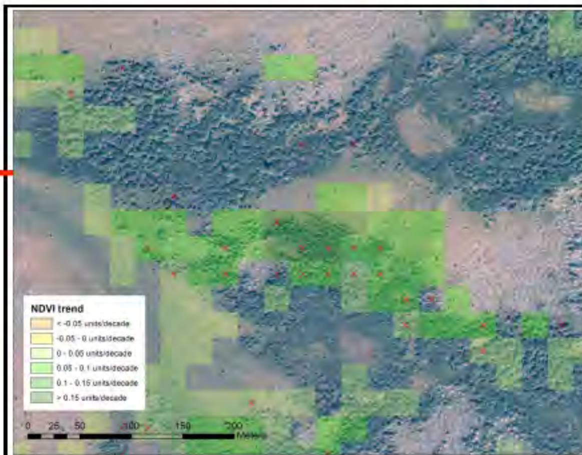


Figure 3. Detail of area shown in Figure 2, showing Landsat pixels with highly significant (p<0.01) linear NDVI trends derived from 12 Landsat scenes from 1985-2009. Red markers denote points with alder cover that developed after 1968.

to Kharp was initially planned for summer 2010, but was postponed because it was not possible to combine work at Kharp with the expedition to Franz Josef Land. Instead, a dedicated expedition to Kharp was undertaken 18 July-2 August, 2011, with a relatively small field crew of five people.

Field methods used at Kharp differ from the previous expeditions to the Yamal region, because study objectives in 2011 were focused more narrowly on the recent history of alder shrubland expansion and increased vegetation productivity at the site. Our objectives at Kharp were to (1) identify important environmental state-factors associated with recent shrub expansion (determined from 1968/2003 high-resolution imagery) and greening (determined from the Landsat NDVI time-series); (2) determine whether alder expansion at Kharp is facilitated by cryogenic disturbance processes in patterned ground; (3) determine whether the distribution of older shrubs can be explained by shrub recruitment on sorted-circle microsites; (4) characterize changes to permafrost thermal regime that occur during shrubland development; and (5) characterize alder shrubland communities and the impacts of shrubification on plant community composition.

STUDY SITE

General description of Kharp site

The Kharp study area is approximately 64 km^2 in size (Figure 4). Terrain in the area varies from ~200-300 m elevation and mostly consists of gently-sloping low hills separated by small alluvial valleys. The study area is bound by an alpine ridge to the north, the S'Ob River valley to the west, the Ob River lowlands to the south, and the Khamyiy River to the east. Ozero Zholte ("Yellow Lake") is a prominent landmark at the center of the study site.

Access and logistics at Kharp are straightforward compared to most of the other field sites investigated along the Eurasian Arctic Transect (EAT). Our group—three Russians and two Americans (see inside cover)—first flew from Moscow to the city of Salekhard, regional center and capital of the Yamalo-Nenets Autonomous Okrug (YNAO). The Kharp site is located

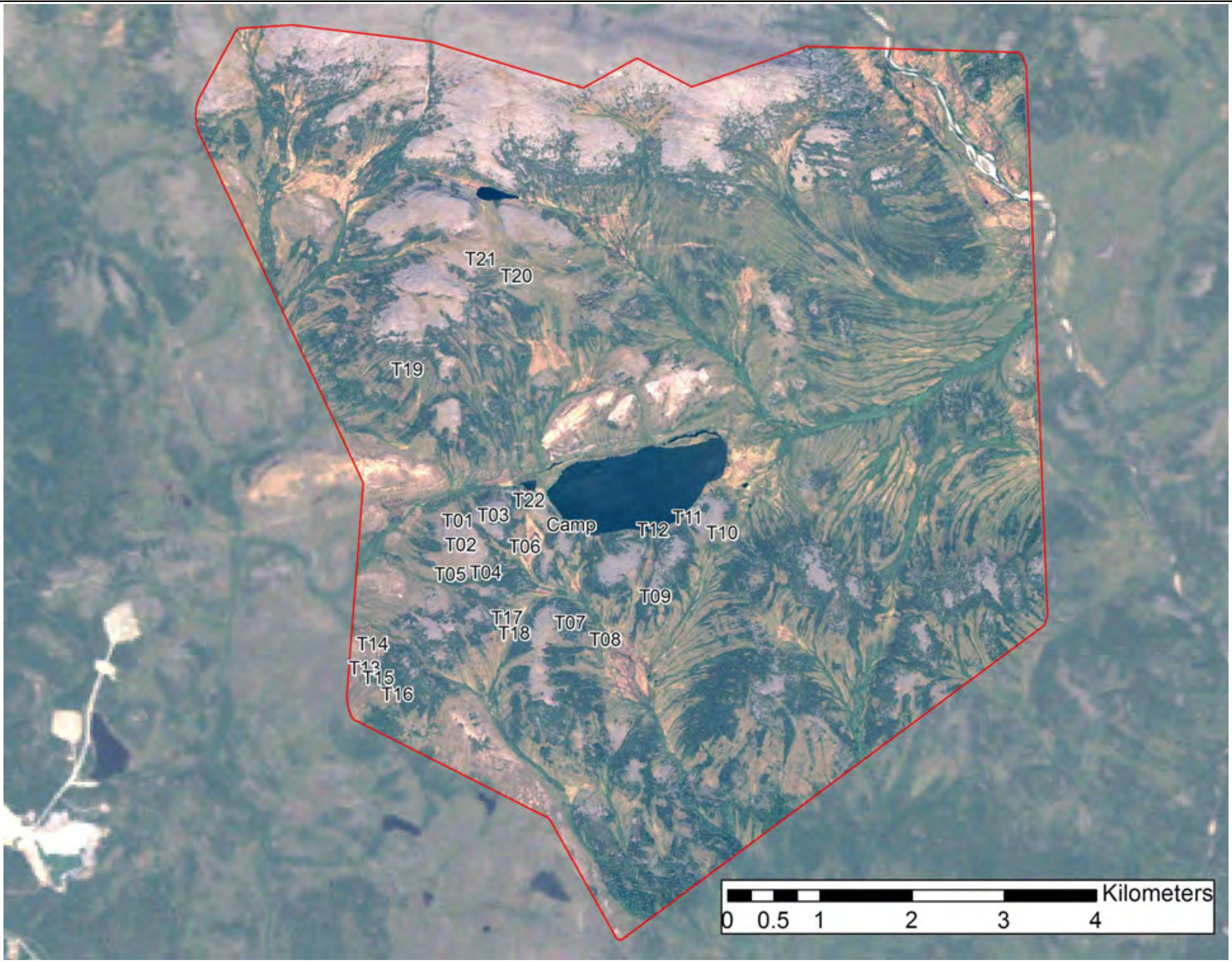


Figure 4. QuickBird image of Kharp study site showing locations of transects and field camp.

only ~35 km northwest of Salekhard. We reached the town of Kharp using local taxis on good roads, including a ferry crossing of the Ob River. At Kharp, we hired a "vezdehod"—a large tracked vehicle resembling an armored personnel carrier—to transport us and our camp outfit about 7 km to the field site (Figure 5). The vezdehod driver was able to take us to the exact spot that we had suggested on the map as a good field camp site: a central, upland location in close proximity to Ozero Zholte (water source), with good visibility and exposure to wind (insect relief) (Figure 6).

Surficial geology

The surficial geology of the Kharp region includes several distinctive rock types that are associated with the complex geologic history of the Ural Mountains and adjacent fold-thrust belts. Ultramafic igneous rocks of early Paleozoic age are common throughout most of the study area, while metamorphosed sedimentary rocks of Proterozoic age are common at higher elevations along the northern margin of the study area (see Harrison et al. 2008). The prevalence of ultramafic parent materials at Kharp has significant implications for soil formation and cryogenic processes, because mafic minerals tend to weather directly to silt- and clay-sized particles. Fine-grained soils are highly susceptible to cryoturbation and differential heave during freeze-thaw cycles (Peterson and Krantz 2003, Daanen et al. 2008), and partly explain the ubiquity of

Figure 5. Scenes of the trip to field camp site using 'vezdehod' tracked vehicle. Clockwise from upper left: J.J., Ksusha, and Roma ready for departure; vezdehod stuck on steep bank of S'ob River; replacing the left track after being towed out of river by another vezdehod ("quickly broken, quickly repaired"); Sergei (vezdehod driver) after arrival at field camp.

active patterned-ground features, such as circles at Kharp. Gabbros, which are comparatively resistant to weathering, are also common and underlie the ultramafic deposits (Figure 6). This often results in the co-occurrence of abundant frost-shattered blocks and the fine-grained mineral soils derived from overlying ultramafic rocks. The co-occurrence of these materials explains in part the very sharp microsite contrasts in soil characteristics within patterned-ground at the site.

Geomorphology and permafrost

Sorted patterned-ground features are common and widespread. The size and spacing of features vary across the study area, but typically occur at one of two scales: large, sorted polygons ~2 m in diameter and spaced ~4 m apart (Figure 6); and small, high-density circles ~70 cm in diameter and spaced ~2 m apart (Figure 7). The margins of sorted polygons are very blocky and often remain barren in exposed locations, while sorted-circles are fringed by narrow, stony inter-circles that are covered by vegetation (primarily dwarf shrubs).

Climate

The Kharp area experiences a continental sub-Arctic climate regime that is moderated to some extent by maritime influences

Figure 6. Kharp field camp and surroundings. Clockwise from upper left: kitchen and gear tent; crew preparing to depart camp for field work; overview of field campsite with Ozero Zholte in background; gear tent being buffeted by wind on 26 July; camp scene during storm of 26 July showing J.J.'s collapsed sleeping tent; Roma in the kitchen.

associated with the North Cape current. Long-term meteorological observations

(1883-2010) at Salekhard, on the Ob River about 35 km southeast of Kharp, indicate a mean annual temperature of -6.3ºC and a mean summer (June-July-August) (JJA) temperature of 11.2ºC. Mean annual precipitation for 1966-2010 was 448 mm. Conditions at Kharp are cooler and probably somewhat moister due to the site's higher

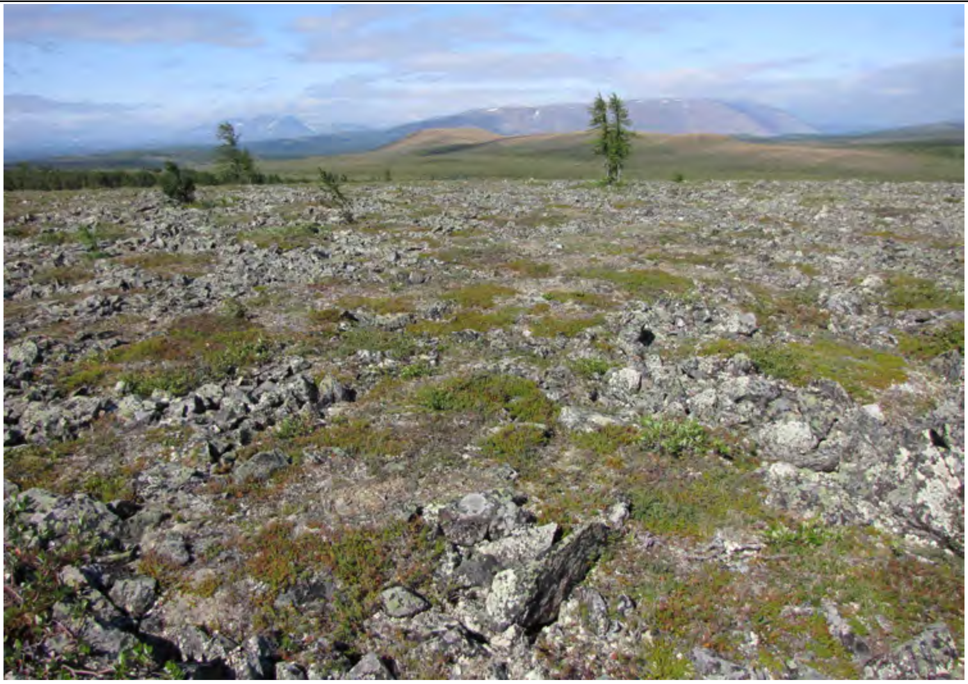


Figure 7. Typical network of large sorted polygons with blocky margins. Polygons are ~2-3 m across and are well-vegetated; the margins are blocky and vegetation mostly consists of crustose lichens. Ultramafic rocks, which appear red (oxidized) in foothills and the Ural Mountains (background), readily weather into very fine-grained materials that co-occur with resistant gabbros (gray frost-shattered rocks, foreground).

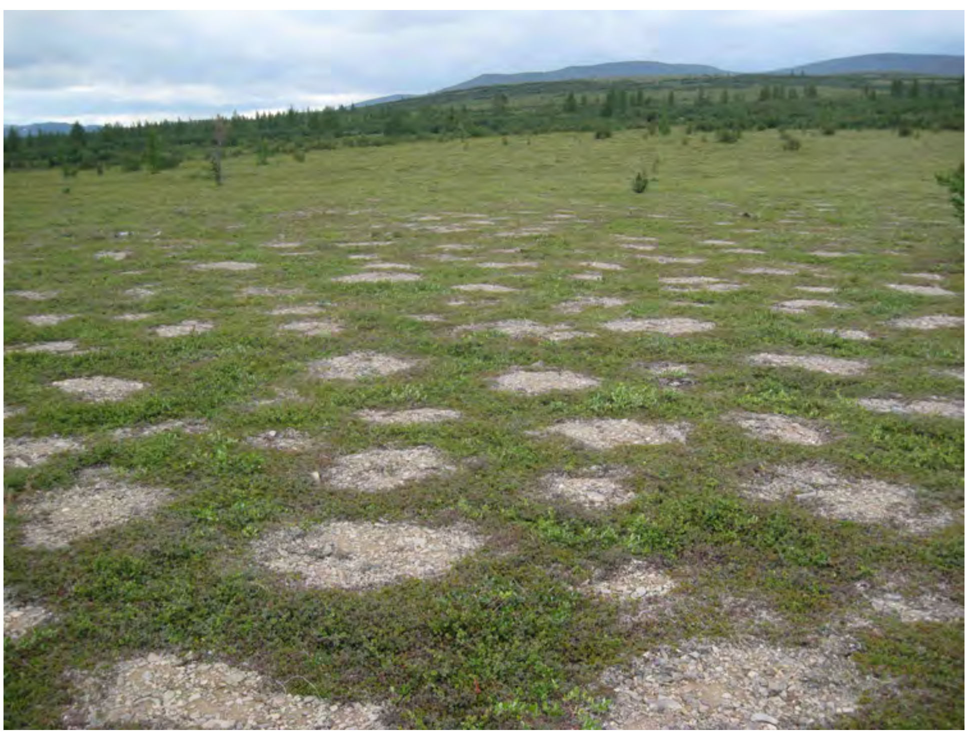


Figure 8. Typical network of small sorted-circles at Kharp site. The semi-barren circles are about 75 cm in diameter, with regular spacing between circle centers of about 1.5 m. Vegetation at inter-circles is primarily dwarf birch and ericaceous shrubs.

elevation and close proximity to the Urals.Mean growing season temperatures at Kharp are near 10ºC, an important threshold value that largely explains the position of the circumpolar treeline. Therefore, small changes in climate are likely to have disproportionate impacts to growth and reproduction of boreal vegetation at the site. Time-series of mean JJA temperature for the period 1965-2010 are shown in Figure 9 for Salekhard and two other stations in the region—Ra-Iz, at high elevation (880 m) in the Ural Mountains ~ 14 km west of Kharp; and Vorkuta, on the west side of the Urals ~ 110 northwest of Kharp. Linear trends are similar at all three sites and indicate a ~1.5ºC increase in JJA temperature since 1965. Thus, it is likely that climate warming has been a contributing factor to shrubland expansion at the site since 1968.

Vegetation

Common vegetation types include dwarf shrub tundra, dominated by dwarf birch (*Betula nana*) and ericaceous shrubs <30 cm in height; low scrub, dominated by dwarf birch and willows (*Salix* spp.); tall alder scrub, strongly dominated by alder; sparse woodlands of Siberian larch (*Larix sibirica*); and, in wet areas, sedge-moss meadows dominated by *Carex* spp., *Rubus chamaemorus*, and *Sphagnum* spp. Dwarf shrub tundra is especially widespread on exposed uplands and hilltops; this type is common in inter-circle areas among small, active sorted-circles. Low scrub is widespread on lower slopes and often forms conspicuous stringers along small drainages and watertracks. Tall alder scrub is most common on slopes and upland plateaus; canopy-cover is quite variable and often appears to depend on the density of patterned-ground features. Larch woodlands are most common on hillslopes in the southern part of the study area; woodlands tend to have heavy shrub cover in the understory, although scattered larches sometimes occur on exposed sites.

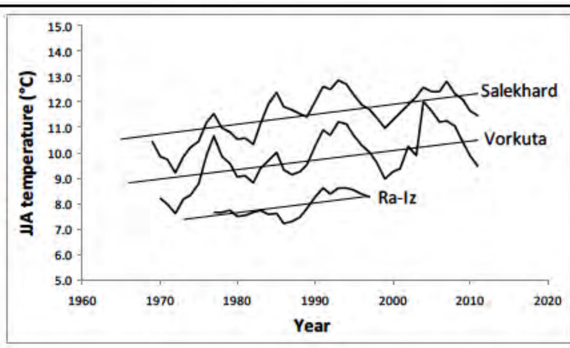


Figure 9. Five-year moving averages and linear trendlines of mean June-July-August (JJA) temperature for Salekhard, Vorkuta, and Ra-Iz meteorological stations, 1965-2011.

Disturbance history

In 2009, we observed abundant evidence of two disturbance agents that have strongly affected biophysical attributes of the landscape at Kharp: differential frost-heave and wildfire. These two forms of disturbance act at very different temporal and spatial scales, but have both had strong and interacting effects on vegetation, soil properties, and geomorphology. Differential frost-heave occurs on an annual basis, producing sharp microsite contrasts in soil conditions and disturbance regime at the meter-scale in areas of patterned-ground (see Peterson and Krantz 2003). The ubiquity of conspicuous, barren circles across the study area offer clear evidence of an active, on-going cryoturbation regime at Kharp. Wildfire, on the other hand, occurs episodically at much larger spatial scales. Although we were not able to determine the date of the last wildfire, tree-ring aging of live trees growing in severe burn areas indicate that the fire occurred at least 190 YBP. This fire was severe enough to burn off the entire surface organic mat in many areas, and vegetation has still not recovered from the fire in many places. The wide distribution of fire-killed larch snags in areas that currently lack live trees, particularly on exposed hilltops and in wet, paludified lowlands, indicates that tree cover was formerly much more extensive. One explanation for this is that extensive woodlands developed during the Medieval Warm Period, but have not fully regenerated after burning during the Little Ice Age (LIA).

In addition to its effects on vegetation, the wildfire presumably affected the cryogenic disturbance regime by burning off a great deal of surface organic matter. The removal of this insulating material restored sharp microsite thermal gradients that drive differential heave in areas of patterned ground, re-activating sorted-circles across the site.

METHODS

Our observations during field reconnaissance on our first full day at Kharp clearly indicated that areas of patterned ground were "hotspots" of alder expansion (evident from 1968 Corona imagery) and greening (evident in spatially-explicit linear regressions of 1985-2010 Landsat NDVI time-series). We therefore developed a field-sampling protocol to document and quantify the relationship between alder shrub distribution and sorted-circle microsites, and the effects of shrubland development on biophysical properties of the landscape including plant canopy structure, active layer thermal regime, and plant community composition.

Transect selection

We established a series of transects according to four categories of alder presence/absence and shrubland stand-age: tundra (no alders), alder colonization zone, mature shrubland, and paludified shrubland (Figure 10). Tundra transects were placed in alder-free areas of patterned ground adjacent to colonization zones, and these transects

Figure 10. Transects in (top to bottom): tundra (foreground), colonization zone, mature shrubland, and paludified shrubland.

usually spanned both colonization zones and neighboring mature shrublands. Transects in alder colonization zones were established along the margins of alder thickets that had not developed until after 1968 (according to Corona imagery). Vegetation and geomorphic features in colonization zones were very similar to the tundra transects, except that circle centers were dominated by young alders (<30 cm tall). Mature shrublands were dominated by large alders (typically >2 m height) that were already evident in 1968 imagery, although seedlings were often common. Paludified shrublands were characterized by open stands of very old alders, often with low vigor (e.g., with many moribund or dead ramets), occurring on wet soils with a thick surface layer of organic material; seedlings were very scarce or absent in paludified shrublands. Colonization zones and mature shrublands almost always had significant NDVI greening trends in Landsat time-series, with the strongest greening in colonization zones; trends tended to be much weaker in tundra and absent in paludified shrublands.

Transect and alder properties

Transect size varied depending on the density of alders and patterned ground features (20-100 m length, 4-10 m width) (Table 1); we established larger transects where alders and/or PGFs occurred at low densities. We recorded systematic measurements of soil organic depth, thaw depth/depth to rock, and Leaf Area Index (LAI) at intervals of 1 m along the transect centerline. Transects were placed in areas with homogeneous vegetation and geomorphology, so we assumed that the systematic measurements reflect the relative extent of circle and inter-circle microsites. We also recorded soil organic depth and thaw depth/depth to rock at the base of each alder, regardless of size, within each transect. We also measured the length of the dominant ramet of each alder. From the soil profile measurements, we calculated the total thickness of mineral soil horizons (thaw depth/depth to rock minus surface organic depth). Soil profile measurements were made with a steel thaw probe, and LAI was measured using a LAI-2000 Plant Canopy Analyzer (LI-COR Biosciences, Lincoln NE, USA). Because the Kharp site is very rocky, most thaw probe measurements were of depth to rock, rather than thaw depth.

Transect mapping

We mapped the locations of alders and the centers of exposed sorted-circles within a subset of the transects using X/Y coordinates; coordinates were measured relative to the transect centerline using a hand tape. When possible, we visually recorded the microsite from which alders emerged (e.g., center of active circle, margin of active circle, inter-circle) (Figure 11). We also measured the height of the dominant ramet of each individual alder, and assessed shrub vigor on a scale of 0 (dead) to 4 (healthy) based on the presence of moribund and/or dead ramets, and other qualitative characters such as the density of annual leaf-bud scars on small twigs (Figure 12).

Figure 11. Young alder growing on active circle showing exposed, deformed root resulting from differential heave.

Figure 12. Alder showing numerous annual leaf-bud scars on small twigs, characteristic of old, slow-growing shrubs in paludified shrublands.

Soil descriptions

We established soil pits immediately adjacent to most of the transects. Nearly all transects had strong microsite variation in soil properties (Figure 13), so we usually established two soil pits, one at circles and one at inter-circles. In paludified shrublands, circles and inter-circles were difficult to distinguish so we established soil pits on and hummocks (where alders tended to occur) inter-hummocks. We collected a mineral soil sample at each pit using a standard USDA soil can. Samples were submitted to the USDA field station at Palmer, AK for physical and chemical analysis (see Walker et al. 2009a). See Appendix 2 for detailed soil description methods.

Soil temperature profiles

We embedded 6-10 Thermochron iButton dataloggers (Embedded Data Systems LLC, Lawrenceburg, KY, USA) to measure microsite variation in soil temperature along a subset of the transects (generally the same ones used for alder/PGF mapping). Dataloggers were distributed at the base of alders (within circles on tundra transects) and in alder-free inter-circles. All iButtons were emplaced at a depth of 5 cm; an additional iButton was placed in a shaded location at a height of 2 m to record air temperature at each transect. Soil temperature measurements were collected at 4-hour intervals; we used 4-hour intervals because we initially intended to retrieve them in June 2012, following the TICOP conference at Salekhard. We collected a total of five days of concurrent data for all transects (27 July-1 August), although observations periods were longer for some transects as not all iButtons were deployed on the same day.

Relevés

We established relevés at most transects. The number of relevés per transect ranged from 2 to 9 (Table 1). All relevés were 5x5 m in size and were centered along the transect centerline. At each relevé, we recorded a complete species list and assigned a Braun-Blanquet cover-abundance score for each species. We also visually estimated the percent-cover of each plant functional type: tree, tall shrub (>1.5 m), low shrub (30 cm–1.5 m), dwarf shrub (≤ 30 cm), sedge, grass, forb, moss, and lichen. Each relevé was permanently marked with an orange pin-flag and an aluminum tag

Figure** 13. **Soil pit at sorted-polygon near transect T-06. Mineral soils at the circle are very fine-textured and lack coarse fragments. Inter-circles are composed of frost-shattered blocks of gabbro.

labeled with the transect number and a unique, sequential identifier (e.g., K-T01-01). We also established relevés in a few common vegetation types that lacked alder, including some that had strong significant trends in NDVI (positive and negative). Results from relevés are summarized in Appendix 3.

RESULTS

Transect attributes

Table 1. Summary of transect attributes, Kharp study area.

Transect ID	Stage	PGF type	Length (m)	Width (cm)	Number of relevés	Number of iButtons	Mapping (y/n)	LAI (y/n)	Soil pit (y/n)	Notes
K-T01	colonization	sorted-circles	50	5	3	6	y	y	y	Mapped alders on first 20 m of transect; relevés centered at 2.5, 25, and 47.5 m.
K-T02	chronosequence	variable	70	n/a	9	12	n	y	y	Transect spans tundra, colonization zone, and mature shrubland.
K-T03	colonization	sorted-polygons	50	5	3	-	y	y	y	Relevés centered at 2.5, 25, and 47.5 m.
K-T04	colonization	sorted-circles	50	4	3	9	y	y	y	Mapped alders on first 20 m of transect; relevés centered at 2.5, 25, and 47.5 m.
K-T05	chronosequence	variable	68	n/a	7	8	n	y	y	Transect spans tundra, colonization zone, and mature shrubland; relevés at 0, 20, 30, 40, 50, 60, and 68 m.
K-T06	colonization	sorted-polygons	50	5	3	-	y	y	y	Relevés centered at 2.5, 25, and 47.5 m.
K-T07	paludified	hummocks	100	8	6	12	y	y	y	Relevés centered at 2.5, 20, 40, 60, 80, and 97.5 m.
K-T08	mature	sorted-polygons	50	8	3	-	y	y	y	Relevés centered at 2.5, 25, and 47.5 m.
K-T09	paludified	hummocks	100	8	5	-	y	y	y	Relevés centered at 2.5, 25, 50, 75, and 97.5 m.
K-T10	mature	sorted-polygons	50	8	3	6	y	y	y	Relevés centered at 2.5, 25, and 47.5 m.
K-T11	colonization	irregular sorted-circles	25	n/a	2	-	n	n	y	Relevés centered at 5 and 20 m.
K-T12	colonization	blockfield	25	n/a	2	-	n	n	y	Relevés centered at 10 and 40 m.
K-T13	colonization	irregular sorted-circles	25	n/a	2	-	n	n	y	Relevés centered at 5 and 20 m.
K-T14	paludified	hummocks	25	n/a	2	-	n	n	y	Relevés centered at 5 and 20 m.
K-T15	colonization	irregular sorted-circles	25	n/a	2	-	n	n	y	Relevés centered at 5 and 20 m.
K-T16	colonization	irregular sorted-circles	25	n/a	2	-	n	n	y	Relevés centered at 5 and 20 m.

Transect ID	Stage	PGF type	Length (m)	Width (cm)	Number of relevés	Number of iButtons	Mapping (y/n)	LAI (y/n)	Soil pit (y/n)	Notes
K-T17	colonization	sorted-circles	25	n/a	-	-	n	n	n	
K-T19	paludified	hummocks	50	n/a	-	-	n	n	n	
K-T20	colonization	sorted-polygons	25	n/a	-	-	n	n	n	
K-T21	mature	sorted-polygons	50	n/a	-	-	n	n	n	
K-T22	colonization	sorted-circles	20	4	-	-	y	n	n	Mapped alders in 20x4 m area.

Table 2. Locations and elevations of transects and relevés. Locations are given in decimal degrees (ddd.ddddd). Datum is WGS1984. Note that GPS locations were not recorded for all relevés; see Table 1 for locations of these relevés along the transects.

Description	North	East	Elev (m)	Description	North	East	Elev (m)
Field Camp	66.83150	65.96150	235	K-T09-75	66.82114	65.99346	216
K-T01-0	66.82954	65.94572	255	K-T09-100	66.82092	65.99352	212
K-T01-12.5	66.82964	65.94562	255	K-T10-0	66.82764	66.00167	230
K-T01-20	66.82970	65.94558	260	K-T10-12.5	66.82754	66.00161	230
K-T01-37.5	66.82984	65.94542	252	K-T10-25	66.82740	66.00154	229
K-T01-50	66.82994	65.94531	257	K-T10-37.5	66.82731	66.00150	229
K-T01-Pit	66.82989	65.94472	252	K-T10-50	66.82720	66.00144	229
K-T01-R1	66.82993	65.94535	251	K-T11-0	66.82906	65.99809	231
K-T01-R2	66.82974	65.94552	253	K-T11-12.5	66.82895	65.99816	228
K-T01-R3	66.82956	65.94569	255	K-T11-25	66.82884	65.99826	231
K-T02-R1	66.82972	65.94535	255	K-T12-0	66.82805	65.99346	233
K-T02-R2	66.82977	65.94572	249	K-T12-25	66.82783	65.99358	232
K-T02-R3	66.82981	65.94587	257	K-T12-50	66.82760	65.99368	238
K-T02-R4	66.82982	65.94616	248	K-T13-0	66.81832	65.92109	223
K-T02-R5	66.82985	65.94629	252	K-T13-12.5	66.81823	65.92121	223
K-T02-R6	66.82988	65.94644	250	K-T13-25	66.81814	65.92131	226
K-T02-R7	66.82991	65.94655	252	K-T14-0	66.81811	65.92298	232
K-T02-R8	66.82992	65.94665	254	K-T14-12.5	66.81803	65.92311	236
K-T02-R9	66.82996	65.94676	255	K-T14-25	66.81794	65.92328	237
K-T03-0	66.82995	65.94821	261	K-T15-0	66.81477	65.92385	227
K-T03-50	66.83027	65.94739	254	K-T15-12.5	66.81474	65.92410	225
K-T03-R1	66.83001	65.94814	265	K-T15-25	66.81473	65.92438	227
K-T03-R2	66.83012	65.94782	255	K-T16-0	66.81298	65.92837	227
K-T03-R3	66.83026	65.94744	254	K-T16-12.5	66.81303	65.92865	227
K-T04-0	66.82469	65.94301	247	K-T16-25	66.81308	65.92892	226
K-T04-10	66.82466	65.94323	245	K-T17-0	66.82001	65.95631	228
K-T04-20	66.82462	65.94341	247	K-T17-12.5	66.81997	65.95657	231
K-T04-30	66.82457	65.94362	249	K-T17-25	66.81994	65.95684	230
K-T04-50	66.82452	65.94413	254	K-T18-0	66.81845	65.95790	229
K-T05-0	66.82483	65.94334	251	K-T18-12.5	66.81843	65.95819	230
K-T05-20	66.82464	65.94322	245	K-T18-25	66.81842	65.95849	227
K-T05-40	66.82446	65.94310	250	K-T19-0	66.84459	65.93502	279
K-T05-60	66.82431	65.94296	251	K-T19-12.5	66.84451	65.93485	275
K-T05-70	66.82423	65.94288	252	K-T19-25	66.84440	65.93469	273
K-T06-0	66.82697	65.96204	230	K-T19-37.5	66.84430	65.93455	271
K-T06-25	66.82679	65.96174	229	K-T19-50	66.84421	65.93435	269
K-T06-50	66.82662	65.96138	235	K-T20-0	66.85326	65.95244	312
K-T07-0	66.81921	65.97094	206	K-T20-12.5	66.85330	65.95269	315
K-T07-25	66.81920	65.97149	207	K-T20-25	66.85333	65.95298	315
K-T07-50	66.81921	65.97207	209	K-T21-0	66.85481	65.95382	309

Table 2. (Continued).

Description	North	East	Elev (m)	Description	North	East	Elev (m)
K-T07-75	66.81919	65.97263	207	K-T21-12.5	66.85486	65.95409	307
K-T08-0	66.81774	65.97297	199	K-T21-25	66.85488	65.95435	307
K-T08-25	66.81753	65.97294	198	K-T21-37.5	66.85490	65.95464	307
K-T08-50	66.81730	65.97291	196	K-T21-50	66.85492	65.95491	307
K-T09-0	66.82180	65.99326	218	K-T22-0	66.83136	65.95921	234
K-T09-25	66.82159	65.99330	217	K-T22-10	66.83135	65.95942	234
K-T09-50	66.82137	65.99340	214	K-T22-20	66.83133	65.95963	233

Transect soil properties by microsite

Table 3. Means and standard deviations of surface organic thickness (cm) and mineral horizon thickness (cm), and number of observations, for systematic transect measurements and alders, by transect. Standard deviations are given in parentheses.

Transect	Stage	Mean organic depth (cm)		Mean mineral thickness (cm)		n	
		Transect	Alders	Transect	Alders	Transect	Alder
K-T01	colonization	7.2 (6.3)	1.4 (1.4)	8.9 (12.5)	31.3 (14.5)	51	103
K-T02	variable	7.0 (4.6)	4.3 (3.4)	8.8 (11.9)	26.8 (14.2)	71	43
K-T03	colonization	1.8 (2.8)	2.1 (1.7)	3.0 (10.3)	25.7 (16.8)	51	18
K-T04	colonization	7.4 (5.5)	1.0 (1.9)	11.3 (14.8)	26.8 (14.0)	31	169
K-T05	variable	6.7 (5.6)	2.3 (2.9)	6.6 (11.3)	18.4 (11.8)	69	67
K-T06	colonization	2.0 (3.8)	2.0 (2.7)	3.3 (9.0)	24.6 (20.9)	51	40
K-T07	paludified	25.2 (7.6)	14.3 (4.6)	21.0 (19.0)	44.3 (15.9)	101	59
K-T08	mature	16.3 (8.9)	2.4 (2.5)	29.9 (24.4)	33.5 (22.8)	51	104
K-T09	paludified	17.9 (6.6)	13.3 (7.8)	25.5 (23.8)	38.5 (22.8)	101	55
K-T10	mature	14.2 (8.4)	1.3 (2.4)	22.0 (28.4)	45.9 (17.6)	51	181
K-T11	colonization	11.9 (8.2)	2.6 (2.2)	17.9 (18.0)	33.5 (16.3)	26	26
K-T12	colonization	0.8 (1.8)	2.7 (2.2)	0.1 (0.4)	10.5 (11.0)	26	26
K-T13	colonization	4.1 (3.8)	0.6 (0.8)	4.0 (7.0)	14.2 (8.4)	26	26
K-T14	paludified	16.2 (4.5)	15.2 (5.3)	9.5 (11.1)	17.8 (12.7)	26	26
K-T15	colonization	5.9 (4.2)	2.2 (1.5)	6.7 (17.2)	19.1 (13.4)	26	26
K-T16	colonization	7.2 (4.6)	3.8 (2.0)	5.4 (7.5)	10.1 (8.0)	26	26
K-T17	colonization	3.0 (4.1)	0.2 (0.4)	11.4 (14.7)	15.2 (9.9)	26	26
K-T18	colonization	3.7 (4.7)	0.2 (0.4)	6.2 (11.1)	23.7 (13.3)	26	26
K-T19	paludified	21.8 (5.6)	17 (5.2)	8.5 (12.6)	17.1 (14.4)	26	26
K-T20	colonization	13.9 (7.3)	3.6 (3.5)	24.1 (18.9)	42.0 (19.8)	26	26
K-T21	mature	11.7 (7.4)	3.9 (2.3)	12.6 (21.0)	21.7 (15.7)	26	26
K-T22	colonization	4.3 (3.8)	0.2 (0.5)	16.4 (13.9)	23.6 (11.0)	21	270
Grand total		11.1 (9.6)	3.0 (5.2)	13.5 (18.9)	28.9 (18.2)	935	1395

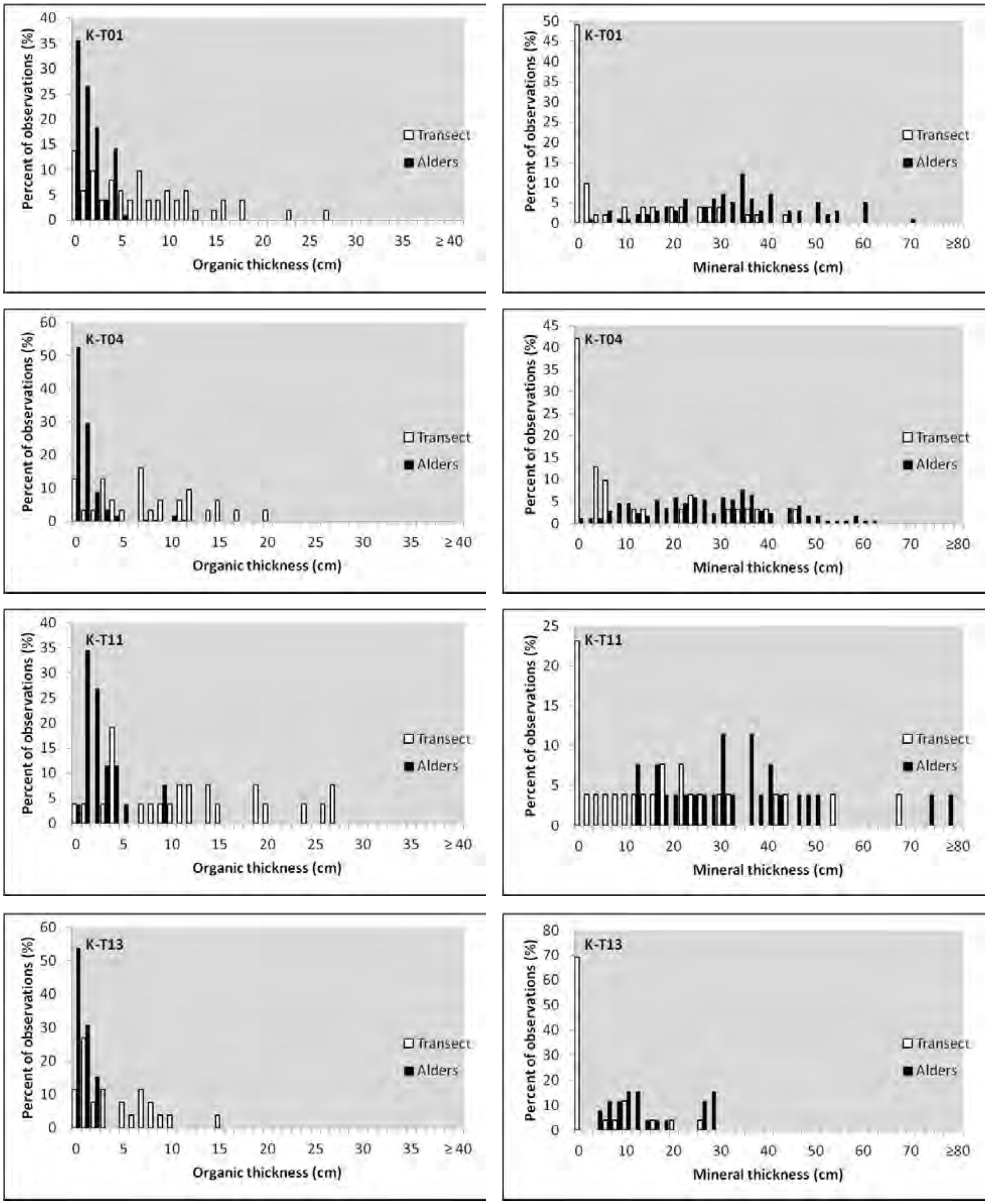


Figure 14. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements for four transects in alder colonization zones: K-T01, K-T04, K-T11, and K-T13. Mineral thicknesses are binned in 2-cm increments.

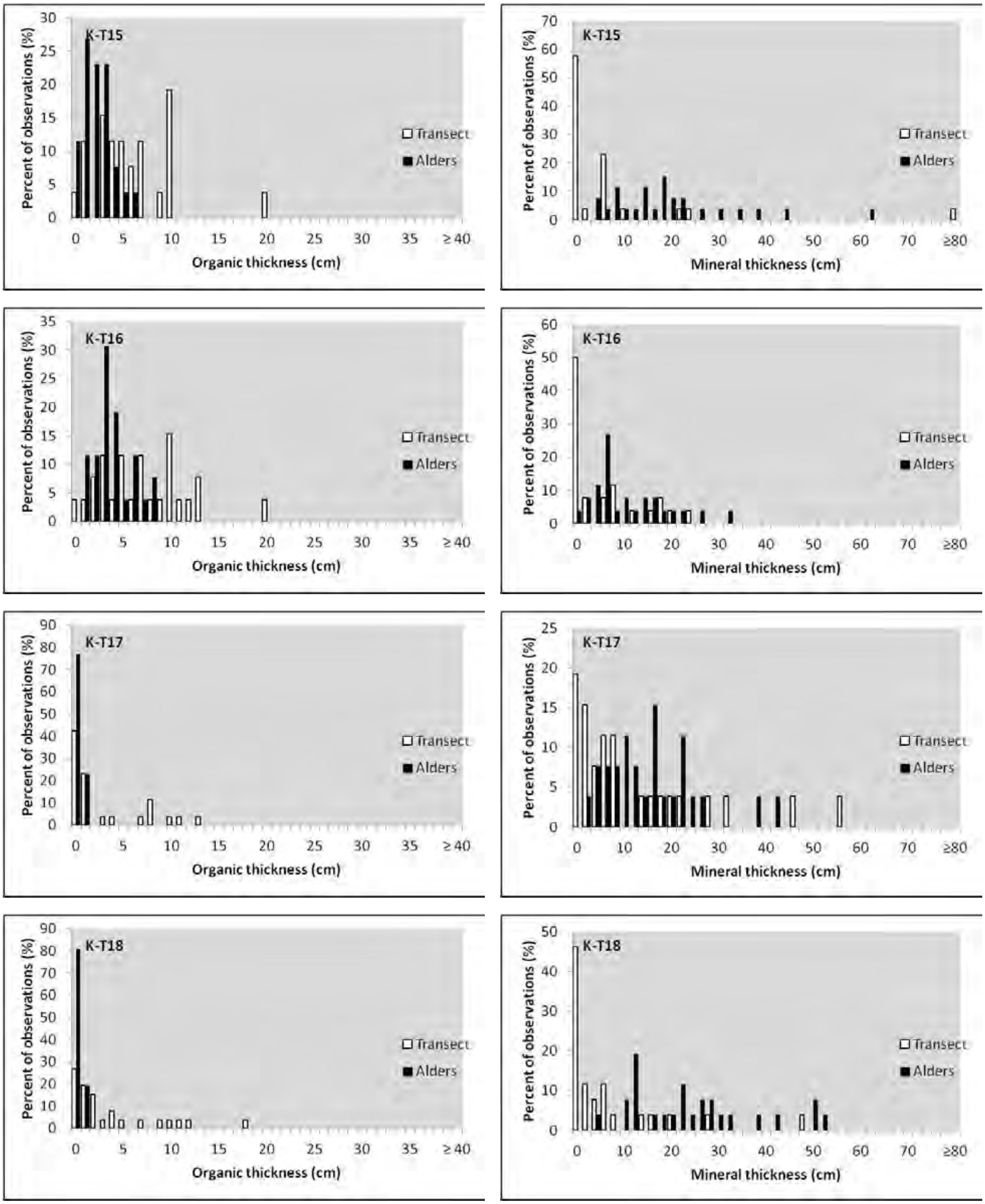


Figure 15. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements (cm) for four transects in alder colonization zones: K-T01, K-T04, K-T11, and K-T13. Mineral thicknesses are binned in 2-cm increments.

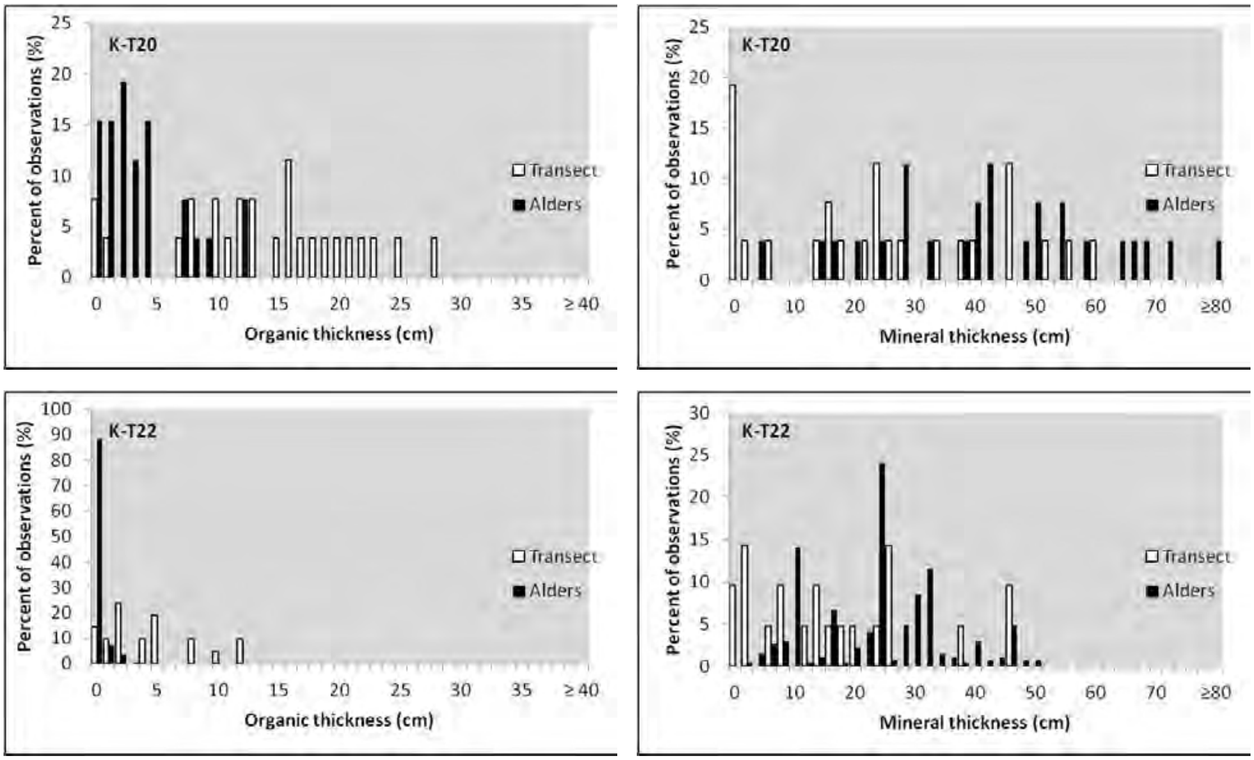


Figure 16. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements (cm) for two transects in alder colonization zones: K-T20 and K-T22. Mineral thicknesses are binned in 2-cm increments.

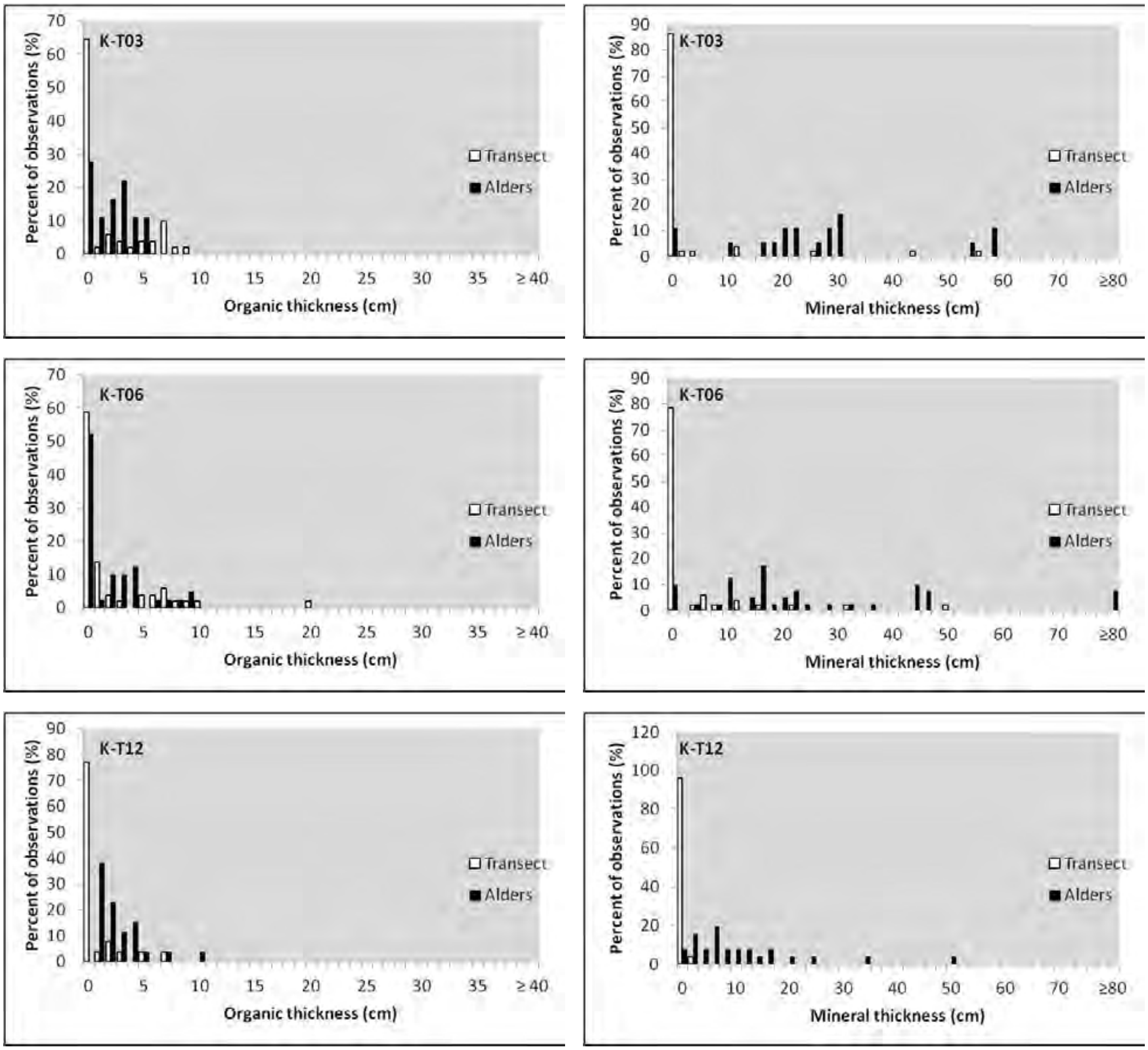


Figure 17. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements (cm) for three transects with very blocky inter-circles: K-T03, K-T06, and K-T12. Mineral thicknesses are binned in 2-cm increments.

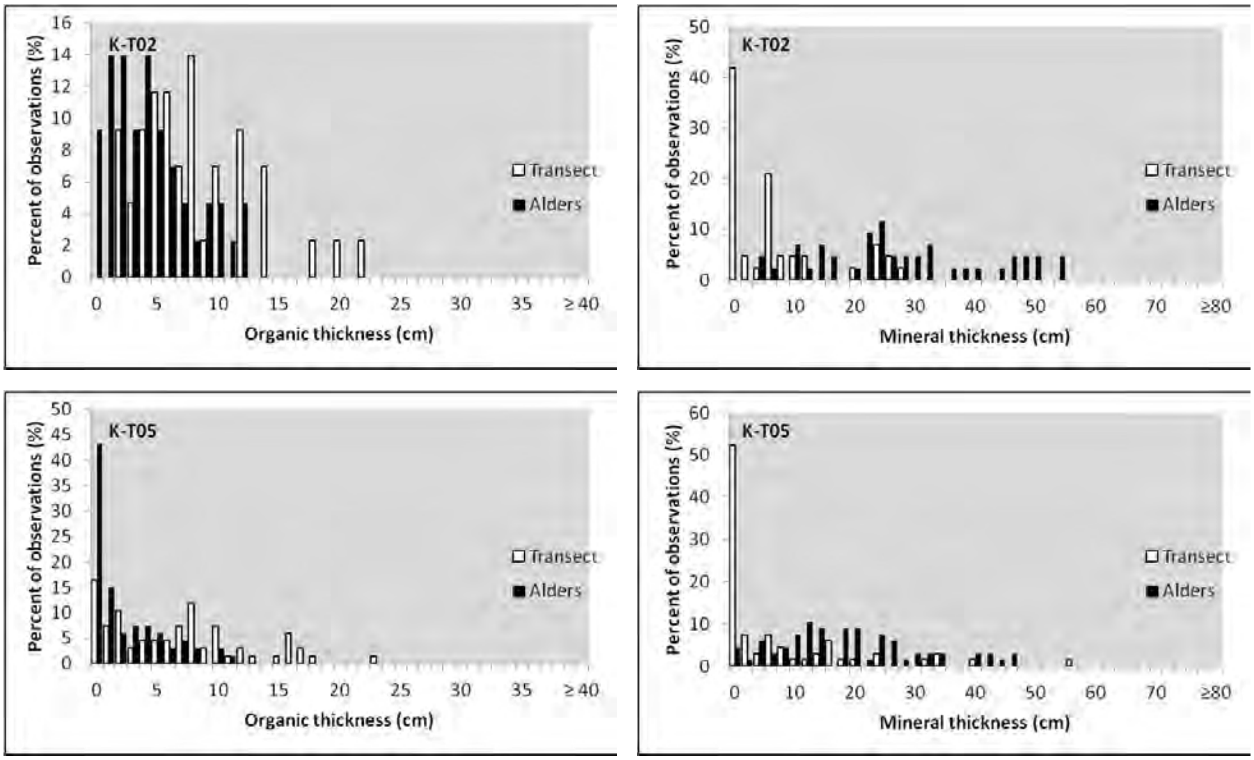


Figure 18. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements (cm) for two transects along successional gradients: K-T02 and K-T05. Mineral thicknesses are binned in 2-cm increments.

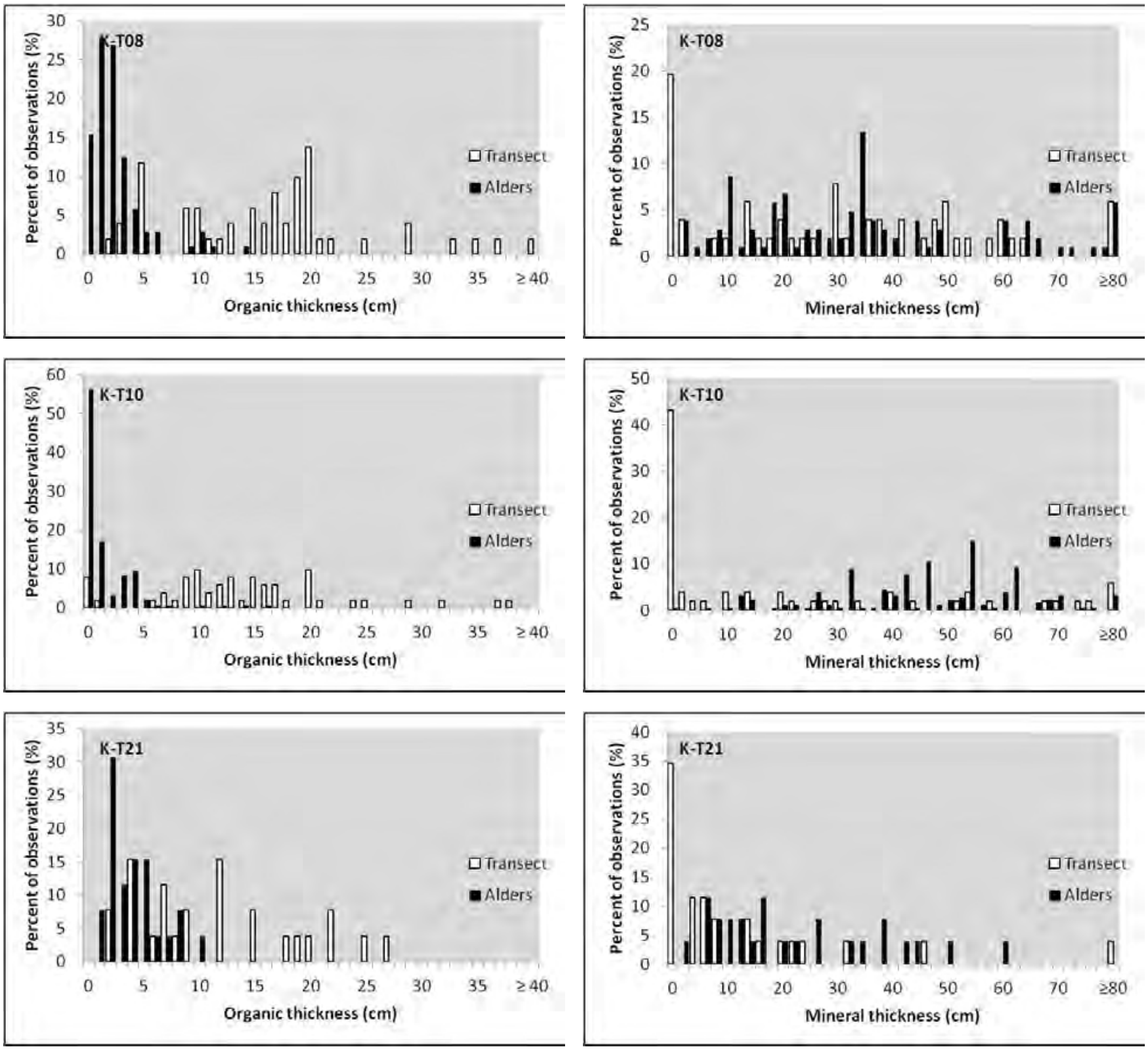


Figure 19. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements (cm) for three transects in mature shrublands: K-T08, K-T10, and K-T21. Mineral thicknesses are binned in 2-cm increments.

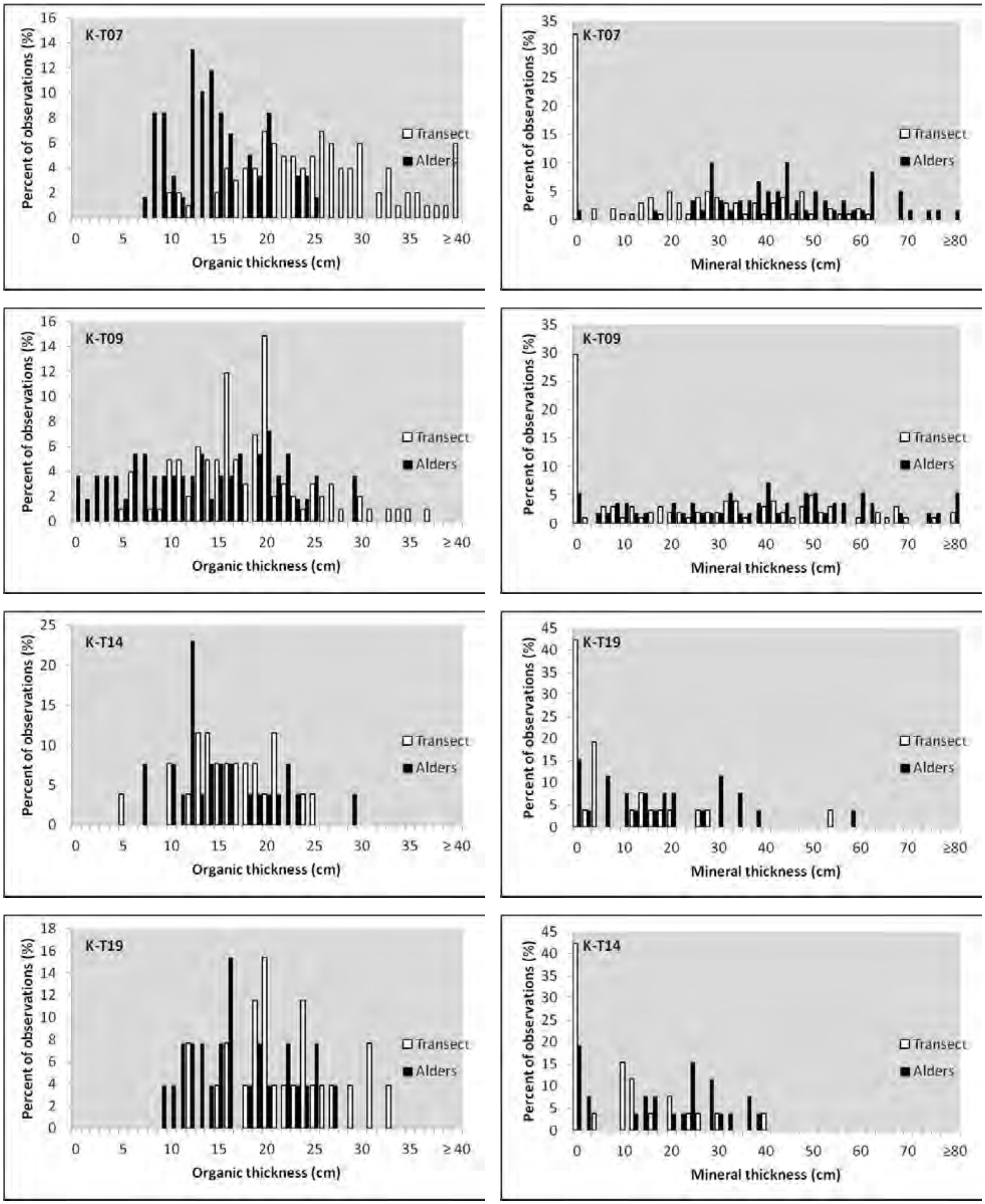


Figure 20. Frequency distributions of surface organic depth (left column) and mineral horizon thickness (right column) measurements (cm) for four transects in paludified shrublands: K-T07, K-T09, K-T14, and K-T19. Mineral thicknesses are binned in 2-cm increments.

Alder properties

Table 4. Mean Leaf Area Index (LAI), alder height, alder vigor, and frequency of alder age-classes, by transect.

Transect	Stage	Mean LAI	Mean height (cm)	Mean vigor	Age-class frequency		
					Adult	Sapling	Seedling
K-T01	colonization	0.7	35.4	5.0	25	59	19
K-T02	variable	1.9	205.2	5.0	-	-	-
K-T03	colonization	0.6	132.7	5.0	16	2	0
K-T04	colonization	0.6	16.3	5.0	17	87	65
K-T05	variable	1.1	123.0	5.0	-	-	-
K-T06	colonization	0.4	87.1	5.0	20	6	14
K-T07	paludified	1.3	90.5	3.6	54	5	0
K-T08	mature	2.1	92.2	4.8	57	37	10
K-T09	paludified	1.1	63.8	3.3	49	6	0
K-T10	mature	1.9	21.8	4.9	19	52	110
K-T11	colonization	-	128.3	5.0	-	-	-
K-T12	colonization	-	174.2	5.0	-	-	-
K-T13	colonization	-	152.5	5.0	-	-	-
K-T14	paludified	-	71.7	2.7	26	0	0
K-T15	colonization	-	160.0	5.0	-	-	-
K-T16	colonization	-	186.1	5.0	-	-	-
K-T17	colonization	-	46.7	5.0	-	-	-
K-T18	colonization	-	38.8	5.0	-	-	-
K-T19	paludified	-	72.1	3.6	26	0	0
K-T20	colonization	-	88.8	5.0	-	-	-
K-T21	mature	-	190.3	5.0	-	-	-
K-T22	colonization	-	16.7	5.0	22	84	164

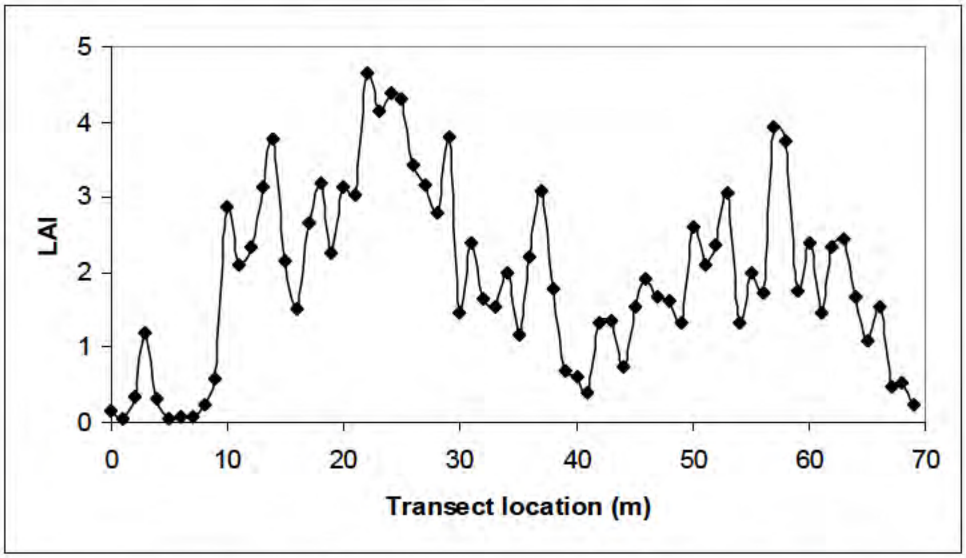


Figure 21. Scatterplot of LAI measurements along transect K-T02. Alder-free tundra extends from approximately 0-5 m; colonization zone ~5-10 m; mature shrubland 10-70 m.

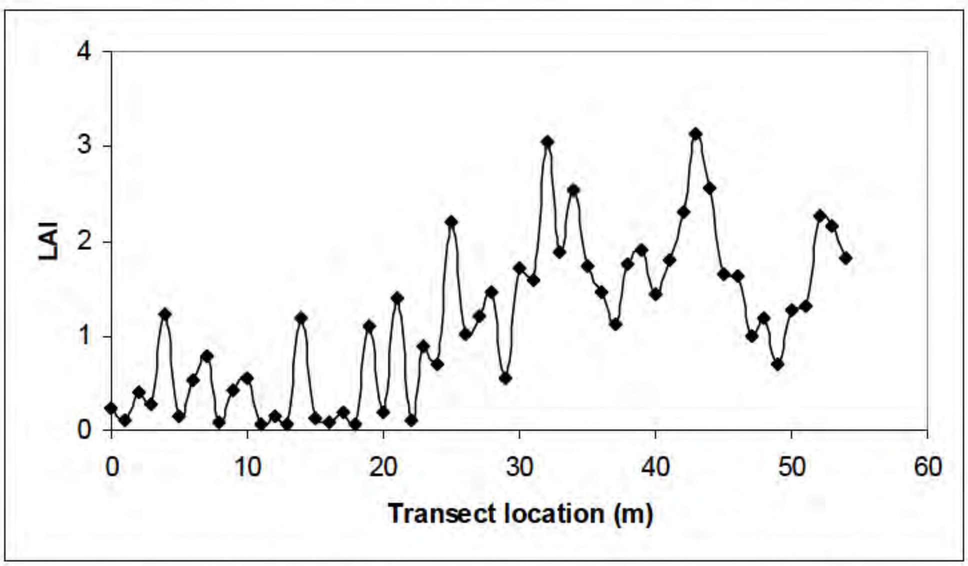


Figure 22. Scatterplot of LAI measurements along transect K-T05. Alder-free tundra extends from approximately 0-5 m; colonization zone ~5-15 m; mature shrubland 15-55 m.

Transect mapping

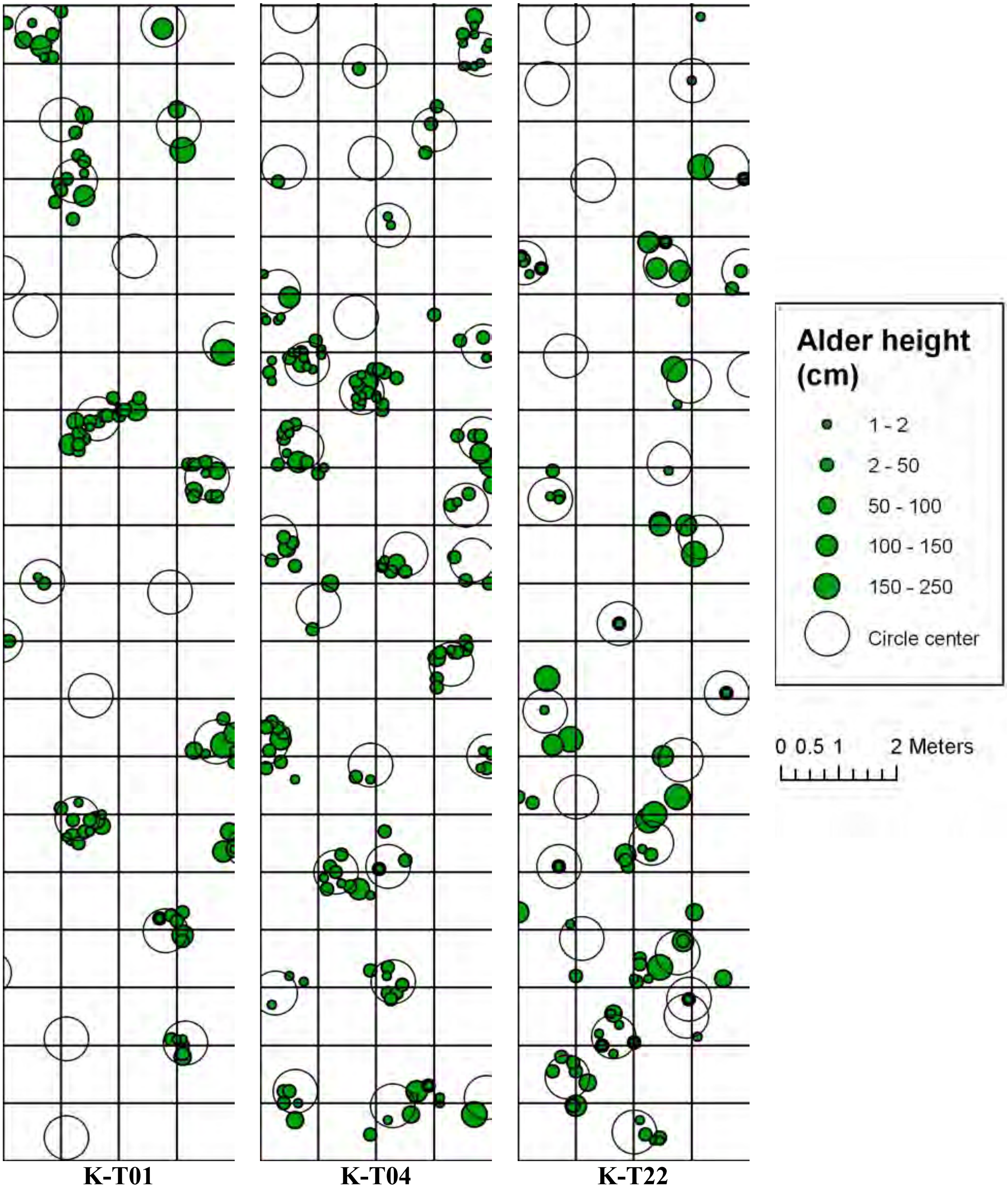


Figure 23. Maps of alder and circle distribution for three colonization zone transects. Each square represents one square meter. Open circles mark the centers of mineral-rich circles, and approximate the overall footprint of circles.

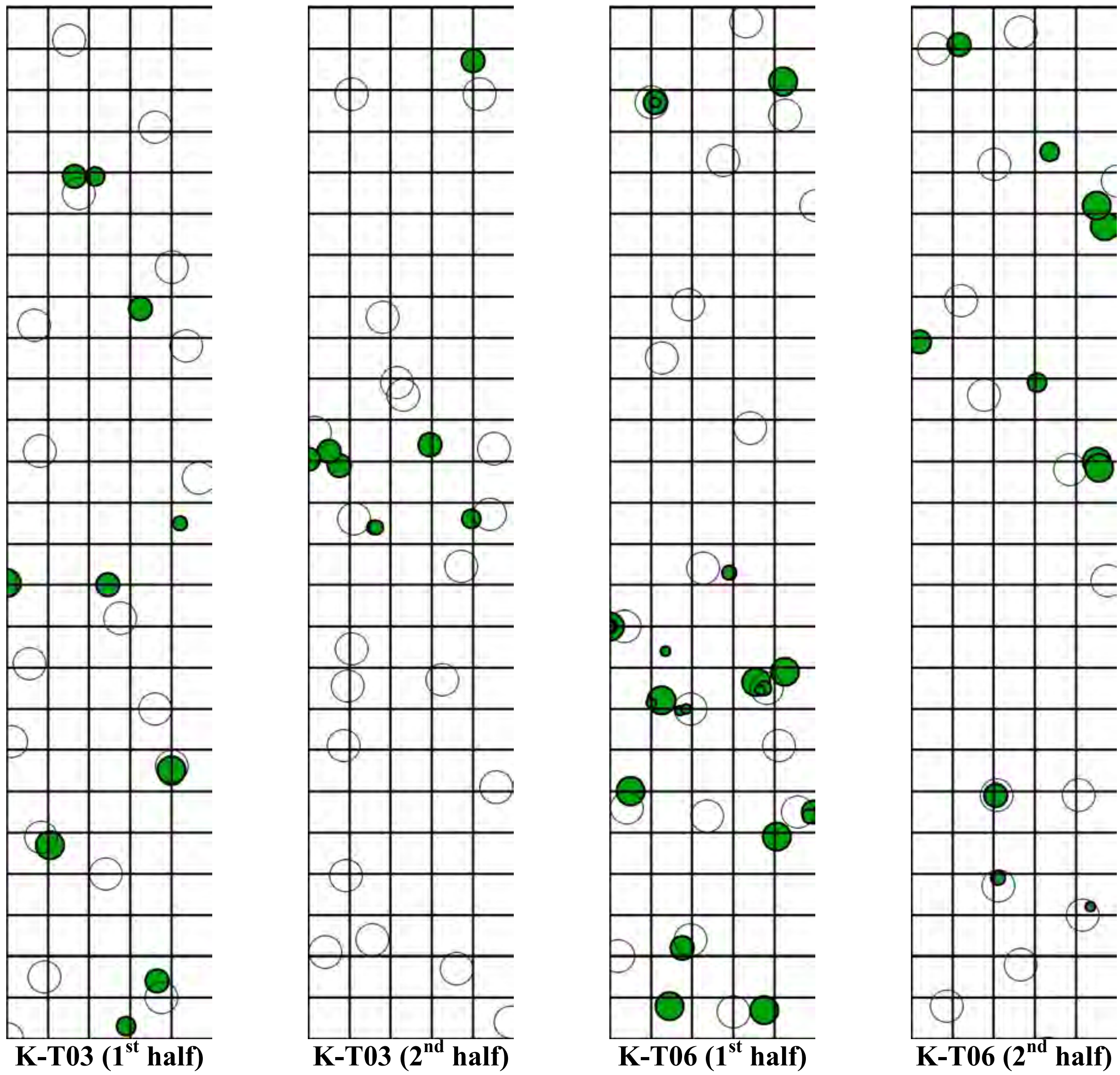


Figure 24. Maps of alder and circle distribution for two transects in mature shrublands among sorted-polygons. Each square represents one square meter. Circle markers represent the centers of sorted-polygons.

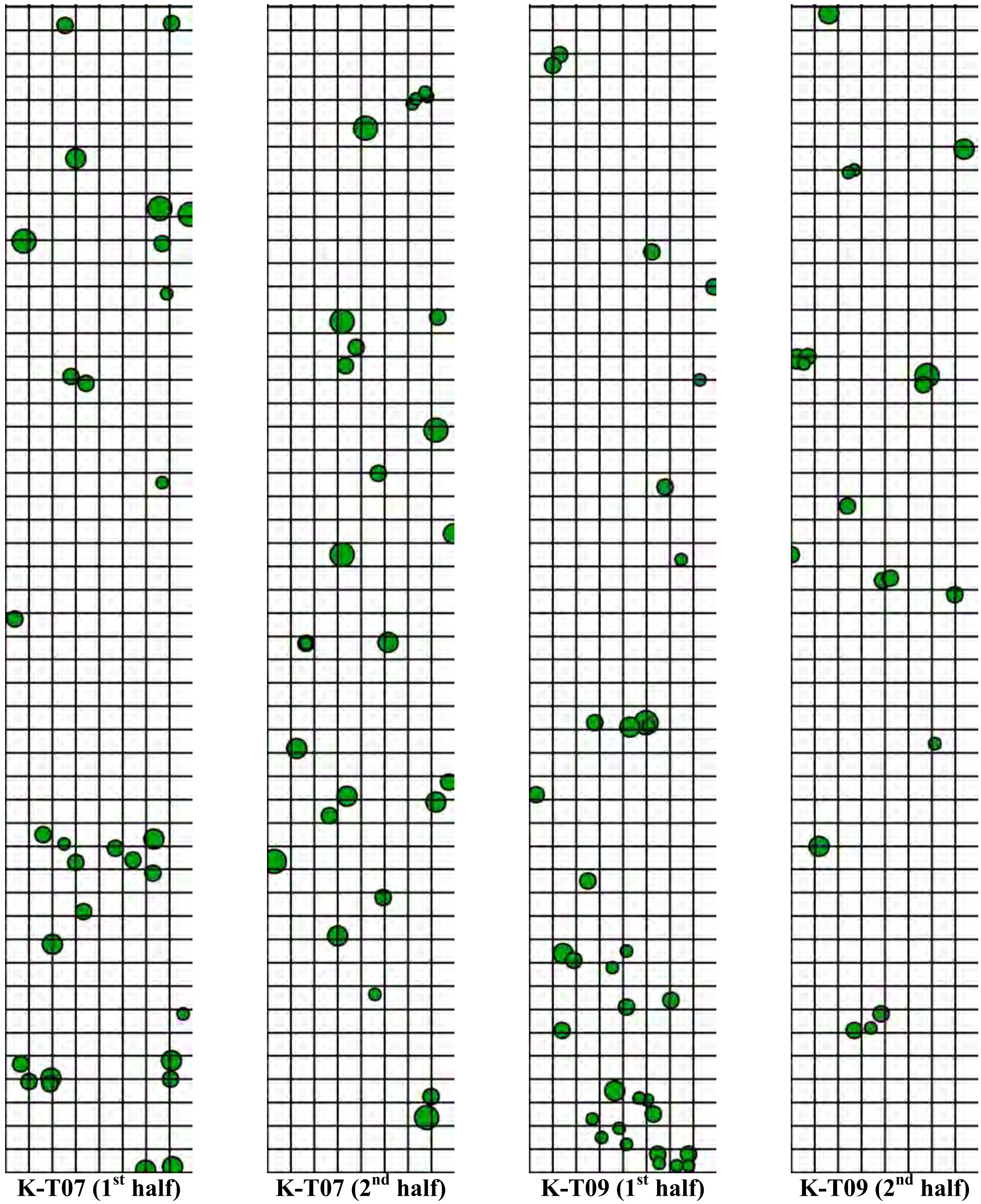


Figure 25. Maps of alder and circle distribution for two transects in paludified shrublands. Each square represents one square meter. Locations of patterned ground features are not shown, because their distribution could not be reliably distinguished by visual observations.

Soil temperature

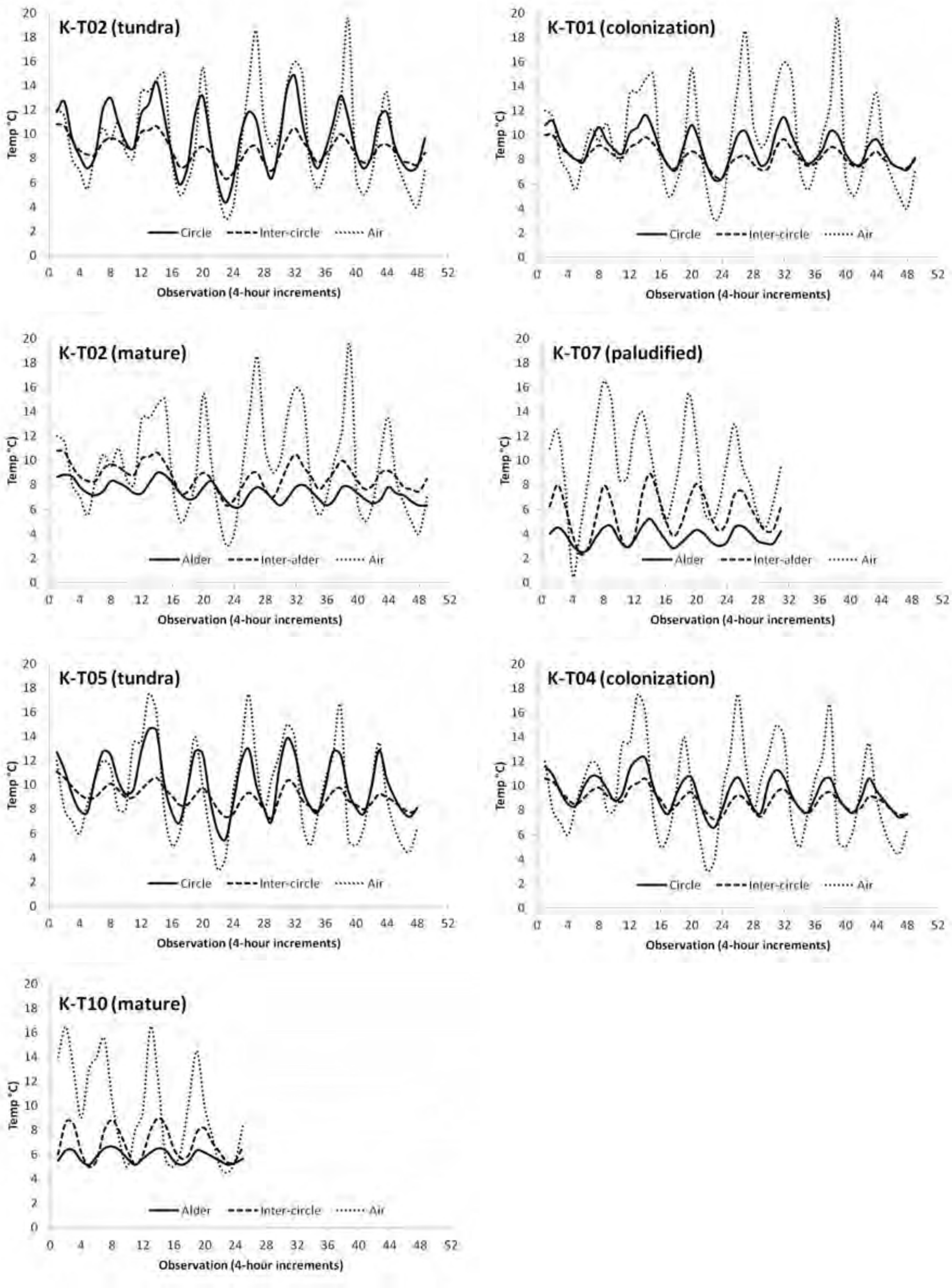


Figure 26. Daily 5-cm soil temperature time-series recorded using iButton dataloggers at two tundra transects (first row), two colonization transects (second row), two mature shrubland transects, and one paludified tundra transect (fourth row). The plotted values of alder and inter-circle soil temperatures represent means from multiple iButtons (3-6 per microsite).

Table 5. Mean values and variance of soil temperature and number of iButtons deployed at transect, by vegetation type and microsite.

Stage	Microsite	Transect	Mean temperature (ºC)	Standard deviation (ºC)	n
tundra	circle	K-T02	9.7	2.5	3
		K-T05	10.1	2.3	4
	inter-circle	K-T02	8.7	1.1	3
		K-T05	9	0.9	4
colonization zone	circle	K-T01	9	1.3	3
		K-T04	9.4	1.4	5
	inter-circle	K-T01	8.3	0.8	3
		K-T04	8.8	0.8	4
mature shrubland	alder	K-T02	7.4	0.7	3
		K-T10	5.8	0.5	3
	inter-alder	K-T02	7.5	1	3
		K-T10	6.9	1.3	3
paludified shrubland	alder	K-T07	3.7	0.7	5
	inter-alder		5.6	1.7	6

REFERENCES

CAVM Team, Walker, D.A., Gould, W.A., Bliss, L.C., Edlund, S.A., Raynolds, M.K., Zoltai, S.C., Daniëls, F.J.A., Bay, C., Wilhelm, M., Einarsson, E., Gudjonsson, G., Elvebakk, A., Johansen, B.E., Ananjeva, G.V., Drozdov, D.S., Katenin, A.E., Kholod, S.S., Konchenko, L.A., Korostelev, Y.V., Melnikov, E.S., Moskalenko, N.G., Polezhaev, A.N., Ponomareva, O.E., Pospelova, E.B., Safronova, I.N., Shelkunova, R.P., Yurtsev, B.A., Fleming, M.D., Markon, C.J., Murray, D.F., and Talbot, S.S. 2003. Circumpolar Arctic vegetation map: Anchorage, AK, Conservation of Arctic Flora and Fauna (CAFF) Map No. 1, U.S. Fish and Wildlife Service.

Daanen, R.P., Misra, D., Epstein, H., Walker, D.A., and Romanovsky, V. 2008. Simulating nonsorted circle development in Arctic tundra ecosystems. Journal of Geophysical Research 113, G03S06, doi:10.1029/2008JG000682.

Harrison, J.C., St-Onge, M.R., Petrov, O., Strelnikov, S., Lopatin, B., Wilson, F., Tella, S., Paul, D., Lynds, T., Shokalsky, S., Hults, C., Bergman, S., Jepsen, H.F., and Solli, A. 2008. Geological map of the Arctic: Ottawa, Canada, Geological Survey of Canada Open File Map Number 5816, Geological Survey of Canada. (1:5,000,000 scale)

Peterson, R.A. and Krantz, W.B. 2003. A mechanism for differential frost heave and its implications for patterned ground formation. Journal of Glaciology 49:69-80.

Walker, D.A., Carlson, S., Frost, G.V., Matyshak, G.V., Leibman, M.E., Orekhov, P., Khomutov, A.V., Khitun, O., Zhurbenko, M.P., Afonina, O., and Barbour, E.M. 2011. 2010 expedition to Krenkel Station, Hayes Island, Franz Josef Land, Russia. Fairbanks, AK: University of Alaska. 63 pp.

Walker, D.A., Epstein, H.E., Leibman, M.E., Moskalenko, N.G., Kuss, J.P., Matyshak, G.V., Kaärlejarvi, E., and Barbour, E.M. 2009a. Data report of the 2007 and 2008 Yamal expeditions: Nadym, Laborovaya, Vaskiny Dachi, and Kharasavey. Fairbanks, AK: University of Alaska. 133 pp.

Walker, D.A., Orekhov, P., Frost, G.V., Matyshak, G.V., Epstein, H.E., Leibman, M.E., Khitun, O., Khomotov, A., Daanen, R., Gobroski, K., and Maier, H.A. 2009b. The 2009 Yamal expedition to Ostrov Belyy and Kharp, Yamal Region, Russia. Fairbanks, AK: University of Alaska. 63 pp + appendices.

Walker, D.A., Epstein, H.E., Leibman, M.E., Moskalenko, N.G., Kuss, J.P., Matyshak, G.V., Kaärlejarvi, E., Forbes, B.C., and Barbour, E.M. 2008. Data report of the 2007 Yamal expedition to Nadym, Laborovaya, and Vaskiny Dachi. Fairbanks, AK: University of Alaska. 102 pp.

Appendix A. List of participants in the five NASA-sponsored Eurasia Arctic Transect expeditions.

Locations visited: N: Nadym; L: Laborovaya; V: Vaskiny Dachi; K: Kharasavey; Kp: Kharp; B: Ostrov Belyy; Kr: Krenkel

Andrey Abramov: Kr
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia

Ronnald Daaen: B, Kp
Geophysical Institute
University of Alaska Fairbanks
P.O. Box 757320
Fairbanks, AK 99775-7320
rdaanen@alaska.edu

Dmitriy S. Drozdov: N, Kr
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6, room 15
119991 Moscow, Russia
+7-495-135-98-71
ds_drozdov@mail.ru

Evgeny Elanchev: N
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia
eelanchev@yandex.ru

Howard E. Epstein: N, L, V, K, B, Kp
Department of Environmental Sciences
University of Virginia
P.O. Box 400123
Clark Hall, 211
Charlottesville, VA 22904-4123
Phone: +1 434-924-4308
Fax: +1 434-982-2137
hee2b@virginia.edu

Andrey Ermakov: Kr
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia

Ksenia Ermokhina: Kp
Vavilov Street 30/6
119991 Moscow, Russia
+7-916-607-83-93
diankina@gmail.com

Gerald V. (JJ) Frost: B, Kr, Kp
Department of Environmental Sciences
University of Virginia
P.O. Box 400123
Clark Hall, 211
Charlottesville, VA 22904-4123
Gvf5y@virginia.edu

Jozef Geml: K
Biology and Wildlife Department University of Alaska Fairbanks
PO Box 757000
Fairbanks, Alaska 99775-7000
jozsef.geml@gmail.com

Ivan Gameev: Kr
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia

Anatoly Gubarkov: L, V, K
Tyumen State Oil and Gas University
Volodarsky Street 38
625000 Tyumen, Russia
agubarkov@mail.ru

Elina Kaarlejärvi: N, L, V, K
Arctic Centre
University of Lapland
Box 122
96101 Rovaniemi, Finland
+358-50-560-86-87
elina.kaarlejarvi@gmail.com

Olga Khitun: B
Khomarov Botanical Institute
St. Petersburg, Russia
Khitun-olga@yandex.ru

Artem Khomutov: L, V, K, B, Kr
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia
akhomutov@gmail.com

Patrick Kuss: N, L, V
Institute of Plant Sciences
University of Bern
Altenbergrain 21
3013 Bern, Switzerland
Phone: +41 31 631 4992
Fax: +41 31 631 4942
patrick.kuss@ips.unibe.ch

Marina Leibman: L, V, K, B, Kr
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6
119991 Moscow, Russia
+7-916-607-83-93
moleibman@gmail.com

Grigory V. Matyshak: N, L, V, K, B, Kp, Kr
Department of Soil Science
Lomonosov Moscow State University
Leninskie Gory
119992 Moscow, Russia
+7-495-939-39-80
matyshak@ps.msu.ru

Nataliya G. Moskalenko: N, L, V, K
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6, room 67
119991 Moscow, Russia
+7-499-135-98-71
nat-moskalenko@hotmail.com

Aleksander Nikitin: N
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6
119991 Moscow, Russia
Aleksandernikol@gmail.com

Olga Opokina: N
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia
+7-3452-688-787
opokina@ikz.ru

Pavel T. Orekhov: N, K, B, Kr
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6, room 67
119991 Moscow, Russia
+7-499-135-98-71
744001@gmail.com

Olga E. Ponomareva: N
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6, room 67
119991 Moscow, Russia
+7-499-135-98-71
o-ponomareva@yandex.ru

Vladimir Romanovsky: N
Department of Geology and Geophysics
University of Alaska Fairbanks
P.O. Box 757320
Fairbanks, Alaska 99775-7320
+1-907-474-7459
veromanovsky@alaska.edu

Stanislaus Sizonenko: B
Salekhard, Russia

Elena Slagoda: Kr
Earth Cryosphere Institute, SB RAS
Malygin Street 86
625026 Tyumen, Russia
akhomutov@gmail.com

Andrei Tarosov: B
Earth Cryosphere Institute, SB RAS
Vavilov Street 30/6
119991 Moscow, Russia

Ina Timling: Kr
Institute of Arctic Biology
Alaska Geobotany Center
University of Alaska Fairbanks
PO Box 757000
Fairbanks, Alaska 99775-7000
Phone: +1 907-474-7957
itimling@alaska.edu

Donald A. (Skip) Walker: N, L, V, K, B, Kp, Kr
Institute of Arctic Biology
Alaska Geobotany Center
University of Alaska Fairbanks
PO Box 757000
Fairbanks, Alaska 99775-7000
Phone: +1 907-474-2460
Fax: +1 907-474-7666
dawalker@alaska.edu

Appendix B. Soils Description of Studied Sites

Kharp, Russia

Physiography: Ural mountain taiga-tundra region, Small Ural mountain province.

Landforms: 5th and 6th marine terraces?

Parent material: eluvial deposits of crystalline rocks, clays and stones.

Soil description for Transect 1

GPS position: 66º49'47.9"N, 065 º56'39.9"E

Elevation: 250 m.

Classification:

Figure 1: Transect №1, soil pit № 1-11

Figure 2: boil

0-5 cm; Bw; pale brown,10YR6/3; silty clay; dry; soft; many cobbles; many vesicular fine pores; few 40-50 cm reversible trans-horizon cracks, weak very fine platy structure; moderately sticky, moderately plastic, few fine roots, gradual wavy boundary.

5-38 cm; Bwjj; yellowish brown, 10YR5/4; (80%) and 10YR5/1; (20%) clay loam; moist; many vesicular fine pores; few fine roots, few cobbles, many fine gravel; weak fine subangular structure; slightly sticky, moderately plastic, few fine roots, few charcoals (3-5mm), clear wavy boundary.

38-80 cm↓; BC; grayish brown, 10YR5/2; silt loam; weak fine angular structure; firm, non-sticky, slightly plastic, few fine roots, 50% gravel.

Figure 3: charcoal inside Bwjj horizon on 35 cm depth

Figure 4: interboil

0-2 cm; Oi; dark grayish brown,10YR4/2; fibric material, dry, loose, slightly decomposed moss, twigs and leafs of shrubs, many fine and medium roots, clear wavy boundary.

2-35 cm; Bh; very dark grayish brown,10YR3/2; dry, friable, sandy loam; moderate fine subangular structure; non-sticky, slightly plastic, many fine roots; few charcoals (3-5mm), gradual irregular boundary.

35-78 cm↓; BC; grayish brown,10YR5/2; silt loam; weak fine angular structure; firm, non-sticky, slightly plastic, few fine roots, 40% stones and 20% gravel, few dark organic films on stones surface.

Soil description for Transect 2

GPS position: 66º49'47.5''N, 065 º56'46.5''E

Elevation: 251 m.

Classification:

Figure 5: Transect №2, soil pit № 2-11

0-5 cm; Oe; dark brown, 7.5YR3/2; loose, moderately decomposed forbs, twigs and leafs; few coarse roots, abrupt wavy boundary.

5-20 cm; Bh; very dark brown,10YR2/2; loam; friable, non-sticky, non-plastic, many fine roots; 10% gravel; clear wavy boundary.

20-30 cm↓; BC; brown, 7.5YR5/4; silt loam; weak fine angular structure; firm, non-sticky, slightly plastic, few fine roots, few charcoals (3-5mm), 60% gravel.

Soil description for Transect 3

GPS position: 66º49'48.6"N, 065 º56'51.8"E

Elevation: 251 m.

Classification:

Figure 6: Transect №3, sorted circles

Figure 7: soil pit № 3-11 inside circle

0-2 cm; Oi; yellowish brown,10YR5/4; fibric material; loose, slightly decomposed lichen, moss, twigs and leafs, many fine and medium roots, 10% fine gravel, abrupt wavy boundary.

2-13 cm; Bw1 (E?); light yellowish brown, 10YR6/4; silt loam; dry; friable; moderate medium granular structure; slightly sticky, slightly plastic; many fine and medium roots; common fine vesicular pores; clear wavy boundary.

13-38 cm; Bw2; light brownish gray (10YR6/2) and yellowish red (5YR5/8, 10%), loam; firm; weak medium angular structure; few fine gravel, few fine pores, moderately sticky, moderately plastic; few medium roots; few charcoals (3-5mm), clear wavy boundary.

38 cm↓; BC; grayish brown,10YR5/2; silt loam; weak fine angular structure; firm, non-sticky, slightly plastic, few fine roots, 50% stones.

Soil description for Transect 4

GPS position: 66º49'28.6"N, 065 º56'36.3"E

Elevation: 261 m.

Classification:

Figure 8: Transect №4, soil pit № 5-11

Figure 9: <u>boil</u>

0-10 cm; Bw (E?); pale brown,10YR6/3; loam; dry; loose; many medium vesicular pores; many fine gravel; many 10-20 cm reversible fine trans-horizon cracks; weak fine platy and fine subangular structure; slightly sticky, moderately plastic; few fine roots; clear wavy boundary.

10-28 cm; Bwjjg; yellowish brown (10YR5/4) and yellowish red (5YR5/8, 30%), clay loam; firm; weak medium angular structure; few fine gravel; common fine pores; moderately sticky, moderately plastic; few medium roots; clear irregular boundary.

28 cm↓; BC; grayish brown,10YR5/2; silt loam; weak fine angular structure; firm, slightly sticky, slightly plastic, 50% gravel.

Figure 10: interboil

0-1 cm; Oi; dark brown, 7.5YR3/2; fibric material, dry, loose, slightly decomposed moss, twigs and leafs of shrubs, many fine and medium roots, clear wavy boundary.

1-10 cm; Bh; dark grayish brown,10YR4/2; friable, clay loam; moderate fine subangular structure; common medium roots and pores; many coarse gravel; clear wavy boundary.

10-21 cm; Bw; yellowish brown (10YR5/4) and yellowish red (5YR5/8, 20%), clay loam; firm; weak medium angular structure; common cobbles; few fine pores; slightly sticky, slightly plastic; common 10-20 cm reversible fine trans-horizon cracks; few medium roots in cracks; few dark organic films on cobbles surface; clear irregular boundary.

21 cm↓; BC; grayish brown,10YR5/2; silt loam; weak fine angular structure; firm, non-sticky, slightly plastic, few fine roots, 50% stones.

Soil description for Transect 5

GPS position: 66º49'28.6"N, 065 º56'36.3"E

Elevation: 260 m.

Classification:

Figure 11: Transect №5, soil pit № 6-11

0-4 cm; Oe; yellowish brown (10YR5/8); loose, moderately decomposed forbes, twigs and leafs; few coarse roots, abrupt wavy boundary.
4-10 cm; Bh; dark brown, 7.5YR3/2; sandy loam; friable, non-sticky, non-plastic, many fine and medium roots; few charcoals (3-5mm); clear wavy boundary.
10 cm↓; BC; grayish brown,10YR5/2; silt loam; weak fine angular structure; firm, non-sticky, slightly plastic, few fine roots, 60% gravel.

Soil description for Transect 6

GPS position: 66º49'37.0"N, 065 º57'43.0"E

Elevation: 228 m.

Classification:

Figure 12: Transect №6, sorted circles, soil pit № 4-11

Figure 13: inside circle

0-3 cm; Oi; yellowish brown, 10YR5/4; fibric material; loose, slightly decomposed lichen, moss, twigs and leafs, many fine and medium roots, abrupt wavy boundary.

3-7 cm; Bw1 (E?); pale brown, 10YR6/3; clay loam; dry; friable; moderate fine subangular structure; moderately sticky, moderately plastic; common fine roots; common fine vesicular pores; many fine gravel; clear wavy boundary.

7-30 cm; Bwjjg2; brown,10YR5/3 and yellowish red (5YR5/8, 30%), silt loam; firm; weak fine angular structure; few cobbles; slightly sticky, slightly plastic; few fine and medium roots; few dark organic films on cobbles surface; clear wavy boundary.

30 cm↓; BC; grayish brown,10YR5/2; silt loam; weak fine angular structure; non-sticky, slightly plastic, 70% stones and cobbles.

Soil description for Transect 7

GPS position: 66º49'08.2"N, 065 º58'19.8"E

Elevation: 196 m.

Classification:

Figure 14: Transect №7, nonsorted circles, soil pit № 7-11

Figure 15: inside circle, microhigh

0-1cm; Oi; dark brown 10YR4/3; loose; slightly decomposed forbs, twigs and leafs.

1-6cm; Oe; dark brown (7.5YR3/2) hemic material, (H7, F1, R3, V2), friable; many fine roots, abrupt wavy boundary.

6-11 cm; Bw1 (E?); vary pale brown, 10YR7/4; clay loam; dry; friable; moderate medium granular structure; slightly sticky, slightly plastic; few medium roots; few fine gravel; clear wavy boundary.

11-40 cm; Bwjjg2; gray (10YR5/1, 50%) and yellowish red (5YR5/8, 50%); clay; firm; moderate angular structure; many fine gravel; few charcoals (3-5mm); moderately sticky, very plastic; few fine and medium roots; clear wavy boundary.

40 cm↓; BCf; brown, 10YR5/3, clay loam; massive (frozen); weak medium platy structure; non-sticky, slightly plastic, many gravel and cobbles; 20% ice.

Figure 16:

charcoals inside Bwjjg (on 30cm depth)

Figure 17: between circles, microlow

0-10 cm; Oi; yellow, 10YR7/8; loose, slightly decomposed mosses.

10-40cm; Oif↓; reddish brown (5YR3/4), fibric material (moss), (H2, F3, R2, V1); friable, common fine and medium roots; 20% ice.

Soil description for Transect 8

GPS position: 66º49'03.0"N, 065 º58'22.6"E

Elevation: 200 m.

Classification:

Figure 18: Transect №8, nonsorted circles, soil pit № 8-11

Figure 19: inside circle

0-5 cm; Oi; dark brown, 7.5YR3/2; fibric material; loose, slightly decomposed moss, twigs and leafs, many fine roots, abrupt wavy boundary.

5-8↓ cm; Bw; brown 10YR5/3; clay loam; firm; weak fine subangular structure; slightly sticky, slightly plastic; few fine roots; 80% gravel and cobbles.

Figure 20: between circles

0-7 cm; Oi; yellowish brown, 10YR5/6; fibric material (H2, F3, R1, V0); loose, slightly decomposed moss; few fine roots, abrupt wavy boundary.

7-15 cm; Oe; dark brown, 7.5YR3/2; hemic material (H5, F3, R2, V1); friable; common fine roots, abrupt wavy boundary.

15-30↓ cm; Bwg; gray, 10YR5/1 and reddish yellow, 5YR6/8, 50%; thixotropic clay; firm; weak medium platy structure; very sticky, very plastic; common fine and medium roots; few fine gravel.

Soil description for Transect 9

GPS position: 66º49'18.0"N, 065 º59'36.3"E

Elevation: 166 m.

Classification:

Figure 21: Transect №9, nonsorted circles, soil pit № 9a-11

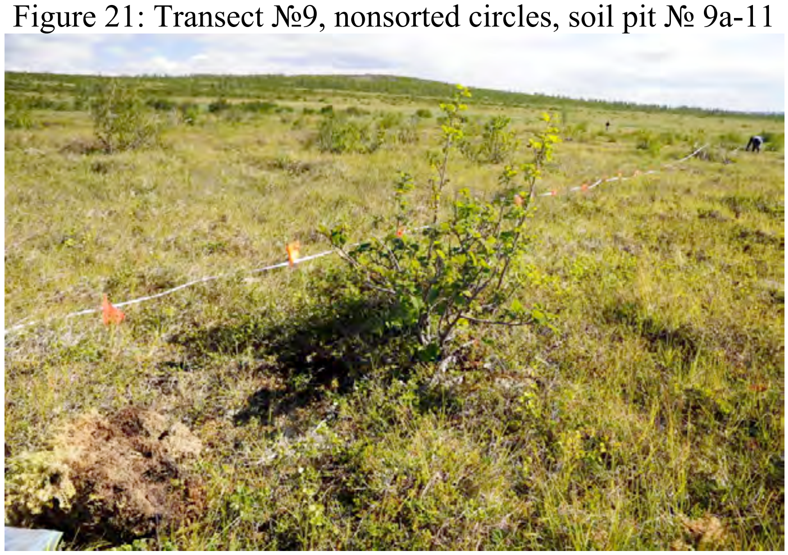


Figure 22: inside circle, microhigh

0-5 cm; Oe; dark brown, 10YR3/3; hemic material (H5, F2, R3, V1); loose; many fine roots, abrupt wavy boundary.

5-8 cm; Bw1; brown, 10YR5/3; clay loam; friable; weak fine subangular structure; moderately sticky, moderately plastic; few fine roots; few fine gravel.

8-20↓ cm; Bw2f; grayish brown, 10YR5/2; clay; thixotropic; firm; weak fine subangular structure; very sticky, very plastic; few fine roots; common gravel.

Figure 23: between circles, microlow

0-5 cm; Oi; yellow, 10YR7/8; loose, slightly decomposed moss.

5-30cm; Oif; yellowish brown, 10YR5/6; fibric material (H3, F3, R1, V0); slightly decomposed moss; few fine roots; 30% ice.

Soil description for Transect 13

GPS position: 66º49'04.0"N, 065 º55'23.2"E

Elevation: 231 m.

Classification:

Figure 24: Transect № 13, soil pit № 9b-11

0-2 cm; Oi; light yellowish brown,10YR6/4; loose, slightly decomposed moss, twigs and leafs, (H3, F3, R1, V0); few fine roots, abrupt wavy boundary.

2-7 cm; Oe; very dark grayish brown,10YR3/2; hemic material (H5, F2, R2, V1); loose; many fine and medium roots, many charcoals (1-5mm); abrupt broken boundary.

7-12↓ cm; Bh (A?); very dark brown,10YR2/2; sandy loam; friable, moderate fine subangular structure; slightly sticky, slightly plastic, common fine roots; 70% gravel.

Soil description for Transect 14

GPS position: 66º49'04.2"N, 065 º55'23.9"E

Elevation: 237 m.

Classification:

Figure 25: Transect № 14, nonsorted circles, soil pit № 10-11

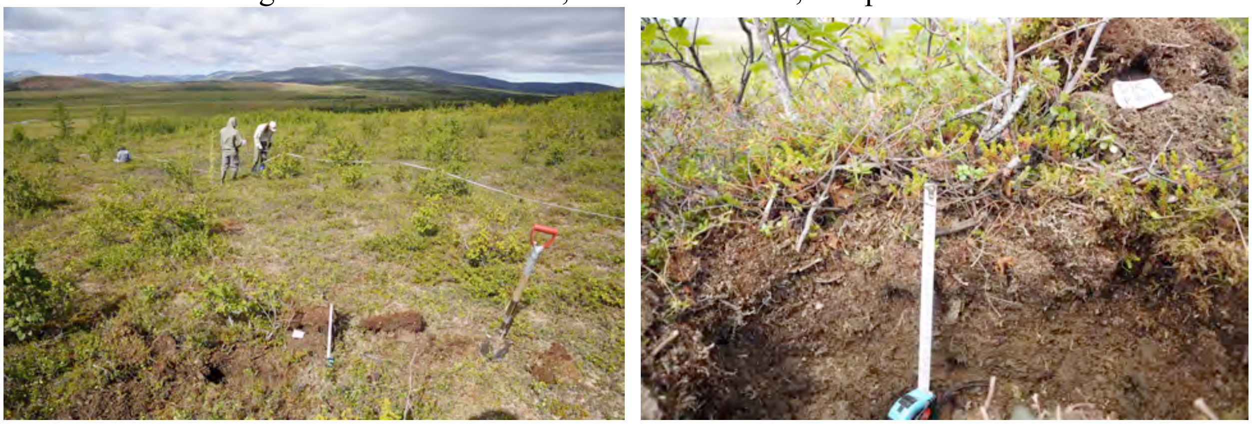


Figure 26: inside circle, microhigh

0-3 cm; Oi; light yellowish brown, 10YR6/4; loose, slightly decomposed moss, twigs and leafs, (H3, F3, R1, V0); few fine roots, abrupt wavy boundary.

3-10 cm; Oe; dark brown 7.5YR4/4; hemic material (H4, F2, R2, V1); loose; many fine and medium roots, many charcoals (1-5mm); abrupt wavy boundary.

10-13cm; Oa; very dark brown (10YR2/2) sapric material (H7, F1, R1, V1); friable, few fine roots, many charcoals (1-5mm); abrupt wavy boundary.

13-20 cm; Bh (A?); dark yellowish brown, 10YR4/4; silt loam; friable, moderate fine subangular structure; non-sticky, slightly plastic, many fine roots; few fine gravel.

20 cm↓; Bw2; brown, 10YR5/3; clay loam; firm; 70% gravel and cobbles.

Figure 27: between circles, microlow

0-1 cm; Oi; light yellowish brown, 10YR6/4; loose, slightly decomposed moss, abrupt wavy boundary.

1-10 cm; Oe; dark brown 7.5YR5/4; hemic material (H5, F3, R3, V1); friable; many fine roots; abrupt wavy boundary.

10 cm↓; Bw; brown, 10YR5/3; clay loam; firm; 80% gravel and cobbles.

Soil description for Transect 15

GPS position: 66º48'53.2"N, 065 º52'27.1"E

Elevation: 222 m.

Classification:

Figure 28: Transect № 15, nonsorted circles, soil pit № 11-11

Figure 29: inside circle

0-1 cm; Oi; light yellowish brown, 10YR6/4; loose, slightly decomposed moss, twigs and leafs.

1-5 cm; Oe; dark brown 7.5YR4/4; hemic material (H5, F1, R1, V1); friable; few fine and medium roots; abrupt wavy boundary.

5-8 cm; Bh; dark yellowish brown, 10YR4/4; silt loam; friable, moderate fine subangular structure; non-sticky, slightly plastic, few fine roots and pores; few fine gravel; abrupt wavy boundary.

8-20 cm; Bwg1; gray, 10YR5/1 (60%) and reddish yellow, 5YR6/8 (40%); thixotropic clay loam; firm; weak medium platy structure; very sticky, very plastic; common fine roots; few fine gravel; abrupt wavy boundary.

20 cm↓; Bw2; brown, 10YR5/3; clay loam; firm; 80% gravel and cobbles.

Figure 30: between circles

0-3 cm; Oi; loose, slightly decomposed moss.

3-14 cm; Oi; brown7.5YR5/4; fibric material (H4, F3, R1, V1); loose; many fine and medium roots; abrupt wavy boundary.

14-18 cm; Bh; very dark brown, 10YR2/2; clay loam; firm, weak fine subangular structure; slightly sticky, slightly plastic; many charcoals (1-5mm); many fine roots; abrupt wavy boundary.

18 cm↓; Bw; brown, 10YR5/3; clay loam; firm; 70% gravel.

Soil description for Transect 16

GPS position: 66º48'46.8"N, 065 º55'42.6"E

Elevation: 220 m.

Classification:

Figure 31: Transect № 16, nonsorted circles, soil pit № 12-11

Figure 32: inside circle, microhigh

0-1 cm; Oi; loose, slightly decomposed moss, twigs and leafs.

1-6 cm; Oi; brown, 7.5YR5/4; fibric material (H4, F3, R2, V1); friable; common fine and medium roots; abrupt wavy boundary.

6-17 cm; Bh; dark grayish brown, 10YR4/2; clay loam; firm, weak fine subangular structure; moderately sticky, moderately plastic; many charcoals (1-5mm); many fine roots; many charcoals (1-5mm); abrupt wavy boundary.

17 cm↓; Bw1; brown, 10YR5/3; clay loam; firm; 70% gravel.

Figure 33: between circles, microlow

0-2 cm; Oi; loose, slightly decomposed moss.

2-17 cm; Oe; brown 7.5YR4/4; hemic material (H6, F2, R2, V0); firm; common fine and medium roots; abrupt wavy boundary.

17 cm↓; Bw1; brown, 10YR5/3; clay loam; firm; 80% gravel and cobbles.

Appendix 1. Temperature data

Figure 1:The temperature of the boil soil horizons

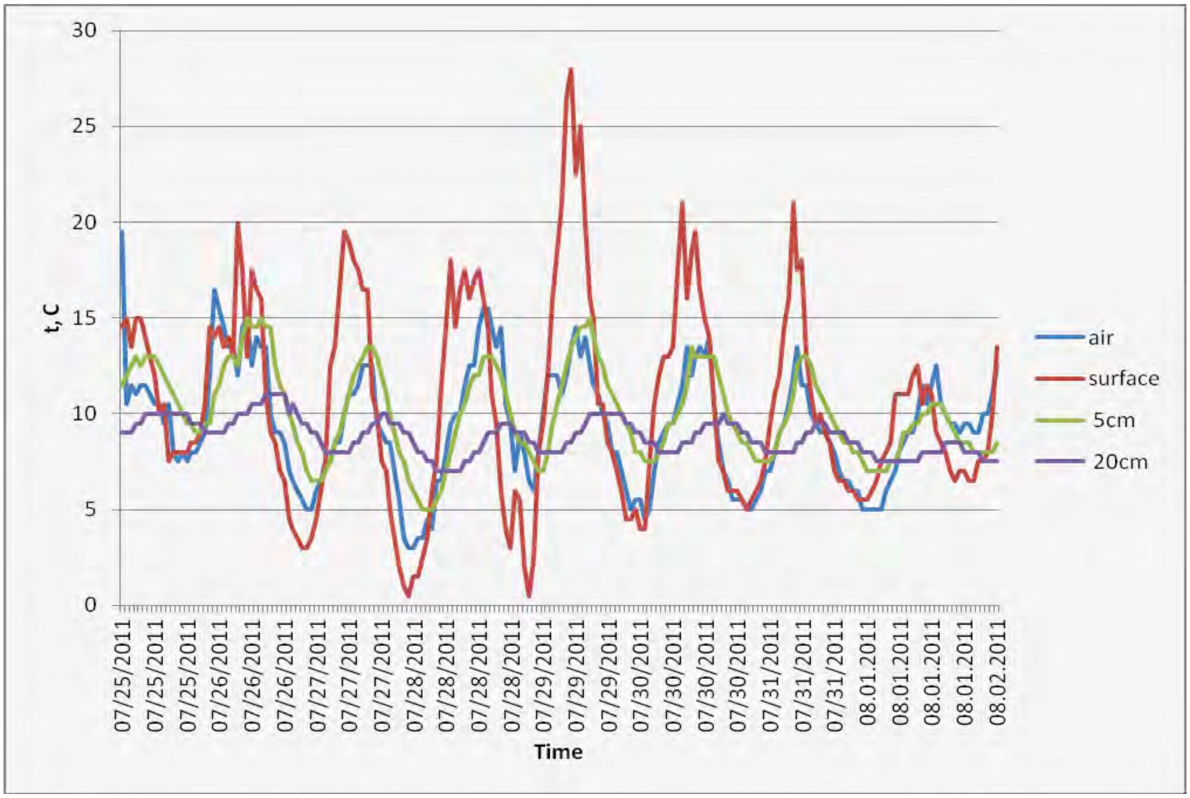
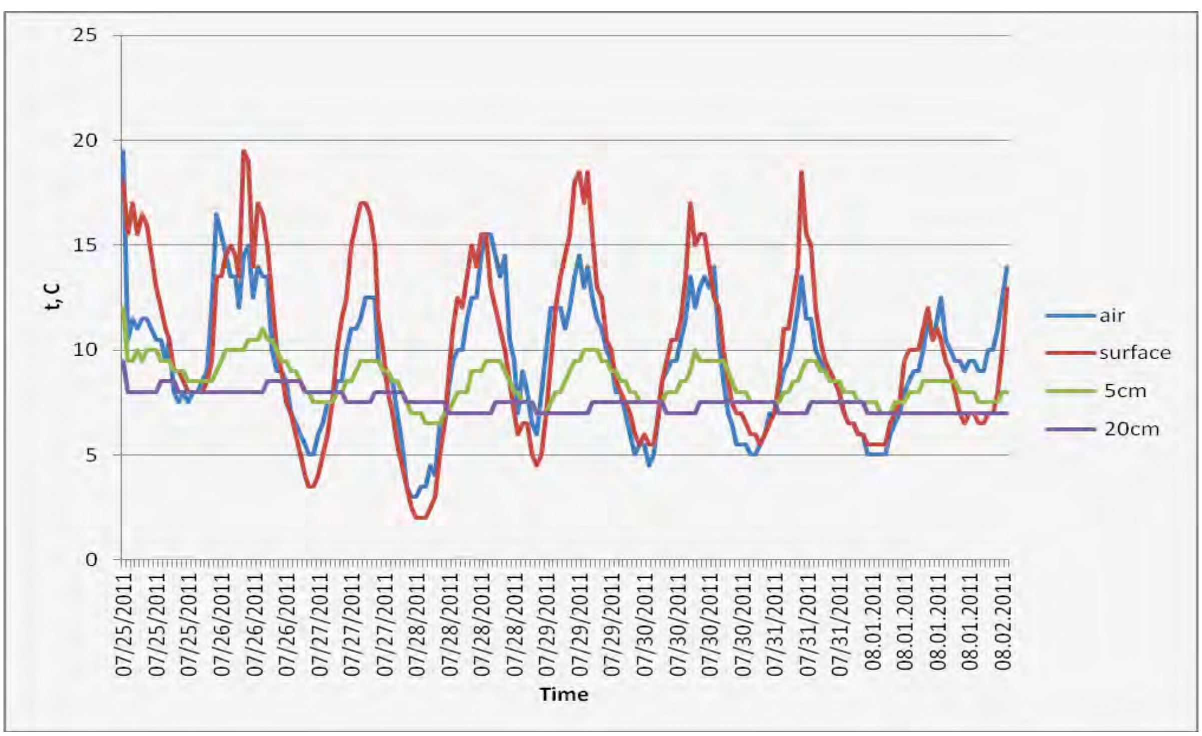
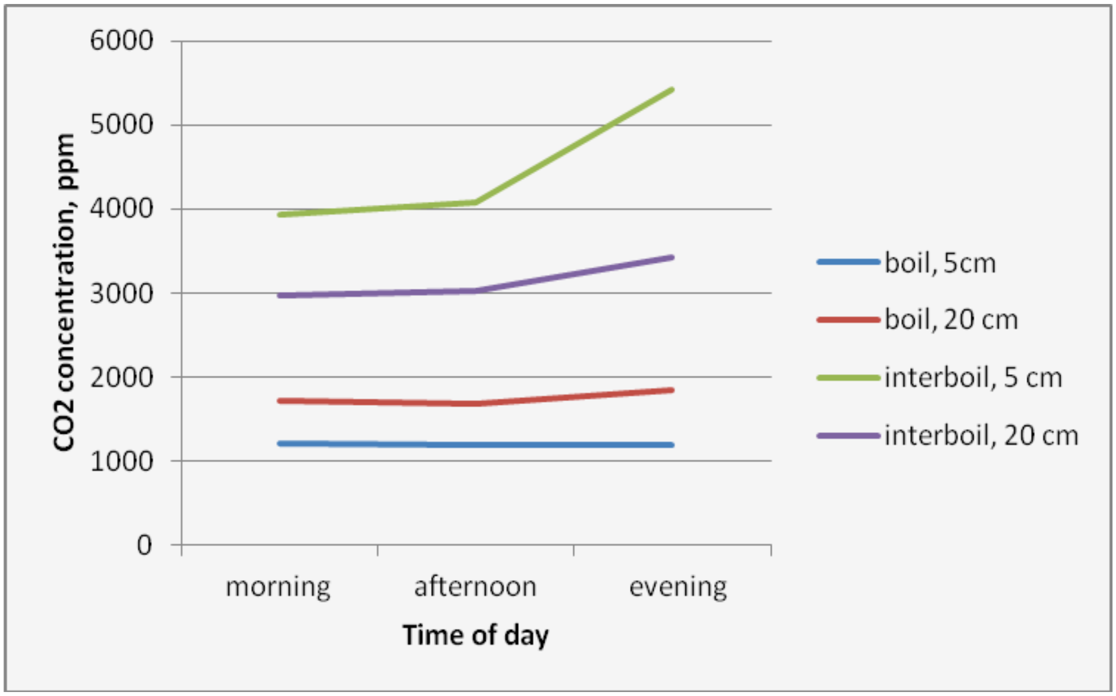


Figure 2:The temperature of the interboil soil horizons



Appendix 2.CO[2] production data

Figure 3: CO[2] concentration on different depths, mean value (measurement duration is 5 days, two replications)



Appendix 3. Some soil properties

Transect	soil pit	Microsite	thickness of the organogenic horizon, mean (cm)	n (cases)	the decomposition degree of organic material	charcoals	rock/ permafrost (*) depth	pH 1:1 (in field), n=3
1	**1-11**	boil	0	10	-	+	50	5,3
		interboil	31	5	fibric material	+	35	4,5
2	**2-11**	alder shrublands	18	5	hemic material	+	15	
3	**3-11**	circle	2	10	fibric material	-	38	
6	**4-11**	circle	3	10	fibric material	-	30	
4	**5-11**	boil	0	10	-	-	28	
		interboil	12	10	fibric material	-	21	
5	**6-11**	alder shrublands	8	5	hemic material	-	10	
7	**7-11**	circle	7	5	hemic material	+	40(*)	
		intercircle	45	5	fibric material	-	40(*)	
8	**8-11**	circle	5	10	fibric material	-	8	
		intercircle	15	10	hemic material	-	30	
9	**9a-11**	circle	5	3	hemic material	-	20	
		intercircle	30	3	fibric material	-	30	
13	**9b-11**	alder shrublands	12	3	hemic material	+++	12	
14	**10-11**	circle	20	3	sapric material	+++	20	
		intercircle	11	3	hemic material	-	10	
15	**11-11**	circle	8	3	hemic material	-	20	
		intercircle	17	3	fibric material	+++	18	
16	**12-11**	circle	16	3	fibric material	+++	17	
		intercircle	20	3	hemic material	-	17	

References

1. Von Post, L. and Granlund, E. 1926. Södra Sveriges Torvtillgångar I. Sveriges Geologiska Undersökning, Yearbook, 19.2 Series C, No. 335. pp1–127, Stockholm. English translation in: Damman AWH and French TW (1987), The Ecology of Peat Bogs of the Glaciated Northeastern United States: A Community Profile. US Department of Interior, Fish and Wildlife Service, Research Development, National Wetlands Research Center. Washington, DC. Biological Report. 85 (7.16) 1-115.
2. Munsell soil color charts. Determination of soil color quoted in part from U.S. Dept. Agriculture Handbook 18-Soil Survey Manual
3. Soil Taxonomy. A Basic System of Soil Classification for Making and Interpreting Soil Surveys; Second Edition, 1999
4. Atlas Yamalo-Nenetskogo Autonomnogo okruga .-Tyumen – Salekhard.- Omsk:FGUP «Omskaja cartographicheskaja fabrika», 2004.- 240 p.

Appendix C. Species cover-abundance in vegetation study plots (relevés). **Nomenclature for vascular plants followed Elven et al. 2007: Checklist of the Panarctic Flora (PAF). Vascular plants. -Draft. University of Oslo. Lichens followed H. Kristinsson & M. Zhurbenko 2006: Panarctic lichen checklist (http://archive.arcticportal.org/276/01/Panarctic_lichen_checklist.pdf). Mosses followed M.S. Ignatov, O.M. Afonina & E.A. Ignatova 2006: Check-list of mosses of East Europe and North Asia. Arctoa 15: 1-130 and for liverworts N.A. Konstantinova & A.D. Potemkin 1996: Liverworts of Russian Arctic: an annotated check-list and bibliography. Arctoa 6: 125-150. Cover-abundance scores: << = rare, < = <0.1% cover, + = 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50% 4 = 51-75%, 5 = 76-100%.** Cover-abundance codes were used for vascular plants, and % cover estimates were used for nonvascular **NOTES:** Ks-16 (all cells): circle near T10-1; Lichen, T12-1: 65% with lichen on rocks; Arctoparmelia separata (Th.Fr.) Hale, T3-2, T6-1, T12-2: from rocks; Hypogymnia physodes (L.) Nyl., T3-3: on the dead branches.

Appendix C. Species cover-abundance in vegetation study plots.

1	№	T1-1	T1-2	T1-3	T2-1	T2-2	T2-3	T2-4	T2-5	T2-6	T2-7	T2-8	T2-9	T3-1	T3-2	T3-3	T4-1	T4-2	T4-3	T5-0	T5-1	T5-2	T5-3	T5-4	T5-5	T5-6	T6-1	T6-2	T6-3	T7-1	T7-2	T7-3	T7-4	T7-5	T7-6	T8-1	T8-2
2	**separate releves/transect releves**	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr
3	**trees**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	<1%
4	**tall shrubs**	<5%	<5%	0%	0%	50%	0%	0%	40%	0%	60%	0%	50%	3%	0%	1%	20%	<5%	7%	0%	2%	20%	50%	40%	60%	40%	3%	<1%	<1%	3%	0%	0%	5%	2%	0%	0%	35%
5	**low shrubs**	<5%	<5%	<5%	0%	15%	60%	<5%	<5%	80%	<5%	20%	0%	2%	5%	35%	45%	7%	4%	25%	10%	10%	20%	30%	1%	2%	1%	5%	1%	7%	7%	8%	2%	15%	10%	45%	25%
6	**erect dwarf shrubs**	10%	20%	20%	<5%	40%	40%	<5%	<5%	<5%	0%	0%	0%	3%	3%	20%	20%	30%	10%	30%	50%	50%	40%	20%	2%	2%	10%	7%	3%	70%	17%	7%	50%	20%	40%	70%	40%
7	**prostrate dwarf shrubs**	20%	40%	50%	10%	20%	<5%	<5%	<5%	<5%	0%	0%	0%	15%	20%	25%	70%	10%	15%	15%	20%	70%	10%	7%	1%	0%	10%	50%	10%	30%	30%	40%	45%	75%	10%	3%	40%
8	**forbs**	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	1%	1%	1%	<5%	<5%	<5%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	1%	<1%	1%	<1%	<1%	<1%	<1%	<1%
9	**graminoides**	<10%	<10%	<10%	<10%	10%	40%	50%	50%	20%	20%	20%	40%	<5%	<5%	<5%	<5%	<5%	<5%	<1%	<1%	<1%	<1%	2%	2%	25%	2%	<1%	10%	3%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
10	**lichen**	90%	80%	90%	90%	60%	40%	80%	<5%	<5%	<5%	<5%	<5%	40%	45%	50%	45%	80%	85%	80%	60%	60%	40%	30%	10%	<5%	50%	50%	40%	5%	4%	25%	40%	<1%	5%	30%	30%
11	**bryophytes**	15%	15%	15%	15%	50%	10%	70%	10%	20%	10%	10%	35%	15%	20%	20%	85%	35%	30%	30%	20%	20%	40%	35%	10%	25%	15%	25%	40%	100%	100%	80%	95%	100%	100%	70%	80%
12	**algae**	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	<5%	0%	0%	0%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	0%	0%	0%	0%	0%	0%	0%	0%
13																																					
14	**Trees**																																				
15	Larix sibirica			1										0.01																							<1%
16	Picea abies subsp. obovata											0.01																									
17	**Shrubs**																																				
18	Salix phylicifolia	2	1	1	1	2	1	1				2		2	2	1	6%	4%	15%	2	2	1	1	0.5			1	2	1	1%	<1%	2%	<1%	5%		1%	<1%
19	Salix phylicifolia x lanata	1	1																																		
20	Salix lapponum																																				
21	Salix recurvigemmis (?)																																				
22	Salix hastata																																				
23	Salix phylicifolia x hastata																																				
24	Salix lanata													1																							
25	Rosa acicularis																																				
26	Salix glauca																																				<1%
27	Alnus fruticosa	1	1	1		3			3		4		3	1			20%	4%	5%	1	2	3	4	3	4	3	1	1	0.5	3%			5%	2%			
28	Betula nana	1	1	2	1	3	4	2	1	5	1	2		2	1	3	35%	4%	4%	2	1	2	2	1		0.5	1	1	0.5	7%	7%	7%	2%	15%	10%	45%	25%
29	Sorbus aucuparia ssp. glabrata																								0.01												
30	**Grasses and dwarf shrubs**																																				
31	Calamagrostis canadensis ssp. langsdorffii									2	1	2																									
32	Campanula rotundifolia																																				
33	Saussurea alpina																																				
34	Carex bigelowii ssp. ensifolia				1				4	2	1			1					4%	1	1						1	0.5	1	5%	3%	5%	5%	10%	7%	20%	<1%
35	Carex parallela																																				
36	Pachypleurum alpinum																																				
37	Dianthus repens																																				
38	Lycopodium clavatum subsp. monostachyon																																				
39	Dupontia fischeri																																				
40	Stellaria palustris																																				
41	Arctogrostis latifolia																																				
42	Festuca ovina	1	1	1	1			1						1	1	1	4%	4%	7%								2	1	1								
43	Carex concolor																																				
44	Equisetum arvense subsp. boreale																																				
45	Calamagrostis neglecta				1		1																														
46	Festuca rubra					1	1													1	0.5	0.5	0.5	1	1	2											<1%
47	Salix myrtilloides																																				
48	Ranunculus lapponicus																																				
49	Carex rariflora																																		3%		
50	Carex globularis																													5%	10%		5%			30%	65%
51	Tofieldia coccinea	1	1	1	1			1						1			4%	4%	3%	1	1	0.5		1			1										<1%
52	Juncus triglumis																																				
53	Poa pratensis																																				
54	Pinguicula alpina																																				
55	Luzula multiflora																																				
56	Bistorta vivipara		1		1				1										2%										0.5								
57	Poa alpigena											1	1																								
58	Silene acaulis																																				
59	Thalictrum minus																																				
60	Thymus glabricaulis																																				
61	Alyssum obovatum																																				
62	Carex capillaris subsp. fuscidula																																				
63	Cerastium regelii tax. Jenisejense																																				
64	Vaccinium myrtillus	2	1	1	1	1								3	2	1	20%	10%	25%	3	2	2															
65	Empetrum nigrum	2	2	2	1	3	1							3	3	2	45%	25%	20%	2	2	3	2	1	0.5	0.5	2	3	2	30%	30%	3%	75%	75%	10%	3%	40%
66	Ledum decumbens	1	1	1	1	1	1	1						2	2	2	10%	4%	4%	1	2	2	0.5				2	2	2	15%	10%	4%	45%	45%	5%	<1%	6%
67	Pedicularis lapponica	1	1	1	1			1						1			4%	4%	4%	0.5		0.5	0.5									<1%			<1%		<1%
68	Arctous alpina	1	2	1	1	1								1	1	2	7%	4%		1	1	1	2	1													
69	Vaccinium vitis-idaea		1	1	1		1							1	1	1	4%	5%		1	1	0.5		0.5			1	2	1	1%	2%	8%	10%	40%	5%	<1%	2%
70	Vaccinium uliginosum ssp. microphyllum		1		1	3	2	3	1					1	1	2					1	2	2	2	2	2	2	2		30%	10%		3%	3%	5%	70%	40%
71	Diapensia lapponica		1					1										4%		0.5	0.5							0.5									
72	Trientalis europaea										1	2	1																								
73	Solidago virgaurea ssp. lapponica										1	2																									
74	Polemonium acutiflorum										1	2	1																								

Appendix C. Species cover-abundance in vegetation study plots (relevés). **Nomenclature for vascular plants followed Elven et al. 2007: Checklist of the Panarctic Flora (PAF). Vascular plants. -Draft. University of Oslo. Lichens followed H. Kristinsson & M. Zhurbenko 2006: Panarctic lichen checklist (http://archive.arcticportal.org/276/01/Panarctic_lichen_checklist.pdf). Mosses followed M.S. Ignatov, O.M. Afonina & E.A. Ignatova 2006: Check-list of mosses of East Europe and North Asia. Arctoa 15: 1-130 and for liverworts N.A. Konstantinova & A.D. Potemkin 1996: Liverworts of Russian Arctic: an annotated check-list and bibliography. Arctoa 6: 125-150. Cover-abundance scores: << = rare, < = <0.1% cover, + = 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50% 4 = 51-75%, 5 = 76-100%.** Cover-abundance codes were used for vascular plants, and % cover estimates were used for nonvascular **NOTES:** Ks-16 (all cells): circle near T10-1; Lichen, T12-1: 65% with lichen on rocks; Arctoparmelia separata (Th.Fr.) Hale, T3-2, T6-1, T12-2: from rocks; Hypogymnia physodes (L.) Nyl., T3-3: on the dead branches.

1	Nº	T8-3	T9-1	T9-2	T9-3	T9-4	T9-5	T10-1	T10-2	T10-3	T11-1	T11-2	T12-1	T12-2	T13-1	T13-2	T14-1	T14-2	T15-1	T15-2	T16-1	T16-2	Ks-1	Ks-2	Ks-3	Ks-4	Ks-5	Ks-6	Ks-7	Ks-8	Ks-9	Ks-10	Ks-11	Ks-12	Ks-13	Ks-14	Ks-15	Ks-16
2	**separate releves/transect releves**	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	tr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr	sr
3	**trees**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	<1%	0%	0%	0%	0%	0%	0%	0%		0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
4	**tall shrubs**	0%	0%	0%	0%	2%	0%	3%	10%	1%	4%	20%	2%	50%	25%	50%	10%	3%	25%	45%	20%	40%	0%		5%	3%	0%	70%										0%
5	**low shrubs**	2%	10%	5%	45%	30%	10%	90%	25%	20%	40%	25%	2%	0%	20%	40%	40%	70%	20%	30%	70%	40%	45%		90%	60%	100%	30%										0%
6	**erect dwarf shrubs**	50%	60%	65%	30%	40%	25%	30%	7%	35%	25%	70%	5%	15%	30%	70%	30%	10%	70%	70%	15%	30%	75%		50%	20%	0%											0%
7	**prostrate dwarf shrubs**	40%	20%	70%	70%	70%	70%	7%	<1%	30%	10%	10%	2%	10%	20%	45%	30%	10%	60%	1%	10%	7%	3%		15%	4%	0%											0%
8	**forbs**	<1%	<1%	<1%	<1%	<1%	<1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	4%		<1%	<1%	50%											<1%
9	**graminoides**	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	4%	2%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	3%		<1%	<1%	2%											<1%
10	**lichen**	<1%	15%	2%	30%	10%	15%	10%	2%	10%	45%	70%	65%	50%	90%	30%	40%	20%	50%	50%	25%	70%	50%	1%	15%	5%	1%							20%	10%			<1%
11	**bryophytes**	100%	90%	80%	50%	90%	70%	70%	65%	95%	40%	35%	5%	50%	3%	60%	60%	80%	40%	50%	30%	15%	50%	1%	70%	65%	50%								98%			<1%
12	**algae**	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%		0%	0%	0%											90%
13																																						
14	**Trees**																																					
15	Larix sibirica															<1%																						
16	Picea abies subsp. obovata																																					
17	**Shrubs**																																					
18	Salix phylicifolia	2%									2%	5%							1%	<1%	5%	20%			10%	10%		35%	20%		1%							
19	Salix phylicifolia x lanata																																					
20	Salix lapponum					<1%		3%	4%																							1%						
21	Salix recurvigemmis (?)																						1%															
22	Salix hastata			<1%	<1%	<1%				3%																	50%											
23	Salix phylicifolia x hastata									2%																												
24	Salix lanata							<1%	1%																		30%	35%			1%							
25	Rosa acicularis												1%												1%													
26	Salix glauca							7%	<1%		3%	5%									<1%				10%	40%	20%	35%	3%		1%	13%		2%		5%		
27	Alnus fruticosa		2%			2%		3%	10%	1%	4%	20%	2%	50%	25%	50%		3%	25%	45%	20%	40%			5%	3%												
28	Betula nana	3%	10%	5%	45%	30%	10%	85%	25%	15%	35%	15%			20%	40%	40%	70%	20%	25%	70%	20%	45%	4%	70%	30%	10%		15%	1%		2%		90%	1%	70%		
29	Sorbus aucupana ssp. glabrata																																					
30	**Grasses and dwarf shrubs**																									10%												
31	Calamagrostis canadensis ssp. langsdorffii																										2%				<1%	<<1%					55%	
32	Campanula rotundifolia												<1%												<<1%													
33	Saussurea alpina												<1%																									
34	Carex bigelowii ssp. ensifolia	<1%	2%	3%			25%	8%	2%	2%	4%	5%				1%	<1%	2%	1%	1%	15%	7%	1%	2%	2%	40%			10%			10%						
35	Carex parallela																						1%															
36	Pachypleurum alpinum																						1%															
37	Dianthus repens																						1%	1%														
38	Lycopodium clavatum subsp. monostachyon																																		1%	1%		
39	Dupontia fischeri																									1%												
40	Stellaria palustris																									<<1%		1%										
41	Arctogrostis latifolia																									1%												
42	Festuca ovina							<1%			<1%	<1%	4%	2%		<1%			2%	1%	2%	<1%	3%	2%	<<1%				<1%									<1%
43	Carex concolor																				2%				<1%		4%										45%	
44	Equisetum arvense subsp. boreale																						<1%		<1%		50%											
45	Calamagrostis neglecta																											60%			<1%			<1%				
46	Festuca rubra																							2%		<<1%								<1%				
47	Salix myrtilloides																														1%							
48	Ranunculus lapponicus																														<1%							
49	Carex rariflora																						5%							50%	50%		60%		30%			
50	Carex globularis	70%		8%	20%	15%	1%	10%	70%	60%										<1%	1%	8%																
51	Tofieldia coccinea							<1%																														<1%
52	Juncus triglumis																																					<1%
53	Poa pratensis																																					<1%
54	Pinguicula alpina																																					<1%
55	Luzula multiflora																																					<1%
56	Bistorta vivipara							<1%										<<1%			<<1%																	
57	Poa alpigena																																					
58	Silene acaulis																						1%															
59	Thalictrum minus																						1%															
60	Thymus glabricaulis																							2%														
61	Alyssum obovatum																							2%														
62	Carex capillaris subsp. fuscidula																							2%														
63	Cerastium regelii tax. Jenisejense													<1%										2%														
64	Vaccinium myrtillus																																					
65	Empetrum nigrum	40%	20%	70%	15%	70%	70%	7%	<1%	20%	10%	10%	2%		20%	45%	30%	10%	60%	1%	7%	6%	2%		10%	4%			50%			20%	60%		2%			
66	Ledum decumbens	7%	50%	60%	30%	35%	20%	7%		10%	<1%	<1%	1%	15%	5%	2%		7%	3%	2%	1%	15%	1%	4%	15%	5%			7%			10%	3%		<1%			
67	Pedicularis lapponica	<1%							<1%		<1%									<<1%	<<1%	<<1%				<<1%			<<1%									
68	Arctous alpina										<1%					<1%					3%		1%						<<1%									
69	Vaccinium vitis-idaea	1%	3%	2%	60%	3%	3%	<1%	<1%	10%	2%	5%	<1%	15%			10%	<1%	<1%	1%		1%			5%	<1%			10%			<1%		20%		1%		
70	Vaccinium uliginosum ssp. microphyllum	50%	10%	1%	3%		5%	30%	7%	30%	25%	60%	1%		25%	70%	30%	4%	70%	70%	15%	15%	75%	3%	35%	15%	<1%		40%			10%	5%	2%	1%	5%		
71	Diapensia lapponica														<1%								<1%	2%														
72	Trientalis europaea																																					
73	Solidago virgaurea ssp. lapponica																																					
74	Polemonium acutiflorum							<1%	<1%																													

Appendix C. Species cover-abundance in vegetation study plots (relevés). **Nomenclature for vascular plants followed Elven et al. 2007: Checklist of the Panarctic Flora (PAF). Vascular plants. -Draft. University of Oslo. Lichens followed H. Kristinsson & M. Zhurbenko 2006: Panarctic lichen checklist (http://archive.arcticportal.org/276/01/Panarctic_lichen_checklist.pdf). Mosses followed M.S. Ignatov, O.M. Afonina & E.A. Ignatova 2006: Check-list of mosses of East Europe and North Asia. Arctoa 15: 1-130 and for liverworts N.A. Konstantinova & A.D. Potemkin 1996: Liverworts of Russian Arctic: an annotated check-list and bibliography. Arctoa 6: 125-150. Cover-abundance scores: << = rare, < = <0.1% cover, + = 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50% 4 = 51-75%, 5 = 76-100%.** Cover-abundance codes were used for vascular plants, and % cover estimates were used for nonvascular **NOTES:** Ks-16 (all cells): circle near T10-1; Lichen, T12-1: 65% with lichen on rocks; Arctoparmelia separata (Th.Fr.) Hale, T3-2, T6-1, T12-2: from rocks; Hypogymnia physodes (L.) Nyl., T3-3: on the dead branches.

1	№	T1-1	T1-2	T1-3	T2-1	T2-2	T2-3	T2-4	T2-5	T2-6	T2-7	T2-8	T2-9	T3-1	T3-2	T3-3	T4-1	T4-2	T4-3	T5-0	T5-1	T5-2	T5-3	T5-4	T5-5	T5-6	T6-1	T6-2	T6-3	T7-1	T7-2	T7-3	T7-4	T7-5	T7-6	T8-1	T8-2
75	Rubus arcticus											1	3																								
76	Stellaria longipes ssp. peduncularis							1	1		1																										
77	Chamerion angustifolium												1																								
78	Dryas octopetala													1					2%																		
79	Salix polaris														1																						
80	Bistorta elliptica																													<1%	1%						
81	Rubus chamaemorus																														10%	5%	8%	20%	8%	<1%	1%
82	Eriophorum vaginatum																														3%		5%		10%		
83	Andromeda polifolia																																		<1%		
84	Saxifraga cernua																																				
85	Pedicularis oederi																																				
86	Nardosmia frigida																																				
87	Oxytropis sordida																																				
88	Veratrum album																																				
89	Aconitum lycoctonum ssp. septentrionale																																				
90	Comarum palustre																																				
91	Galium uliginosum																																				
92	Eriophorum polystachion																																				
93	Ledum palustre																																				
94	Parnassia palustris																																				
95	**Moss**																																				
96	Rhytidium rugosum (Ehrh. ex Hedw.) Kindb.	5	4	1	3									7	6	7	15	4	8		5						4		10								
97	Dicranum fuscescens subsp. congestum (Brid.) K	3		2			1					1								5	1		12							6			5				
98	Polytrichum hyperboreum R. Br.	3	2	3	3												10	4					+											16	10		
99	Aulacomnium turgidum (Wahlenb.) Schwägr.	1	2			12	1	11		2	3	3			1	+	15	8	8	5		5		10	3	7	4					15	17		10		8
100	Dicranum spadiceum Zett.	1	4	2	1									5			10	8	4					+		5											+
101	Racomitrium lanuginosum (Hedw.) Brid.	1	1					+						1	6	7	20	10	4			+	+				4	11	12								
102	Abietinella abietina (Hedw.) M. Fleisch.	1		1					4	6																											
103	Polytrichum juniperinum Hedw.		1	2	+	2	+			6	+		+			2			2	2		3		6				4	6								
104	Pogonatum dentatum (Menzies ex Brid.) Brid.		1																																		
105	Pleurozium schreberi (Willd. ex Brid.) Mitt.			3	4					2	3	1	15				10	1	2							5			6					2			8
106	Hylocomiastrum pyrenaicum (Spruce) M. Fleisch.			1																																	
107	Polytrichastrum alpinum (Hedw.) G.L. Sm.				3				3		3		10						2							1											
108	Ptilium crista-castrensis (Hedw.) De Not.				1		1			+		1		1	4									2					2			5					
109	Hylocomium splendens (Hedw.) Schimp.					8	2	15								2				5	5	5	12	10		7		1		20	20	18	17	20	30	15	14
110	Dicranum fuscescens Turner					8	2		1			3			1										3												
111	Drepanocladus aduncus (Hedw.) Warnst.					6														2			3								8						
112	Polytrichum strictum Menzies ex Brid.			+		6	2	7	1						1	+	2			5	3	2	10					1		14		5				10	6
113	Ptilidium ciliare (L.) Hampe					6		15			+		5		1					3	3	2	3	6	3			4			3						
114	Sphagnum rubellum Wilson					2																														10	
115	Pseudobryum cinclidioides (Huebener) T.J. Kop.						1					1								3																	
116	Dicranum fuscescens var. flexicaule (Brid.) Wilson							15	1	4			5			2			+			3	+	+	+		2	4									+
117	Aulacomnium palustre (Hedw.) Schwägr.							7																						14	15	9		16		5	8
118	Dicranum bonjeanii De Not.													1			3												2		8	9	5		5	+	
119	Polytrichum jensenii I. Hagen																				3																
120	Ptilidium pulcherrimum (Weber) Hampe																					+															
121	Tomentypnum nitens (Hedw.) Loeske																							1									5				
122	Sanionia uncinata (Hedw.) Loeske										+									+					+					14	15		6	20			
123	Distichium capillaceum (Hedw.) Bruch & Schimp.																										1		2								
124	Dicranum angustum Lindb.																													14			12	2			
125	Sphagnum girgensohnii Russow	+	+									+																		9	8					15	14
126	Pohlia nutans (Hedw.) Lindb.												+							+			+	+						9	3		12		15		2
127	Polytrichum commune Hedw.									+	+																			+	15	9	17	20	15	15	8
128	Climacium dendroides (Hedw.) F. Weber & D. Mohr																														5						1
129	Dicranum elongatum Schleich. ex Schwägr.	+				+													+	+	+											5		2		+	
130	Campylium chrysophyllum (Brid.) Lange																															5					
131	Brachythecium mildeanum (Schimp.) Schimp.																																	2	10		1
132	Amblystegium serpens (Hedw.) Schimp.																																		5		
133	Sphagnum warnstorfii Russow																															+					8
134	Sphagnum balticum (Russow) C.E.O. Jensen																																				
135	Loeskypnum badium (Hartm.) H.K.G. Paul																																				
136	Ditrichum flexicaule (Schwägr.) Hampe																																				
137	Plagiothecium nemorale (Mitt.) A. Jaeger																																				
138	Cynodontium strumiferum (Hedw.) Lindb.																																				
139	Tortella tortuosa (Hedw.) Limpr.																																				
140	Hypnum callichroum Brid.																																				
141	Plagiothecium denticulatum (Hedw.) Schimp.																									+											
142	Oncophorus wahlenbergii Brid.																																				
143	Mnium stellare Reichard ex Hedw.																																				
144	Sciurohypnum reflexum (Starke) Ignatov et Huttunen											+	+												+												
145	Philonotis fontana (Hedw.) Brid.																																				
146	Rhytidiadelphus subpinnatus (Lindb.) T.J. Kop.																																				
147	Calliergon cordifolium (Hedw.) Kindb.																																				

Appendix C. Species cover-abundance in vegetation study plots (relevés). **Nomenclature for vascular plants followed Elven et al. 2007: Checklist of the Panarctic Flora (PAF). Vascular plants. -Draft. University of Oslo. Lichens followed H. Kristinsson & M. Zhurbenko 2006: Panarctic lichen checklist (http://archive.arcticportal.org/276/01/Panarctic_lichen_checklist.pdf). Mosses followed M.S. Ignatov, O.M. Afonina & E.A. Ignatova 2006: Check-list of mosses of East Europe and North Asia. Arctoa 15: 1-130 and for liverworts N.A. Konstantinova & A.D. Potemkin 1996: Liverworts of Russian Arctic: an annotated check-list and bibliography. Arctoa 6: 125-150. Cover-abundance scores: << = rare, < = <0.1% cover, + = 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50% 4 = 51-75%, 5 = 76-100%.** Cover-abundance codes were used for vascular plants, and % cover estimates were used for nonvascular **NOTES:** Ks-16 (all cells): circle near T10-1; Lichen, T12-1: 65% with lichen on rocks; Arctoparmelia separata (Th.Fr.) Hale, T3-2, T6-1, T12-2: from rocks; Hypogymnia physodes (L.) Nyl., T3-3: on the dead branches.

1	№	T8-3	T9-1	T9-2	T9-3	T9-4	T9-5	T10-1	T10-2	T10-3	T11-1	T11-2	T12-1	T12-2	T13-1	T13-2	T14-1	T14-2	T15-1	T15-2	T16-1	T16-2	Ks-1	Ks-2	Ks-3	Ks-4	Ks-5	Ks-6	Ks-7	Ks-8	Ks-9	Ks-10	Ks-11	Ks-12	Ks-13	Ks-14	Ks-15	Ks-16
75	Rubus arcticus													1%											1%		<1%											
76	Stellaria longipes ssp. peduncularis																	<<1%		<<1%																		
77	Chamerion angustifolium																																					
78	Dryas octopetala														2%									4%					1%									
79	Salix polaris														1%	<1%							<1%	4%														
80	Bistorta elliptica	<1%	<1%					<1%							<1%	<1%			<1%	<<1%	<<1%		<1%	2%	<1%		<1%							1%		<<1%		
81	Rubus chamaemorus	1%	15%	3%	1%	7%	<1%		2%	2%																1%						20%	10%	2%	10%	65%		
82	Eriophorum vaginatum	3%		1%			10%			<1%																10%			2%				4%		40%			
83	Andromeda polifolia	1%	2%	1%	2%	<1%	<1%		4%	7%		<<1%										1%	5%	2%								<<1%	<1%		1%			
84	Saxifraga cernua																						1%					1%										
85	Pedicularis oeden																						1%	1%	<<1%				<<1%									
86	Nardosmia frigida							<1%																			10%	1%			1%							
87	Oxytropis sordida							<1%																					<<1%									
88	Veratrum album																										1%	1%										
89	Aconitum lycoctonum ssp. septentrionale																										1%	1%										
90	Comarum palustre																											10%			1%							
91	Galium uliginosum																											1%										
92	Eriophorum polystachion																													50%	50%							
93	Ledum palustre																																		1%			
94	Parnassia palustris																																				<<1%	
95	**Moss**																																					
96	Rhytidium rugosum (Ehrh. ex Hedw.) Kindb.										1	5	2	12										+					+									
97	Dicranum fuscescens subsp. congestum (Brid.) K																																					
98	Polytrichum hyperboreum R. Br.			4	+		9	20	10								2	10			1	1	4		12	10	5	>>					>>>					
99	Aulacomnium turgidum (Wahlenb.) Schwägr.				6			15	10	25	6						12	20	10	11	6	4	12	+	12	10	10		>>>			>>>		+				
100	Dicranum spadiceum Zett.													+			2	4		+									>>					>>				
101	Racomitrium lanuginosum (Hedw.) Brid.							+	+					10			+	+						+					+									
102	Abietinella abietina (Hedw.) M. Fleisch.													3										+														
103	Polytrichum juniperinum Hedw.										6	8	1	10		10								+					+					>>				
104	Pogonatum dentatum (Menzies ex Brid.) Brid.											1																										
105	Pleurozium schreberi (Willd. ex Brid.) Mitt.			15		9				10	8			12	+	12	10	6								10			>									
106	Hylocomiastrum pyrenaicum (Spruce) M. Fleisch.						6																															
107	Polytrichastrum alpinum (Hedw.) G.L. Sm.													3	1					4		1												>				
108	Ptilium crista-castrensis (Hedw.) De Not.																								+													
109	Hylocomium splendens (Hedw.) Schimp.	20	15	10	12	14	20	25	20	25		8				12	12	15	10	11	9	8	12		15	15	10	>>	>>>			>>>	>>>	>>>>				
110	Dicranum fuscescens Turner	5						3	15		10	8	1		+	6	10				1		5															
111	Drepanocladus aduncus (Hedw.) Warnst.																2					1											>>					
112	Polytrichum strictum Menzies ex Brid.	5	10	4	6	9						5	1		1	10		6	2	8	6		6				4		>>			>>			8			
113	Ptilidium ciliare (L.) Hampe								2						+	2			6	6	1		2			2							+					
114	Sphagnum rubellum Wilson	10				9												3													+		>>		15			
115	Pseudobryum cinclidioides (Huebener) T.J. Kop.																									2								+				
116	Dicranum fuscescens var. flexicaule (Brid.) Wilso																		2								8											
117	Aulacomnium palustre (Hedw.) Schwägr.		5	10	4	14	12		3																8		6					>>	>>>		15			
118	Dicranum bonjeanii De Not.									10						6			2	6																		
119	Polytrichum jensenii I. Hagen																							+						+				+				
120	Ptilidium pulcherrimum (Weber) Hampe																			2																		
121	Tomentypnum nitens (Hedw.) Loeske	5					2					+			+												2	+		+		+						
122	Sanionia uncinata (Hedw.) Loeske	10	10													1											+	>>				+						
123	Distichium capillaceum (Hedw.) Bruch & Schimp.																							+														
124	Dicranum angustum Lindb.		10																						6				+			>>	>>>					
125	Sphagnum girgensohnii Russow	20	+	20						+		+																		+	+				25	+		
126	Pohlia nutans (Hedw.) Lindb.							3						+			10	10	6		6		6					+	+				>>>					
127	Polytrichum commune Hedw.	20	15		12				3	10															8	8												
128	Climacium dendroides (Hedw.) F. Weber & D. Mo																																					
129	Dicranum elongatum Schleich. ex Schwägr.	5			+	5	9	+			8							+							3	8												
130	Campylium chrysophyllum (Brid.) Lange																																					
131	Brachythecium mildeanum (Schimp.) Schimp.			2		+																			6													
132	Amblystegium serpens (Hedw.) Schimp.															1																+						
133	Sphagnum warnstorfii Russow		25	15	8	20	12																				2		+		+	+	>>		20			
134	Sphagnum balticum (Russow) C.E.O. Jensen				+	5		+	+																				+					+				
135	Loeskypnum badium (Hartm.) H.K.G. Paul					5																																
136	Ditrichum flexicaule (Schwägr.) Hampe							4		10													2															
137	Plagiothecium nemorale (Mitt.) A. Jaeger								2	5																												
138	Cynodontium strumiferum (Hedw.) Lindb.										1																											
139	Tortella tortuosa (Hedw.) Limpr.										+																											
140	Hypnum callichroum Brid.														+					2																		
141	Plagiothecium denticulatum (Hedw.) Schimp.																	3																				
142	Oncophorus wahlenbergii Brid.																	3																				
143	Mnium stellare Reichard ex Hedw.																		2																			
144	Sciurohypnum reflexum (Starke) Ignatov et Huttu																										2		+									
145	Philonotis fontana (Hedw.) Brid.																											+						+				
146	Rhytidiadelphus subpinnatus (Lindb.) T.J. Kop.																											+										
147	Calliergon cordifolium (Hedw.) Kindb.																											+		+						+		

Appendix C. Species cover-abundance in vegetation study plots (relevés). **Nomenclature for vascular plants followed Elven et al. 2007: Checklist of the Panarctic Flora (PAF). Vascular plants. -Draft. University of Oslo. Lichens followed H. Kristinsson & M. Zhurbenko 2006: Panarctic lichen checklist (http://archive.arcticportal.org/276/01/Panarctic_lichen_checklist.pdf). Mosses followed M.S. Ignatov, O.M. Afonina & E.A. Ignatova 2006: Check-list of mosses of East Europe and North Asia. Arctoa 15: 1-130 and for liverworts N.A. Konstantinova & A.D. Potemkin 1996: Liverworts of Russian Arctic: an annotated check-list and bibliography. Arctoa 6: 125-150. Cover-abundance scores: << = rare, < = <0.1% cover, + = 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50% 4 = 51-75%, 5 = 76-100%.** Cover-abundance codes were used for vascular plants, and % cover estimates were used for nonvascular **NOTES:** Ks-16 (all cells): circle near T10-1; Lichen, T12-1: 65% with lichen on rocks; Arctoparmelia separata (Th.Fr.) Hale, T3-2, T6-1, T12-2: from rocks; Hypogymnia physodes (L.) Nyl., T3-3: on the dead branches.

1	№	T1-1	T1-2	T1-3	T2-1	T2-2	T2-3	T2-4	T2-5	T2-6	T2-7	T2-8	T2-9	T3-1	T3-2	T3-3	T4-1	T4-2	T4-3	T5-0	T5-1	T5-2	T5-3	T5-4	T5-5	T5-6	T6-1	T6-2	T6-3	T7-1	T7-2	T7-3	T7-4	T7-5	T7-6	T8-1	T8-2
148	Limprichtia revolvens (Sw.) Loeske																																				
149	Meesia uliginosa Hedw.																																				
150	Paludella squarrosa (Hedw.) Brid.																																				
151	Dicranum acutifolium (Lindb. et H.Arnell) C.Jens. ex Weinm.				+			+																													
152	Stereodon plicatulus Lindb.							+												+	+					+											
153	Dicranum scoparium Hedw.									+		+														+											
154	Dicranella cerviculata (Hedw.) Schimp.																					+															
155	Straminergon stramineum (Dicks. ex Brid.) Hedenäs									+																											
156	Sphagnum russowii Warnst.																													+	+		+	+		+	+
157	Sphagnum angustifolium (C. Jens. ex Russ.) C. Jens.																													+	+	+	+	+			+
158	Sphagnum lenense H. Lindb. ex Pohle																														+	+		+	+		
159	Sphagnum capillifolium (Ehrh.) Hedw.																																		+		
160	Sphagnum inundatum Russ.																																				
161	Sphagnum obtusum Warnst.																																				
162	Sphagnum aongstroemii C. Hartm.																																				
163	Bryum caespiticium Hedw.																																				
164	Dicranum bergeri Bland. in Starke																																				
165	Polytrichum piliferum Hedw.																																				
166	Plagiomnium ellipticum (Brid.) T. Kop.																																				
167	Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer et Scherb.																																				
168	Brachythecium salebrosum (Hoffm. ex F. Weber & D. Mohr) Schimp.																																				
169	Ceratodon purpureus (Hedw.) Brid.																										+										
170	Eurhynchium pulchellum (Hedw.) Jenn.																																				
171	**Lichen**																																				
172	Cetraria islandica (L.) Ach.					4%											1%		3%	1%		+	+	+						<<		+	+			2%	
173	Flavocetraria nivalis (L.) Kärnefelt et A.Thell													5%	4%	+				4%	+	+		+			6%		5%	<<	<<						
174	Cladonia amaurocraea (Flörke) Schaer.	5%					+	12%						+	1%	4%	3%		+				32%				35%		30%		1%	8%	5%	<<	1%		+
175	Cladonia arbuscula ssp. mitis (Sandst.) Ruoss	15%	4%	8%	6%	13%		3%						10%	8%	4%	+	30%	10%	12%	1%	15%	5%	18%			1%	2%		3%	+	1%	3%		+	2%	8%
176	Cladonia rangiferina (L.) F.H. Wigg	5%	8%	8%	6%	4%	40%	43%	<5%	<5%	<5%	<5%	<5%	3%	4%	13%			10%	25%	15%	4%	3%	2%	10%	<5%	1%	8%	2%	1%	2%	3%	20%		+	15%	3%
177	Thamnolia vermicularis (Sw.) Schaer.	1%													+			1%		+	1%	+						2%	2%								
178	Flavocetraria cucullata (Bellardi) Kärnefelt et A.Thell		+	<<				<<						+	+	+	1%	2%	+	1%	+	2%									+	+					1%
179	Peltigera aphthosa (L.) Willd.	30%																																+			6%
180	Cladonia uncialis (L.) F.H.Wigg.	15%	20%	30%	15%	26%		12%						1%	2%	2%	30%	18%	30%	25%		11%		6%			1%	4%	1%	+					3%	11%	12%
181	Cladonia fimbriata (L.) Fr.							3%																													
182	Dactylina arctica (Hook.) Nyl.			<<														+		1%	+		+														
183	Cetraria laevigata Rass.		+	1%										3%							2%	+															
184	Cladonia gracilis (L.) Willd. subsp. gracilis		1%	3%		13%								<<	1%	7%		2%	10%	+				3%			1%	3%		1%		5%	2%			+	+
185	Asahinea chrysantha (Tuck.) C.F.Culb. & W.L.Cul	20%	8%	30%	10%									8%	8%	2%			7%	11%	7%	2%						5%									
186	Cladonia pleurota (Flörke) Schaer.	+														1%					+	+					2%					+					
187	Peltigera scabrosa Th.Fr.		9%	3%	15%														2%												<<						
188	Bryocaulon divergens (Ach.) Kärnefelt		9%	5%	11%									+						+								5%									
189	Sphaerophorus globosus (Huds.) Vain.		20%		11%													7%			5%	20%															
190	Cladonia carneola (Fr.) Fr.		<<																																		
191	Rhizocarpon geographicum (L.) DC.		+																																		
192	Cladonia stellaris (Opiz) Pouzar & Vezda			2%																																	
193	Ochrolechia frigida (Sw.) Lynge				16%																																
194	Peltigera leucophlebia (Nyl.) Gyeln.							7%																								2%	5%				
195	Stereocaulon rivulorum H.Magn.													5%																							
196	Alectoria ochroleuca (Hoffm.) A. Massal.													5%	6%	4%				+	4%							6%									
197	Cetraria odontella (Ach.) Ach.													+														13%									
198	Bryoria nitidula (Th.Fr.) Brodo & D.Hawksw.													+	+																						
199	Alectoria nigricans (Ach.) Nyl.													+																							
200	Cladonia merochlorophaea Asahina														+																						
201	Sphaerophorus fragilis (L.) Pers.														+		10%		2%									2%									
202	Parmelia omphalodes (L.) Ach.														<<	+																					
203	Mycobilimbia hypnorum (Lib.) Kalb & Hafellner														<<	2%								+													
204	Toninia cinereovirens (Schaer.) A.Massal.														<<	1%																					
205	Arctoparmelia separata (Th.Fr.) Hale														10%												3%										
206	Hypogymnia physodes (L.) Nyl.															10%																					
207	Stereocaulon paschale (L.) Hoffm.																	20%						<<													
208	Peltigera polydactylon (Neck.) Hoffm.																		12%													5%					
209	Peltigera membranacea (Ach.) Nyl.																				25%																
210	Cladonia subfurcata (Nyl.) Arnold																				+																
211	Cladonia chlorophaea (Flörke ex Sommerf.) Spreng.																					+															
212	Cladonia verticillata (Hoffm.) Schaer.																					+															
213	Peltigera malacea (Ach.) Funck																					6%															
214	Cladonia borealis S. Stenroos																											1%									
215	Lecanora epibryon (Ach.) Ach.																											1%									
216	Nephroma arcticum (L.) Torss.																																5%	+			
217	Cladonia bacilliformis (Nyl.) Glück																																				
218	Peltigera rufescens (Weiss) Humb.																																				
219	Cladonia cornuta (L.) Hoffm.																																				
220	Melanelia panniformis (Nyl.) Essl.																																				

Appendix C. Species cover-abundance in vegetation study plots (relevés). **Nomenclature for vascular plants followed Elven et al. 2007: Checklist of the Panarctic Flora (PAF). Vascular plants. -Draft. University of Oslo. Lichens followed H. Kristinsson & M. Zhurbenko 2006: Panarctic lichen checklist (http://archive.arcticportal.org/276/01/Panarctic_lichen_checklist.pdf). Mosses followed M.S. Ignatov, O.M. Afonina & E.A. Ignatova 2006: Check-list of mosses of East Europe and North Asia. Arctoa 15: 1-130 and for liverworts N.A. Konstantinova & A.D. Potemkin 1996: Liverworts of Russian Arctic: an annotated check-list and bibliography. Arctoa 6: 125-150. Cover-abundance scores: << = rare, < = <0.1% cover, + = 1%, 1 = 1-5%, 2 = 6-25%, 3 = 26-50% 4 = 51-75%, 5 = 76-100%.** Cover-abundance codes were used for vascular plants, and % cover estimates were used for nonvascular **NOTES:** Ks-16 (all cells): circle near T10-1; Lichen, T12-1: 65% with lichen on rocks; Arctoparmelia separata (Th.Fr.) Hale, T3-2, T6-1, T12-2: from rocks; Hypogymnia physodes (L.) Nyl., T3-3: on the dead branches.

1	№	T8-3	T9-1	T9-2	T9-3	T9-4	T9-5	T10-1	T10-2	T10-3	T11-1	T11-2	T12-1	T12-2	T13-1	T13-2	T14-1	T14-2	T15-1	T15-2	T16-1	T16-2	Ks-1	Ks-2	Ks-3	Ks-4	Ks-5	Ks-6	Ks-7	Ks-8	Ks-9	Ks-10	Ks-11	Ks-12	Ks-13	Ks-14	Ks-15	Ks-16
148	Limprichtia revolvens (Sw.) Loeske																													+	+							
149	Meesia uliginosa Hedw.																														+							
150	Paludella squarrosa (Hedw.) Brid.																														+				15			
151	Dicranum acutifolium (Lindb. et H.Arnell) C.Jens.																						+															
152	Stereodon plicatulus Lindb.																		+										+						+			
153	Dicranum scoparium Hedw.							+	+																													
154	Dicranella cerviculata (Hedw.) Schimp.																																					
155	Straminergon stramineum (Dicks. ex Brid.) Heden								+																					+	+							
156	Sphagnum russowii Warnst.	+	+				+																															
157	Sphagnum angustifolium (C. Jens. ex Russ.) C. J						+			+																										+		
158	Sphagnum lenense H. Lindb. ex Pohle	+		+		+																											+	+				
159	Sphagnum capillifolium (Ehrh.) Hedw.																																					
160	Sphagnum inundatum Russ.					+																																
161	Sphagnum obtusum Warnst.																													+								
162	Sphagnum aongstroemii C. Hartm.																																+					
163	Bryum caespiticium Hedw.									+															+													
164	Dicranum bergeri Bland. in Starke																	+																				
165	Polytrichum piliferum Hedw.													+																								
166	Plagiomnium ellipticum (Brid.) T. Kop.																										+	+										
167	Bryum pseudotriquetrum (Hedw.) Gaertn., Meyer																										+											
168	Brachythecium salebrosum (Hoffm. ex F. Weber &																											+										
169	Ceratodon purpureus (Hedw.) Brid.																								+													
170	Eurhynchium pulchellum (Hedw.) Jenn.																																+					
171	**Lichen**																																					
172	Cetraria islandica (L.) Ach.	<<	+	<<	2%				<<	1%						<<			1%		12%		9%												1%			
173	Flavocetraria nivalis (L.) Kärnefelt et A.Thell		+										7%		3%								9%	+										+				
174	Cladonia amaurocraea (Flörke) Schaer.	+	5%	2%	20%	10%	3%			2%	3%	20%		7%	40%		15%		5%			+	11%		5%									3%	1%	+		
175	Cladonia arbuscula ssp. mitis (Sandst.) Ruoss	+	+				9%	3%		<<			13%	15%	25%	10%	8%	3%	20%	1%		10%	17%	+	8%									12%				
176	Cladonia rangiferina (L.) F.H. Wigg	<<	10%					3%	+	2%	5%	20%	1%	1%	10%	20%	15%	3%	13%	15%	13%	25%	4%		+				+					<<	5%			
177	Thamnolia vermicularis (Sw.) Schaer.														1%									+														
178	Flavocetraria cucullata (Bellardi) Kärnefelt et A.Th	<<		+	6%			1%					1%		10%	+			5%			+			2%									<<				
179	Peltigera aphthosa (L.) Willd.										15%															5%												
180	Cladonia uncialis (L.) F.H.Wigg.							1%		+	20%		8%	15%			2%	14%		33%		40%							+					5%	3%			
181	Cladonia fimbriata (L.) Fr.																												<<									
182	Dactylina arctica (Hook.) Nyl.														1%			+																+				
183	Cetraria laevigata Rass.										2%	5%																						<<				
184	Cladonia gracilis (L.) Willd. subsp. gracilis			<<			3%	1%		<<		6%	3%	1%				+	5%	+														<<	1%			
185	Asahinea chrysantha (Tuck.) C.F.Culb. & W.L.Cul												13%																									
186	Cladonia pleurota (Flörke) Schaer.																			+																		
187	Peltigera scabrosa Th.Fr.									<<		1%																										
188	Bryocaulon divergens (Ach.) Kärnefelt																																					
189	Sphaerophorus globosus (Huds.) Vain.																																					
190	Cladonia carneola (Fr.) Fr.																																					
191	Rhizocarpon geographicum (L.) DC.																																					
192	Cladonia stellaris (Opiz) Pouzar & Vezda																																					
193	Ochrolechia frigida (Sw.) Lynge																																					
194	Peltigera leucophlebia (Nyl.) Gyeln.									3%		18%																										
195	Stereocaulon rivulorum H.Magn.												3%																									
196	Alectoria ochroleuca (Hoffm.) A. Massal.												13%																									
197	Cetraria odontella (Ach.) Ach.																																					
198	Bryoria nitidula (Th.Fr.) Brodo & D.Hawksw.																																					
199	Alectoria nigricans (Ach.) Nyl.																																					
200	Cladonia merochlorophaea Asahina																																					
201	Sphaerophorus fragilis (L.) Pers.												1%	5%																								
202	Parmelia omphalodes (L.) Ach.																																					
203	Mycobilimbia hypnorum (Lib.) Kalb & Hafellner																																					
204	Toninia cinereovirens (Schaer.) A.Massal.																																					
205	Arctoparmelia separata (Th.Fr.) Hale													3%																								
206	Hypogymnia physodes (L.) Nyl.																																					
207	Stereocaulon paschale (L.) Hoffm.									<<																												
208	Peltigera polydactylon (Neck.) Hoffm.								2%																													
209	Peltigera membranacea (Ach.) Nyl.																																					
210	Cladonia subfurcata (Nyl.) Arnold																																					
211	Cladonia chlorophaea (Flörke ex Sommerf.) Spre													1%																								
212	Cladonia verticillata (Hoffm.) Schaer.												1%																									
213	Peltigera malacea (Ach.) Funck																																					
214	Cladonia borealis S. Stenroos																																					
215	Lecanora epibryon (Ach.) Ach.																																					
216	Nephroma arcticum (L.) Torss.																																					
217	Cladonia bacilliformis (Nyl.) Glück				2%																																	
218	Peltigera rufescens (Weiss) Humb.							1%																														
219	Cladonia cornuta (L.) Hoffm.												1%																									
220	Melanelia panniformis (Nyl.) Essl.													1%																								

Appendix D. List of birds observed in Kharp study area and their breeding status.

Common Name	Scientific Name	Breeding status
Eurasian Wigeon	*Anas penelope*	confirmed
Green-winged Teal	*Anas crecca*	confirmed
Long-tailed Duck	*Clangula hyemalis*	
Black Scoter	*Melanitta nigra*	
Willow Ptarmigan	*Lagopus lagopus*	confirmed
Arctic Loon	*Gavia arctica*	confirmed
Northern Harrier	*Circus cyaneus*	
Eurasian Kestrel	*Falco tinnunculus*	
European Golden-Plover	*Pluvialis apricaria*	confirmed
Wood Sandpiper	*Tringa glareola*	confirmed
Ruff	*Philomachus pugnax*	
unidentified snipe	*Gallinago* sp.	
Common Sandpiper	*Actitis hypoleucos*	
Common Black-headed Gull	*Larus ridibundus*	
Heuglin's Gull	*Larus heuglini*	probable
Common Gull	*Larus canus*	confirmed
Arctic Tern	*Sterna paradisaea*	confirmed
Rock Pigeon	*Columba livida*	
Bank Swallow	*Riparia riparia*	
Meadow Pipit	*Anthus pratensis*	confirmed
Yellow Wagtail	*Motacilla flava*	
White Wagtail	*Motacilla alba*	confirmed
Northern Shrike	*Lanius excubitor*	
European Magpie	*Pica pica*	
Hooded Crow	*Corvus cornix*	probable
Common Raven	*Corvus corax*	
Willow Warbler	*Phylloscopus trochilus*	confirmed
Arctic Warbler	*Phylloscopus borealis*	confirmed
Northern Wheatear	*Oenanthe oenanthe*	confirmed
Bluethroat	*Luscinia svecica*	confirmed
Fieldfare	*Turdus pilaris*	confirmed
House Sparrow	*Passer domesticus*	confirmed
Eurasian Tree Sparrow	*Passer montanus*	confirmed
Brambling	*Fringilla monifringilla*	
Common Redpoll	*Acanthis flammea*	confirmed
Little Bunting	*Ocyris pusillus*	confirmed

Appendix. E. Texture and chemistry properties of soil samples from Kharp. Chemical analyses were conducted after oven-drying to 100° C. Analyses performed by University of Alaska Palmer Research Center, Palmer, AK.

		Soil texture					Soil chemistry							
		%	%	%	%		%	%		meq/100g	meq/100g	meq/100g	meq/100g	meq/100g
Plot ID	Microsite	Gravel >2mm	Sand	Silt	Clay	USDA texture	C	N	pH	CEC	K	Ca	Mg	Na
K-T01	Boil	8.36	17.20	56.00	26.80	SiL	0.41	0.02	3.95	12.28	0.12	4.44	2.86	0.09
K-T01	Interboil	5.13	37.20	44.00	18.80	L	2.58	0.15	3.65	16.65	0.11	3.36	2.09	0.07
K-T02	nd	<.01	65.33	23.33	11.33	SaL	11.90	0.80	3.83	46.25	0.35	6.61	4.15	0.06
K-T03	Boil	13.12	21.20	54.00	24.80	SiL	0.60	0.01	4.18	15.45	0.11	6.28	2.01	0.18
K-T04	Boil	5.57	19.20	52.00	28.80	SiCL	0.59	0.01	3.81	17.40	0.12	4.23	4.39	0.10
K-T04	Interboil	4.14	29.20	44.00	26.80	L	3.00	0.16	3.67	13.58	0.15	3.72	3.59	0.07
K-T05	Interboil	15.06	67.43	22.86	9.71	SaL	12.65	0.63	3.58	39.10	0.15	1.90	1.13	0.08
K-T06	Boil	9.66	29.20	46.00	24.80	L	1.87	0.08	3.80	18.88	0.16	6.08	2.93	0.05
K-T07	Boil	<.01	25.20	46.00	28.80	CL	1.99	0.06	3.71	20.41	0.16	6.93	3.73	0.10
K-T07	Interboil	4.75	na	na	na	org	47.57	1.19	3.72	70.51	0.42	5.88	1.97	<.01
K-T08	Boil	20.79	31.20	50.00	18.80	SiL	4.37	0.10	3.54	19.77	0.18	3.97	1.76	0.04
K-T08	Interboil	19.61	17.20	52.00	30.80	SiCL	0.79	<.01	3.86	5.89	0.19	7.05	3.12	0.09
K-T09	Boil	2.54	21.20	50.00	28.80	CL	1.62	0.06	3.38	23.43	0.23	3.86	4.73	0.05
K-T09	Interboil	<.01	na	na	na	org	42.18	0.75	3.78	69.87	0.19	6.21	3.96	0.06
K-T10	Boil	20.32	33.20	50.00	16.80	SiL	0.11	<.01	6.09	19.38	0.42	12.00	9.83	0.13
K-T13	Oe	0.81	na	na	na	org	47.20	1.36	4.45	24.00	0.31	5.23	8.13	0.02
K-T14	nd	33.19	33.20	46.00	20.80	L	4.40	0.22	4.07	16.53	0.09	4.34	1.91	0.07
K-T15	Interboil	<.01	52.00	36.67	11.33	L	20.37	1.22	4.44	85.88	0.30	16.47	22.22	0.12
K-T15	Boil	6.30	29.20	50.00	20.80	SiL	2.54	0.06	3.83	20.28	0.07	2.77	4.71	0.07
K-T16	Interboil	<.01	45.33	40.00	14.67	L	16.61	0.99	4.82	75.76	0.34	28.53	24.95	0.15
K-T16	Boil	1.06	27.20	46.00	26.80	L	3.47	0.22	4.43	36.36	0.22	11.48	12.42	0.11

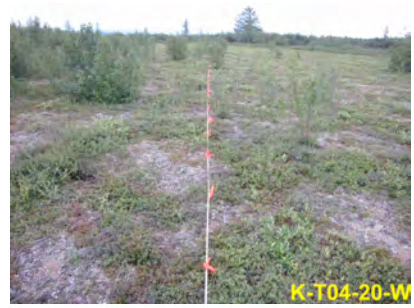
Appendix F. Photos of Kharp transects, July-August 2011. The photo identifiers consist of the transect number, followed by the location (m) on each transect that the photo was taken, followed by a cardinal direction indicating the approximate photo azimuth.

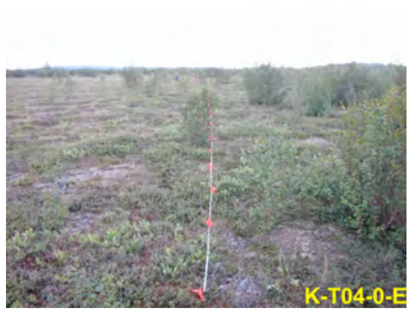
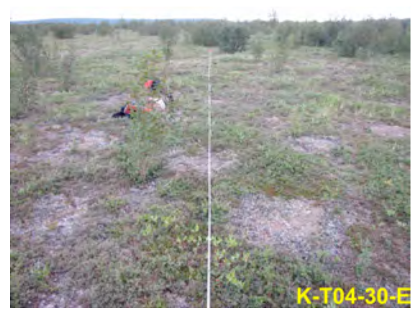

K-T03-12.5-NW

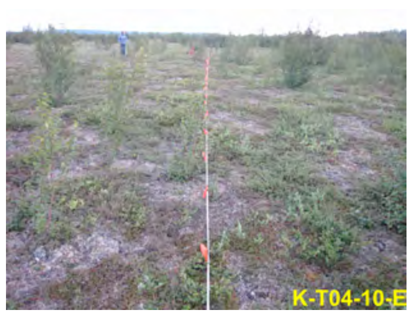
K-T03-37.5-SE

K-T04-20-E

K-T03-12.5-SE

K-T03-

K-T04-20-W

K-T03-25-NW

K-T04-0-E

K-T04-30-E

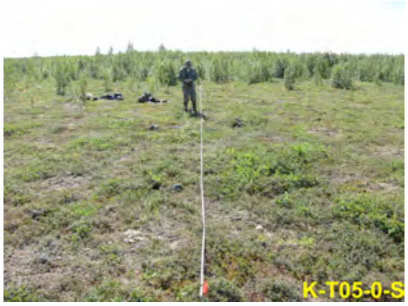
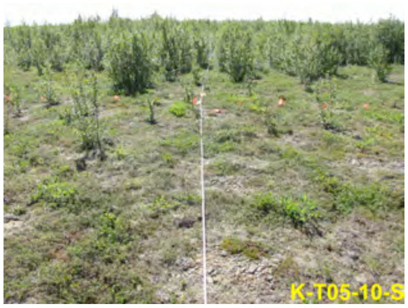
K-T03-25-SE

K-T04-10-E

K-T04-30-W

K-T03-37.5-NW

K-T04-10-W

K-T04-50-W


K-T05-0-S

K-T05-10-S

K-T05-20-S

K-T05-30-S

K-T05-30-N

K-T05-40-S

K-T05-40-N

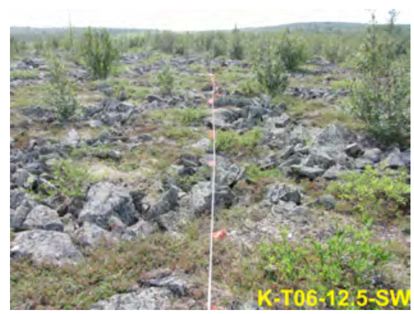
K-T05-50-S

K-T05-50-N

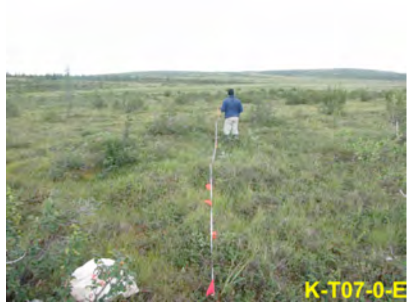
K-T05-60-S

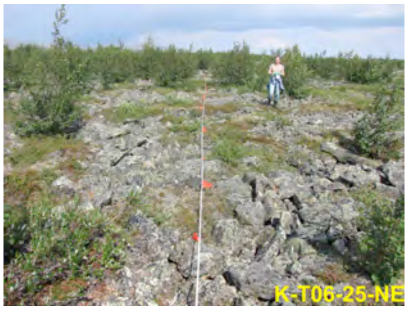
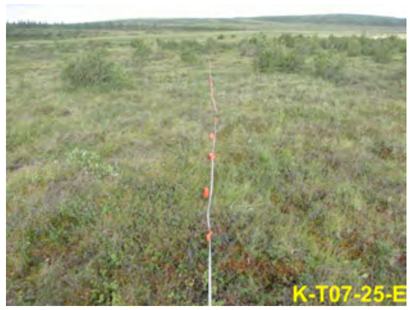
K-T05-60-N

K-T05-70-N

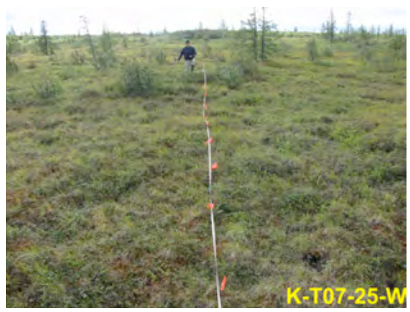
K-T06-0-SW

K-T06-12.5-SW

K-T06-12.5-NE

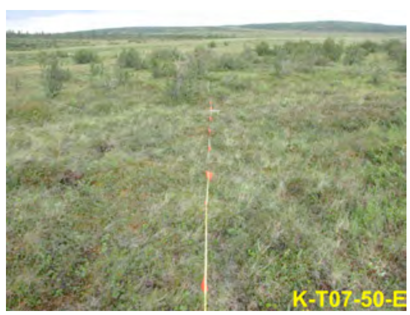

K-T06-25-SW

K-T07-0-E

K-T07-75-E

K-T06-25-NE

K-T07-25-E

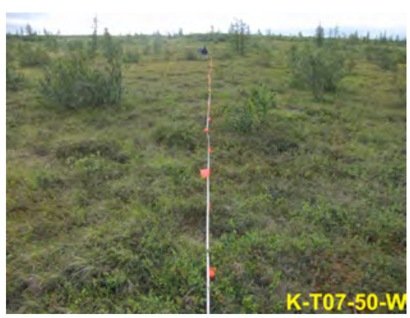
K-T07-75-W

K-T06-37.5-SW

K-T07-25-W

K-T07-100-W

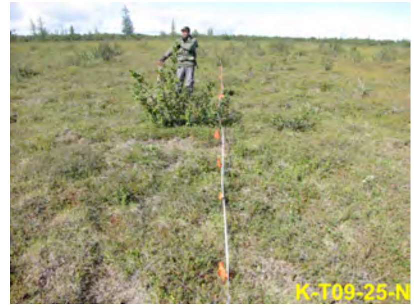
K-T06-37.5-NE

K-T07-50-E

K-T08-0-S

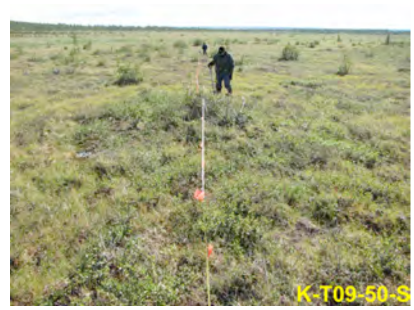
K-T06-50-NE

K-T07-50-W

K-T08-10-S

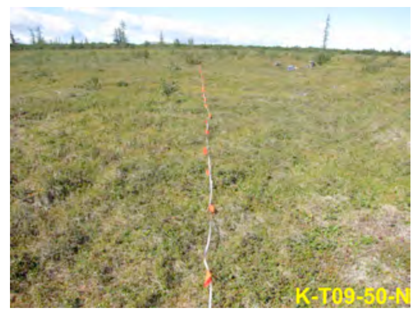

K-T08-10-N

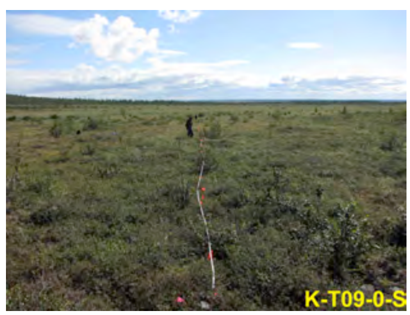
K-T08-40-S

K-T09-25-N

K-T08-20-S

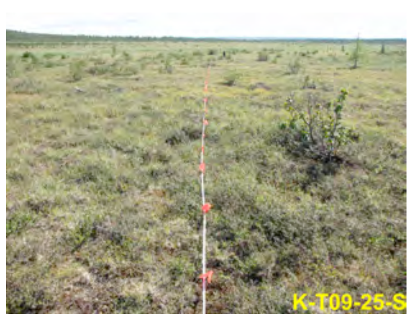
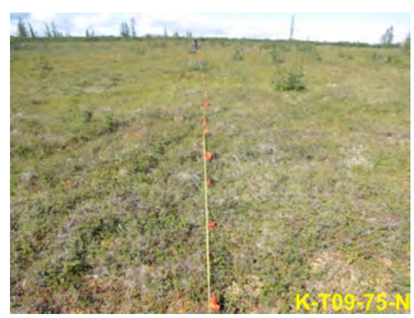
K-T08-40-N

K-T09-50-S

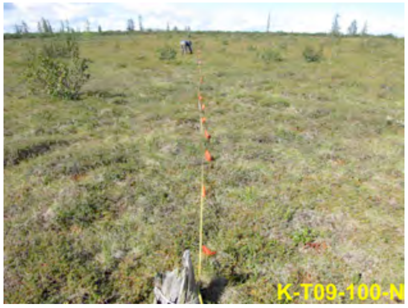
K-T08-20-N

K-T08-

K-T09-50-N

K-T08-30-S

K-T09-0-S

K-T09-75-S

K-T08-30-N

K-T09-25-S

K-T09-75-N


K-T09-100-N

K-T10-25-N

K-T11-12.5-S

K-T10-0-S

K-T10-37.5-S

K-T11-12.5-N

K-T10-12.5-S

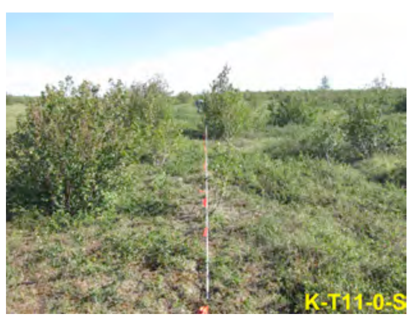
K-T10-37.5-N

K-T11-25-N

K-T10-12.5-N

K-T10-50-N

K-T12-50-N

K-T10-25-S

K-T11-0-S

K-T12-25-N


K-T12-25-S

K-T13-0-SE

K-T14-25-NW

K-T12-0-S

K-T14-0-SE

K-T15-0-E

K-T13-25-NW

K-T14-12.5-SE

K-T15-12.5-E

K-T13-12.5-SE

K-T14-12.5-NW

K-T15-12.5-W

K-T13-12.5-NW

K-T14-25-NW

K-T15-25-W


K-T16-0-NE

K-T17-12.5-E

K-T18-12.5-E

K-T16-12.5-NE

K-T17-12.5-W

K-T18-12.5-W

K-T16-12.5-SW

K-T17-25-W

K-T18-25-W

K-T16-25-SW

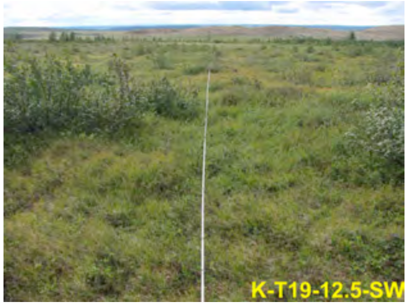
K-T17-25-W

K-T19-0-SW

K-T17-0-E

K-T18-0-E

K-T19-0-SW

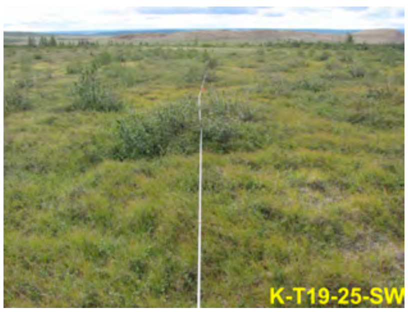

K-T19-12.5-SW

K-T19-37.5-NE

K-T20-25-W

K-T19-12.5-NE

K-T19-50-NE

K-T21-0-E

K-T19-25-SW

K-T20-0-E

K-T21-12.5-E

K-T19-25-NE

K-T20-12.5-W

K-T21-12.5-W

K-T19-37.5-SW

K-T20-12.5-E

K-T21-25-E


K-T21-25-W


K-T21-50-W


K-T22-12.5-W


K-T21-37.5-E


K-T22-0-E


K-T22-20-W


K-T21-37.5-W


K-T22-12.5-E