



Vegetation Sampling in the Arctic Inventory and Monitoring Network, 2009-2012

Natural Resource Data Series NPS/ARCN/NRDS—2012/408



ON THE COVER

Sampling vegetation on the “Avalanche Slope” transect of the Walker Lake North sampling node in Gates of the Arctic National Park. This plot was dominated by low shrubs such as crowberry (*Empetrum hermaphroditum*) and lowbush cranberry (*Vaccinium vitis-idaea*). The plot is at about 900 m (2950 ft) above sea level. White spruce (*Picea glauca*) forest is visible in the valley below, and the mountains in the background reach about 1350 m (4400 ft) elevation. The samplers are wearing headnets against numerous mosquitos. The pole apparatus on the right holds a laser used for point-intercept sampling. Photograph by: Nic Jelinski, NPS ARCN.

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David K. Swanson

National Park Service
4175 Geist Road
Fairbanks, AK 99709

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Data in this report were collected and analyzed using methods based on established, peer-reviewed protocols and were analyzed and interpreted within the guidelines of the protocols.

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Abstract

The National Park Service Arctic Inventory and Monitoring Network (ARCN) is in the process of establishing a system of permanent vegetation monitoring plots across 5 roadless National Park Service (NPS) units in northern Alaska. Plots are located at “nodes”, which consist of a base camp and approximately 20 plots accessible by foot or boat from the camp. Node locations are chosen for accessibility via fixed-wing aircraft and proximity to a variety of ecosystems. Plot locations are systematic along transects with a randomized start within strata based on major landforms. Sampling includes cover and height, using point intercept, by species of vascular plants and by species or species-group of non-vascular plants; tree measurements on a fixed-area plot, and soil and site descriptions including herbivory observations.

To date we have sampled 305 plots at 16 nodes, with approximately 10 more nodes and 200 more plots anticipated in 2013-14. Coverage of major ecological gradients by the plots sampled to date was evaluated. Coverage of different elevations shows some bias toward lower elevations but is generally adequate. Ecotypes identified on an existing ARCN-wide map are generally well represented, with most major gaps to be filled by planned future sampling. The main exception is the Upland Alder-Willow Tall Shrub ecotype, which is likely to be under-sampled due to difficult access and safety issues (poor grizzly bear visibility).

The transects are an attractive unit for which to summarize the vegetation data, because the plots within them are chosen objectively and have greatly reduced variance in plant cover as compared to groups of plots from different transects or different nodes. However, coefficients of variation remain high between plots within a transect for both plant species cover and ground cover types (litter, rock, etc.).

Tree stands had low basal area and were often dominated by “saplings” (diameter at breast height < 12 cm), which in the subarctic often represent mature trees. Most stands were dominated by a single species in all strata, though a few showed evidence for succession from hardwoods to spruce.

Lichen grazing effects by caribou were localized to just two nodes, while browsing effects (by moose, and locally hares) were widespread and occasionally heavy on willows and poplars throughout the network.

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Introduction

Vegetation and soils comprise one of the monitoring vital signs of the National Park Service Arctic Inventory and Monitoring Network (ARCN; Fig. 1) (Lawler et al. 2009). The monitoring vital sign has several components (Swanson and Neitlich 2011), two of which have network-wide coverage: 1) plant cover by point-intercept, and tree measurements, in 8-m radius plots; and 2) lichen composition and diversity monitoring in large (35 m radius) plots by a modified Forest Inventory and Analysis (FIA) protocol. The latter study is based primarily on plots that were established prior to ARCN in the Western Arctic National Parklands (WEAR; Holt and Neitlich 2010), supplemented by plots placed in Gates of the Arctic National Park and Preserve (GAAR) by ARCN in 2012. The former project, commonly known as the “vegetation nodes”, is the subject of the present report. The vegetation nodes were established by ARCN to provide data not available from the other studies: network-wide sampling of cover of all plants (vascular and nonvascular) by a highly repeatable method, and tree size measurements. The stated objectives for the vegetation node monitoring program are: 1) to detect change in major structural properties of vegetation within deliberately selected representative physiographic areas; and 2) to provide ground reference data for sampling and modeling based on remote sensing (Swanson and Neitlich 2011).

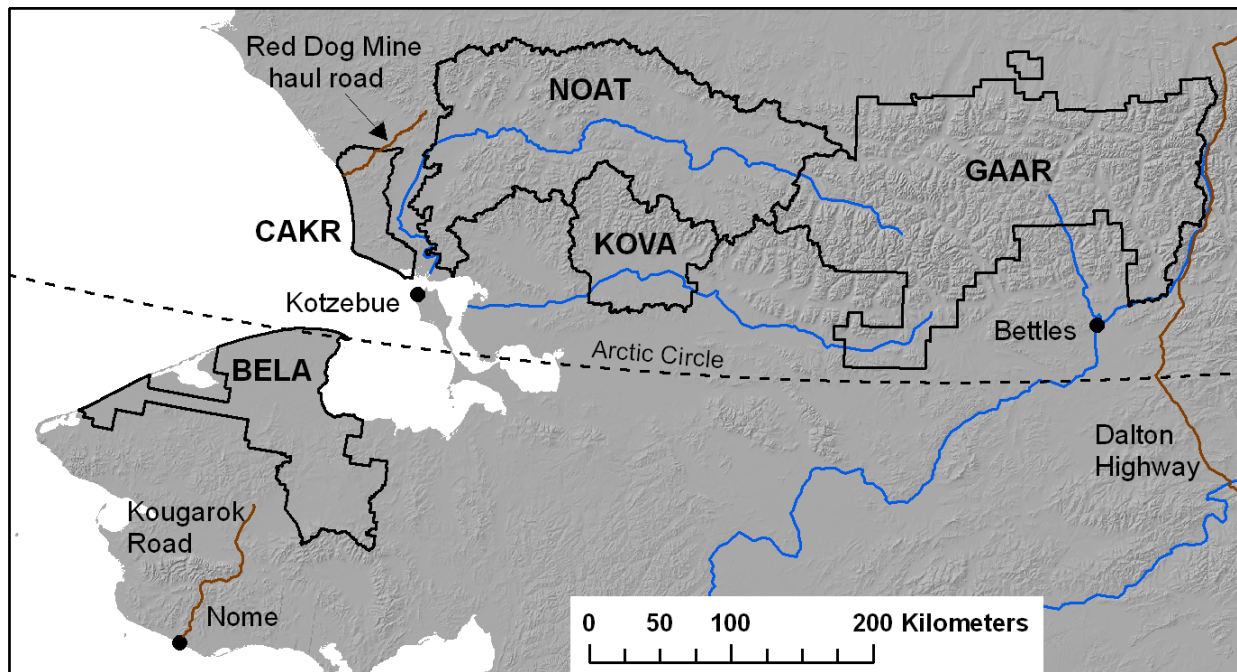


Figure 1. The NPS Arctic Inventory and Monitoring Network (ARCN). BELA – Bering Land Bridge National Preserve, CAKR – Cape Krusenstern National Monument, GAAR – Gates of the Arctic National Park and Preserve, KOVA – Kobuk Valley National Park, NOAT – Noatak National Preserve.

The vegetation node sampling scheme was tested in 2009-10 (Swanson 2010, Swanson 2011a), and its methods are detailed in a draft protocol (Swanson and Neitlich 2011). Sampling entered “production” phase in 2011 (Swanson 2011b) and continued in 2012. The initial sampling of the vegetation nodes is currently more than half completed. We expect it to be largely completed in 2013, with minor additions in 2014, and re-sampled in the future at a 10- to 15-year interval. The

purpose of the present report is to evaluate the progress to date, especially the coverage and adequacy of data to meet monitoring objectives, before embarking on the final major year of new plot establishment. All data gathered to date are analyzed in the current report, with the exception of plants recorded in the field as unknowns; these plants are currently being identified by botanical experts.

Methods

The Study Area

ARCN is a nearly completely roadless area of over 8 million hectares, nearly one-fourth of the total land area managed by the National Park Service (Fig. 1). The vegetation of ARCN consists mainly of arctic tundra, with spruce and birch forest (taiga) in the south at low elevations in the interior parks (Fig. 2). Low shrub- and herb-dominated vegetation occurs in taiga wetlands and burned areas in the south, and on lowland tundra throughout the network. Sparse alpine vegetation and barrens dominate at high elevations. Tall shrub communities are most common on floodplains and near treeline. They occur in small patches at low to moderate elevations throughout the network, with their most extensive occurrences shown in Fig. 2.

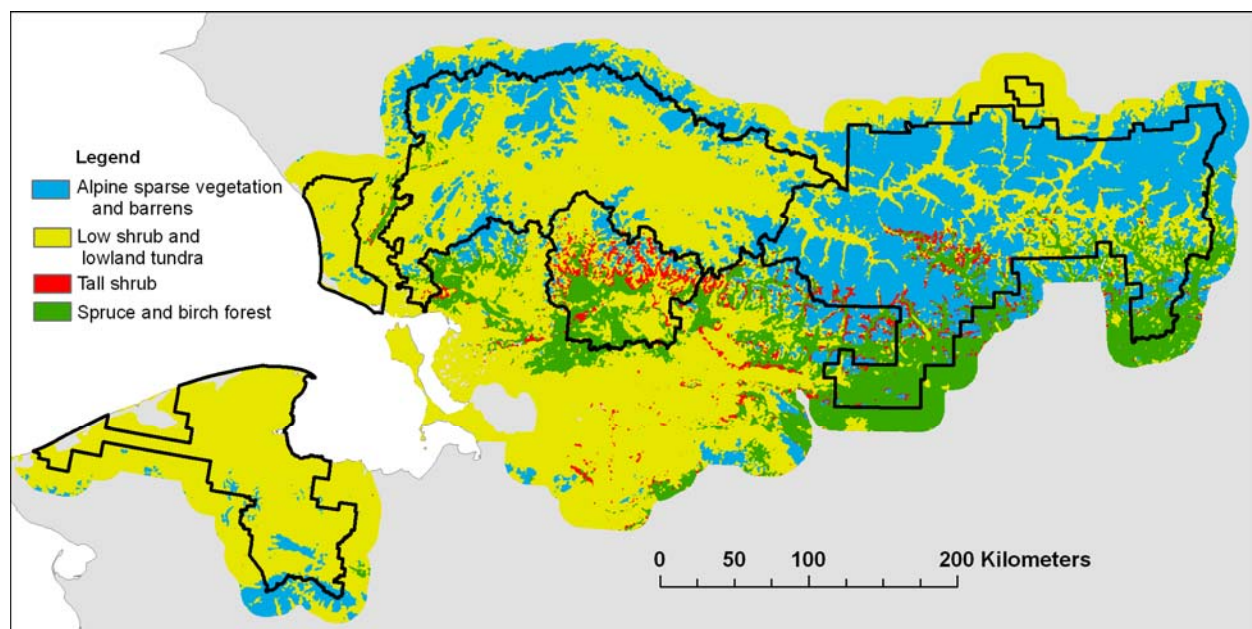


Figure 2. Vegetation of ARCN, generalized from 44 ecotypes mapped by Jorgenson et al. (2009).

Sampling Methods

Each vegetation node consists of a set of approximately 20 plots accessed on foot from a central base campsite (Fig. 3). Plots are located with high-resolution GPS and marked with a buried magnet for future re-sampling. The node locations are chosen to be readily accessible and representative of major ARCN ecosystems as defined by Jorgenson et al. (2009). All nodes to date are accessible by fixed-wing aircraft landing on lakes or river gravel bars. Future nodes will be similar, except for the possible inclusion of one or two helicopter-access nodes near Kotzebue. The vicinity of each node is stratified into landform-based physiographic units, and proposed transect locations are placed within the strata. Transect starting points and azimuths are

randomized (within limits, to avoid straying out of the physiographic strata), and plots are located systematically thereafter. A few plots with deliberately chosen locations have also been sampled, to target features of special interest. At each plot, plant cover and height by species (or species group for many non-vascular plants) are measured by point intercept using a laser at 100 points spaced 25 cm apart on two lines. Trees, saplings, and seedlings are inventoried on an 8-m radius fixed-area plot. Comprehensive site and soil descriptions are made at each plot, and the intensity of herbivore effects on vegetation is assessed. For sampling method details see Swanson and Neitlich (2011).

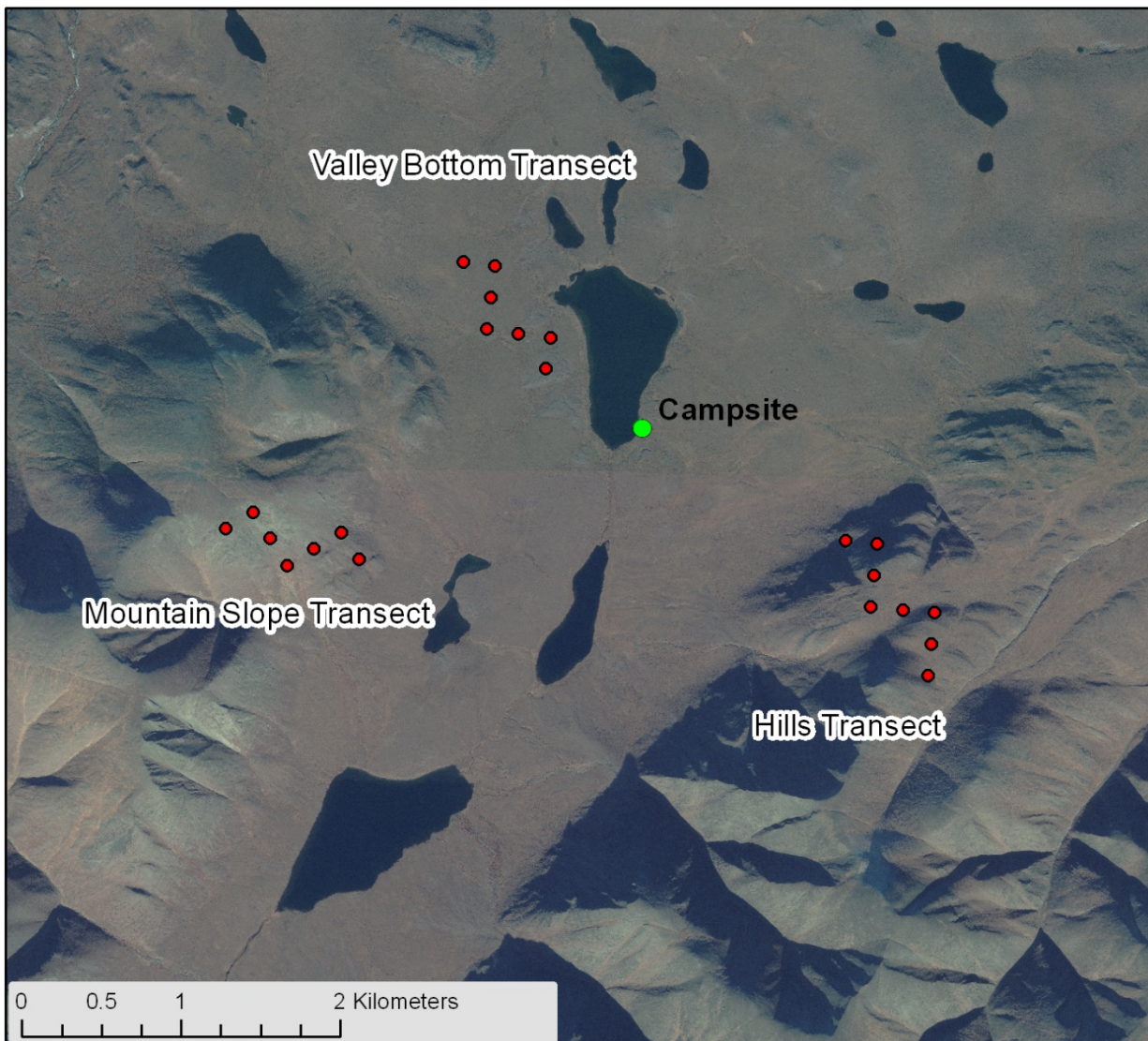


Figure 3. An example ARCN vegetation sampling node: Goedecke's Lake in Gates of the Arctic National Park. The base campsite was established by floatplane. The plots (8 m radius, shown as red dots) are arrayed systematically along transects chosen to represent major landforms.

Results and Discussion

As of 2012 we had sampled 16 nodes that contained 295 systematically chosen plots along 47 transects (Fig. 4, Table 1). As a measure of sampling intensity, we divide the total land area of ARCN (82,000 km²) by 295 plots to obtain an average of 278 km² of land area represented by each plot. An additional 6 deliberately located plots were sampled, for 301 plots total. The discussion below is based primarily on the 295 systematically chosen plots.

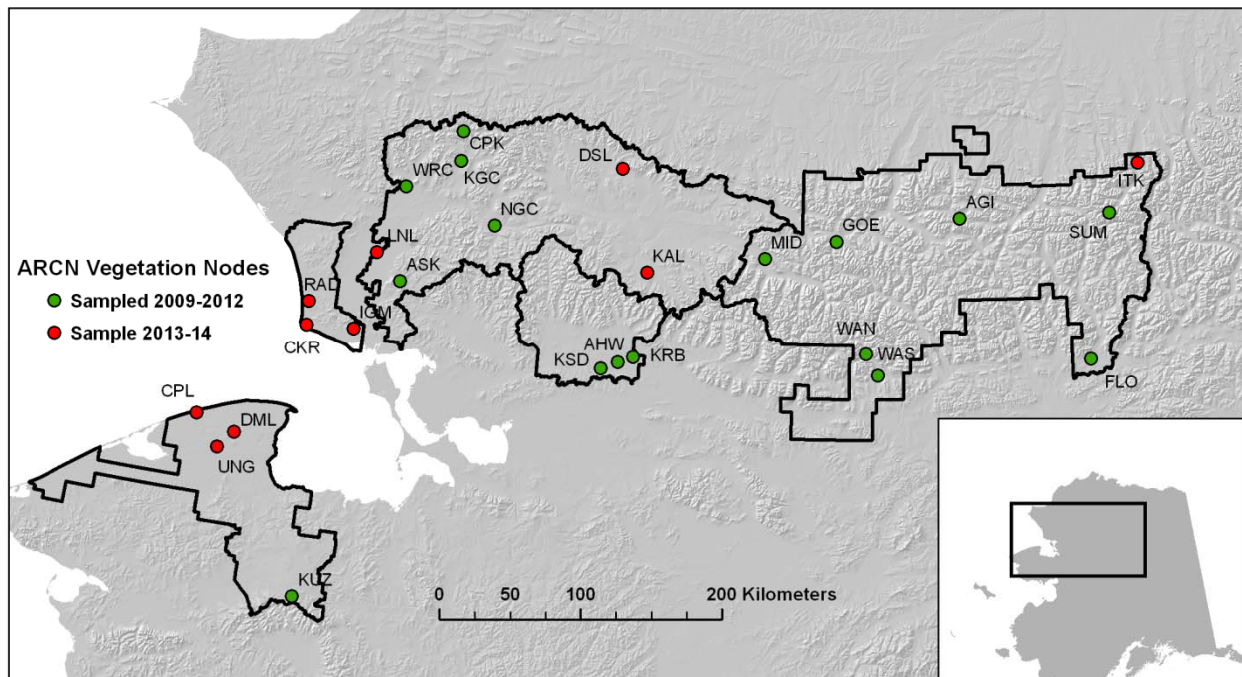


Figure 4. The ARC� vegetation monitoring nodes. Node abbreviations are explained in Table 1.

Sampling has covered a wide variety of environments (Table 2). Most transects contained between 4 and 8 plots and had fairly consistent elevation, slope, soil parent material, depth to frozen material, and depth to water or saturated soil. Numerous plots had no frozen soil observed (“>” in Table 2). Permafrost is in fact present over most of ARC� (Jorgenson et al. 2008) and thus these plots probably had permafrost at depth. The “no permafrost” observations result from the fact that coarse-grained soils typically thaw to a depth of more than 50 cm each summer, while they are difficult to excavate beyond about 50 cm given our constraints for time and permitted surface disturbance.

Table 1. The ARCN vegetation monitoring nodes.

NPS Unit Node Abbreviation	Node Name	Count of Plots¹	Latitude WGS84	Longitude WGS84	Sample Year
Bering Land Bridge National Preserve (BELA)					
<i>CPL</i>	Cowpack Lagoon	-	66.45206	-165.169	2013-14 (proposed)
<i>DML</i>	Devil Mountain Lakes	-	66.36909	-164.536	2013-14 (proposed)
<i>KUZ</i>	Kuzitrin Lake	18 (2)	65.38974	-163.272	2009
<i>UNG</i>	Upper Nug	-	66.25775	-164.767	2013-14 (proposed)
Cape Krusenstern National Monument (CAKR)					
<i>CKR</i>	Cape Krusenstern	-	67.11888	-163.649	2013-14 (proposed)
<i>IGM</i>	Igisukruk Mountain	-	67.1326	-162.882	2013-14 (proposed)
<i>RAD</i>	Radio Hill	-	67.26786	-163.668	2013-14 (proposed)
Gates of the Arctic National Park and Preserve (GAAR)					
<i>AGI</i>	Agiak Lake	21 (1)	68.06832	-152.976	2010
<i>FLO</i>	Florence Creek Lake	16 (2)	67.14147	-150.874	2009
<i>GOE</i>	Goedecke's Lake	22	67.91988	-155.043	2012
<i>ITK</i>	Itkillik Lake	-	68.38419	-149.925	2013-14 (proposed)
<i>MID</i>	Midas Lake	22	67.79653	-156.23	2012
<i>SUM</i>	Summit Lake	24	68.07428	-150.453	2012
<i>WAN</i>	Walker Lake North	15	67.19945	-154.538	2012
<i>WAS</i>	Walker Lake South	13	67.06375	-154.342	2012
Kobuk Valley National Park (KOVA)					
<i>AHW</i>	Ahnewetut Wetlands	13	67.0894	-158.563	2012
<i>KRB</i>	Kobuk River Bar	11	67.12627	-158.323	2012
<i>KSD</i>	Kobuk Sand Dunes	23	67.04123	-158.834	2012
Noatak National Preserve (NOAT)					
<i>ASK</i>	Asik	21	67.47198	-162.226	2011
<i>CPK</i>	Copter Peak	22	68.47322	-161.469	2011
<i>DSL</i>	Desperation Lake	-	68.32749	-158.699	2013-14 (proposed)
<i>KAL</i>	Kaluich	-	67.67515	-158.182	2013-14 (proposed)
<i>KGC</i>	Kagvik Creek	16	68.28367	-161.453	2011
<i>LNL</i>	Lower Noatak Lowlands	-	67.63656	-162.674	2013-14 (proposed)
<i>NGC</i>	Noatak Grand Canyon	24 (1)	67.89364	-160.775	2011
<i>WRC</i>	Wrench Creek	20	68.08044	-162.322	2011

¹Total count of plots at the node, with the count of deliberately chosen plots, if any, in parentheses.

Table 2. Physical characteristics of ARCN vegetation node sampling transects.

NPS unit1	Node2	Transect Name	Count of Plots	Elevation Mean (SD), m	Slope Mean (SD), %	Soil Parent Material	Depth to Frozen ³ , Median, cm	Depth to Water ³ , Median, cm
BELA	KUZ	Alpine	3	660 (33)	32 (7)	Residuum felsic	>	>
BELA	KUZ	Lava	4	451 (7)	4 (2)	Residuum mafic	>	>
BELA	KUZ	Slope	9	483 (19)	5 (4)	Colluvium/residuum felsic	>	>
GAAR	AGI	Alpine	4	1214 (71)	52 (14)	Colluvium	>	>
GAAR	AGI	Moraine	7	985 (16)	9 (10)	Till	>	>
GAAR	AGI	Talus	3	1049 (18)	61 (4)	Colluvium	>	>
GAAR	AGI	Willow	6	964 (15)	6 (3)	Till	42	18
GAAR	FLO	Floodplain	3	259 (6)	0 (0)	Alluvium	58	>
GAAR	FLO	Muskeg	6	255 (1)	0 (0)	Organic/alluvium	70	>
GAAR	FLO	Slope	5	322 (43)	17 (19)	Eolian	50	>
GAAR	GOE	Hills	8	1179 (78)	14 (12)	Colluvium/ residuum fine sed- metamorphic	>	>
GAAR	GOE	Mountain slope	7	1136 (130)	26 (2)	Colluvium/ residuum fine sed- metamorphic	>	>
GAAR	GOE	Valley bottom	7	894 (8)	3 (1)	Till	>	>
GAAR	MID	Hills	8	618 (23)	10 (7)	Colluvium, residuum coarse sed-metamorphic, till	>	>
GAAR	MID	Moraine	6	531 (7)	3 (1)	Till	>	>
GAAR	MID	Riparian	8	490 (5)	1 (1)	Alluvium	46	37
GAAR	SUM	Dryas plain	8	1091 (14)	5 (3)	Till	51	49
GAAR	SUM	Mountain slope	8	1354 (156)	24 (10)	Colluvium	>	>
GAAR	SUM	Shrub slope	8	1129 (15)	4 (2)	Till	75	15
GAAR	WAN	Avalanche slope	4	846 (107)	36 (7)	Colluvium/ residuum coarse sed-metamorphic	>	>
GAAR	WAN	Riparian spruce	4	208 (4)	4 (1)	Alluvium	34	>
GAAR	WAN	Spruce slope	7	396 (85)	17 (9)	Colluvium/ residuum coarse sed-metamorphic	>	>
GAAR	WAS	Moraine	6	224 (3)	10 (8)	Till	>	>
GAAR	WAS	Spruce slope	7	368 (94)	27 (17)	Colluvium/till	>	>
KOVA	AHW	Polygons NE	5	30 (4)	1 (2)	Organic/alluvium	46	26
KOVA	AHW	Polygons SW	8	33 (2)	0 (1)	Organic/alluvium	54	20
KOVA	KRB	Big point bar	7	23 (4)	5 (7)	Alluvium	>	>
KOVA	KRB	Wet terrace	4	20 (3)	1 (2)	Organic/alluvium	34	29
KOVA	KSD	Dryas flats	6	76 (4)	3 (2)	Eolian	>	>
KOVA	KSD	Sandy woodland	7	73 (6)	4 (4)	Eolian	>	>
KOVA	KSD	Steppe	6	86 (2)	4 (5)	Eolian	>	>
KOVA	KSD	Wetland	4	58 (2)	3 (2)	Eolian, organic/lacustrine	40	38

Table 2. (continued).

NPSunit ¹	Node ²	TransectName	Count of Plots	Elevation Mean (SD), m	Slope Mean (SD), %	Soil Parent Material	Depth to Frozen ³ , Median, cm	Depth to Water ³ , Median, cm
NOAT	ASK	Mountain slope	8	208 (84)	24 (10)	Colluvium/residuum calcareous	>	>
NOAT	ASK	Terrace	6	97 (4)	1 (2)	Alluvium	>	>
NOAT	ASK	Tussock slope	7	172 (8)	8 (2)	Colluvium/residuum mafic	>	>
NOAT	CPK	Carbonate barrens	6	630 (83)	58 (9)	Residuum calcareous	>	>
NOAT	CPK	Noncarbonate mountains	8	567 (70)	55 (24)	Colluvium/residuum fine sed-metamorphic	>	>
NOAT	CPK	Shrub terrace	8	414 (16)	6 (4)	Alluvium	>	>
NOAT	KGC	Floodplain	8	218 (4)	0 (1)	Alluvium	>	>
NOAT	KGC	Tundra lowlands	8	242 (7)	4 (4)	Organic/lacustrine	31	10
NOAT	NGC	Mesic floodplain	6	144 (3)	3 (5)	Alluvium	75	>
NOAT	NGC	Tussock slopes	9	189 (12)	4 (4)	Organic/eolian	29	16
NOAT	NGC	Wet floodplain	8	146 (1)	0 (1)	Alluvium	30	3
NOAT	WRC	Alpine slope	4	292 (72)	36 (24)	Colluvium	>	>
NOAT	WRC	Floodplain	3	117 (1)	0 (0)	Alluvium	>	>
NOAT	WRC	Spruce slope	6	159 (16)	10 (4)	Colluvium	>	>
NOAT	WRC	Tussock plain	7	125 (3)	5 (7)	Organic/alluvium	42	17

¹ARCN NPS unit abbreviations are given in Fig 1.

²Node abbreviations are given in Table 2.

³">" indicates below the depth of observation, usually about 50 cm in the rocky soils where frozen material and water are typically not observed. "Frozen" material was ice-cemented on the day of sampling (July to early August). "Water" refers to the lesser depth of: free water table in the soil pit (where present), or, in the case of fine-grained soils, saturated viscous soil.

Distribution of Plots Across ARCN

Park Units

To date BELA has just one sampled node (completed as a part of the protocol testing in 2009) and CAKR has none (Fig. 4, Table 3). These park units will be the focus of sampling in 2013. The southern half of BELA is weakly represented, due to a lack of landing sites and the good coverage of this area by another monitoring project, the BELA Ungulate Grazing Enclosures (Swanson and Neitlich 2011). GAAR and NOAT currently have similar plot densities (260 and 258 km² per plot, respectively). Dispersal of plots is currently better in GAAR than NOAT; only the western half of NOAT has been covered to date, but planned additional plots will improve this situation (Fig. 4). KOVA currently has the best plot density with just 151 km² of territory represented by each plot, though all 3 nodes there are clustered in lowland areas near the Great Kobuk Sand Dunes and Kobuk River. There are no fixed-wing accessible landing areas sufficient for aircraft large enough for our purposes (e.g., a Cessna 185) in the mountainous northern half of KOVA.

Elevation

Plots sampled to date are biased somewhat towards lower elevations (Figs. 5 and 6). This reflects the fact that fixed-wing access points (mostly river gravel bars and lakes) are in valley bottoms, and the safety and travel problems (cliffs, etc.) involved in sampling high-elevations. The one node sampled to date in BELA was in the mountains, and the low elevations that dominate the Preserve have yet to be covered. Plots in GAAR are

distributed fairly well across the range of elevations present. Plots sampled in KOVA to date are all in the lowlands, which as mentioned above is due to the lack of fixed-wing landing sites in the northern, mountainous part of the park. Our current plan is to place no more nodes in KOVA and accept the bias toward low elevations due to accessibility. Plots in NOAT are weighted toward the lower elevations, as a result of our 2011 field season based out of river valley landing sites in the lower, western half of the Preserve. This situation should be improved by future sampling in the eastern part of the Preserve.

Comparison of modern and historical aerial photographs shows that lower elevations are much more prone to change than high altitudes in ARCN, which are sparsely vegetated rock, talus, and scree (Swanson, 2013). This could change, of course, if climate change allows plants to colonize higher elevations, but large portions of high elevations should remain unchanged (unvegetated) indefinitely due to steep, unstable slopes.

Table 3. Count of nodes, transects, and plots by NPS unit, completed as of August, 2012.

NPS unit	Count of Nodes	Count of Transects	Count of Plots	Area ¹ per plot, km ²
BELA	1	3	16	644
CAKR	0	0	0	-
GAAR	7	21	130	260
KOVA	3	8	47	149
NOAT	5	15	102	258
All	16	47	295	271

¹Area of NPS unit divided by the count of plots.

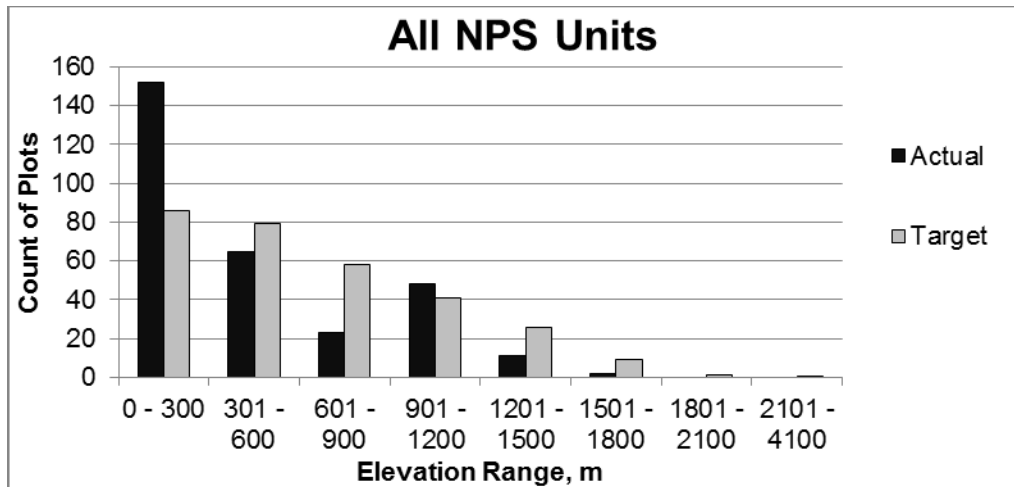


Figure 5. Elevation distribution of plots in ARCN. “Actual” bars give the count of plots in each elevation range. “Target” bars give the ideal distribution that would be produced by allocating the current sample of plots across elevations in proportion to the area in each elevation class.

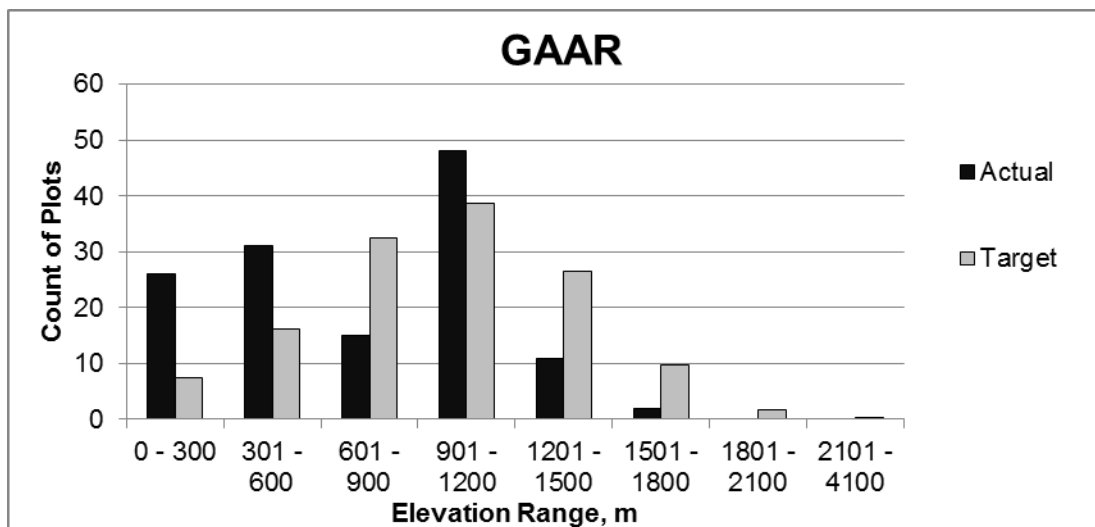
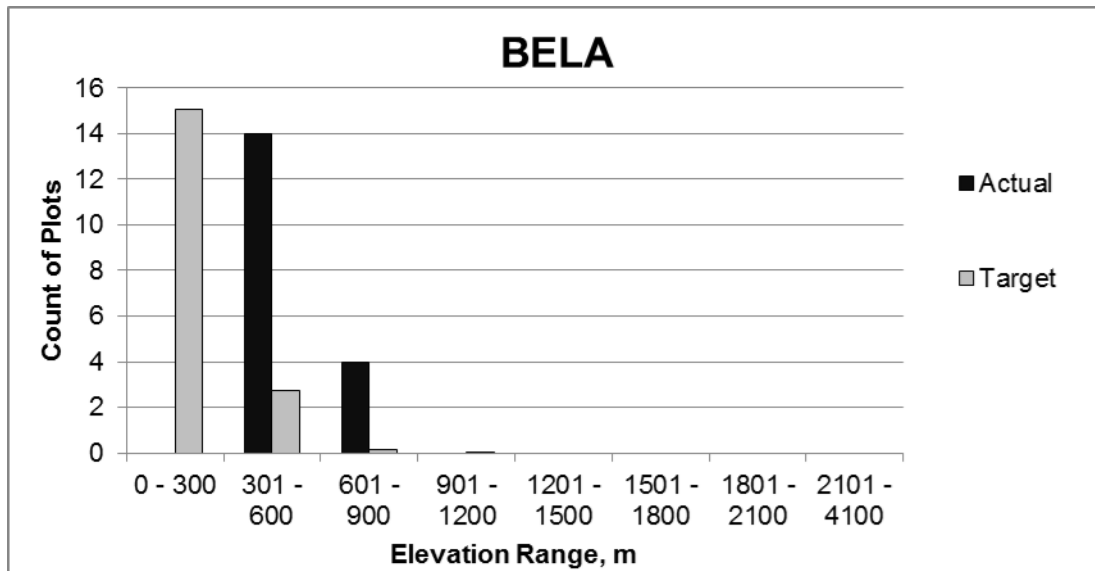


Figure 6. Elevation distribution of plots in individual units of ARCN. “Actual” bars give the count of plots in each elevation range. “Target” bars give the ideal distribution that would be produced by allocating the current sample of plots across elevations in proportion to the area in each elevation class. The NPS unit abbreviations are explained in Fig. 1.

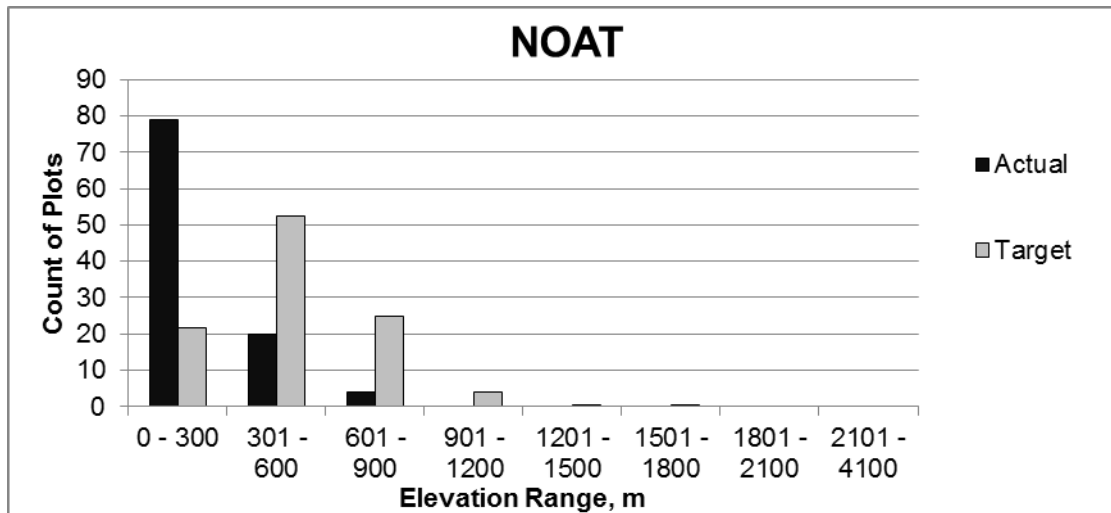
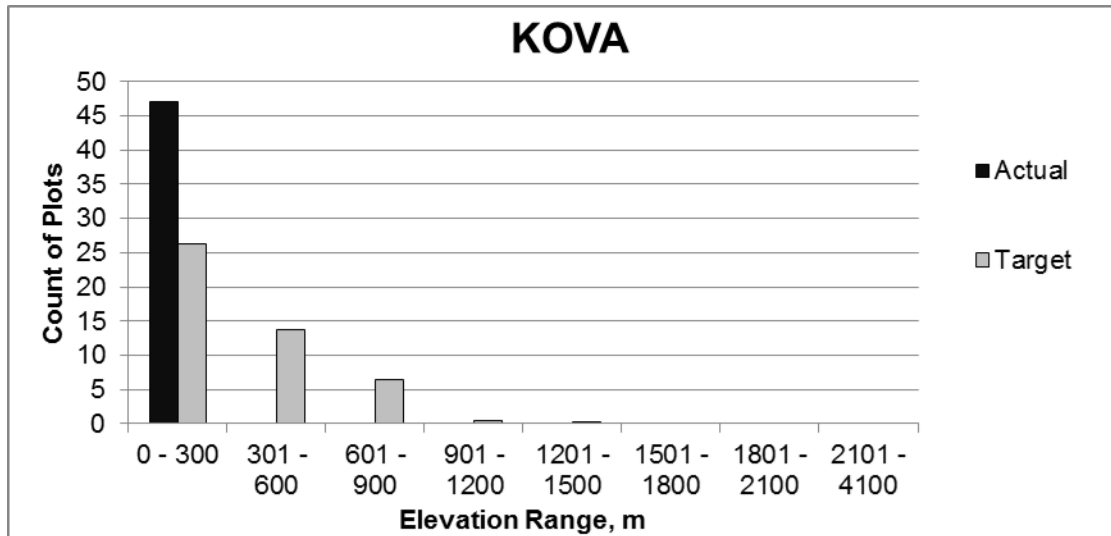


Figure 6 (continued)

Ecotypes

A picture of the dispersion of plots across ecosystems in ARCN is given by the classification of plots into the ecotypes (vegetation-soil landscape units) mapped by Jorgenson et al. (2009). Plots have been sampled in all the mapped ecotypes in ARCN except the coastal ecotypes, Alpine Mafic Barrens, and Riverine Barrens (Table 4). The coastal ecotypes cover very little area and occur only BELA and CAKR; they are a priority for sampling 2013. We plan to sample Alpine Mafic Barrens from the proposed Desolation Lake node in NOAT in 2013. Riverine Barrens have been excluded from sampling because they are periodically under water during the field season and they are subject to strong erosion and deposition that would disrupt plot markers.

Table 4. Distribution of plots amongst ARCN ecotypes¹

Ecotype	Count of Plots ²	Area ³ per Plot, km ²	Area ⁴ , % of ARCN
Alpine Acidic Barrens	15	482	9.23
Alpine Alkaline Barrens	3	999	3.83
Alpine Dryas Dwarf Shrub	22	534	15.00
Alpine Ericaceous Dwarf Shrub	27	60	2.08
Alpine Mafic Barrens	0	-	1.31
Alpine Wet Sedge Meadow	4	139	0.71
Coastal Barrens	0	-	0.11
Coastal Brackish Sedge-Grass Meadow	0	-	0.07
Coastal Crowberry Dwarf Shrub	0	-	0.06
Coastal Dunegrass Meadow	0	-	0.02
Lowland Alder Tall Shrub	2	274	0.70
Lowland Birch-Ericaceous-Willow Low Shrub	18	149	3.42
Lowland Black Spruce Forest	10	120	1.53
Lowland Ericaceous Shrub Bog	2	426	1.09
Lowland Sedge Fen	5	207	1.32
Lowland Sedge-Dryas Meadow	10	116	1.48
Lowland Willow Low Shrub	2	367	0.94
Riverine Alder or Willow Tall Shrub	7	68	0.61
Riverine Barrens	0		0.65
Riverine Birch-Willow Low Shrub	1	471	0.60
Riverine Dryas Dwarf Shrub	6	19	0.15
Riverine Poplar Forest	6	10	0.08
Riverine Wet Sedge Meadow	8	43	0.44
Riverine White Spruce-Poplar Forest	4	11	0.06
Riverine White Spruce-Willow Forest	9	42	0.48
Riverine Willow Low Shrub	5	27	0.17
Upland Alder-Willow Tall Shrub	7	572	5.11
Upland Birch Forest	2	145	0.37
Upland Birch-Ericaceous-Willow Low Shrub	41	225	11.78
Upland Dwarf Birch-Tussock Shrub	32	515	21.04
Upland Mafic Barrens	2	112	0.29
Upland Sandy Barrens	12	5	0.08
Upland Sedge-Dryas Meadow	6	826	6.33
Upland Spruce-Birch Forest	3	106	0.41
Upland White Spruce Forest	18	253	5.82
Upland White Spruce-Lichen Woodland	7	9	0.08
Upland Willow Low Shrub	5	398	2.54

¹Ecotypes are vegetation soil units mapped at 30-m pixel resolution in ARCN by Jorgenson et al. (2009). Ecotypes with both low overall plot count (less than 10) and high average area of land represented by each plot (more than 400 km² per plot) are written in **boldface** and discussed in the text.

²The total number of plots in each ecotype (ecotypes as identified using field data, not by GIS analysis of the ecotype raster);

³The area covered by the ecotype in ARCN (as mapped by Jorgenson et al. 2009) divided by the number of plots; this is a measure of sampling intensity: a large area indicates sparse sampling.

⁴The proportion of ARCN area covered by the ecotype, as mapped by Jorgenson et al. (2009).

When assessing sampling adequacy for ecotypes, we are most concerned with ecotypes that have both a low total count of plots (e.g., less than 10 total plots) and a large average area represented by each plot (e.g., the area of the ecotype divided by count of plots in the ecotype is more than 400 km²). Types weak in both criteria include Alpine Alkaline Barrens, Lowland Ericaceous Shrub Bog, Riverine Birch-Willow Low Shrub, and Upland Alder-Willow Tall Shrub. We have future nodes planned to access Alpine Alkaline Barrens in CAKR (Radio Hill) in GAAR (Itkillik Lake). We expect to supplement our sample of Lowland Ericaceous Shrub Bog with nodes in the BELA lowlands. Riverine Birch-Willow Low Shrub is a minor type found on floodplains in the taiga zone that we encountered only once in five nodes in this environment; it will likely remain with its current sample, as we have no more taiga-zone floodplain nodes planned. Upland Alder-Willow Tall Shrub is most common in the mountains of KOVA (which as discussed previously will probably remain unsampled) and locally in CAKR, GAAR, and NOAT. Crew productivity is very low in the Upland Alder-Willow Tall Shrub ecotype, owing to difficult travel, plot layout, and sampling, and safety is a problem due to poor grizzly bear visibility. We may pick up a few more plots of this type in CAKR and NOAT, but it will probably remain under-sampled. The NPS Southwest Alaska Inventory and Monitoring Network chose to remove this ecotype completely from its sampling program for these same access and safety issues (Amy Miller, NPS-SWAN, personal communication)

Characteristics of the Vegetation Data

Plant Cover

Vegetation cover data is notoriously difficult to analyze because each plot has many possible dimensions (the cover by each species or species group), most of which have a value of zero on any given plot (because only a small subset of the species occur on any one plot). In our protocol we proposed that the transects would be useful units of aggregation for change detection. Each transect has a set of common plants with substantial cover on most of the plots. To explore the degree to which the transect succeeds as an explanatory variable, I ran a nested analysis of variance of the cover of common plants (Tables 5 and 6). An example analysis for alder (*Alnus viridus*) is displayed in detail (Table 5). The mean-square variance in alder cover within transects (71, the “error” variance), is considerably smaller than the mean-square variance between transects within nodes (427), which in turn is smaller than the mean-square variance between nodes (888). The corresponding F-ratios are $427/71 = 6.0$ and $888/427 = 2.1$. Analogous F-ratios are reported for all common plants with no remaining identification issues (Table 6). Probability values are not reported for the F-ratios, because of the non-normal nature of the data. The within-transect mean-square variance of cover is smaller than the mean-square variance between transects for all the listed plants; and in nearly all cases the between-node mean-square variance is greater yet. This unsurprising result confirms that vegetation differences are driven by both local (between-transect) and regional (between-node) environmental variations.

Table 5. Nested analysis of variance for effects of transect and node on cover of alder (*Alnus viridus*)

Source	SS	df	MS	F ¹
Between nodes	13318	15	888	2.1
Between transects within a node	13251	31	427	6.0
Within transects (error)	17611	248	71	
All	44179	294	150	

¹The upper F-ratio is for groups over subgroups: “Between nodes” mean square variance divided by the “Between transects within nodes” mean square variance. The lower F-ratio is for subgroups over error: “Between transects within nodes” mean square variance divided by the “Within transects (error)” mean square variance.

Table 6. F-ratios from analyses of variance for effect of transect and node on cover of common ARCN plants¹

Plant	F of group/subgroup	F of subgroup/error
<i>Vaccinium uliginosum</i>	2.0	2.0
<i>Hylocomium splendens</i>	3.4	2.6
<i>Betula nana</i> ssp. <i>exilis</i>	1.0	7.2
<i>Vaccinium vitis-idaea</i>	1.3	4.0
<i>Dryas integrifolia</i>	2.9	8.3
<i>Sphagnum</i>	4.2	2.6
<i>Ledum palustre</i> ssp. <i>decumbens</i>	1.1	5.7
<i>Alnus viridis</i> ssp. <i>fruticosa</i>	2.1	6.0
<i>Cladin arangiferina</i> & <i>C. stygia</i>	2.2	6.3
<i>Cladina arbuscula</i> & <i>C. mitis</i>	1.3	11.1
<i>Picea glauca</i>	1.8	4.6
<i>Eriophorum vaginatum</i>	4.0	6.2
<i>Polytrichum</i>	1.2	3.9
<i>Empetrum hermaphroditum</i>	3.0	2.7
<i>Dryas alaskensis</i>	2.8	2.5
<i>Cetraria cucullata</i>	1.8	7.1
<i>Peltigera</i>	1.3	4.8
<i>Salix reticulata</i>	2.5	1.7
<i>Pleurozium schreberi</i>	2.7	1.6
<i>Andromeda polifolia</i>	16.8	5.0
<i>Rhytidium rugosum</i>	4.8	7.7
<i>Salix alaxensis</i>	0.8	9.8
<i>Cassiope tetragona</i>	2.0	2.8
<i>Equisetum arvense</i>	1.9	1.4
<i>Picea mariana</i>	2.3	4.2
<i>Stereocaulon</i>	1.2	18.3
<i>Betula glandulosa</i>	2.6	4.4
<i>Rubus chamaemorus</i>	0.9	2.3
<i>Cetraria islandica</i>	4.5	3.9
<i>Dryas octopetala</i>	0.8	2.7
<i>Cladina stellaris</i>	1.4	2.3
<i>Dicranum</i>	3.9	2.9
<i>Populus balsamifera</i>	1.8	4.4
<i>Arctous rubra</i>	1.4	4.2

¹For an explanation of the F-ratios, see the text and Table 5. This table includes all plants with at least 200 total point-intercept hits (corresponding to 0.7% total cover to date) and no remaining identification issues.

While the analysis of variance supports the strength of transects as an explanatory variable, the within-transect variance in plant cover is still substantial. A plot of the standard deviation in cover versus mean cover on each transect for all of the plants listed in Table 6 shows that the standard deviation of cover in a transect often exceeds the mean at low cover (Fig 7). Thus as expected, analyses that compute change over time on a per-plot basis will be needed. An example is a paired t-test for cover of a certain plant on each plot in a transect, where the pairs consist of two sample dates of each plot. The power of such tests will depend on the still-unknown variance in the amount of change per plot. We have reason to be optimistic that this variance will be manageable among plots within a transect, because future change in cover by a plant species should be closely related to the environmental variables held relatively constant across a transect (e.g. soil type, elevation, wetness; Table 2).

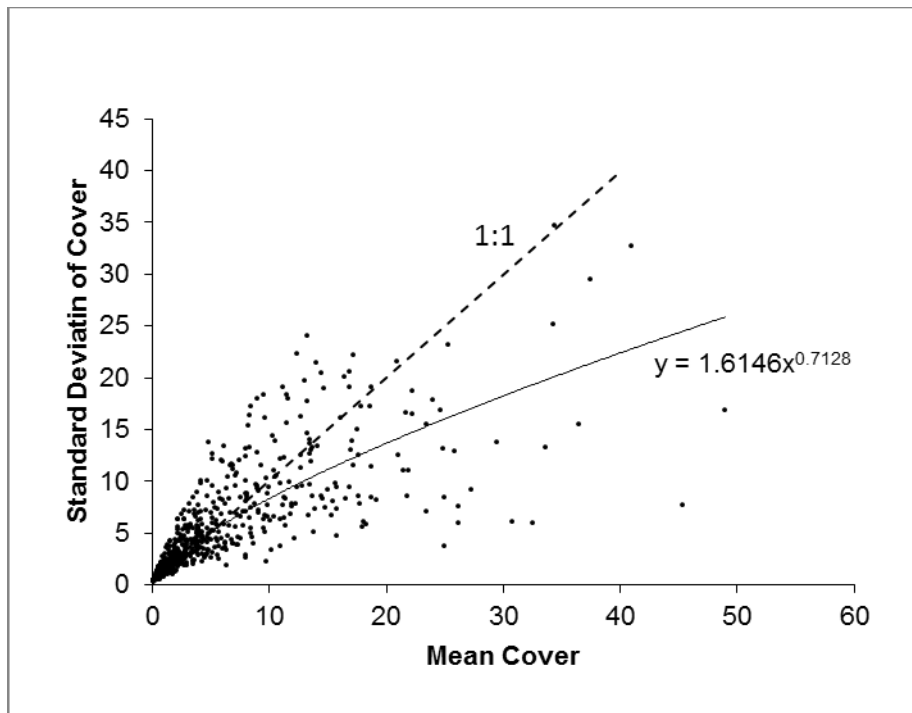


Figure 7. Standard deviation of cover versus mean cover for all common plants listed in Table 6. The dashed line labeled “1:1” marks where the standard deviation equals mean. The regression line (solid) rises slightly above the 1:1 line before falling below it beyond a mean cover of about 5%

Ground Cover

Ground cover in ARCN is dominated by plant litter (Table 7). Only sparsely vegetated transects had ground cover with less than 80% litter cover. These are mainly transects on rocky substrates and steep slopes, where the cover by rock and gravel is substantial. Cover by bare soil was high on the moraine transect at Walker Lake South, a former lichen woodland that burned about 20 years ago and has yet to accumulate a complete litter layer; on two sparsely vegetated transects on the Kobuk Sand Dunes; and on the mesic floodplain transect of the Noatak Grand Canyon node, where the ground was covered with sediment from recent floods. Ash cover was high on the tussock slopes transect of the Noatak Grand Canyon, due to a fire in the previous year. Cover by the basal vegetation ground cover type is low and consists mostly of tufted graminoids (mainly cottonsedge, *Eriophorum vaginatum*).

Table 7. Ground cover characteristics of the transects

NPS Unit Node	Transect Name	Ash	Basal Vegetation	Crypto- gam Crust	Gravel (2-75 mm)	Litter	ROCK (>75 mm)	Soil	Water	Wood
----- Mean (standard deviation) cover in percent -----										
Bering Land Bridge National Preserve (BELA)										
KUZ	Alpine	0 (0)	0.7 (0.6)	1.3 (1.5)	20.7 (26.8)	23.7 (15.7)	50.7 (11)	2.7 (3.1)	0.3 (0.6)	0 (0)
KUZ	Lava	0 (0)	0 (0)	0.2 (0.5)	0.8 (1.5)	49.5 (38.1)	46.8 (40.2)	2.5 (2.1)	0 (0)	0.2 (0.5)
KUZ	Slope	0 (0)	0.2 (0.7)	0.7 (1.3)	1.1 (3)	73.9 (25.7)	23.8 (26.2)	0.1 (0.3)	0.1 (0.3)	0.1 (0.3)
Gates of the Arctic National Park and Preserve (GAAR)										
AGI	Alpine	0 (0)	0 (0)	0 (0)	12 (22.7)	60.8 (36.9)	27.2 (15.5)	0 (0)	0 (0)	0 (0)
AGI	Moraine	0 (0)	0 (0)	0 (0)	1.1 (1.5)	76.1 (24.2)	21.9 (24.3)	0.6 (0.8)	0 (0)	0 (0)
AGI	Talus	0 (0)	0 (0)	0 (0)	0 (0)	1 (1)	99 (1)	0 (0)	0 (0)	0 (0)
AGI	Willow	0 (0)	4.8 (11.8)	0 (0)	0.2 (0.4)	85.2 (15.7)	0 (0)	0.3 (0.8)	9.5 (12.3)	0 (0)
FLO	Floodplain	0 (0)	1.7 (1.2)	0 (0)	0 (0)	91.7 (2.5)	0 (0)	0 (0)	0 (0)	6.7 (3.5)
FLO	Muskeg	0 (0)	8.3 (6.8)	0 (0)	0 (0)	91.7 (6.8)	0 (0)	0 (0)	0 (0)	0 (0)
FLO	Slope	0 (0)	1.6 (1.5)	0 (0)	0 (0)	98 (1.9)	0 (0)	0 (0)	0 (0)	0.4 (0.9)
GOE	Hills	0 (0)	0.1 (0.4)	0.2 (0.7)	6.9 (8.3)	82.6 (18.6)	5.4 (7.2)	4.8 (6)	0 (0)	0 (0)
GOE	Mountain slope	0 (0)	0.3 (0.5)	0 (0)	32.1 (25)	45 (36.3)	19.4 (17.7)	3.1 (3.4)	0 (0)	0 (0)
GOE	Valley bottom	0 (0)	0.4 (0.8)	0 (0)	0.9 (1.2)	94.1 (7.6)	0.4 (1.1)	2.3 (5.6)	1.9 (4.1)	0 (0)
MID	Hills	0 (0)	1 (0.5)	0 (0)	0 (0)	94.6 (6.7)	0 (0)	2 (2.4)	2.4 (6.7)	0 (0)
MID	Moraine	0 (0)	1.5 (1)	1.7 (1)	0 (0)	94.3 (2.3)	0 (0)	2.5 (2)	0 (0)	0 (0)
MID	Riparian	0 (0)	0.6 (0.7)	0.1 (0.4)	0 (0)	80.9 (31.7)	0 (0)	0.4 (1.1)	18 (32.3)	0 (0)
SUM	Dryas plain	0 (0)	1 (0.8)	0 (0)	1.1 (2.4)	89.5 (12.3)	2.1 (4.5)	0.8 (1.2)	5.5 (13.2)	0 (0)
SUM	Mountain slope	0 (0)	0.1 (0.4)	0 (0)	15 (24.5)	48.9 (42.5)	34.6 (37.2)	1.2 (1)	0.1 (0.4)	0 (0)
SUM	Shrub slope	0 (0)	0.2 (0.5)	1 (1.4)	0.6 (1.8)	92.8 (8.7)	0.1 (0.4)	3 (6.5)	2.2 (4)	0 (0)
WAN	Avalanche slope	0 (0)	1.8 (1)	0 (0)	0 (0)	92.2 (6.2)	2.2 (3.9)	2.8 (1.5)	0 (0)	1 (2)
WAN	Riparian spruce	0 (0)	2.2 (2.1)	0 (0)	0 (0)	97 (2.6)	0 (0)	0 (0)	0 (0)	0.8 (1)
WAN	Spruce slope	0.1 (0.4)	1.4 (1.1)	0 (0)	0 (0)	94.7 (3.5)	0.3 (0.8)	0.7 (1.1)	0 (0)	2.7 (2.6)
WAS	Moraine	0 (0)	0 (0)	0 (0)	0.3 (0.8)	72.5 (15.6)	0 (0)	24.7 (15.6)	0 (0)	2.5 (2.6)
WAS	Spruce slope	0 (0)	1.1 (1.6)	0 (0)	0 (0)	94.1 (4.2)	0 (0)	3.1 (4.5)	0 (0)	1.6 (1.9)

Table 7 (continued)

NPS Unit Node	Transect Name	Ash	Basal Vegetation	Crypto- gam Crust	Gravel (2-75 mm)	Litter	ROCK (>75 mm)	Soil	Water	Wood
Kobuk Valley National Park (KOVA)										
AHW	Polygons NE	0 (0)	4 (2.5)	0 (0)	0 (0)	85.2 (8.6)	0 (0)	0 (0)	10.8 (6.9)	0 (0)
AHW	Polygons SW	0 (0)	4.9 (2.2)	0 (0)	0 (0)	86.5 (12.5)	0 (0)	0 (0)	8.6 (11.7)	0 (0)
KRB	Big point bar	0 (0)	1 (1)	0 (0)	0 (0)	86 (15.4)	0 (0)	8.6 (14.8)	0 (0)	4.3 (2.6)
KRB	Wet terrace	0 (0)	4.5 (2.5)	0 (0)	0 (0)	95 (2.8)	0 (0)	0 (0)	0.5 (1)	0 (0)
KSD	Dryas flats	0 (0)	1.2 (0.8)	4.2 (2.9)	0 (0)	33 (22.7)	0 (0)	61.5 (22.9)	0 (0)	0 (0)
KSD	Sandy woodland	0 (0)	1.1 (1.5)	0 (0)	0 (0)	97.7 (1.7)	0 (0)	0 (0)	0 (0)	1.1 (1.1)
KSD	Steppe	0 (0)	0.5 (0.8)	0 (0)	5.5 (5.8)	1.3 (1.4)	0 (0)	92.7 (4.8)	0 (0)	0 (0)
KSD	Wetland	0 (0)	6.2 (6)	0 (0)	0 (0)	93.5 (6.1)	0 (0)	0 (0)	0.2 (0.5)	0 (0)
Noatak National Preserve (NOAT)										
ASK	Mountain slope	0 (0)	0.4 (0.7)	0 (0)	3.2 (5)	87.8 (16.2)	5.5 (7.2)	3 (5)	0 (0)	0.1 (0.4)
ASK	Terrace	0 (0)	0 (0)	1.8 (3.1)	0 (0)	95.2 (9)	0.8 (2)	0.5 (1.2)	1.7 (4.1)	0 (0)
ASK	Tussock slope	0 (0)	1.7 (3)	0 (0)	0 (0)	97.7 (3.1)	0 (0)	0.6 (0.8)	0 (0)	0 (0)
CPK	Carbonate barrens	0 (0)	0 (0)	0 (0)	49.2 (20.5)	20.7 (25.9)	26.3 (16.6)	3.8 (8)	0 (0)	0 (0)
CPK	Noncarbonate mountains	0 (0)	0.4 (0.7)	0 (0)	1.5 (2.1)	97 (3.8)	0.1 (0.4)	1 (1.6)	0 (0)	0 (0)
CPK	Shrub terrace	0 (0)	1 (1.7)	0 (0)	0 (0)	98.8 (1.7)	0 (0)	0 (0)	0 (0)	0.2 (0.7)
KGC	Floodplain	0 (0)	0.8 (0.9)	0 (0)	0 (0)	95.5 (5.9)	0 (0)	0.8 (1.4)	2.5 (6)	0.4 (0.7)
KGC	Tundra lowlands	0 (0)	3.5 (8.1)	0.1 (0.4)	0 (0)	85.5 (15.2)	0 (0)	0 (0)	10.9 (16)	0 (0)
NGC	Mesic floodplain	0 (0)	0.2 (0.4)	0.2 (0.4)	0.2 (0.4)	29.5 (18.9)	0 (0)	69.7 (18.9)	0 (0)	0.3 (0.5)
NGC	Tussock slopes	39.4 (29.4)	3.8 (4.4)	0 (0)	0 (0)	55 (30.6)	0 (0)	0.3 (0.7)	1.3 (3)	0 (0)
NGC	Wet floodplain	0 (0)	1.1 (0.6)	0 (0)	0.1 (0.4)	95.9 (5.9)	0 (0)	0.1 (0.4)	2.8 (5.5)	0 (0)
WRC	Alpine slope	0 (0)	0 (0)	0 (0)	1 (0.8)	61.8 (40.4)	35.5 (41.2)	1.8 (2.2)	0 (0)	0 (0)
WRC	Floodplain	0 (0)	1 (0)	0 (0)	1 (1.7)	95.7 (3.1)	0.3 (0.6)	0.3 (0.6)	0 (0)	1.7 (1.5)
WRC	Spruce slope	0 (0)	0.3 (0.5)	0 (0)	1.3 (2.8)	97.5 (4.3)	0.3 (0.8)	0.3 (0.8)	0 (0)	0.2 (0.4)
WRC	Tussock plain	0 (0)	0.7 (1.1)	0 (0)	0 (0)	92.7 (15.4)	0 (0)	0 (0)	6.4 (15.7)	0.1 (0.4)

Tree Measurements

Trees were recorded at 9 of the 16 nodes. We expect to establish just one more node with trees (Igisukruk Mountain, in the southeastern part of CAKR). On many plots the same single tree species dominated trees, saplings, and seedling, though in a few cases (FLO slope, WAS moraine, and WAN spruce slope) succession was indicated by an overstory of birch or aspen with spruce regeneration (Table 8). Stand basal areas were quite low, with just two transects averaging over 10 m²/ha, both with white spruce (the floodplain transect at Florence Creek Lake and the spruce slope transect at Walker Lake North, both in southern GAAR). As in the case of the plant cover data, tree basal area and sapling/seedling counts per hectare in a transect have high standard deviations. Many of the forest stands in ARCN are dominated by saplings (dbh < 12 cm) as a result of the small stature of subarctic trees.

Herbivory

Lichen Utilization

Lichen utilization was rated as “none”, “trace”, or “slight” on all plots except at the Agiak Lake node in GAAR (where all except one plot on the alpine and moraine transects had “heavy” utilization) and the Kuzitrin Lake node in BELA (where “moderate” or “heavy” utilization was recorded on 7 of 13 plots on the alpine and slope transects). (“Slight” is defined as no foraging craters apparent in the lichen mat, less than 25% of the surface disturbed in any fashion; “moderate” is defined as shallow craters and 25-50% surface disturbance; “heavy” is defined as 75-100% surface disturbance, deep craters, and heavy trampling; J. D. Swanson and Barker 1992). On the sandy woodland transect at the Kobuk Sand Dunes node, the luxuriant lichen mat was composed of pure patches of early seral *Stereocaulon* lichens amongst late seral *Cladonia* lichens (*C. rangiferina/stygia*, *C. arbuscula/mitis*, and *C. stellaris*). These *Stereocaulon* patches occurred in small forest clearings and could be patches that were heavily grazed in the past before recovering to *Stereocaulon* by succession, though no recent grazing activity was apparent.

Shrub Browsing

We examined all deciduous trees (birch *Betula neoalaskana*, poplar *Populus balsamifera*, and aspen *P. tremuloides*), and all non-prostrate, non-ericaceous shrubs (*Alnus* sp., *Betula* sp., *Pentaphylloides* sp., *Ribes* sp., *Salix* sp., *Spiraea* sp., and *Viburnum* sp.) for browsing effects. Of the 295 systematically chosen plots, 228 had one or more of these trees or shrubs present in sufficient quantity to evaluate browse status. On 40 of these plots, browsing of one or more species was in one of the “heavy” categories (uninterrupted-broomed, retrogressed, released, or arrested; Table 9). The heavily browsed plants were mainly *Populus balsamifera*, *Salix alaxensis*, *S. pulchra*, and *S. richardsonii* (Table 10). At the Kagvik Creek node were some striking example of released poplar (Fig. 8), indicating heavy browsing in the past, followed by reduced pressure that allowed the trees to escape. On the Florence Creek Lake node we observed some unusual browsed *Alnus viridus* shrubs (Fig. 9). In general, however, alder and birch shrubs showed little or no browsing, while some level of browsing was the rule for most willow species (Table 10).

Table 7. Tree data summary for the ARCN vegetation monitoring transects¹.

NPS Unit Node	Transect Name	Species	Tree basal area, m ² /ha, mean (SD)	Sapling basal area, m ² /ha, mean (SD)	Sapling Count, mean(SD)	Seedling Count, mean(SD)
Gates of the Arctic National Park and Preserve (GAAR)						
FLO	floodplain	PIGL	21.6 (10.7)	0.5 (0.8)	159 (276)	1096 (1808)
FLO	floodplain	POBA	5.1 (4.5)	0 (0)	0 (0)	0 (0)
FLO	muskeg	PIMA	0 (0)	0.4 (0.5)	990 (1420)	1901 (3485)
FLO	muskeg	POBA	0 (0)	0 (0)	0 (0)	133 (325)
FLO	slope	BENE	2.7 (3.4)	0.9 (1.9)	637 (1038)	159 (356)
FLO	slope	PIGL	0.2 (0.5)	0.1 (0.2)	318 (712)	2865 (6406)
FLO	slope	PIMA	0.3 (0.6)	2.9 (4.1)	2387 (2924)	2228 (4150)
WAN	avalanche slope	PIGL	0 (0)	0 (0)	0 (0)	156 (312)
WAN	avalanche slope	POBA	0 (0)	0 (0.1)	93 (186)	312 (625)
WAN	riparian spruce	PIGL	1.3 (0.5)	2.4 (0.5)	743 (137)	1562 (361)
WAN	spruce slope	BENE	0 (0)	0.1 (0.2)	15 (26)	0 (0)
WAN	spruce slope	PIGL	10.8 (11.4)	1.8 (2)	682 (785)	1429 (1642)
WAN	spruce slope	PIMA	1.8 (2.8)	0.9 (1.8)	409 (601)	1161 (2055)
WAS	moraine	BENE	0 (0)	0.1 (0.3)	97 (238)	0 (0)
WAS	moraine	PIMA	0 (0)	0 (0)	35 (55)	4792 (4251)
WAS	moraine	POTR	0.1 (0.2)	1.5 (1.3)	1830 (1664)	2812 (2192)
WAS	spruce slope	BENE	2 (3.1)	0.1 (0.2)	45 (64)	0 (0)
WAS	spruce slope	PIGL	5.5 (6.6)	0.2 (0.2)	152 (246)	179 (305)
WAS	spruce slope	PIMA	0.6 (1.1)	1.2 (1.8)	584 (1013)	2054 (4157)
WRC	alpine slope	PIGL	0 (0)	0 (0)	13 (27)	0 (0)
Kobuk Valley National Park (KOVA)						
AHW	polygons SW	PIGL	0 (0)	0 (0)	0 (0)	156 (442)
KRB	big point bar	PIGL	6.1 (7.3)	0.9 (0.8)	371 (321)	1161 (1417)
KRB	big point bar	POBA	0 (0)	0.6 (1.4)	440 (867)	1696 (2991)
KRB	wet terrace	PIMA	0 (0)	0.3 (0.3)	729 (440)	17188 (13545)
KSD	dryas flats	PIGL	0 (0)	0 (0.1)	44 (108)	104 (255)
KSD	sandy woodland	PIGL	3.2 (2.5)	5.6 (3.9)	2562 (1944)	536 (431)
KSD	sandy woodland	POTR	0 (0)	0 (0)	0 (0)	179 (305)
KSD	wetland	PIMA	0 (0)	0 (0)	13 (27)	0 (0)
Noatak National Preserve (NOAT)						
ASK	Mountainslope	PIGL	2.5 (3)	2.2 (2.5)	590 (530)	5625 (4748)
ASK	terrace	PIGL	0.6 (1.3)	0.1 (0.2)	27 (65)	2500 (4541)
ASK	Tussockslope	PIGL	0.4 (1)	0.9 (1.9)	311 (641)	804 (1384)
KGC	floodplain	POBA	2.9 (5)	0.9 (1.6)	1293 (1651)	1797 (1903)
KGC	Tundralowlands	POBA	0 (0)	0 (0.1)	13 (38)	78 (221)
WRC	floodplain	PIGL	2.2 (3.8)	20.4 (35.3)	531 (531)	24792 (27897)
WRC	floodplain	POBA	0.3 (0.5)	0.3 (0.5)	1203 (1899)	5417 (2602)
WRC	Spruceslope	PIGL	4.2 (3.5)	1.6 (1.3)	442 (375)	4583 (4621)
WRC	Tussockplain	PIGL	0.4 (0.9)	0.3 (0.4)	152 (268)	536 (562)

¹Species: BENE *Betula neoalaskana*, PIGL *Picea glauca*, PIMA *Picea mariana*, POBA *Populus balsamifera*, POTR *Populus tremuloides*. Trees are defined as diameter at breast height (dbh) >12 cm; saplings dbh 1-12 cm; and seedlings dbh <1 cm.

Table 9. Forage plant architecture classes¹

Abbreviation	Description
	Uninterrupted: produced by light-moderate browsing ² ; height growth continues until limited by climate and plant species characteristics
UnintNobrowse	Unbrowsed: no signs of being browsed prior to the current year
UnintBrowse	Browsed: show evidence of browsing in past years, but less than half of current annual growth twigs between 0.5 and 3.0 m arise from lateral stems that were produced from browsing
UnintBroom	Broomed: more than half of current annual growth twigs between 0.5 and 3.0 m arise from lateral stems that were produced as a result of browsing. Plant still gains height every year.
Arrest	Arrested: produced by intense browsing ³ throughout the life of the plant. Usually “broomed” as defined above except that height is static.
Retro	Retrogressed: produced by a change from light-moderate to intense browsing while the terminal leader is still in the browse zone. The plant grew beyond the height where continuous intense browsing would normally stop it, but before it grew large enough to escape browsing, height growth was halted or the height reduced by killing of top branches.
Release	Released: produced by a change from intense to light-moderate browsing. The plant was previously <i>Arrested</i> , then began adding height every year through new growth originating from the preceding year's segment

¹after Keigley and Frisina 1998, Seaton 2002

²Light- to moderate browsing – part or none of the current year's growth segment is killed by browsing. Each year's annual segment develops from the preceding year's stem segment.

³Intense browsing – a complete annual growth segment is killed. Most new growth arises from stems that are more than 1 year old. Includes stems where current annual growth of the leader is killed and lateral branch assumes apical dominance even if some current annual growth on the lateral branch survives.

Table 10. Count of plots with plant in various browse classes¹

Browse Plant	----- Uninterrupted -----			Arrested	Retrogressed	Released
	Unbrowsed	Browsed	Broomed			
<i>Alnus viridus</i>	24	5	0	3	0	0
<i>Alnus tenuifolia</i>	1	0	0	0	0	0
<i>Betula (hybrid)</i>	0	0	0	1	0	0
<i>Betula glandulosa</i>	19	1	0	0	0	0
<i>Betula nana</i>	64	16	0	0	0	0
<i>Betula neoalaskana</i>	0	1	0	1	0	1
<i>Populus balsamifera</i>	2	3	1	4	0	2
<i>Populus tremuloides</i>	4	1	0	1	0	0
<i>Salix alaxensis</i>	3	17	2	6	2	0
<i>Salix bebbiana</i>	1	1	0	0	0	0
<i>Salix glauca</i>	7	25	0	1	0	1
<i>Salix niphoclada</i>	2	0	0	0	0	0
<i>Salix pulchra</i>	27	57	9	8	0	0
<i>Salix richardsonii</i>	7	15	4	5	0	0
<i>Spiraea stevenii</i>	3	0	0		0	0

¹For definitions of the classes, see Table 9.

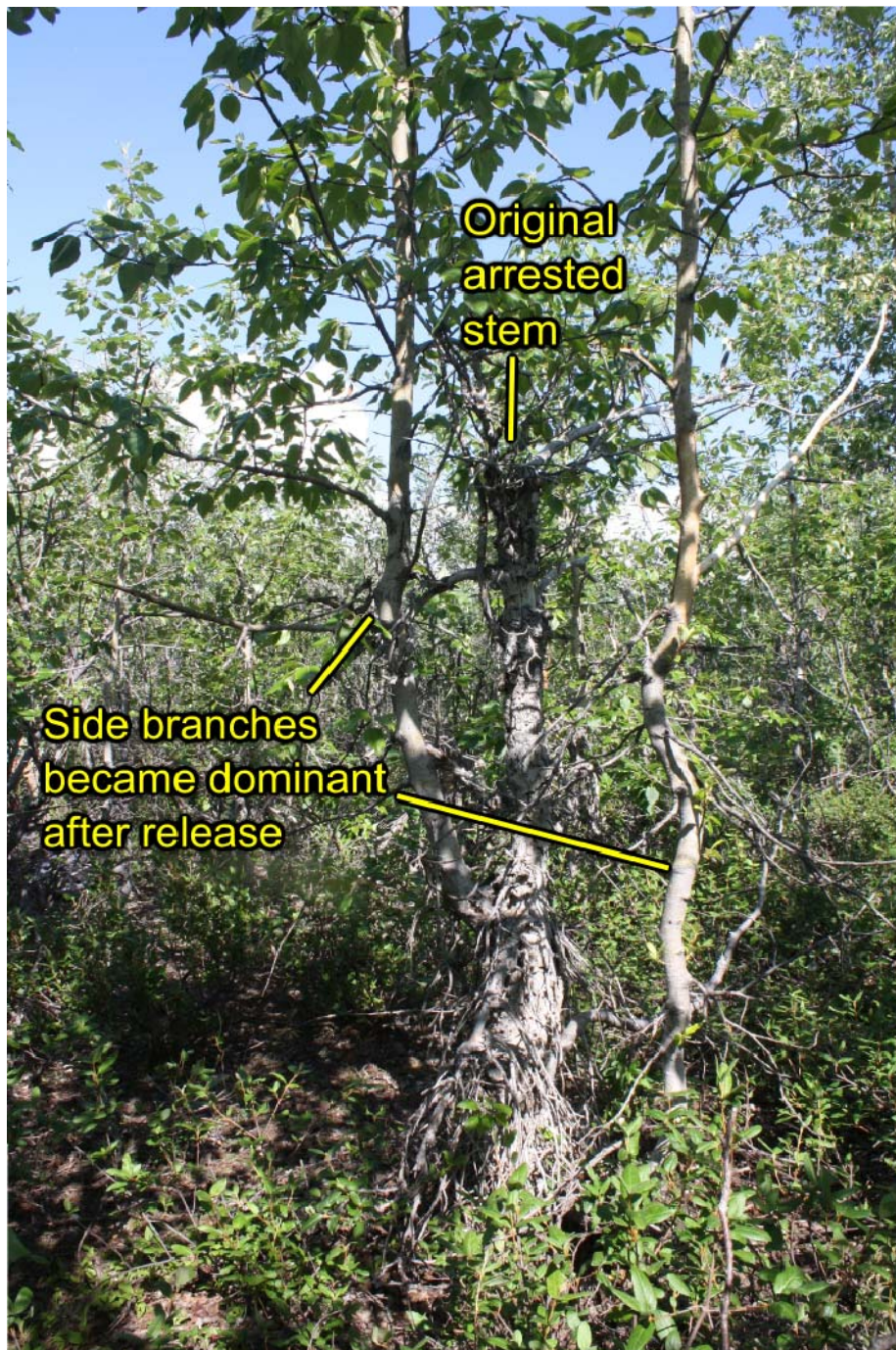


Figure 8. Poplar with released growth form, indicating heavy browsing with a pause sufficient for side branches to escape and assume apical dominance. Kagvik Creek node (NOAT), plot 8.



Figure 9. Alder (*Alnus fruticosa*) with unusual signs of browsing. Florence Creek Lake node (GAAR), plot 2.

Future Plans

Our sampling design has provided good coverage of major vegetation and elevation gradients in the areas sampled to date. We expect most of the remaining gaps to be filled by completion of planned sampling. We anticipate sampling approximately 10 more nodes with 180 to 200 plots. An effort in 2013 similar to 2012 (Table 1) should nearly complete the initial round of sampling, with a minor final effort expected in 2014. The anticipated final total of nodes is about 26, with about 500 total plots.

Literature Cited

- Holt, E. A. and P. N. Neitlich. 2010. Lichen inventory synthesis: Western Arctic National Parklands and Arctic Network, Alaska. Natural Resource Technical Report NPS/AKR/ARCN/NRTR—2010/385. National Park Service, Fort Collins, Colorado.
- Jorgenson, T., K. Yoshikawa, M. Kanevskiy, Y. Shur, V. Romanovsky, S. Marchenko, G. Grosse, J. Brown, and B. Jones. 2008. Permafrost characteristics of Alaska. Proceedings of the Ninth International Conference on Permafrost. University of Alaska Fairbanks, Institute of Northern Engineering.
- Jorgenson, M. T., J. E. Roth, P. F. Miller, M. J. Macander, M. S. Duffy, A. F. Wells, G. V. Frost, and E. R. Pullman. 2009. An ecological land survey and landcover map of the Arctic Network. Natural Resource Technical Report NPS/ARCN/NRTR—2009/270. National Park Service, Fort Collins, Colorado.
- Keigley, R. B. and M. R. Frisina. 1998. Browse evaluation by analysis of growth form. Volume I. Methods for evaluating condition and trend. Helena: Montana Fish Wildlife & Parks. 153 pp.
- Lawler, J. P., S. D. Miller, D. M. Sanzone, J. VerHoef, J., and S. B. Young. 2009. Arctic network vital signs monitoring plan. Natural Resource Report NPS/ARCN/NRR-2009/088. U.S. Department of the Interior, National Park Service, Natural Resource program Center, Ft. Collins, Colorado.
- Seaton, C. T. 2002. Winter forage ecology of moose in the Tanana Flats and Alaska Range foothills. M.S. Thesis, University of Alaska, Fairbanks.
- Swanson, D. 2010. Vegetation and Soils Monitoring Protocol Testing Arctic Inventory and Monitoring Network Progress Report, March 2010. National Park Service Unpublished Report, Fairbanks, Alaska. Available at <http://science.nature.nps.gov/im/units/arcn/documents/documents/ARCN-VS24-VegVitalSignProgressReport-2010-03-10.pdf> (Accessed 5 October 2012).
- Swanson, D. 2011a. Vegetation and Soils Monitoring Protocol Testing Arctic Inventory and Monitoring Network Progress Report, December 2010. National Park Service Unpublished Report, Fairbanks, Alaska. Available at <http://science.nature.nps.gov/im/units/arcn/documents/documents/VegVitalSignProgRptDec2010.pdf> (Accessed 5 October 2012).
- Swanson, D. 2011b. Vegetation and Soils Vital Sign Monitoring Arctic Inventory and Monitoring Network Progress Report, December 2011. National Park Service Unpublished Report, Fairbanks, Alaska. Available at <http://science.nature.nps.gov/im/units/arcn/documents/documents/VegVitalSignProgRptDec2011.pdf> (Accessed 5 October 2012).

Swanson, D. K. 2013. Three decades of landscape change in Alaska's Arctic National Parks: Analysis of aerial photographs. Natural Resource Technical Report NPS/ARC/NRTR—2013/668. National Park Service, Fort Collins, Colorado.

Swanson, D. K. and P. Neitlich. 2011. Terrestrial vegetation monitoring protocol for the Arctic Alaska Network: Establishment, sampling, and analysis of permanent monitoring plots. Natural Resource Report NPS/XXXX/NRR—20XX/XXX. National Park Service, Fort Collins, Colorado. (In Review)

Swanson, J. D. and M. H. W. Barker. 1992. Assessment of Alaska reindeer populations and range conditions. *Rangifer* 12(1):33-43.